Development and feasibility evaluation of a sedentary behaviour intervention in individuals with paraplegia

A Thesis Submitted for the Degree of Doctor of Philosophy

By

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Thesis Abstract

Background: Individuals with spinal cord injury (SCI), such as paraplegia, are at a higher risk of cardiovascular disease (CVD) than non-disabled individuals. Furthermore, these individuals have high levels of sedentary behaviour, which is an independent risk factor for CVD. Reducing and breaking up sedentary behaviour could be a potential intervention focus for individuals with paraplegia. Currently, evidence around the effectiveness of sedentary behaviour interventions in individuals with paraplegia is unclear. Sedentary behaviour interventions have been shown to be effective in non-disabled individuals. However, due to the unique needs of manual wheelchair-users with paraplegia, it is unlikely that interventions designed for non-disabled individuals would be acceptable or effective for this population. Therefore, tailored sedentary behaviour interventions should be developed for individuals with paraplegia.

Methods: A mixed-methods approach was used throughout this thesis. The initial 'Development' phase of the Medical Research Council (MRC) framework for developing and evaluating complex interventions was undertaken via a systematic review to explore the effects of interventions on sedentary behaviour and CVD biomarkers in individuals with paraplegia (Chapter 4), and development of a sedentary behaviour intervention using the Behaviour Change Wheel (Chapter 5). Subsequently, the 'Feasibility' phase of the MRC framework was undertaken via a feasibility study to evaluate the acceptability, safety, feasibility and preliminary efficacy of the intervention in individuals with paraplegia (Chapter 6).

Results: The systematic review found that interventions specifically targeting sedentary behaviour show promise for improving this outcome and CVD biomarkers. The co-design study identified 29 barriers and facilitators to reducing and breaking up sedentary behaviour, which were then selectively targeted by specific intervention components: a wearable activity

tracker, educational booklet, goal setting, motivational support, peer support and activity tools. Evaluation of this intervention found that it was acceptable, safe and feasible. In addition, the intervention showed preliminary efficacy for improving sedentary behaviour, physical activity, some CVD biomarkers and psychosocial health outcomes.

Conclusion: This research contributes a novel co-designed, theory-driven sedentary behaviour intervention in individuals with paraplegia. The intervention was acceptable, safe and feasible to deliver, which can inform progression to a future definitive randomised controlled trial. If found to be effective, this research could inform future healthcare policy and public health guidelines in individuals with paraplegia, with a focus on reducing and breaking up sedentary behaviour to improve CVD biomarkers.

List of Publications and Presentations

Journal Publications

Cooper, DL., Warland, A., Norris, E., Kilbride, C., Paddison, S., & Bailey, DP. (2025). Effects of interventions on sedentary behaviour and cardiovascular disease biomarkers in individuals with spinal cord injury: a systematic review. *Disability and Rehabilitation*. 1-24. https://doi.org/10.1080/09638288.2025.2592500

Cooper, DL., Warland, A., Norris, E., Kilbride, C., Paddison, S., & Bailey, DP. (2025). Using the Behaviour Change Wheel to co-design a sedentary behaviour intervention in individuals with spinal cord injury. *Clinical Rehabilitation*. Under review. Preprint: https://doi.org/10.64898/2025.12.02.25338957

Conference Presentations

Oral Presentations

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Poster Presentations

Cooper, DL., Warland, A., Norris, E., Kilbride, C., Paddison, S., & Bailey, DP. (2024*). The effects of sedentary behaviour and physical activity interventions on sedentary time and biomarkers of cardiovascular disease in individuals with spinal cord injury: a systematic review.* Brunel University Doctoral Research Poster Conference. Uxbridge, United Kingdom, 29th May 2024.

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Abbreviations

APEASE	Acceptability, Practicability, Effectiveness, Affordability, Safety/Side effects and Equity
ApoA1	Apolipoprotein A1
ApoB	Apolipoprotein B
AUC	Area Under the Curve
BCT	Behaviour Change Technique
BCTTv1	Behaviour Change Technique Taxonomy version 1
BCW	Behaviour Change Wheel
BMI	Body Mass Index
C	Cervical
CCG	Community Caregiver
CI	Confidence Interval
COM-B	Capability, Opportunity and Motivation to change Behaviour
CONSORT	Consolidated Standards of Reporting Trials - guidelines for feasibility and pilot trials
COREQ	COnsolidated criteria for REporting Qualitative research
CVD	Cardiovascular Disease
GAD-7	Generalized Anxiety Disorder 7-item questionnaire
GGIR	Generalised GPS and Inertial Research
GRADE	Grading of Recommendations Assessment, Development, and Evaluation
GRAMMS	Good Reporting of A Mixed-Methods Study guidelines
HbA1C	Glycated Haemoglobin A1C
HCP	Healthcare Professional
HDL	High Density Lipoprotein

HOMA-%B	Homeostatic Model Assessment of Percentage Beta cell function
HOMA-%S	Homeostatic Model Assessment of Percentage insulin Sensitivity
HOMA-IR	Homeostatic Model Assessment of Insulin Resistance
IPAQ	International Physical Activity Questionnaire
ISNCSCI	International Standards for Neurological Classification of Spinal Cord Injury
L	Lumbar
LDL	Low Density Lipoprotein
LPL	Lipoprotein Lipase
MAP	Mean Arterial Pressure
MET	Metabolic Equivalent of Task
MFIS	Modified Fatigue Index Scale
MPQ	McGill Pain Questionnaire
MRC	Medical Research Council
MVPA	Moderate-to-Vigorous intensity Physical Activity
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
ONS-4	Office for National Statistics 4-item questionnaire
PAR-Q	Physical Activity Readiness Questionnaire
PHQ-9	Participant Health 9-item Questionnaire
PICOS	Participant, Intervention, Comparator, Outcome and Study design
PIS	Participant Information Sheet
PPI	Patient and Public Involvement
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
PROSPERO	International Prospective Register of Systematic Reviews

PwP	Participant with Paraplegia
RCT	Randomised Controlled Trial
REACH-SCI	Reducing sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury
RoB-2	Risk of Bias tool 2
SCI	Spinal Cord Injury
SD	Standard Deviation
SF-36ww	Short-Form 36-item health-related quality of life walk-wheel questionnaire
SWiM	Synthesis Without a Meta-analysis
T	Thoracic
T2DM	Type 2 Diabetes Mellitus
TDF	Theoretical Domains Framework
TFA	Theoretical Framework of Acceptability
UK	United Kingdom
US	United States
USA	United States of America
WHO	World Health Organization

Chapter 1: Thesis Introduction

1.1 Spinal Cord Injury

Spinal cord injury (SCI) has been defined by the World Health Organization (WHO, 2013) as damage to the spinal cord as a result of trauma, disease or degeneration. Individuals with SCI experience motor, sensory and autonomic dysfunction across and below the site of the lesion (Kirshblum et al., 2011). The extent of the neurological deficit that results from SCI can be classified using the American SCI Association International Standards for Neurological Classification of SCI (ISNCSCI) scale (Kirshblum et al., 2020). The ISNCSCI scale is comprised of two main criteria. Firstly, the extent of the damage to the spinal cord, which is assessed in respect to whether the spinal cord is sufficiently damaged to eradicate all sensory and motor function below the lesion (i.e. a complete SCI), or whether some sensory and/or motor function below the lesion is spared (i.e. an incomplete SCI). Secondly, the neurological level of the injury is classified as the longitudinal section of the spinal cord column that is affected (cervical, thoracic, lumbar or sacral). The neurological level of injury has a disproportionate influence on the severity of the symptoms experienced (Kirshblum et al., 2011) and can be classified according to two main categories. Tetraplegia is the highest level and most severe SCI, characterised by impairment in large parts of the body. It has been defined as loss of motor, sensory and autonomic function in the upper limbs, trunk, lower limbs, cardiac and respiratory system caused by injury to cervical spinal levels (Paddison & Hexter, 2018). Paraplegia is defined as dysfunction of the trunk and lower limbs as a result of damage to the spinal cord at or below the first thoracic vertebrae (T1) (Figure 1). The condition is considered less severe than tetraplegia, as there is less arm, respiratory and autonomic involvement (Paddison & Hexter, 2018). As a result, individuals with paraplegia have greater capacity to remain physically active using the upper limbs and are, therefore, the population group of focus for this thesis.

In a long-term observational study across two British spinal injury centres from 1943 to 2010, 47% of individuals with SCI were classified as tetraplegic, whereas 53% were classified as paraplegic (Savic et al., 2017). Between 1990 and 2010, 51.7% of individuals with SCI were classified as tetraplegic, whereas 48.3% were classified as paraplegic (Savic et al., 2017).

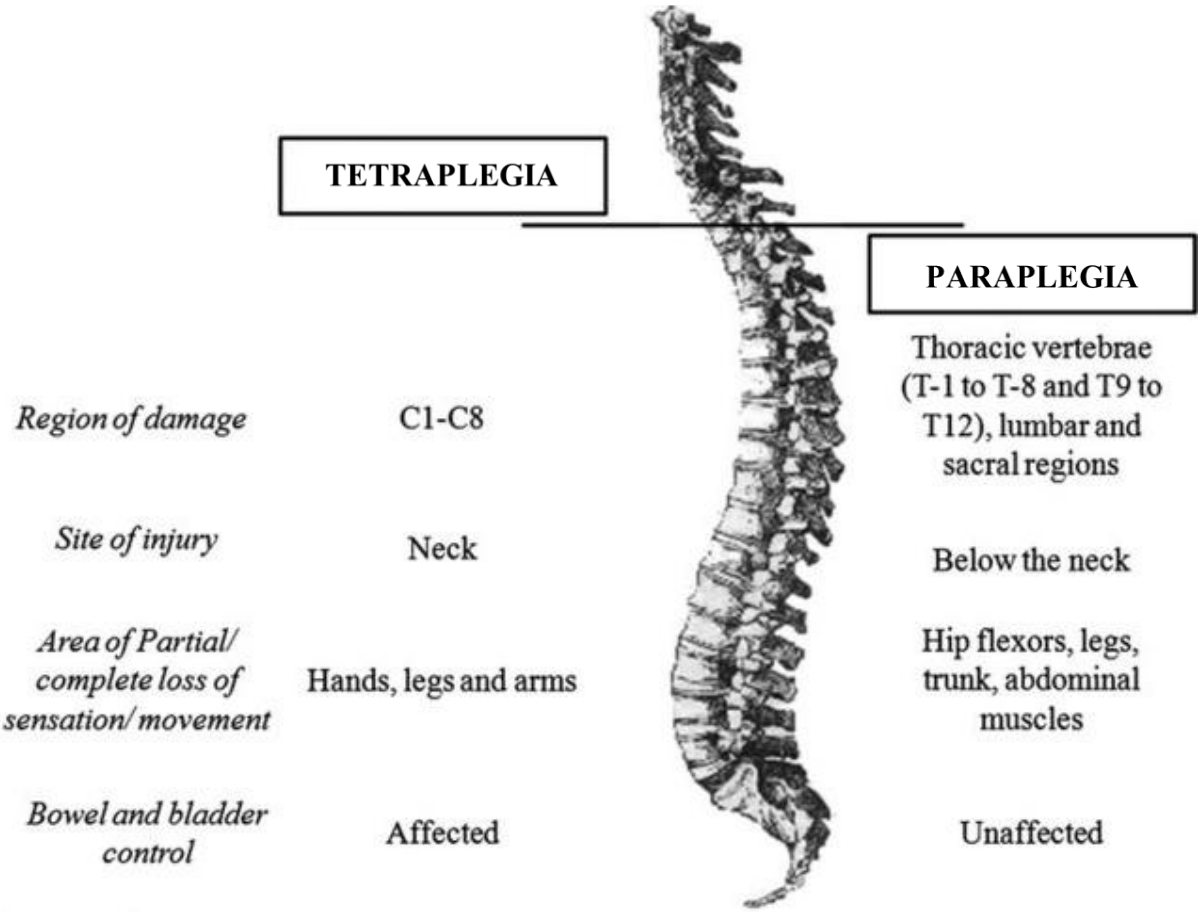

Figure 1. Neurological level of spinal cord injury, adapted from Shroff et al. (2016, pp. 6).

1.2 Prevalence of Spinal Cord Injury

In the United Kingdom (UK), there are approximately 4,400 new SCI cases each year (Spinal Research, 2024), a large upsurge from the previous figure of 2,500 per year in 2019 (Spinal Injuries Association, 2019). This increase is thought to be a result of improved reporting (Spinal Research, 2024). Physical trauma accounted for 49% of SCI patients admitted to UK spinal injury centres between 2017 and 2018, including causes such as falls, traffic collisions

and sport injuries (National Health Service [NHS] England, 2019). The remaining 51% of SCI cases were caused by non-traumatic events, including tumours, infection and spinal degeneration (NHS England, 2019). Young adult males aged 20-29 are disproportionately affected by SCI (Spinal Research, 2015), likely due to this group taking more risks and undertaking more physical or dangerous professions (Ibrahim et al., 2013). The average age at injury has increased since the turn of the century in the UK (McCaughey et al., 2016), United States of America (USA) (Devivo & Chen, 2011), Finland (Ahoniemi et al., 2008) and Spain (Berg et al., 2011). McCaughey et al. (2016) attributed this to the ageing of the general population.

1.3 Living With Paraplegia

Classification of paraplegia is broad, including complete or incomplete injuries at the thoracic, lumbar or sacral regions (Kirshblum et al., 2011), meaning the degree of remaining function and sensation can vary greatly between individuals. Those with a thoracic injury generally have reduced function of the trunk, lower limbs, bladder and bowel, but arm and hand function remain intact. Lumbar injury usually results in a loss of function within the lower limbs, bladder and bowel, but arm, hand, and trunk function remain. Those with sacral nerve damage usually lose some function within the lower limbs, bladder and bowel, but retain much more function than those with a lumbar or thoracic injury, meaning they are usually ambulant (Nas et al., 2015). Thoracic and lumbar injury causes severe physical disability, meaning these individuals are generally manual wheelchair-users (Haisma et al., 2006; Post et al., 1997). Wheelchair use poses personal, interpersonal and environmental barriers to undertaking functional activities and participating socially (Meyers et al., 2002). However, retained arm function in those with paraplegia permits them to maintain significant levels of independence, via the ability to perform transfers and manual wheeling for movement (Jiang et al., 2021).

1.4 Rehabilitation

Treatment and rehabilitation from SCI are lengthy and complex processes (Nas et al., 2015). Therefore, the rehabilitation process requires a multi-disciplinary approach to ensure optimal recovery, with strategies in place to support mobility, respiratory function, management of spasticity, bone density, attenuation of muscle atrophy and maximise quality of life (Nas et al., 2015).

The rehabilitation journey typically begins in an inpatient setting, after it is ensured that the individual is medically stable and has established spinal stability (Kirshblum et al., 2007). After which, the individual is ready to start targeting medical, physical, social, emotional, recreational, vocational and functional recovery from SCI (Kirshblum et al., 2007). Inpatient rehabilitation in a specialised SCI unit involves an individualised rehabilitation plan facilitated by a multi-disciplinary team (Kirshblum et al., 2007). However, some individuals experience delays in admission or do not get admitted to a specialised unit, meaning they receive hospital care that is not focused on SCI (Donovan et al., 2017). It has been shown that those who are admitted to a specialised unit experience improved outcomes than those who do not (McRae et al., 2020; Smith, 2002). Such difference in patient outcomes highlights a disparity in care between individuals with SCI across the UK that may affect time of discharge, functional attainment, presence of comorbidities and preparedness to adapt to a community-based setting (McRae et al., 2020; Smith, 2002).

Upon initial discharge from inpatient rehabilitation, individuals may receive advice and support from charities and community organisations, receive support from family and friends, and may schedule out-patient appointments at a hospital or SCI unit (Bray et al., 2025; Lennox et al., 2018; Vissers et al., 2008). Due to the difficult process of adapting to the home environment after this initial discharge into the community, individuals with SCI need continued support

during the transition process (Vissers et al., 2008). However, there is often a gap in services whilst individuals are on the waiting list for community physiotherapy and occupational therapy services (Bray et al., 2025). Therefore, community rehabilitation is often delayed and limited in comparison to inpatient services, meaning further support may be required throughout this stage of SCI rehabilitation.

1.5 Secondary Health Conditions

Due to significant improvements in medical care and treatment, average remaining life expectancy after traumatic paraplegia has increased from 25.5 years (52.3% of that of the general population) in the 1940s to 47 years (78.6% of that of the general population) between 2010 and 2014 (Savic et al., 2017). Despite this, SCI is still a life-changing incident that causes serious physical disability and a range of secondary health conditions that can negatively affect quality of life (Adriaansen et al., 2016; Dijkers, 2005). Individuals with SCI generally report 8-14 secondary health problems per year (e.g. pressure ulcers, pain, poor psychological and/or social wellbeing, obesity, high blood pressure, type 2 diabetes, high cholesterol), which often occur concurrently (Piatt et al., 2016). Therefore, the development and implementation of interventions that can reduce the risk of and better manage secondary health conditions after SCI is needed.

1.6 Cardiovascular Disease

A major secondary health condition experienced by individuals with SCI is cardiovascular disease (CVD) (Cragg et al., 2013a). Cardiovascular disease is a group of conditions that adversely affects the function and/or structure of the cardiovascular system (Lopez et al., 2023; Stefanovska & Bračič, 1999). Examples of CVD include coronary artery disease (resulting in myocardial ischaemia, heart attack and/or heart failure), cerebrovascular disease (including stroke), peripheral artery disease and aortic atherosclerosis (Benjamin et al., 2018).

1.7 Prevalence of Cardiovascular Disease

The global incidence of CVD has risen from 271 million in 1990 to 523 million in 2019 (Roth et al., 2020). Cardiovascular disease was the leading cause of death worldwide in 2022, accounting for 19.8 million deaths (Mensah et al., 2023a; Mensah et al., 2023b). This represents a significant increase from the 12.1 million deaths caused by CVD in 1990 (Mensah et al., 2023a; Mensah et al., 2023b). This is despite better prevention and treatment options in recent years, including enhanced hypertension control, greater use of statins to lower cholesterol, more common arterial bypass surgeries, and the application of thrombolysis and stents to prevent myocardial infarction (Mensah et al., 2017).

Greater CVD incidence and mortality in the general population may be due to population ageing (Xie et al., 2022) and the industrialisation of modern society (Lopez et al., 2023). Modern industrialisation is characterised by sedentary office jobs, working from home, longer working hours, longer commutes, less leisure time for physical activity, intake of highly processed foods with high saturated fat content, and a high caloric intake (Lopez et al., 2023). Given the upsurge in CVD incidence and mortality in recent decades, alongside the adverse lifestyle factors observed in modern society, it is evident that CVD remains a significant burden globally, necessitating interventions that aim to reduce its risk factors.

Individuals with SCI are at a significantly greater risk of CVD than the general population, with a 2.72-fold and 3.72-fold greater odds of heart disease and stroke, respectively (Cragg et al., 2013a). Among those with SCI (n = 356), 5.7% had experienced a stroke and 17.1% had experienced heart disease, compared to just 1.1% and 4.9%, respectively, amongst non-disabled individuals (n = 60,675) (Cragg et al., 2013a). This increased risk is understood to be due to a decrease in metabolic rate, progressive sarcopenia (age related loss of skeletal muscle mass and function) and increased body fat after injury (Gorgey & Dudley, 2007). Additionally,

due to improved medical treatments and management of injury, the average remaining life expectancy after sustaining SCI is higher than in previous decades (Savic et al., 2017). Therefore, as individuals with SCI are living for longer, this increases time of exposure to CVD risk factors (Dhingra & Vasan, 2012). This rationalises the need for interventions to reduce CVD risk in this population group.

1.8 Risk Factors for Cardiovascular Disease

Intrinsic, uncontrollable factors that increase CVD risk include family history of CVD (Kolber & Scrimshaw, 2014), genetic dispositions such as familial hypercholesterolaemia or familial combined hyperlipidaemia (Skoumas et al., 2007), South Asian or African ethnicity (Chiu et al., 2015), being male (Kaseta et al., 1999), and older age (Dhingra & Vasan, 2012). The strongest modifiable risk factors for CVD across 52 countries, regardless of age or sex, were smoking, hyperlipidaemia, history of hypertension, diabetes, visceral obesity, psychosocial factors, fruit and vegetable intake, alcohol consumption, and physical activity (Yusuf et al., 2004). Due to the prevalence of modifiable lifestyle factors that exert an influence on CVD risk, Public Health England (2019) published guidelines that recommended eating a diet plentiful in fruit, vegetables, fibre and oily fish, whilst low in salt sugar and saturated fat, reducing excess alcohol consumption, stopping smoking, and performing at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity per week. To know if guidelines are effective, a number of biomarkers linked to CVD should be investigated.

1.9 Cardiovascular Disease Biomarkers

A biomarker is “a characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention” (Biomarkers Definitions Working Group, 2001, pp. 91). Biomarkers are useful tools to identify high-risk individuals, diagnose conditions promptly and accurately, make

prognoses, and guide treatment options (Vasan, 2006). A biomarker may be measured via a biological sample (e.g. blood, urine or tissue), a recording obtained from an individual (e.g. blood pressure, body composition or anthropometry), or via an imaging test (e.g. echocardiogram or computed tomography scan) (Vasan, 2006). The measurement of biomarkers in clinical trials is an effective and reliable way of assessing the effectiveness of interventions to improve health outcomes (Biomarkers Definitions Working Group, 2001).

Multiple biological pathways have been implicated in the aetiology of CVD, meaning the potential for biomarkers is wide-reaching, and the measurement of more than one is common practice (Stoner et al., 2013). Cardiovascular disease biomarkers are often grouped according to the pathologic process they represent, such as inflammation, oxidative stress or metabolic function (Dhingra & Vasan, 2017). In this PhD project, CVD biomarkers are grouped according to body composition, blood pressure, glycaemia and lipid profile. The following sections discuss CVD biomarkers in the general population, whereas SCI-specific literature is reviewed in Chapters 3 and 4.

1.9.1 Body Composition Biomarkers

Body composition is the relative proportion of tissue types in an individual, including lean mass, fat mass and overall mass (Hawkesworth, 2012). Anthropometry is the measurement of body size and proportions relating to height, length, and circumference (Wang et al., 2000). Both are used for monitoring overweight and obesity in the population, which are at epidemic levels globally. In 2022, 29% of UK adults were obese (Body Mass Index [BMI] $\geq$ 30), and 64% were either overweight or obese (BMI $\geq$ 25) (NHS England, 2024). This is in comparison to 15% being obese and 53% being overweight or obese, respectively, in 1993 (NHS England, 2024). Obesity can accelerate the risk for CVD, as greater body fat mass can have a detrimental impact on lipid profile, blood pressure, glycaemia, and inflammation (Ortega et al., 2016).

Excess adiposity in central areas surrounding key organs is a strong indicator of CVD (Lear et al., 2012), with biomarkers of central adiposity such as waist circumference significantly associated with adverse risk factors for CVD such as glucose, blood pressure, and lipid profile (Lam et al., 2015). As a result of body composition being closely related to CVD, such measures should be utilised as CVD risk biomarkers.

1.9.2 Blood Pressure Biomarkers

Blood pressure is linked to CVD risk in two different ways. Firstly, greater blood pressure variability can act as a trigger for CVD events such as myocardial infarction and stroke, via increased mechanical stress on vascular walls. Secondly, a high resting blood pressure (hypertension) causes endothelial dysfunction and atherosclerosis (Kario et al., 2017). Both of these conditions lead to the narrowing of arteries, restricting blood flow to major organs and increasing risk of myocardial infarction and stroke (Bentzon et al., 2014). Resting blood pressure is measured as systolic blood pressure, diastolic blood pressure and mean arterial pressure (MAP) (Turner et al., 2007). High levels of systolic blood pressure, diastolic blood pressure and MAP were significant predictors of CVD incidence in a large cohort study of 11,150 men (52 ± 3 years) (Sesso et al., 2000). The evidence discussed here suggests that blood pressure is strongly linked to CVD, meaning these biomarkers should be measured in research related to CVD.

1.9.3 Glycaemic Biomarkers

Glucose is an essential substrate for energy production, with uptake from the bloodstream being mediated by the hormone insulin (Satoh, 2014). Chronic high levels of blood glucose can blunt the response to insulin (insulin resistance), meaning insufficient glucose passes into the cells and instead remains in the bloodstream. Insulin resistance has an adverse effect on endothelial function, blood pressure and inflammation (Bornfeldt & Tabas, 2011; Paneni et al., 2014),

which are all contributing factors to atherosclerosis (Kario et al., 2017). A meta-analysis of 65 studies (n = 516,325) showed that fasting glucose, fasting insulin and homeostatic model assessment of insulin resistance (HOMA-IR) were associated with incident CVD in individuals without diabetes (Gast et al., 2012). Insulin resistance may also lead to type 2 diabetes mellitus (T2DM), which is when the body can no longer produce enough insulin to compensate for the progression of insulin resistance. In 2022, 10% of UK adults had glycated haemoglobin A1C (HbA1C) levels indicative of T2DM (NHS England, 2024). Individuals with T2DM are more likely to experience myocardial infarction and death than individuals without T2DM (Haffner et al., 1998). Therefore, glycaemic biomarkers appear to be risk factors for CVD, meaning their measurement is warranted in CVD research.

1.9.4 Lipid Profile Biomarkers

Lipids are fatty, waxy or oily compounds found in adipocytes, cell membranes and the bloodstream, and are fundamental for energy production, cell signalling and cell structure (Ekroos et al., 2020). Their water insolubility means they must bind to proteins to form lipoproteins, facilitating lipid transport in the bloodstream (Feingold & Grunfeld, 2000). High levels of low-density lipoprotein (LDL) cholesterol, apolipoprotein B (ApoB), total cholesterol and non-high-density lipoprotein (HDL) cholesterol, as well as low levels of HDL cholesterol and apolipoprotein A1 (ApoA1) are associated with an increased risk of myocardial infarction (Parish et al., 2009). This is because LDL cholesterol cells (containing ApoB cells) and triglycerides initiate atherosclerotic plaques by penetrating the walls of arteries, leading to subsequent proliferation and rupture, which can cause clots and stroke (Goldstein & Brown, 2015). Conversely, HDL cholesterol cells (containing ApoA1 cells) dampen the number and activity of LDL cholesterol and triglycerides, which protects against atherosclerosis (Goldstein & Brown, 2015). Therefore, both pro- and anti-atherogenic lipids are linked to CVD risk, warranting their measurement as a CVD biomarker.

It has been suggested that modifiable lifestyle factors, such as sedentary behaviour, should be targeted to improve CVD biomarkers related to blood pressure, body composition, glycaemia and lipid profile (Bell et al., 2023).

1.10 Sedentary Behaviour

Sedentary behaviour has been defined as any waking behaviour characterised by an energy expenditure of ≤ 1.5 metabolic equivalents (MET) whilst in a sitting or lying posture (Tremblay et al., 2017). Metabolic equivalents are used to measure how much energy above an individual's basal metabolic rate (1.0 MET) is required to perform a given task, measured as kilocalories expended per kilogram of body weight per hour (kcal/kg/h) (Ainsworth et al., 2011). Sedentary behaviour constitutes a range of very low-intensity activities such as television viewing, playing video games, using a computer, sitting at school or work, and sitting whilst commuting (Park et al., 2020). The UK Chief Medical Officer's (2019) physical activity guidelines recommend that disabled and non-disabled adults should minimise the amount of time spent being sedentary and, when physically possible, to break up long periods of inactivity with physical activity of at least light intensity. However, there are no numerical sedentary behaviour guidelines, necessitating further research to inform the development of specific thresholds.

Sedentary behaviour is measured quantitatively using subjective or objective methods. Subjective measures can include self-report recall questionnaires, such as the International Physical Activity Questionnaire (Craig et al., 2003), Global Physical Activity Questionnaire (Armstrong & Bull, 2006), SIT-Q (Wijndaele et al., 2014), and the Sedentary Behaviour Questionnaire (Rosenberg et al., 2010). Subjective measures of sedentary behaviour are useful to gain insight into an individual's activity profile, either directly via a sedentary time measurement, or through proxy via measurement of sitting time, television time or screen time.

Proxy measurements are generally considered accurate reflections of sedentary time but do not include all sedentary behaviours that occur throughout the day, so any conclusions must be stated in terms that are limited to those behaviours (Tremblay et al., 2010). Additionally, subjective methods are prone to recall bias, response bias, social desirability and overreporting or underreporting (Healy et al., 2011a). An objective measurement of sedentary behaviour can be attained via the use of accelerometers worn at the wrist, thigh or chest, that gather data on human movement based on the inertial force exerted by the user across a number of axes. Accelerometry-measured sedentary behaviour is considered more accurate than self-report (Prince et al., 2020). However, accelerometry comes with drawbacks, including wear-time differences between users, lack of context of behaviour (work, leisure, commuting) and possible activity misclassification (Dempsey et al., 2018).

1.11 Distinction Between Sedentary Behaviour and Physical Activity

Any waking behaviour above the sedentary threshold of 1.5 MET is classified as physical activity (Tremblay et al., 2017), which is defined as energy expenditure via contraction of skeletal muscles (Caspersen et al., 1985). Sedentary behaviour and physical activity exist along an energy expenditure continuum, starting with sedentary behaviour at the lowest end and ascending with light-intensity physical activity (e.g. wheeling on tile, dusting, folding clothes), moderate-intensity physical activity (e.g. wheeling on pavement, vacuuming) and finally, vigorous-intensity physical activity (e.g. wheeling on carpet, playing sport, weight training) at the highest end (Collins et al., 2010; Sedentary Behaviour Research Network, 2012; Verschuren et al., 2016). The UK Chief Medical Officer's (2019) physical activity guidelines recommends that each week, disabled and non-disabled adults should accumulate at least either 150 minutes of moderate-intensity physical activity, 75 minutes of vigorous-intensity physical activity, even shorter duration of very vigorous-intensity physical activity, or a combination of these.

Physical activity guidelines were developed in 2018 to improve fitness and cardiometabolic health in individuals with SCI (Martin Ginis et al., 2018). Recommendations included 20 minutes of moderate to vigorous-intensity aerobic exercise two times per week, and three sets of moderate to vigorous-intensity strength exercises for each major functioning muscle group, twice weekly (Martin Ginis et al., 2018). A study found that just 12% (n = 9) of a sample of 73 individuals with SCI met these physical activity guidelines (Rocchi et al., 2017). In comparison, 63.4% of UK adults reach the general population physical activity guidelines of 150 minutes of MVPA per week (Sport England, 2025). This discrepancy is likely due to wheelchair-users with SCI facing unique intrapersonal, interpersonal, institutional, community and policy level barriers to physical activity (Mat Rosly et al., 2018). This data suggests that increasing MVPA as a target to reduce CVD risk may be challenging for this group.

The terms sedentary behaviour and physical inactivity are often used interchangeably, but in fact they each refer to distinct concepts (van der Ploeg & Hillsdon, 2017). Whilst sedentary behaviour concerns periods of very low energy expenditure (Tremblay et al., 2017), physical inactivity can be defined as not meeting guidelines of 150 minutes of moderate to vigorous-intensity physical activity per week (Sedentary Behaviour Research Network, 2012; Tremblay et al., 2017). Therefore, an individual can be both sedentary and physically active in the same day. By the same logic, they can also be physically inactive, but not sedentary (van der Ploeg & Hillsdon, 2017). This helps to explain why public health guidelines include distinct recommendations for sedentary behaviour and physical activity. While guidelines exist around sedentary behaviour for the general population, quantitative recommendations regarding time and breaks in sedentary behaviour are not included. Additionally, there are no sedentary behaviour guidelines for individuals with SCI. Therefore, more research into sedentary behaviour needs to be conducted in order to inform the development of quantitative guidelines for the general population and individuals with SCI.

1.12 Prevalence of Sedentary Behaviour

A US general population study including 51,896 individuals showed that between 2001 and 2016, average sitting time amongst adults increased significantly from 5.5 hours/day to 6.4 hours/day (Yang et al., 2019). European Union population data comprising 96,004 individuals showed that between 2002 and 2017, the percentage of adults engaging in sedentary behaviour at least 8.5 hours/day significantly increased from 49.3% to 54.5% (López-Valenciano et al., 2020). This increase in sedentary behaviour may be due to technological advancements and greater screen time with the use of television, computers and smartphones (Bertuol et al., 2023). These findings suggest that sedentary behaviour has increased in recent years in higher-income countries.

1.13 Sedentary Behaviour in Individuals With Paraplegia

There has been limited research in relation to sedentary behaviour in individuals with paraplegia (Verschuren et al., 2016). The lack of knowledge in this area explains why there are no public health or rehabilitation guidelines for sedentary behaviour in individuals with SCI. In addition, the widespread measurement of sitting time as a proxy of sedentary time does not translate to SCI populations as many wheelchair-users with SCI are sitting for the majority of waking hours. Therefore, the use of sitting time as a proxy of sedentary behaviour does not take into account the upper-limb physical activity required for daily activities and mobility for a manual wheelchair-user. In the limited evidence to date, accelerometry data revealed that a sample of 47 individuals with SCI spent 12.2 hours of the waking day sedentary (energy expenditure of $\leq$ 1.5 METs) (Postma et al., 2020). Research to inform public health guidelines concerning sedentary behaviour in individuals with SCI is warranted, because evidence suggests that sedentary behaviour is an independent risk factor for CVD. While useful, guidelines alone are not always enough to encourage long-term behaviour change.

1.14 Behaviour Change Interventions

Behaviour change interventions have been defined as theory-driven strategies to encourage healthy behaviour (Jiménez & Mills, 2012). Health interventions targeting behaviours such as tobacco smoking, alcohol intake, diet and physical activity (Conner & Norman, 2017) are especially important, as a high proportion of chronic diseases are linked to modifiable lifestyle behaviours (Christ & Latz, 2019; Jiménez & Mills, 2012; NICE, 2014). The purpose of health behaviour interventions is to reduce undesirable behaviours and replace them with healthier behaviours, with the aim of reducing overall risk or improving management of chronic disease (An & Song, 2020).

Health behaviour change interventions can be implemented across a number of levels, including individual, community and societal (Jiménez & Mills, 2012). Firstly, the individual level involves encouraging someone to change their behaviour. This can include lifestyle changes (e.g., changing diet, doing exercise, cessation of smoking) and healthcare-seeking behaviour changes (e.g. regular testing to measure biomarkers) (Cutler, 2004; Jiménez & Mills, 2012). Secondly, community-level interventions involve encouraging behaviour change via modification of the environment amongst a subset of the population who belong to a particular group, such as those who live in the same neighbourhood, attend the same school or work for the same company (Jiménez & Mills, 2012). This may include mass media, population screening and the use of community organisations to communicate messages promoting healthy behaviour (Cutler, 2004). Lastly, societal-level interventions involve governing bodies conducting large-scale, national initiatives to change the behaviour of the general population (Jiménez & Mills, 2012). This may include national advertising campaigns, policy change or restrictions (Cutler, 2004). Although behaviour change interventions operate over a number of levels and settings, their effectiveness is largely dependent on how they are delivered and the theoretical principles that underpin them.

1.15 Behaviour Change Theory

Literature suggests that behaviour can be modified effectively by utilising behaviour change interventions, but that greater efficacy can be achieved by grounding the intervention with appropriate theory (Davis et al., 2015). Interventions grounded in pertinent behaviour change theory bring about greater behaviour change outcomes than those developed without theory in both non-disabled individuals (Davis et al., 2015) and individuals with physical disabilities, such as paraplegia (Ma & Martin Ginis, 2018). It is likely that the effectiveness of interventions incorporating behaviour change theory stems from the identification of precursors to behaviour and causal factors of change, each of which can be selectively targeted and exploited with appropriate behaviour change techniques (BCT) (Davis et al., 2015; Michie et al., 2008). Interventions that are not developed using appropriate behaviour change theory may be imprecise, with a predisposition to select ineffective BCTs to target a given behaviour (McEwan et al., 2019). Therefore, interventions should be grounded in behaviour change theory so that they are more likely to be effective.

1.16 Aims

The overall aim of this doctoral thesis was to develop and evaluate an intervention targeting reductions and breaks in sedentary behaviour to improve CVD biomarkers in individuals with paraplegia. This doctoral thesis is divided into three distinct studies, each with its own aims.

1.16.1 Study 1

The aims of this study were to systematically review (1) the effects of interventions on sedentary behaviour, and (2) the effects of these interventions on CVD biomarkers in individuals with paraplegia (Chapter 4).

1.16.2 Study 2

The aim of this study was to develop an intervention, using the Behaviour Change Wheel (BCW) framework, to reduce and break up sedentary behaviour in individuals with paraplegia across different stages of the SCI rehabilitation pathway (Chapter 5). The objectives were to (1) explore the lived experiences of individuals with paraplegia regarding barriers and facilitators to breaking up and reducing sedentary behaviour, and (2) identify intervention content and implementation options for the intervention.

1.16.3 Study 3

The primary aim of this study was to assess the acceptability, safety and feasibility of the intervention to reduce and break up sedentary behaviour in individuals with paraplegia (Chapter 6). The main objectives were to explore participant (1) acceptability by ascertaining agreement between qualitative and quantitative data using a combined mixed-methods approach, (2) safety and (3) feasibility of the intervention. The secondary objectives were to evaluate (4) participant engagement, (5) acceptability of data collection procedures, (6) feasibility of recruiting and retaining participants in the study, and (7) preliminary efficacy of the intervention.

1.17 Thesis Structure

Following the introductory section (Chapter 1), this thesis will include a methodology section which will detail the frameworks and methodological approaches adopted during this PhD (Chapter 2). The methodology will be followed by a general overview of the literature to give a broad summary of previous research into sedentary behaviour, CVD and interventions in individuals with SCI, other clinical populations and non-disabled individuals (Chapter 3). Each PhD study will follow, comprising a systematic review of the effects of interventions on sedentary behaviour and CVD biomarkers in individuals with paraplegia (Chapter 4), a study

detailing the development of a sedentary behaviour intervention for this population using the BCW (Chapter 5), and then a feasibility study evaluating the intervention (Chapter 6). The thesis will conclude with a general discussion and conclusion of the findings from this research (Chapter 7).

1.18 Contributions of Each Chapter to Intervention Development

Each chapter of this thesis is intended to contribute to the overall intervention development, with the findings of each chapter largely informing the resulting steps taken in the next. The General Overview of the Literature (Chapter 3) provides context of favourable intervention approaches in other populations, which informs the design of the systematic review in individuals with paraplegia (Chapter 4). The findings of the systematic review (Chapter 4) provide data around which intervention characteristics may or may not be effective in the target population, which contributes to the design of the intervention in the intervention development study (Chapter 5). The needs, preferences and suggestions of key stakeholders in the co-design process (Chapter 5) also directly informed the development of the intervention. Data around the experiences of participants taking part in the developed intervention and feasibility evaluation (Chapter 6) can inform amendments to improve acceptability, safety and feasibility prior to future evaluation in a larger trial.

Chapter 2: Methodology

2.1 Philosophical Standpoint

This PhD thesis adopts a pragmatist paradigm. Pragmatism is a paradigm that rejects concepts such as "truth" and "reality", instead focusing on "what works" (Teddlie & Tashakkori, 2009). In pursuit of finding what works, it advocates for the use of mixed-methods research (Johnson & Onwuegbuzie, 2004; Teddlie & Tashakkori, 2009). As a result, this thesis also adopts a mixed-methods approach, in which both qualitative and quantitative methods are undertaken to carry out the research and the results integrated (Creswell, 2021). Mixed-method approaches allow for more in-depth, comprehensive research, considering both subjective data that deals with thoughts and feeling, and objective data that deals with absolutes (Creswell, 2021). Utilising mixed-methods is also able to compensate for deficiencies in either method alone and, therefore, has been suggested to produce higher-quality research (Creswell, 2021; Johnson & Onwuegbuzie, 2004; Teddlie & Tashakkori, 2009). The Medical Research Council (MRC) Framework for Developing and Evaluating Complex Interventions encourages mixed-methods to solve real-world problems (Skivington et al., 2021), further demonstrating the relevance of this approach in the present research.

When considering the philosophical standpoint of this PhD thesis, positivist and interpretivist approaches were considered, which may align well with the quantitative and qualitative aspects of some chapters, respectively. However, neither of these paradigms were adopted, as neither matched the aims and practical needs of this multidisciplinary project as well as pragmatism did. Pragmatism provided a flexible, more comprehensive framework, from which suitable methodological decisions were made (Alharahsheh & Pius, 2020).

2.2 Researcher Positionality Statement

Health interventions should be generalisable to people with diverse characteristics within their target populations (de Boer et al., 2025). However, unconscious bias stemming my personal characteristics and background (see more detail in Chapter 5; Page 101) could have affected the intervention development. In addition, I have a family member with paraplegia, meaning any pre-conceived ideas I had about which intervention components may work for this one individual could have been projected, sub-consciously, into the development of an intervention intended for a wider population. Additionally, as an individual with a background in sport, health and exercise science research, I have prior knowledge of the types of intervention components that have been successful in improving sedentary behaviour and CVD biomarkers in sedentary behaviour interventions, which could have influenced the type of intervention developed. However, input from the researchers in intervention development could also be considered a strength, as their expertise could strengthen the design process (Kramer et al., 2010).

As bias is inevitable in research, it cannot be eradicated entirely (Gerhard, 2008). Instead, reasonable steps should be taken to minimise its impact throughout the research, where possible (Gerhard, 2008). For example, frameworks and guidelines were adhered to strictly to ensure best practice was followed, study protocols were pre-registered to ensure replicability and trustworthiness, group discussions between researchers were undertaken to check individual biases, and the input of key stakeholders was sought regularly throughout the intervention development process to ensure its appropriateness. More detail around these steps is included within the individual chapters.

2.3 Medical Research Council Framework for Developing and Evaluating Complex Interventions

Health interventions are generally complex, with multiple interacting components, resulting in room for interpretation in how they are developed and evaluated by researchers (Zang et al., 2022). In an effort to ensure consistency and generalisability between interventions, the MRC developed a framework for developing and evaluating complex interventions (Skivington et al., 2021). This framework consists of four phases, including development, feasibility, evaluation, and implementation. The research studies completed as part of this thesis were conducted in line with development (Chapters 4 and 5) and feasibility (Chapter 6) phases of the MRC framework.

2.3.1 Development

The first step of the development process includes reviewing the evidence base, which can be achieved with a systematic review of the current literature in the field, as detailed in Chapter 4 (Skivington et al., 2021). This helps to identify research gaps and reveal favourable intervention characteristics and delivery modes (Higgins et al., 2024).

The second step of intervention development involves the creation of an intervention protocol, which is detailed in Chapter 5. It is important to ensure that the protocol is appropriate for the needs of the target population to maximise its chances of success when evaluated and implemented (Chapter 6). Methods of ensuring suitability to the target population include gaining input from patient and public involvement (LeMaster, 2020), as well as using participatory research approaches, such as co-design, to include the target population in the intervention development process (Vargas et al., 2022).

2.3.2 Feasibility and Piloting

The feasibility phase of the MRC framework is to conduct a feasibility and/or pilot study to determine whether the intervention is feasible to undertake within a research study, which is reported in Chapter 6. Outcomes usually include recruitment, eligibility and drop-out rates, acceptability to the participants, safety of the participants and researchers, and, where appropriate, efficacy in affecting the proposed primary outcome of the final study (Skivington et al., 2021). This process can also help refine procedures and determine sample size requirements for a full study. Depending upon its feasibility, alongside consideration of acceptability, safety and preliminary efficacy, a decision will be made as to whether the intervention should progress to a definitive randomised controlled trial (RCT) (1) unchanged, (2) with changes, or (3) not progress at all (Avery et al., 2017; Herbert et al., 2019).

2.3.3 Evaluation

Interventions deemed feasible and appropriate for progression via a pilot and/or feasibility study should be evaluated for their efficacy to impact the primary outcomes of the study and cost-effectiveness in a further, longer-term study (Ahuja, 2019; Hariton & Locascio, 2018). The MRC framework recommends the use of an RCT to evaluate these outcomes (Skivington et al., 2021). This was not completed as part of this thesis as it is outside the scope of this PhD project.

2.3.4 Implementation

Interventions deemed effective for impacting primary outcomes and cost-effective are considered appropriate to be implemented into healthcare policy and/or guidance (Skivington et al., 2021). This phase was also not completed due to being beyond the scope of this PhD thesis.

2.4 Behaviour Change Theory

A number of health-related theories have been applied in the design of behaviour change interventions, such as the Health Belief Model (Rosenstock, 1977), Theory of Planned Behaviour (Ajzen, 1991), Self-determination Theory (Ryan & Deci, 2000) and Social Cognitive Theory (Bandura, 1986). Whilst these theories allow us to consider and explain some of the key influences of behaviour, they focus on separate influences of behaviour and were not developed to explicitly inform intervention development. The COM-B model was developed with the specific intention of informing intervention development, hence this model being at the hub of the Behaviour Change Wheel (BCW) intervention development framework (explained in section 2.4) (Michie et al., 2011). Capability (C) refers to the physical or psychological capability of an individual to perform a behaviour (B), Opportunity (O) refers to external factors (social and physical) that make the desired behaviour possible or not, whilst Motivation (M) refers to the conscious and sub-conscious desire to engage in a particular behaviour. The COM-B is a comprehensive model, with other theories being incorporated into the development of each of its domains. For example, the Capability domain overlaps with Social Cognitive Theory. the Opportunity domain overlaps with the Theory of Planned Behaviour, and the Motivation domain overlaps with the Theory of Planned Behaviour, Health Belief Model and Self-determination Theory. Therefore, the comprehensive nature of the COM-B model incorporates individual strengths of other behavioural theories and compensates for the weaknesses of using any one theory alone. As a result of these factors, the COM-B model was the core theory used within this thesis.

2.5 Behaviour Change Wheel

Whilst a behaviour change theory explains behaviour, frameworks are commonly utilised as a practical tool for using this behavioural explanation to design coherent interventions. Whilst numerous frameworks exist to guide the design process of behaviour change interventions, few

are linked to a prior behavioural diagnosis. The Intervention Mapping Framework provides detailed guidance through the intervention development process, with a strong link to a prior behavioural diagnosis (i.e. exploring determinants of behaviour via barriers and facilitators) (Bartholomew et al., 1998). However, once intervention concepts are developed using the Intervention Mapping Framework, there is minimal structure to map these concepts to pre-defined taxonomies to allow easy comparison with other interventions. Therefore, an alternative strategy is required to underpin this PhD thesis, which adequately links behavioural diagnoses to intervention design; this can then be mapped to pre-defined taxonomies to facilitate categorisation and comparison with other interventions.

The BCW (Figure 2) was developed in 2011 by researchers in the field of health psychology, with the intention of being the most comprehensive intervention development framework (Michie et al., 2011). The BCW integrates 19 behaviour change theories into one coherent framework and encourages a systematic and evidence-based approach to behaviour change, promoting more successful intervention outcomes (Michie et al., 2014). Unlike many other behavioural frameworks, the BCW is centred around the process of intervention development. In addition, the BCW is strongly aligned with UK health and care research and has been adopted within many public health services (Public Health England, 2019b). The adoption of the BCW into public health services suggests that health interventions guided by this framework may benefit from seamless implementation into usual clinical practice. Most crucially, however, at the crux of the initial behavioural diagnosis of the BCW framework lies the core theory used at the heart of this thesis, the COM-B model, aligning it closely with this PhD thesis. Therefore, the BCW was selected as the most appropriate framework to mobilise the COM-B model and guide the development stage of the MRC framework in this thesis.

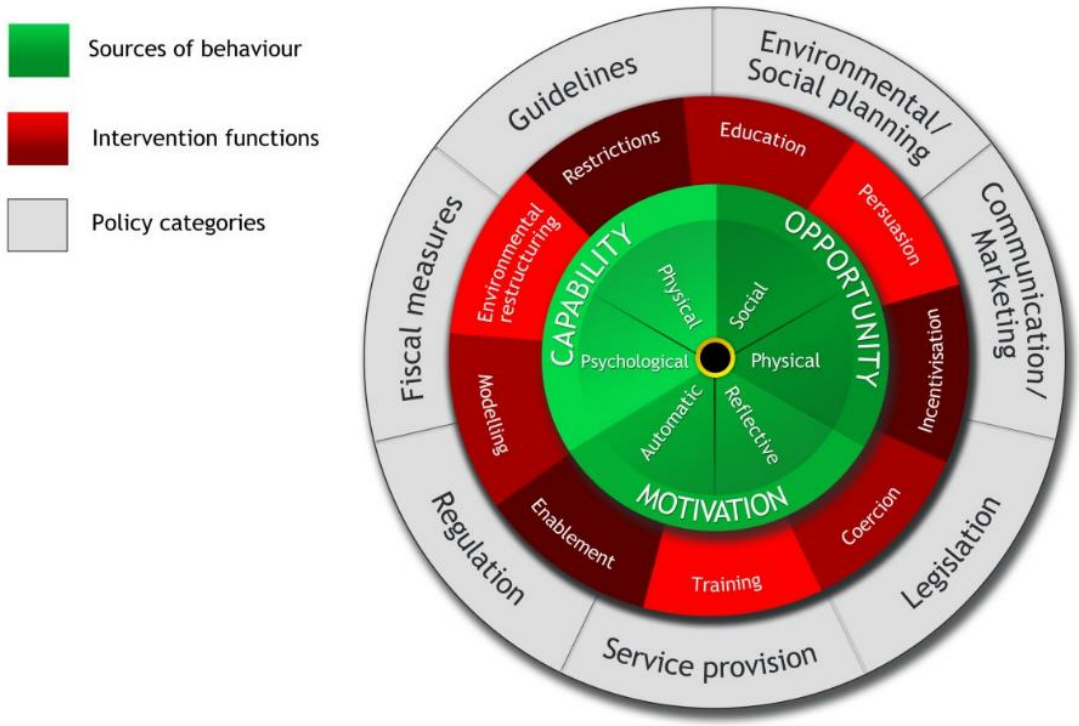

Figure 2. The Behaviour Change Wheel, reused from Michie et al. (2011, pp. 1).

2.5.1 Stage 1: Understanding the Behaviour

The first stage of the BCW is to understand the behaviour by defining the problem in behavioural terms, selecting and specifying the target behaviour and identifying what needs to change in order for a behaviour change intervention to be effective (Figure 3). This can be achieved via the COM-B model which outlines three main factors which are key to behaviour change. This can be further supported with the Theoretical Domains Framework (TDF) (Cane et al., 2012), which is used in intervention design to identify, assess and address determinants of behaviour according to 14 domains (knowledge, skills, social/professional role and identity, beliefs about capabilities, optimism, beliefs about consequences, reinforcement, intentions, goals, memory, attention and decision processes, environmental context and resources, social

influences, emotion, and behavioural regulation). This framework provides a link between understanding the behaviour (stage 1) and the development of intervention options (stage 2).

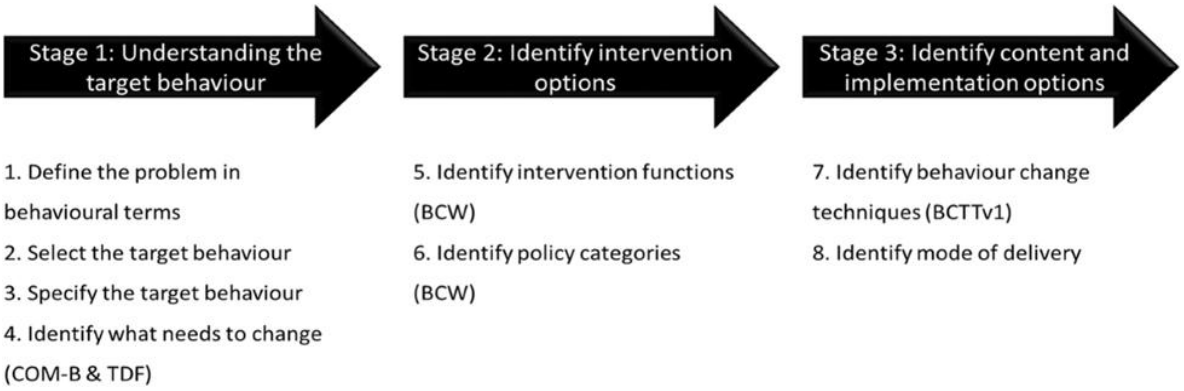

Figure 3. Steps and stages of the Behaviour Change Wheel, adapted from Michie et al. (2011, pp.1).

2.5.2 Stage 2: Identifying Intervention Options

The second stage of the BCW is to identify intervention options. This involves the identification of intervention functions (education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling, and enablement) and policy categories (communication/marketing, guidelines, fiscal measures, regulation, legislation, environmental/social planning, and service provision) that can be implemented to change behaviour. The BCW guide makes suggestions of the best fit intervention functions and policy categories based on the prior COM-B analysis. This structured mapping allows systematic, objective translation of behavioural diagnosis into appropriate intervention strategies, reducing reliance on subjective, ad-hoc decision-making.

2.5.3 Stage 3: Identifying Content and Implementation Options

The final stage is to identify content and implementation options, namely through the selection of 93 possible BCTs from the Behaviour Change Technique Taxonomy (BCTTv1) (Michie et al., 2013). These include, but are not limited to, goal setting, self-monitoring, feedback, social

support, cues and prompts, incentives, information provision, modelling of the desired behaviour, and problem solving. Selection of BCTs not only facilitates easy comparison with previous interventions but also provides transparency in decision making and more precise targeting of determinants of behaviour. The BCW framework does not prescribe specific modes of delivery, instead opting for flexibility around specific circumstances. This flexibility in delivery mode may facilitate improved tailoring of an intervention to the unique needs of individuals with paraplegia. The viability of the identified intervention options, and content and implementation options, can be assessed using the APEASE criteria, comprising of the Affordability, Practicability, Effectiveness, Acceptability, Side-effects/safety, and Equity of each option (West et al., 2019). The APEASE criteria is useful to provide early data around whether interventions are likely to be appropriate, meaning improvements can be made before resources are expended in evaluating them. Therefore, the use of the APEASE criteria means that an intervention that is more developed, and may be less likely to present fundamental issues, is evaluated for its acceptability, safety and feasibility, which could aid its progression to a full trial.

2.6 Co-design of Interventions

Participatory approaches to intervention development are growing more popular in healthcare research, as creation with input from the end-users may help to develop interventions which are more engaging, acceptable and useful to end-users than conventional researcher-developed interventions (Thabrew et al., 2018). One way of achieving this is through co-creation, which involves a collaborative approach at all project stages, starting with identification of the purpose of the intervention (i.e. the problem and target behaviours), all the way through to evaluation and implementation (Vargas et al., 2022). Co-design focuses on the design stage, including stakeholders in deciding the content of the intervention and relevant materials and resources (Vargas et al., 2022). Co-production involves stakeholders in appraisal of the

proposed intervention and its delivery (Vargas et al., 2022). The problem and target behaviours within this thesis were already clearly defined by previous research as "excessive sedentary behaviour" and "to reduce and break up sedentary behaviour", respectively. Therefore, these behaviours were the focus of this project. As a result of the problem and target behaviours being pre-defined, a collaborative approach that tackles a pre-determined problem was more appropriate to guide this research. Therefore, co-design was used to develop the intervention in this thesis (Chapter 5).

Co-design is a widely employed intervention development technique in which key stakeholders, end-users and researchers play an active role in the design and development of an intervention to overcome a pre-defined problem (Boyd et al., 2012; Vargas et al., 2022). This includes collaboration in the design process, including needs assessment, development of intervention content, and appraisal of intervention concepts (Boyd et al., 2012). Inclusion of patients in the design of healthcare services has been found to enhance adherence to treatment (Elg et al., 2012). Co-design methodology has been successfully utilised in the development of sedentary behaviour interventions in a range of demographic groups, such as office workers (Engelen et al., 2019), older adults (Blake et al., 2025), and those with severe mental illness (Trott et al., 2025). Involvement of the intervention end-users alongside key stakeholders may help to identify important barriers and facilitators that need to be targeted, and the intervention content and implementation options required to address these. This approach was employed in Chapter 5 of this PhD thesis to help fulfil the development phase of the MRC framework.

Chapter 3: General Overview of the Literature

The aim of this section is to give an overview of previous research on sedentary behaviour, CVD and interventions in non-disabled individuals, clinical populations and individuals with paraplegia. This general overview of the literature is separate from the systematic review of interventions on sedentary behaviour and CVD biomarkers in individuals with paraplegia (Chapter 4). Instead, this section focuses more broadly on sedentary behaviour, CVD and interventions in general, including the types of interventions that have been developed in other population groups and whether they are effective in changing behaviour and/or improving CVD biomarkers.

Findings from this section feed into the design and focus of the systematic review (Chapter 4), including the intervention characteristics used to categorise eligible studies in the data synthesis.

3.1 Cardiovascular Disease Biomarkers in Individuals With Paraplegia

Post-injury, SCI exerts a number of physiological changes to the body, typified by a decrease in metabolic rate, increased sarcopenia (age related loss of skeletal muscle mass and function), and accumulation of body fat (Gorgey & Dudley, 2007; McMillan et al., 2021).

3.1.1 Body Composition Biomarkers in Individuals With Paraplegia

The prevalence of overweight (BMI $\geq$ 25 kg/m^2) or obesity (BMI $\geq$ 30 kg/m^2) in individuals with SCI has been estimated as 65.8% (Gupta et al., 2006a), compared to 68.7% in non-disabled individuals (Fryar et al., 2012). However, BMI is a poor indicator of obesity in individuals with SCI, as the loss of lean tissue and accumulation of adiposity after SCI does not necessarily elicit a change in body weight, and the measurement of height after SCI is challenging and difficult to reproduce (Buchholz & Bugaresti, 2005; Jones et al., 2003; Shojaei et al., 2017). In a cross-sectional study of 20 non-disabled individuals and 20 individuals with

SCI, despite no differences in body weight or BMI, those with SCI had significantly greater total fat mass and percentage body fat, alongside significantly lower total lean tissue mass than non-disabled individuals (Jones & Legge, 2019). Similarly, 100 wheelchair-dependent individuals with SCI (53% paraplegia) had significantly greater waist circumference, total fat mass and body fat percentage than 51 non-disabled individuals, despite no difference in BMI (Cirnigliaro et al., 2021). In conclusion, individuals with paraplegia experience an increase in total body fat, particularly in central areas, and a reduction in total lean mass after injury, which could make these individuals more susceptible to CVD.

3.1.2 Blood Pressure Biomarkers in Individuals With Paraplegia

Literature suggests that individuals with SCI generally have reduced blood pressure control compared to non-disabled individuals as a result of impaired autonomic function (Rosado-Rivera et al., 2011). This is because SCI above T6 is more likely to impair sympathetic cardiovascular control than lower-level injuries. As a result, these individuals may be predisposed to orthostatic hypotension, characterised by a chronic drop in blood pressure (Claydon et al., 2006). Orthostatic hypotension reduces cerebral blood flow, causing dizziness and fatigue, which may act as a barrier to physical activity interventions in individuals with tetraplegia (Mathias et al., 1999). Conversely, lack of autonomic control above T6 can lead to transient periods of hypertension, known as autonomic dysreflexia (Lindan et al., 1980). This is a life-threatening condition characterised by bradycardia and a catastrophic rise in blood pressure, which is the main cause of death from autonomic dysreflexia (Hagen et al., 2011). Exercise has been identified as a trigger for autonomic dysreflexia, meaning that it may also impede participation in physical activity (Wheeler et al., 1994). Orthostatic hypotension and autonomic dysreflexia are less likely to represent a barrier to physical activity in individuals with paraplegia due to a lower injury level than tetraplegia. A meta-analysis of 1,968 individuals found that there were no differences in resting heart rate, systolic blood pressure or

diastolic blood pressure between individuals with paraplegia and non-disabled individuals (West et al., 2012). Additionally, it has been demonstrated that heart rate, systolic blood pressure and diastolic blood pressure in individuals with tetraplegia and high-level paraplegia are lower than those of individuals with lower-level paraplegia and non-disabled individuals (West et al., 2012; Raguindin et al., 2021). Measurement of blood pressure as a CVD biomarker in individuals with paraplegia is still warranted, as most of the spinal cord that signifies paraplegia is located below T6. The sixth thoracic vertebra is the neurological level at which spinal nerves that control blood pressure are situated, meaning individuals with an injury below this level have lower risk of orthostatic hypotension and autonomic dysreflexia. Therefore, it could be hypothesised that blood pressure is a modifiable CVD biomarker in many individuals with paraplegia.

3.1.3 Glycaemic Biomarkers in Individuals With Paraplegia

Despite the incidence of T2DM being 66% higher in individuals with SCI than non-disabled individuals (Cragg et al., 2013b), the evidence around elevated glycaemic biomarkers is varied and unclear in this population. In a cohort of 95 individuals with SCI, 33% were classified as insulin resistant according to HOMA-IR measurement, indicating poor glycaemic status. However, the SCI cohort had no difference in fasting insulin and lower fasting glucose and HbA1C than non-disabled individuals (Solinsky et al., 2022). Another study found that only 10% of individuals with paraplegia (n = 135) had a high fasting glucose concentration ($\geq$ 6.1 mmol/L) (Wahman et al., 2010). Furthermore, a meta-analysis found no differences in fasting glucose or insulin between individuals with and without SCI (Boehl et al., 2022). On the other hand, in a study of 20 males with SCI and 20 non-disabled males, those with SCI had a significantly higher postprandial insulin, insulin area under the curve (AUC; total postprandial insulin response), HOMA-IR, postprandial glucose, and glucose AUC than non-disabled individuals (Jones & Legge, 2019). This is in agreement with a study of 100 individuals with

SCI that observed significantly greater fasting plasma insulin and HOMA-IR, but a lower fasting plasma glucose than non-disabled controls (Cirnigliaro et al., 2021). There is some conflicting evidence as to the glycaemic status of individuals with paraplegia, which warrants further research. Though, there is evidence to suggest that individuals with paraplegia do have adverse levels of some glycaemic biomarkers, meaning exploration of the effects of interventions on glycaemia is warranted.

3.1.4 Lipid Profile Biomarkers in Individuals With Paraplegia

Previous evidence demonstrates that individuals with paraplegia have an adverse lipid profile. For example, individuals with SCI (n = 95) had significantly higher total cholesterol and triglycerides, and lower HDL and LDL cholesterol than 1,609 non-disabled individuals in one study (Solinsky et al., 2022). This supports the findings of a study including 100 manual wheelchair-users with SCI, which observed higher triglycerides, triglyceride:HDL cholesterol ratio and total cholesterol:HDL cholesterol ratio, and lower HDL cholesterol, than 51 non-disabled controls (Cirnigliaro et al., 2021). In a meta-analysis, individuals with SCI had significantly lower total cholesterol and HDL cholesterol, alongside a significantly higher total cholesterol:HDL cholesterol ratio (Gilbert et al., 2014). These findings suggests that individuals with SCI have a worse lipid profile than the general population. However, none of the sample mean values observed in this meta-analysis placed individuals with SCI in the high-risk range for CVD. In addition, there were no significant differences in non-HDL cholesterol or triglycerides between individuals with SCI and non-disabled individuals (Gilbert et al., 2014). Data from meta-analyses suggest that there is conflicting evidence as to the lipid profile of individuals with SCI. Despite this conflicting evidence, there is data to suggest that individuals with SCI have an unfavourable lipid profile compared to non-disabled individuals, increasing risk of CVD (Cirnigliaro et al., 2021; Gilbert et al., 2014; Solinsky et al., 2022).

Based on these findings, lipid biomarkers should be explored when testing the effects of interventions on CVD risk.

In summary, there is evidence to suggest that individuals with paraplegia have unfavourable levels of CVD biomarkers relating to body composition, blood pressure, glycaemia and lipid profile, compared to non-disabled individuals. This warrants the investigation of lifestyle factors that can be targeted to improve CVD risk biomarkers in individuals with paraplegia.

3.2 Sedentary Behaviour and Cardiovascular Disease

The detrimental associations between sedentary behaviour and health outcomes have been demonstrated in a large number of observational studies in adults of the general population. Sedentary behaviour has been associated with an increased risk of non-communicable diseases, including T2DM (Bailey et al., 2019; Guo et al., 2020; Patterson et al., 2018; Wilmot et al., 2012), some cancers (Shen et al., 2014), obesity (Guo et al., 2020), metabolic syndrome (Edwardson et al., 2012) and CVD (Bailey et al., 2019; Biswas et al., 2015; Patterson et al., 2018; Wilmot et al., 2012). Sedentary behaviour is also associated with increased all-cause mortality and CVD mortality (Ekelund et al., 2019; Patterson et al., 2018; Wilmot et al., 2012). The associations between sedentary behaviour and CVD are often independent of physical activity (Bailey et al., 2019; Wilmot et al., 2012), suggesting that sedentary time may be a distinct risk factor. This rationalises the distinct focus on sedentary behaviour as an intervention target for reducing CVD risk.

Causality between sedentary behaviour and CVD is likely due to a number of mechanisms related to the multitude of physiological processes that influence CVD risk (Stoner et al., 2013). These processes have been linked to adiposity (Luo & Liu, 2016), lipid profile (Bey & Hamilton, 2003) and glycaemic status (Quan et al., 2021). Research suggests that sedentary behaviour may deleteriously affect cardiovascular health via a number of mechanisms. These

include, but are not limited to, reduced lipoprotein lipase (LPL) activity which negatively affects cholesterol status (Bey & Hamilton, 2003), downregulation of glucose transporter activity, which is detrimental to glycaemic status (Latouche et al., 2013), endothelial damage that restricts cardiovascular function and haemodynamics (Chandrasekaran et al., 2021), and lowered metabolic rate, which leads to a positive energy balance, obesity and low-grade inflammation (Dempsey et al., 2018). To better understand the key physiological mechanisms of CVD that are most affected by sedentary behaviour and to what extent, specific biomarkers related to each of the aforementioned physiological processes should be measured individually in both healthcare and research (Dhingra & Vasan, 2017).

3.3 Sedentary Behaviour and Cardiovascular Disease Biomarkers

3.3.1 Sedentary Behaviour and Body Composition Biomarkers

Sedentary behaviour is widely regarded as a risk factor for obesity (Leitzmann, 2017). The underlying mechanism is likely to be very low energy expenditure tilting the energy balance equation to an energy surplus, encouraging the storage of excess energy as body fat (Luo & Liu, 2016). Body mass index and waist circumference are commonly included in studies investigating the associations between sedentary time and CVD biomarkers. In cross-sectional studies that measured sedentary behaviour via self-report questionnaires or accelerometry, there were significant positive associations between daily sitting time and both BMI and waist circumference, independent of physical activity (León-Latre et al., 2014; Staiano et al., 2014; Thorp et al., 2010). In a cohort of Swiss adults, there were adverse associations between self-reported sitting time and body fat percentage, but not BMI, waist circumference, waist-to-hip ratio or waist-to-height ratio (n = 3,042) (Wanner et al., 2016). In community-dwelling older adults, there were adverse associations between accelerometry-measured sitting time and total body fat mass, total body lean mass, body fat percentage and lean mass percentage (n = 123)

(Reid et al., 2018). In conclusion, the evidence suggests that higher volumes of sedentary behaviour are adversely associated with body composition, regardless of how sedentary behaviour was measured.

3.3.2 Sedentary Behaviour and Blood Pressure Biomarkers

It has been suggested that excessive sedentary behaviour can elevate blood pressure and lead to hypertension in the adult general population (Sohn et al., 2014). During prolonged sitting, the lack of muscle contraction reduces metabolic demand and lessens the production of vasodilatory metabolites. As a result, blood flow decreases, reducing vascular shear stress, which is a key regulator of nitric oxide synthase. Lower shear stress reduces nitric oxide availability and leads to vasoconstriction, which contributes to peripheral resistance and higher blood pressure (Paniagua et al., 2001). Chronically high blood pressure can impair vascular function and lead to CVD (Dempsey et al., 2018).

In a sample of adults from a US population study, there were no significant associations between self-reported daily sitting time and systolic blood pressure or diastolic blood pressure (n = 4,560) (Staiano et al., 2014). However, in Australian adults, there were significant positive associations between self-reported sitting time and systolic blood pressure for all participants, and for diastolic blood pressure in females (n = 4,864) (Thorp et al., 2010). Furthermore, in Spanish adults, there was a significant positive association between self-reported daily sitting time and diastolic blood pressure, but not systolic blood pressure (n = 929) (León-Latre et al., 2014). Though, accelerometry data shows a different picture, as in a US population study (n = 4,757) (Healy et al., 2011b), an Australian diabetes study (n = 698) (Healy et al., 2015a) and another Australian diabetes study (n = 279) (Healy et al., 2015b), there were no associations between accelerometry-measured daily sedentary time and systolic blood pressure or diastolic blood pressure. In contrast, after adjustment for MVPA, accelerometry-measured sedentary

behaviour was positively associated with systolic blood pressure and blood pressure in 707 adults with or at risk for osteoarthritis (Sohn et al., 2014). Therefore, after adjustment for physical activity, accelerometry-measured sedentary behaviour is adversely associated with blood pressure biomarkers. Together, these findings suggest that blood pressure should be included as a CVD biomarker outcome when evaluating sedentary behaviour interventions.

3.3.3 Sedentary Behaviour and Glycaemic Biomarkers

Sedentary behaviour has been linked to the development of T2DM. Although the exact mechanism behind this is not completely understood, a number of processes have been suggested (Holloszy, 2005). The reduction in regular muscle contractions associated with prolonged sedentary bouts can disrupt the glucose uptake pathway via a reduction in the expression of muscle glucose transporter 4, independent of insulin (Bergouignan et al., 2016; Holloszy, 2005; Ojuka et al., 2002; Quan et al., 2021). This mechanism may be explained by prolonged inactivity increasing the saturated fatty acid composition of phospholipids in skeletal muscle, leading to inhibition of glucose transport and insulin sensitivity (Andersson et al., 1998; Quan et al., 2021). Via a separate mechanism, sedentary behaviour decreases the activity of enzymes such as glycogen synthase and hexokinase, which are integral to maintaining insulin sensitivity (Bergouignan et al., 2016; Quan et al., 2021). Alternatively, sedentary behaviour has been linked to reduced capacity for fat oxidation, which is a key factor promoting insulin sensitivity (Quan et al., 2021; Robinson et al., 2015).

In a cross-sectional US study (n = 6,931), there was a significant positive association between self-reported daily sitting time and insulin resistance measured by HOMA-IR, independent of physical activity (Parker et al., 2023). In another US-based study (n = 4,560), there was a significant, unfavourable association between self-reported daily sitting time and plasma insulin, HOMA-IR and HOMA beta cell function (HOMA-%B), which was maintained after

controlling for self-reported MVPA (Staiano et al., 2014). After controlling for physical activity, self-reported sitting time was adversely associated with fasting insulin in British adults (n = 505) (Yates et al., 2012), and with fasting insulin and postprandial glucose in Australian adults (n = 4,864) (Thorp et al., 2010). This suggests that higher levels of self-reported sedentary behaviour are adversely associated with glycaemic biomarkers, including when controlling for physical activity. In a US-based study (n = 4,757), there were adverse associations between accelerometry-measured daily sedentary time and fasting plasma insulin, HOMA-%B, and HOMA insulin sensitivity (HOMA-%S), but not fasting plasma glucose or 2-hour postprandial glucose (Healy et al., 2011b). Additionally, a systematic review (k = 25) found consistent evidence that accelerometry-measured sedentary time is unfavourably associated with insulin sensitivity, independent of physical activity. These findings suggests that the adverse associations observed with self-reported sedentary behaviour are also present with accelerometry measurements. As a consequence of the independent associations between sedentary time and glycaemic biomarkers demonstrated in this section, glycaemic biomarkers should be explored to determine the effectiveness of sedentary behaviour interventions.

3.3.4 Sedentary Behaviour and Lipid Profile Biomarkers

It has been suggested that sedentary behaviour has an adverse effect on lipid profile. This is most likely due to the inhibitory effect of low muscle contractile activity on the enzyme LPL (Bey & Hamilton, 2003). The function of LPL is to convert triglycerides into fatty acids and glycerol, an important process for healthy lipid metabolism (Pirahanchi et al., 2022). Low levels of LPL are associated with increased triglycerides and low HDL cholesterol, increasing the risk of CVD (Tsutsumi, 2003).

In Spanish adults (n = 929), there were unfavourable associations between self-reported daily sedentary time and triglycerides, triglycerides:HDL cholesterol ratio, ApoA1 and HDL

cholesterol, which were maintained after adjustment for weekly energy expenditure (León-Latre et al., 2014). In a US study (n = 4,757), accelerometer-derived daily sedentary time was unfavourably associated with HDL cholesterol, and fasting triglycerides, both independent of MVPA (Healy et al., 2011b). Similarly, in Australian adults (n = 739), accelerometer-derived daily sedentary time was unfavourably associated with HDL cholesterol and triglycerides after adjustment for MVPA (Bellettiere et al., 2017). Lastly, participants from an Australian diabetes study (n = 698) had adverse associations between accelerometry-measured daily sedentary time and total cholesterol:HDL cholesterol ratio, triglycerides and HDL cholesterol (Healy et al., 2015a). These findings suggest that adverse associations after adjustment for physical activity are also present when sedentary behaviour is measured using accelerometry. Due to the independent associations between sedentary time and lipid profile biomarkers outlined above, the measurement of lipid profile biomarkers is warranted in the evaluation of sedentary behaviour interventions.

In conclusion, sedentary behaviour is independently associated with a number of CVD biomarkers. These findings suggest that reducing sedentary behaviour may lower the risk of CVD and this overview has identified a number of biomarkers that should be measured when evaluating interventions targeting sedentary behaviour.

3.4 Sedentary Behaviour and Cardiovascular Disease Biomarkers in Individuals With Paraplegia

Unlike in non-disabled populations, there have been limited studies investigating the association between sedentary behaviour and CVD biomarkers in individuals with SCI. A cross-sectional study undertaken as part of a Master's thesis found an adverse correlation between sedentary behaviour and Framingham CVD risk score in individuals with SCI (Fjelltveit, 2024). However, the sample size was small (n = 20), and a large proportion were

ambulatory, meaning the findings may not be generalisable to manual wheelchair-users. In addition, the analysis did not control for any covariates such as physical activity. This makes it difficult to identify if sedentary behaviour is independently associated with CVD risk. Further research is required to determine whether sedentary behaviour is independently associated with CVD biomarkers in individuals with SCI.

3.5 Sedentary Behaviour Interventions in the General Population

Interventions to reduce and break up sedentary behaviour have been evaluated in the general population. Systematic reviews and meta-analyses have shown these interventions to be effective for reducing sedentary time (Curran et al., 2021; Gardner et al., 2016; Martin et al., 2015; Nguyen et al., 2020; Prince et al., 2014; Shrestha et al., 2018) and improving CVD biomarkers (Brierley et al., 2019; Hadgraft et al., 2021; Saunders et al., 2018). Therefore, effectiveness of such interventions in the general population may be relevant in the prevention of CVD in individuals with paraplegia.

Identification of key intervention characteristics, such as intervention target, duration, setting, delivery mode and use of behaviour change theory are important considerations during intervention design (O'Cathain et al., 2019). Characteristics employed in successful interventions in other populations may provide relevant information to inform intervention development in individuals with paraplegia. The following sub-sections will give an overview of interventions in the general population and clinical populations, as well as the effectiveness of these interventions for improving sedentary behaviour and CVD biomarkers in the context of specific intervention characteristics.

3.5.1 Targeting Sedentary Behaviour or Physical Activity

Interventions that target physical activity have the potential to reduce sedentary time, as physical activity can be used to displace bouts of sedentary behaviour. However, it has been

suggested that a focus specific to sedentary behaviour could be more effective for reducing this behaviour (Gardner et al., 2016; Martin et al., 2015; Prince et al., 2014).

In a meta-analysis of 33 interventions with potential to affect sedentary behaviour in the general population, those that targeted either physical activity or a combination of sedentary behaviour and physical activity led to modest reductions in sedentary time (Prince et al., 2014). Interventions that specifically target sedentary behaviour were more effective, leading to large reductions in sedentary time (Prince et al., 2014). A meta-analysis (k = 34) found that interventions targeting physical activity or a combination of sedentary behaviour and physical activity had no effect on sedentary time (Martin et al., 2015). However, interventions that focused solely on sedentary behaviour significantly reduced sedentary time (Martin et al., 2015). Similarly, a systematic review of 26 interventions that showed promise in improving sedentary time tended to target sedentary behaviour instead of physical activity (Gardner et al., 2016). These findings suggest that interventions targeting sedentary behaviour, specifically, may be most effective for achieving reductions in sedentary time.

3.5.2 Intervention Duration

Evidence suggests it can be challenging to maintain long-term physical activity behaviour change (Müller-Riemenschneider et al., 2008). This challenge may be due to the long-term nature of gaining automaticity, as research suggests that new habit formation can take between 18 to 254 days (Lally et al., 2010). Consistent with this wide heterogeneity in time taken to gain habit automaticity between individuals, sedentary behaviour interventions often differ widely in their duration. A meta-analysis of two sedentary behaviour interventions lasting five and 14 weeks also saw a reduction in sedentary time (Martin et al., 2015). In comparison, another meta-analysis of seven sedentary behaviour interventions lasting between three weeks and three months found significant reductions in daily sedentary time (Prince et al., 2014). However, there were no significant differences in sedentary time when synthesised by

intervention length (< 4 weeks vs. 5-24 weeks vs. 25 weeks) or length of study follow-up. These findings suggest that interventions lasting at least three weeks in duration may be effective for eliciting reductions in sedentary time. Though, there is limited evidence for interventions of shorter durations or longer-term follow-ups.

There are no definitive guidelines as to the minimum duration of sedentary behaviour intervention to improve CVD biomarkers. Evidence from physical activity research interventions suggests that longer-term interventions yield superior improvements (Reiner et al., 2013). A meta-analysis found small, but significant, improvements in body mass (k = 25), waist circumference (k = 19), systolic blood pressure (k = 25), plasma insulin (k = 10) and high-density lipoprotein cholesterol (k = 22) in sedentary behaviour interventions lasting between two weeks and 36 months (Hadgraft et al., 2021). Intervention duration (< 3 months vs. 3-6 months vs. > 6 months) had no effect on most CVD biomarkers in this review. Though, there was a paucity of interventions lasting more than 12 months, limiting comparisons of effectiveness between different intervention durations (Hadgraft et al., 2021). Another review found that 20 sedentary behaviour interventions lasting between two weeks and 13 months improved at least one CVD biomarker (Brierley et al., 2019). Intervention effectiveness was not synthesised by duration and there was also a limited number of interventions lasting 12 months or more (Brierley et al., 2019). Whilst the effects of longer-term interventions on CVD biomarkers is unclear, there is evidence that sedentary behaviour interventions lasting at least two weeks could be effective for improving CVD biomarkers in the general population.

3.5.3 Setting

Systematic reviews of workplace-based interventions have shown them to be effective for reducing sedentary time (Chu et al., 2016; Peachey et al., 2020; Shrestha et al., 2018) improving CVD biomarkers related to blood pressure, body composition, glycaemia and lipid profile in the general population (Brierley et al., 2019). Similarly, reviews in non-workplace settings

showed effectiveness for reducing sedentary time (Curran et al., 2021; Peachey et al., 2020). Despite individual studies highlighting improvements in CVD biomarkers as a result of community-based, multi-component sedentary behaviour interventions (Ball et al., 2017; Keadle et al., 2014), there is no specific, isolated meta-analytical or systematic review evidence for non-workplace interventions improving CVD biomarkers, specifically. Previous reviews have provided pooled estimates across a number of intervention settings (workplace, community, hospital, primary care, domestic, education), showing significant reductions in a number of biomarkers (Hadgraft et al., 2021). However, differences in CVD biomarker results between different settings was not analysed (Hadgraft et al., 2021). Further evidence around non-workplace sedentary behaviour interventions is needed to inform future inform strategies for specific non-workplace settings. There is, however, evidence to suggest that sedentary behaviour interventions could be effective for changing this behaviour and improving CVD biomarkers across different settings.

3.5.4 Delivery Mode

Sedentary behaviour interventions have included a wide variety of behavioural strategies. An umbrella review of systematic reviews exploring interventions on sitting time in the general population split intervention components/delivery modes into three categories: motivational/volitional component (e.g. educational materials, goal setting, self-monitoring, motivational interviewing), physical environmental changes (e.g. sit-stand desk, pedal machine/ergometer, prompts/reminders, monitoring/tracking devices), and policy changes (e.g. curriculum change, walking/standing meetings, scheduled activity breaks) (Nguyen et al., 2020). One included review found that motivational/volitional components were the most common intervention components, followed by physical environmental changes (Chu et al., 2016). In contrast, another review cited physical environmental changes as the most commonly utilised, followed by motivational/volitional components. However, these were mainly

workplace-based interventions, limiting generalisability (Shrestha et al., 2018). The umbrella review found that although all three categories of delivery reduced sitting time, those targeting physical environmental changes, such as active workstations and prompts/reminders, were most effective in the pooled analysis (Nguyen et al., 2020). However, there was only sufficient data to determine this in workplace settings; success of delivery modes may differ in other settings.

In a review across multiple settings, the most common delivery modes in sedentary behaviour interventions included counselling/education, environmental modification and device-self-monitoring (Hadgraft et al., 2021). Almost all workplace interventions used physical environment modification, a large number used counselling/education, and some used device self-monitoring, device-based social comparison, prompts/reminders and structured activity (Hadgraft et al., 2021). The majority of non-workplace interventions used counselling/education, most used device-based self-monitoring, and some used environmental modification, prompts/reminders, structured activity and financial incentive (Hadgraft et al., 2021). However, analysis was not undertaken to determine which of these led to greater improvements in sedentary behaviour or CVD biomarkers (Hadgraft et al., 2021). One review quantitatively analysed the effectiveness of intervention on sitting time across a number of settings (not just workplace-based interventions), categorised by intervention/delivery modes across the following categories: (a) environmental (e.g. active workstations, screen-based prompts), (b) behavioural (mobile applications [apps], activity trackers, educational workshops), and (c) multi-component (including environmental and behavioural components) (Peachey et al., 2020). Despite all delivery modes being successful, environmental components elicited the greatest reduction, followed by multi-component and behavioural interventions (Peachey et al., 2020). To conclude, a number of delivery modes have been adopted to target sedentary behaviour in interventions. Environmental, behavioural and multi-component

interventions show promise for reducing sedentary time and should be adopted in future interventions.

3.5.5 Use of Behaviour Change Theory

Behaviour change theory has been suggested to be a useful component of effective sedentary behaviour interventions in the general population (Curran et al., 2021; El Kirat et al., 2024; Gardner et al., 2016). Sedentary behaviour interventions utilising theory generally use one, or a combination of, Social Cognitive Theory, the Socio-Ecological Model, Self-Determination Theory, the Transtheoretical Model, Theory of Planned Behaviour, Empowerment theory, Habit Theory of Behaviour Change, Behaviour Choice Theory and Common-Sense Model Dual-Process Theory (Curran et al., 2021; El Kirat et al., 2024; Gardner et al., 2016).

Gardner et al. (2016) found that only 42% of sedentary behaviour interventions used theory, whilst Davis et al. (2015) concluded that inclusion of theory was often superficial in health behaviour change interventions. Lack of theory is problematic, as interventions utilising theory have demonstrated greater levels of physical activity behaviour change than those that do not (Davis et al., 2015; Howlett et al., 2019; Michie et al., 2008). Though, meta-analytical evidence for behaviour change theory in relation to improving sedentary behaviour, specifically, is lacking. This suggests that further sedentary behaviour interventions grounded in behaviour change theory should be evaluated in order to better understand their potential effectiveness.

Use of BCTs, described as the building blocks of interventions, is commonplace in the development, implementation and evaluation of behaviour change interventions (Michie et al., 2013). Integration of BCTs ensures transparency and reproducibility in interventions to maintain rigour, as well as facilitating seamless comparison with other interventions and to help identify what does and does not work for behaviour change (Michie et al., 2013). The most common BCTs in previous sedentary behaviour interventions included setting

behavioural goals, social support, adding objects to the environment, problem-solving, instruction for how to perform the behaviour, self-monitoring, information about health consequences and prompts and cues (Curran et al., 2021; El Kirat et al., 2024; Gardner et al., 2016). The BCTs with the most promise for reducing sedentary behaviour in a systematic review included self-monitoring of behaviour, problem solving, and changing the social or physical environment (Gardner et al., 2016). Those present exclusively in the most effective interventions for improving sedentary behaviour in another review included feedback on behaviour and goal setting (Curran et al., 2021). It is evident that interventions including self-monitoring of behaviour, problem solving, changing the social or physical environment, feedback on behaviour and goal setting are most effective for reducing sedentary behaviour, and should be considered when developing interventions. The use of behaviour change theory and inclusion of appropriate BCTs may be relevant in the development and delivery of sedentary behaviour interventions for individuals with paraplegia to maximise acceptability and effectiveness.

3.6 Sedentary Behaviour Interventions in Clinical Populations

A number of sedentary behaviour interventions have been developed and evaluated across different clinical populations, such as CVD (Prince et al., 2018), stroke (English et al., 2016; Ezeugwu & Manns, 2018; Hall et al., 2020), chronic obstructive pulmonary disease (Orme et al., 2016) and multiple sclerosis (Manns et al., 2020; Ryan et al., 2020). A meta-analysis of sedentary behaviour interventions in clinical populations (overweight/obesity, T2DM, CVD, stroke, multiple sclerosis, serious mental illness) showed that such interventions were effective for reducing sedentary time and improving CVD biomarkers related to HbA1C, body fat percentage and waist circumference (Nieste et al., 2021). Another review of digitally-delivered sedentary behaviour interventions in clinical populations (healthy adults, overweight/obesity, T2DM, CVD, cancer, depression, osteoarthritis) generally showed improvements in energy

expenditure, physical activity, body composition, quality of life and self-efficacy (Martín-Martín et al., 2021). Similarly to those in non-disabled individuals, identification of the characteristics of effective and ineffective interventions is key to inform successful future intervention development.

3.6.1 Targeting Sedentary Behaviour or Physical Activity

All but one of the 18 studies included a review of sedentary behaviour interventions in clinical populations primarily targeted sedentary behaviour (Nieste et al., 2021). The one other study targeted physical activity and did not lead to reductions in sedentary time (Holliday et al., 2018). The meta-analysis showed a significant reduction in sedentary behaviour (Nieste et al., 2021). Another review in individuals with T2DM showed that the only included intervention that did not improve sedentary behaviour targeted physical activity, suggesting that those targeting sedentary behaviour are more effective (Smith et al., 2024). A review of interventions in stroke survivors found that there was no effect on sedentary behaviour (Saunders et al., 2021). The lack of improvement in sedentary behaviour in this review may have been due to half of the included studies targeting physical activity (Saunders et al., 2021); it has been suggested that physical activity interventions target inappropriate BCTs for changing sedentary behaviour (Martin et al., 2015).

Therefore, it appears that interventions targeting physical activity do not lead to reductions in sedentary behaviour, whereas those specifically targeting sedentary behaviour are effective for reducing this outcome in clinical populations.

3.6.2 Intervention Duration

A scoping review of sedentary behaviour interventions lasting between six weeks to one year in individuals with CVD showed improvements in sedentary behaviour (Peng et al., 2023). In one meta-analysis of sedentary behaviour interventions in a number of clinical populations,

interventions ranged from six to 24 weeks and led to a significant reduction in sedentary behaviour (Nieste et al., 2021). Additionally, the sedentary behaviour interventions included in this review significantly improved body fat percentage, waist circumference and HbA1C, suggesting that reducing and breaking up sedentary behaviour over six to 24 weeks may be sufficient to improve CVD biomarkers in clinical populations (Nieste et al., 2021). However, in a meta-analysis of shorter-term (three hours to four days) and longer-term (five weeks to three years) sedentary behaviour interventions in individuals with T2DM, there was a significant improvement in CVD biomarkers for both intervention durations (Smith et al., 2024). Despite the apparent efficacy of shorter-term interventions, these studies did not measure sedentary behaviour. In contrast, all but one longer-term intervention showed promise for improving sedentary behaviour (Smith et al., 2024).

This evidence across clinical populations suggests that interventions lasting approximately five weeks or more may be effective for reducing sedentary behaviour. Whilst short-term studies showed promise for improving CVD biomarkers in one review, there is more evidence for the effectiveness of interventions lasting five weeks or more on sedentary behaviour and CVD biomarkers.

3.6.3 Setting

Although intervention setting was not specifically reported in the studies included in a review of digital sedentary behaviour interventions in clinical populations, from the digital health nature of the review, it can be assumed that interventions were delivered remotely in a home/community setting (Martín-Martín et al., 2021). Energy expenditure, physical activity, body composition, quality of life and self-efficacy were improved by the interventions included in this review (Martín-Martín et al., 2021). Similarly, in a scoping review of sedentary behaviour interventions in individuals with T2DM, most took place in home and community settings, with consistent improvement in sedentary behaviour (Peng et al., 2023). Neither of

these reviews synthesised outcomes by intervention setting, limiting conclusions as to the importance of this characteristic within interventions. Settings in a review of sedentary behaviour interventions in multiple clinical populations included home and community-based and workplace-based (Nieste et al., 2021). Both sedentary behaviour and CVD biomarkers were improved across different settings (Nieste et al., 2021). However, setting was not reported for every intervention, limiting the ability to determine the settings in which sedentary behaviour and CVD biomarkers were improved most consistently (Nieste et al., 2021).

In conclusion, although there is more evidence regarding the effectiveness of interventions for improving sedentary behaviour and CVD biomarkers in home- and community-based interventions, it appears that these outcomes may be improved in a number of settings in clinical populations. A number of studies did not explicitly report the intervention setting, necessitating clearer reporting of intervention characteristic in future studies to better understand the nature of effective interventions.

3.6.4 Delivery Mode

A review of digital behaviour change interventions to reduce sedentary behaviour identified a number of delivery modes. All of the included interventions used text messages, whilst most of them employed communication tools, such as phone calls and emails, as well as mobile apps and activity trackers (Martín-Martín et al., 2021). However, the effectiveness of delivery modes was not explored in this review. Delivery modes varied in a scoping review of sedentary behaviour interventions in individuals with T2DM, including individual-based, group-based, mobile phone-based, internet-based and learning material-based components (Peng et al., 2023). Mobile or internet-based technologies were the most common delivery mode, including app access, text messaging and phone call reminders (Peng et al., 2023). Despite improvements in sedentary behaviour across included studies, effectiveness of each delivery mode was also not determined in this review. A review of sedentary behaviour interventions encompassing a

wide range of delivery modes in clinical populations (overweight/obesity, type 2 diabetes, CVD, neurological/cognitive, or musculoskeletal disorders) identified that interventions generally used one or more of the following components: self-monitoring, education in combination with motivational counselling, the use of a website/app and social facilitation (Nieste et al., 2021). Sedentary behaviour was significantly reduced, by 64 min/day on average (Nieste et al., 2021). Reductions in sedentary behaviour were most pronounced in multi-component interventions compared to those utilising a single component, specifically those including elements of motivational counselling, self-monitoring, social facilitation and technology (Nieste et al., 2021). Reducing sedentary time also led to reductions in HbA1C, body fat percentage and waist circumference (Nieste et al., 2021).

Therefore, sedentary behaviour interventions utilising multiple components such as motivational counselling, self-monitoring, social facilitation and/or technology appear to be promising for reducing sedentary time and improving CVD biomarkers in clinical populations; this should be investigated in individuals with paraplegia.

3.6.5 Use of Behaviour Change Theory

Use of behaviour change theory in sedentary behaviour interventions for clinical population is limited (Hall et al., 2020). A review of sedentary behaviour interventions in clinical populations (overweight/obese, CVD, cancer, depression, osteoarthritis) noted that theoretical models are not clearly described, with only 6 of 18 interventions informed by behaviour change theory (social cognitive theory, control theory, health promotion model, non-specific behaviour change theory) (Martín-Martín et al., 2021). This same review found that the most common BCTs in digital sedentary behaviour interventions in clinical populations were goal setting, problem solving, reviewing outcomes/goals, feedback on behaviour and outcomes of behaviour, self-monitoring of behaviour, social support, information about health consequences, and behaviour practice/rehearsal (Martín-Martín et al., 2021). In spite of

improvements in energy expenditure, physical activity, body composition, quality of life and self-efficacy across included interventions, the authors did not report on which BCTs may lead to better intervention outcomes due to difficulty in determining causality. In addition, the review only included digitally-delivered interventions, excluding other potentially relevant sedentary behaviour interventions with a different delivery mode (Martín-Martín et al., 2021). In a review of interventions of sedentary behaviour in stroke survivors, only one study specifically targeted sedentary behaviour and described the behaviour change approach employed by the intervention; an improvement in sitting time was observed (Saunders et al., 2021). The lack of theory in included interventions may explain the limited improvement in sedentary behaviour seen in this review (Saunders et al., 2021). A scoping review of sedentary behaviour interventions in individuals with CVD identified that three of 11 included interventions were informed by behaviour change theory (Social Cognitive Theory and Behavioural Decision Theory), demonstrating a lack of theoretical underpinning amongst interventions (Peng et al., 2023). This same review also noted that the most commonly used BCTs included were self-monitoring of behaviour, others monitoring with awareness, instruction on how to perform behaviour, feedback on behaviour, graded tasks, goal setting (behaviour), action planning, behavioural rehearsal/practice, review behavioural goals, and behaviour substitution (Peng et al., 2023). Despite seeing improvements in sedentary behaviour across included interventions, this review also did not explore effectiveness of each BCT, limiting implications for future intervention development.

These findings demonstrate the limited reporting of behaviour change theory in sedentary behaviour interventions, as well as a lack of reviews on the effectiveness of different BCTs in clinical populations. Future studies should specify their theoretical approach in order to improve reproducibility, inform future intervention development and understand the most effective BCTs for reducing and breaking up sedentary behaviour in clinical populations.

3.7 Physical Activity Interventions in Individuals With Paraplegia

Interventions targeting physical activity can be used to displace sedentary behaviour. Indeed, engagement in light physical activity was strongly correlated with time spent in sedentary behaviour in the general population (Healy et al., 2008). Furthermore, a meta-analysis found that breaking up sedentary behaviour with light, moderate or vigorous-intensity physical activity is associated with improvements in CVD biomarkers (Chastin et al., 2015). Consequently, physical activity interventions could inform development of sedentary behaviour interventions. Therefore, the exploration of interventions targeting physical activity, in both this section, and the systematic review (Chapter 4), is justified. This section will give a general overview of physical activity interventions in individuals with paraplegia, whereas the systematic review (Chapter 4) will explore the effectiveness of these interventions on sedentary behaviour and CVD biomarkers.

Physical activity interventions have been evaluated in individuals with paraplegia who are wheelchair users (Akkurt et al., 2017; Nightingale et al., 2017, 2018). The majority of interventions involve regular arm crank ergometry exercise, which is possible due to retained function in the upper limbs (Van Der Scheer et al., 2017). Arm crank ergometry exercise training protocols delivered over six weeks have generally been successful for increasing MVPA and measures of cardiorespiratory fitness, such as peak volume of oxygen consumption, in individuals with paraplegia (Nightingale et al., 2017, 2018). Some efficacy has also been observed for CVD biomarkers, such as reductions in fasting insulin and insulin resistance in individuals with paraplegia (Nightingale et al., 2017, 2018) and SCI between C7 and T5 (Bresnahan et al., 2018). Conversely, in individuals with SCI between C3 and T11, no improvements in blood pressure, glycaemia or lipid profile were seen following a 16-week arm crank ergometry intervention (de Zepetnek et al., 2015) that followed SCI-specific exercise guidelines of 40 minutes per week of MVPA (Martin Ginis et al., 2018).

It appears that physical activity interventions could have mixed effectiveness for improving CVD biomarkers in individuals with SCI. This may be because these interventions employ an exercise protocol approach and, therefore, do not target the remainder of the waking day where high volumes of sedentary behaviour and low levels of activity may be present. It has been suggested that focusing on increasing activities of daily living via a whole of the day approach could be an effective approach to health-enhancing behaviour change in individuals with SCI (Manns et al., 2012). Furthermore, reducing and breaking up sedentary behaviour as a target for long-term health behaviour change in individuals with SCI, using a stepwise approach, may be a more realistic initial approach than targeting increases in MVPA (Dogra et al., 2022). Therefore, evaluating sedentary behaviour interventions in terms of their effects on CVD biomarkers in this group is warranted.

3.8 Sedentary Behaviour Interventions in Individuals With Paraplegia

Although sedentary behaviour has been suggested as a more acceptable and realistic target for improving cardiovascular health than MVPA in individuals with paraplegia (Dogra et al., 2022; Manns et al., 2012), there has been a scarcity of studies exploring the reduction and breaking up of this behaviour. A scoping review identified only eight acute sedentary behaviour studies in individuals with SCI (Adams et al., 2024). The authors could not draw any conclusions as to the nature, extent or impact of sedentary behaviour interventions due to the limited amount of studies and their heterogeneity, as each varied widely in study design and outcomes (Adams et al., 2024). Also, this review largely included acute, laboratory-based studies, with only five interventional in nature, unlike other reviews of longer-term, behavioural sedentary behaviour interventions in other clinical populations (Martín-Martín et al., 2021; Nieste et al., 2021) and the general population (Hadgraft et al., 2021; Martin et al., 2015; Prince et al., 2014). Acute, laboratory-based interventions provide limited understanding of the relevance of behaviour change theory and effectiveness of different BCTs for reducing sedentary behaviour in

individuals with paraplegia. In order to better understand these factors, the development and evaluation of longer-term, behavioural, theory-based sedentary behaviour interventions is required in this group.

Bailey et al. (2020) found that, in individuals with paraplegia, breaking up sedentary time with two minutes of moderate-intensity arm ergometry every 20 minutes over 5.5 hours reduced postprandial glucose. There is limited evidence of the longer-term CVD biomarker benefits of reducing sedentary behaviour in individuals with SCI; this is possibly because of the challenge of reducing sedentary time in a population that is required to sit for long periods due to manual wheelchair use. An eight-month coaching-based behavioural intervention targeting increases in physical activity did not reduce accelerometry-measured sedentary behaviour in individuals with paraplegia and tetraplegia (Nooijen et al., 2016). On the contrary, a 16-week virtual exercise intervention, comprising online resources, virtual support meetings, and an exercise equipment pack, in individuals with paraplegia and tetraplegia, led to a significant decrease in self-reported sitting time (measured using the IPAQ 'daily sitting time' question) from baseline to two months post-intervention (Froehlich-Grobe et al., 2022). This contrast in sedentary behaviour change between the studies may be explained by difference in sedentary behaviour measurement. Sitting time is reported despite the participants using a wheelchair for >50% of the waking day; it is unclear whether the IPAQ sitting question was adapted for this study so that it was appropriate for this sample (Froehlich-Grobe et al., 2022). Also, there were no significant improvements in body mass, BMI, or blood pressure (Froehlich-Grobe et al., 2022). Despite reporting sedentary behaviour (or sitting time, a proxy of sedentary behaviour), the primary aim of these two interventions (Froehlich-Grobe et al., 2022; Nooijen et al., 2016) was to increase physical activity, as opposed to reducing sedentary behaviour. This may limit the effectiveness of such interventions for reducing sedentary behaviour, as inappropriate BCTs may be employed for affecting sedentary behaviour (Martin et al., 2015). The uncertainty and

scarcity of evidence in this field may explain why there are no SCI-specific guidelines regarding sedentary behaviour. Interventions targeting sedentary behaviour need to be developed and evaluated in individuals with paraplegia to inform the relevance of sedentary behaviour in healthcare and public health guidelines for this population.

Chapter 4: Study 1. Effects of Interventions on Sedentary Behaviour and Cardiovascular Disease Biomarkers in Individuals With Paraplegia: A Systematic Review

This systematic review has been published in a peer-reviewed journal:

Cooper, D. L., Warland, A., Norris, E., Kilbride, C., Paddison, S., & Bailey, D. P. (2025). Effects of interventions on sedentary behaviour and cardiovascular disease biomarkers in individuals with spinal cord injury: a systematic review. *Disability and Rehabilitation*, 1–24. https://doi.org/10.1080/09638288.2025.2592500 (Appendix 1).

The results of this study provide context around the effectiveness of interventions targeting sedentary behaviour in improving CVD biomarkers, as well as favourable and non-favourable intervention characteristics to improve sedentary behaviour and CVD biomarkers in individuals with paraplegia. These findings were used to inform the intervention design process in the intervention development study (Chapter 5).

4.1 Introduction

Individuals with SCI have been reported to spend more than 12 hours per day being sedentary when measured using accelerometry (Postma et al., 2020). This population group inherently spend long periods of time sitting due to regular or complete reliance on a wheelchair for mobility. The positive effects of reducing sedentary behaviour in non-disabled individuals could be of clinical relevance in those with SCI. Reducing and breaking up sedentary behaviour may also be more achievable than increasing MVPA for individuals with chronic conditions, such as paraplegia (Dogra et al., 2022). However, the evidence around sedentary behaviour in this population is not clearly understood.

A systematic review is needed to understand the potential effectiveness of interventions for reducing sedentary behaviour and improving CVD biomarkers in individuals with SCI. This

could help inform sedentary behaviour guidelines specific to this group. A focus on individuals with paraplegia may be particularly relevant, as this type of SCI provides a greater opportunity to break up sedentary behaviour than tetraplegia due to retained upper limb function.

Sedentary behaviour is an independent risk factor for CVD (Bailey et al., 2019; Wilmot et al., 2012) and is associated with CVD biomarkers (Jones et al., 2025). To address CVD risk, interventions targeting sedentary behaviour have been developed in a number of populations. These interventions have demonstrated effectiveness for reducing sedentary time and improving CVD biomarkers in the general population (Hadgraft et al., 2021; Martin et al., 2015; Prince et al., 2014) and clinical populations (Nieste et al., 2021). The measurement of both behavioural (sedentary time) and health (CVD biomarker) outcomes is important in studies of health behaviour change interventions to provide context around causality (Hardeman et al., 2005). Therefore, both sedentary behaviour and CVD biomarker outcomes were explored in this review.

The aims of this study were to systematically review (1) the effects of interventions on sedentary behaviour, and (2) the effects of these interventions on CVD biomarkers, in individuals with paraplegia.

4.2 Methods

The systematic review protocol was registered prospectively on the International Prospective Register of Systematic Reviews database (PROSPERO; CRD42023420260) and is reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines (Appendix 2) (Page et al., 2021).

4.2.1 Eligibility Criteria

The Population, Intervention, Comparators, Outcomes and Study design (PICOS) process (Amir-Behghadami & Janati, 2020) was used as the framework to guide the eligibility criteria (Table 1). Articles were excluded if the publication was not in English. Published journal articles, conference papers, theses and pre-printed papers were eligible for inclusion.

Conference abstracts were only eligible if the review team could obtain the necessary data from the abstract or study authors.

Table 1. Population, intervention, comparator, outcomes, and study design criteria for the review.

PICOS component	Eligibility criteria
Population	Adult participants (≥ 18 years old) of any sex with paraplegia.
Intervention	Any intervention that targeted a reduction in sedentary behaviour, or targeted an increase in physical activity and included a measurement of sedentary behaviour as an outcome.
Comparator	Studies with or without comparators, including either passive control or active control.
Outcomes	Aim 1: Primarily aim to target sedentary behaviour and/or include a quantitative measurement of sedentary behaviour by self-report or device. Aim 2: Be eligible for Aim 1 and include ≥ 1 cardiovascular disease biomarker.
Study design	Randomised controlled trials, uncontrolled trials, crossover trials, quasi-experimental studies, pre-post studies, pilot studies, and feasibility studies.

4.2.1.1 Population

Studies with adults (≥ 18 years old) with paraplegia were eligible. It was anticipated that articles would vary in their definition of paraplegia; therefore, this review kept the definition purposefully broad to capture all articles that may provide data relevant to the review aims. For example, studies that provided brief or detailed definitions of paraplegia, or where individual level of injury were included. Studies that included participants with paraplegia and tetraplegia were included irrespective of the proportion of the sample with paraplegia as the outcomes would be relevant to the review's target population. Studies were excluded if participants were predominantly ambulant.

4.2.1.2 Intervention

Interventions that targeted a reduction in sedentary behaviour and/or an increase in physical activity (if sedentary behaviour was reported as an outcome) were eligible. As such, interventions targeting physical activity, which could lead to displacement of sedentary

behaviour, were included. Interventions were not limited with respect to any characteristic, delivery mode or dose.

4.2.1.3 Comparator

Studies with or without comparators were eligible, including passive or active control.

4.2.1.4 Outcome

Interventions that specifically target sedentary behaviour and/or include a quantitative measure of sedentary behaviour (self-reported, device-assessed) (Aim 1). Interventions that are eligible for aim 1 and report outcomes for ≥ 1 CVD biomarker (Aim 2).

4.2.1.5 Study Design

Randomised controlled trials, uncontrolled trials, crossover trials, quasi-experimental studies, pre-post studies, pilot studies and feasibility studies were eligible for inclusion.

4.2.2 Search Strategy

Searches were conducted on 12 June 2023, followed by updated searches on 13 August 2024 and 2 September 2025, using the following databases: CINAHL Plus (via EBSCO Host), ClinicalTrials.gov, Cochrane library, ISRCTN Registry, MEDLINE (via EBSCO Host), PsycInfo (via EBSCO Host), Physiotherapy Evidence Database, PubMed, Scopus, SPORT Discus (via EBSCO Host), and Web of Science. There were no search restrictions on publication date or publication type. The full list of search strings is included within Appendix 3. Reference lists of eligible articles were searched to identify any further potential studies for inclusion.

4.2.3 Study Selection

Identified articles were exported to an online systematic review data management system (www.covidence.org) for screening, following removal of duplicates. Two independent reviewers screened titles and abstracts. Full texts were obtained for potentially eligible studies.

The same reviewers independently reviewed the full texts. The reviewers reached a consensus through discussion in cases of disagreement.

4.2.4 Quality Appraisal

Risk of bias was assessed using the Cochrane Risk of Bias 2 tool for randomised trials (RoB-2) and relates to five domains: randomisation, deviation from intended intervention, missing outcome data, measurement of the outcome and selection of the reported results (Sterne et al., 2019). Risk of bias was determined as low, high or some concerns (Sterne et al., 2019).

4.2.5 Data Extraction

Two reviewers independently extracted items into a custom data extraction spreadsheet using Microsoft Excel (Redmond, WA, USA). Extracted data included publication details, study design, participant characteristics (age, sex, and level of injury), intervention characteristics (type, duration, frequency, intensity, delivery mode, setting, provider, use of behaviour change theory), the methods used to measure outcomes, and outcome results (effects on sedentary behaviour and CVD biomarkers). Use of behaviour change theory was determined by the study mentioning the use of a behaviour theory, model or framework within the methods section. Potential uses of behaviour change theory include guiding the intervention development process, retrospective mapping of components to theoretical domains, or being used in intervention delivery.

4.2.6 Quality of Evidence

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) criteria were used to assess certainty of evidence for each outcome (sedentary behaviour and CVD biomarkers) across five domains: risk of bias, inconsistency of results, indirectness of evidence, imprecision and publication bias (Guyatt et al., 2011a). Overall certainty of evidence was rated as high, moderate, low or very low for each outcome (Guyatt et al., 2011a).

4.2.7 Data Synthesis

There was wide heterogeneity in study design and intervention characteristics. Therefore, a meta-analysis was not undertaken. Instead, a qualitative synthesis was undertaken following Synthesis Without a Meta-analysis guidelines (SWiM; Appendix 4) (Campbell et al., 2020). Eligible studies were grouped into suitable categories to interpret the results. Between-group change data was used to determine significance, where possible. If not available, within-group data was used. When neither P-values nor confidence intervals (CI) were reported in a study, 95% CIs for mean differences were calculated to enable determination of statistical significance and aid interpretation. When SD for the mean difference was not available, this was estimated following Cochrane guidelines with a conservative *r* correlation of 0.5 assumed between baseline and follow-up SDs (Higgins et al., 2024). The 95% CIs were then calculated using a paired-samples *t* distribution, with adjustment for width of the interval according to sample size (Altman, 1990). Studies were synthesised in relation to the nature of the intervention (i.e. the target behaviour), intervention characteristics (dose, setting, delivery mode, duration, use of behaviour change theory), study population, outcome measurement method and risk of bias appraisal.

4.3 Results

4.3.1 Study Identification

A total of 11,221 records were identified, from which 5,290 duplicates were removed (Figure 4). Titles and abstract screening of the remaining 5,931 records resulted in 5,868 exclusions. The full-text of the 63 remaining records were assessed for eligibility, resulting in the removal of 54 records. Nine articles were included in the final synthesis. Nightingale et al. (2017, 2018) and Nooijen et al. (2016, 2017) reported findings from a single study across two separate articles; therefore, these were each considered one single intervention. Martinez et al. (2025) reported findings from two different interventions within a single article; therefore, these were considered two distinct interventions (interventions A and B). As a result, the review comprised eight distinct interventions that were investigated in seven studies. The findings of these studies are reported across nine articles.

4.3.2 Study Characteristics

Characteristics of the included studies are shown in Table 2. Three of the seven studies were undertaken in the UK (Bailey et al., 2020; Farrow et al., 2024; Nightingale et al., 2018), two in the US (Froehlich-Grobe et al., 2022; Martinez et al., 2025), one in the Netherlands (Nooijen et al., 2016) and one in Norway (Piira et al., 2020). Five studies were randomised controlled trials (Farrow et al., 2024; Froehlich-Grobe et al., 2022; Nightingale et al., 2018; Nooijen et al., 2016; Piira et al., 2020), one was a randomised comparative effectiveness trial (Martinez et al., 2025) and one employed a randomised controlled crossover design (Bailey et al., 2020).

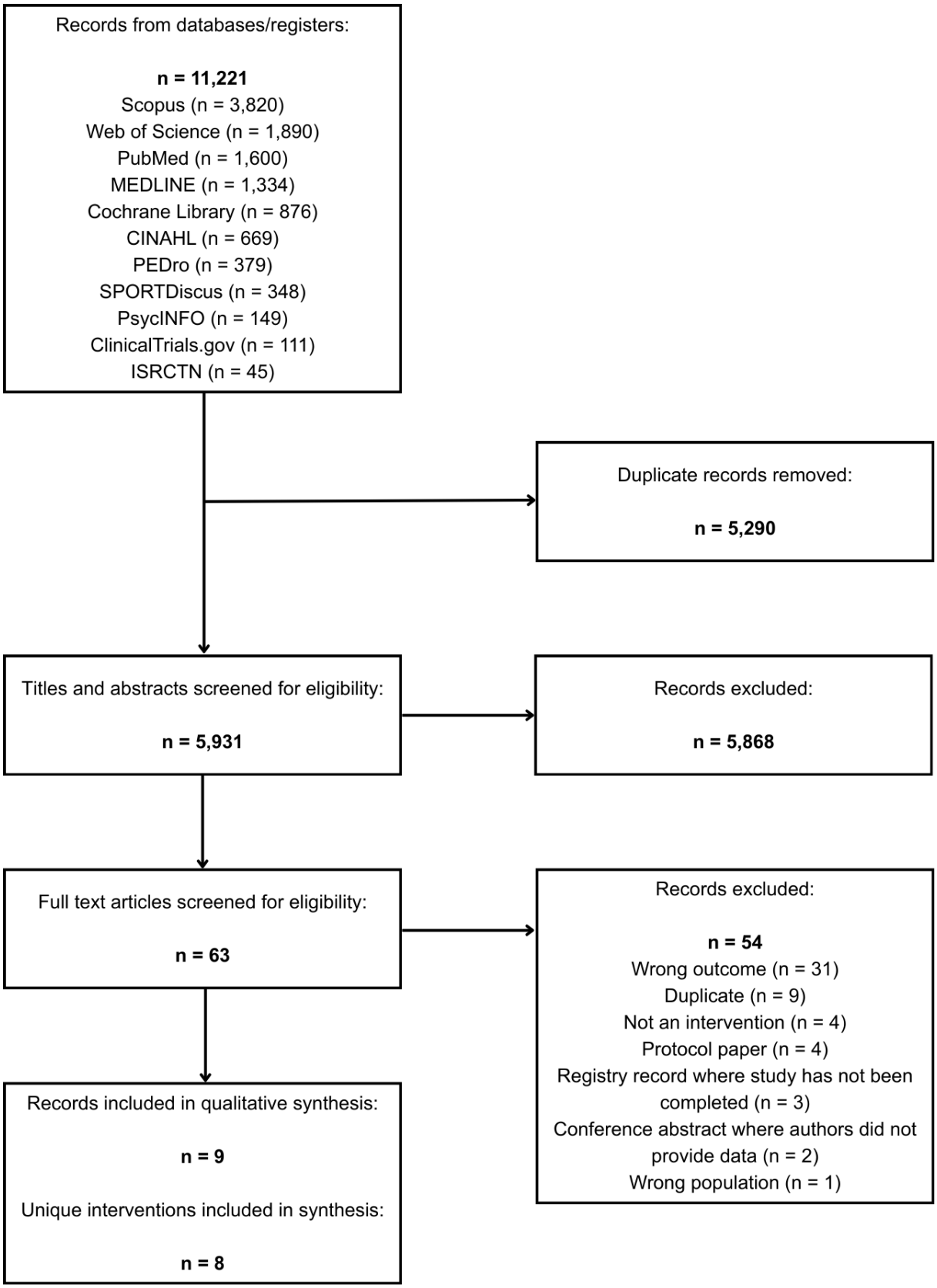

Figure 4. PRISMA flowchart for article identification.

Table 2. Characteristics of included studies.

Study, country	Study design	Participants	Intervention and control characteristics	Intervention delivery mode and setting
Bailey et al. (2020), United Kingdom.	Two-condition randomised controlled crossover design.	N = 14 (8 F, 6 M). Mean age = 51 ± 9 years. Paraplegia between T6 - L5 (plus one participant with post-polio syndrome). Wheelchair user N = 9. Ambulatory N = 5.	Intervention: Participants performed moderate-intensity physical activity for 2 min every 20 min over 5.5 h using an arm ergometer. No behaviour change theory reported. Control: Participants remained seated and sedentary in a wheelchair over 5.5 h.	Controlled condition undertaken individually within University Sport and Exercise Science Laboratories.
Farrow et al. (2024), United Kingdom.	Randomised controlled trial.	N = 27 (14 F, 13 M). Mean age 46 ± 8 years. Paraplegia between T2 and L2. Self-reported use of a wheelchair for >75% of their waking day.	Intervention: Four intervention sessions per week for six weeks involving 10 x 60 s intervals at 80 - 90% of peak heart rate. Intensity increased by 5% every two weeks. No behaviour change theory reported Control: Participants were asked to maintain their habitual diet and physical activity routine.	Home-based exercise training undertaken individually.
Froehlich-Grobe et al. (2022), United States.	Randomised, wait-list controlled trial.	N = 168 (72 F, 96 M). Mean age 49.6 ± 12.3 years. Paraplegia N = 100. Tetraplegia N = 66. Not known N = 2. Manual wheelchair user N = 104. Power wheelchair user N = 60. Scooter user N = 4.	Intervention: 16-week programme providing participants (a) unlimited website access with exercise information, resources, and 16 skill-building modules; (b) virtual 60-minute, group-based 1x/week meetings, (c) unlimited access to a starter package of exercise equipment. The programme was founded upon Social Cognitive Theory and the Relapse Prevention model.	Home and community. Online educational resources and learning modules, group-based meetings, access to personal exercise equipment.

			Control: Participants underwent testing twice before being invited to participate in the intervention programme after a 4-month delay.	
Martinez et al. (2025), United States.	Randomised comparative effectiveness trial.	Sedentary behaviour intervention (A): N = 21 (5 F, 16 M). Mean age 41 (range 27-57) years. Paraplegia between T2 and L3. All manual wheelchair users. Physical activity intervention (B): N = 28 (5 F, 23 M). Mean age 41 (range 22-61) years. Paraplegia between T2 and L3. All manual wheelchair users.	Sedentary behaviour intervention (A): Designed to decrease sedentary time and increase overall physical activity by measuring and accumulating activity throughout the day. Given a wrist-worn activity monitor and phone app to view and track physical activity. Individualised goal-setting to progressively increase daily physical activity and decrease sedentary time and review of activity data with a physical therapist. Given home-based shoulder flexibility and strengthening exercises and recommendations for movement techniques that reduce shoulder demands associated with PA and daily activities. Physical activity intervention (B): Planned arm-crank ergometry. Individualised goal-setting to progressively increase daily physical	Sedentary behaviour intervention (A): Home- and community-based. Physical activity intervention (B): Home- and community-based.

			activity and review of activity data with a physical therapist. Participants were asked to perform 3 x 15 min cycling sessions each week at 70% of maximum heart rate. Participants were encouraged to progressively increase session duration from 15 to 30 min between Weeks 2 and 4 and to 33 min by Week 5. Last, participants were instructed to exercise for 33 - 35 min per sessions, but at a higher intensity (target 85% of maximum heart rate) between week 5 and intervention end. Given home-based shoulder flexibility and strengthening exercises and recommendations for movement techniques that reduce shoulder demands associated with PA and daily activities.	
Nightingale et al. (2017, 2018), United Kingdom.	Randomised controlled trial.	N = 24 (9 F, 15 M). Mean age 47 ± 8 years. Participants had paraplegia below the T4 level. Those with an incomplete injury used a wheelchair >75% of their waking day.	Intervention: 4 x 45-minute moderate-intensity (60%-65% peak oxygen uptake) arm-crank exercise sessions per week for 6 weeks. No behaviour change theory reported. Control: Participants were asked to maintain their habitual physical activity behaviour.	Portable desktop arm-crank ergometer set up in their own home for individual exercise training.
Nooijen et al. (2016, 2017), Netherlands.	Single-blind, multicentre, randomised controlled trial.	N = 39 (6 F, 33 M). Mean age 44 ± 15 years. Paraplegia N = 26. Tetraplegia N = 13. All wheelchair users.	Intervention: Behavioural intervention promoting an active lifestyle after discharge. Intervention involved 13 individual 1-hour sessions delivered by a coach trained in motivational interviewing	Specialised rehabilitation Centres administered the rehabilitation. Face-to-face, individual sessions with a coach were planned for intervention group. Some

			beginning 2 months before and ending 6 months after discharge from inpatient rehabilitation. Motivational interviewing was based on the transtheoretical model. Control: Participants in both groups received usual care, which included a handcycle training program and advice on physical activity after discharge	sessions after discharge were conducted remotely by telephone.
Piira et al. (2020), Norway.	Two parallel independent single-blinded randomised controlled trials.	N = 37 (14 F, 23 M). Mean age 50 ± 13 years. Paraplegia n = 20. Tetraplegia n = 17. Wheelchair-dependent for ambulation N = 24.	Intervention: 60 training days of body weight supported locomotor training, either with manual or robotic assistance 60–90 min per day, 3–5 days per week over 6 months. Telephone follow-up secured compliance. No behaviour change theory reported. Control: Usual care, typically one-on-one, by their local physical therapists 1–3 times per week (range 0–5). Telephone follow-up secured compliance.	Body weight supported locomotor training individual exercise training programme, either with manual or robotic assistance. Two inpatient rehabilitation facilities and one outpatient clinic in Norway.

Notes: F, female; L, lumbar; M, male; T, thoracic.

Sample size ranged from 14 (Bailey et al., 2020) to 168 (Froehlich-Grobe et al., 2022) participants (Table 2). Four studies had a sample including only individuals with paraplegia (Bailey et al., 2020; Farrow et al., 2024; Martinez et al., 2025; Nightingale et al., 2018). Three studies included participants with paraplegia and tetraplegia, in which outcomes were reported for the whole sample (Froehlich-Grobe et al., 2022; Nooijen et al., 2016; Piira et al., 2020). None of the study sample sizes were powered a-priori to detect changes in sedentary behaviour. One study was powered a-priori to detect changes in physical activity (Froehlich-Grobe et al., 2022), and one was underpowered for detecting changes in physical activity as the target sample size was not achieved (Nooijen et al., 2016). Two studies were powered to detect changes in CVD biomarkers, namely postprandial glucose (Bailey et al., 2020) and fasting insulin (Nightingale et al., 2017). One study was underpowered to detect changes in fasting insulin due to an insufficient sample size (Farrow et al., 2024), whilst the remaining three studies did not conduct power calculations for CVD biomarker outcomes (Froehlich-Grobe et al., 2022; Martinez et al., 2025; Nooijen et al., 2017).

4.3.3 Intervention Characteristics

Of the eight interventions identified across the seven studies, six interventions targeted increases in physical activity (Farrow et al., 2024; Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention B]; Nightingale et al., 2018; Nooijen et al., 2016; Piira et al., 2020), whilst two targeted sedentary behaviour (Bailey et al., 2020; Martinez et al., 2025 [intervention A]). Interventions varied from one day (Bailey et al., 2020) to eight months (Nooijen et al., 2016) in duration. Three interventions were home-based exercise training protocols (Farrow et al., 2024; Martinez et al., 2025 [intervention B]; Nightingale et al., 2018), one was a home-based online programme (Froehlich-Grobe et al., 2022), one used an exercise training protocol within a rehabilitation centre (Piira et al., 2020), one used motivational interviewing within a rehabilitation centre (Nooijen et al., 2016), one involved a whole-day approach to replace

sedentary behaviour with physical activity (Martinez et al., 2025 [intervention A]), and one involved supervised breaks in sedentary behaviour within a controlled laboratory setting (Bailey et al., 2020). Four interventions were explicitly informed by behaviour change theory, including Social Cognitive Theory and the Relapse Prevention Model (Froehlich-Grobe et al., 2022), Brief Action Planning (Martinez et al., 2025 [intervention A]) and motivational interviewing based on the Transtheoretical Model (Nooijen et al., 2016).

4.3.4 Risk of Bias

Risk of bias was consistent for both sedentary behaviour and CVD biomarker outcomes across studies. Therefore, risk of bias in each domain is presented as a single judgement for each study (Figure 5). With regards to bias arising from the randomisation process, six of seven studies were deemed low risk (Bailey et al., 2020; Farrow et al., 2024; Martinez et al., 2025; Nightingale et al., 2018; Nooijen et al., 2016; Piira et al., 2020), with one deemed high risk as allocation sequence was not concealed (Froehlich-Grobe et al., 2022). For deviations from the intended intervention protocol, five studies had a low risk of bias (Bailey et al., 2020; Farrow et al., 2024; Martinez et al., 2025; Nightingale et al., 2018; Nooijen et al., 2016) and two had a high risk due to concerns around participant adherence (Froehlich-Grobe et al., 2022; Piira et al., 2020). Five of seven studies had a low risk of bias arising from missing outcome data (Bailey et al., 2020; Farrow et al., 2024; Froehlich-Grobe et al., 2022; Nightingale et al., 2018; Piira et al., 2020), one study raised some concerns as a result of unexplained missing data points (Nooijen et al., 2016), and one study was high risk due to missing data points (Martinez et al., 2025). Regarding measurement of outcome variables, five of seven studies were judged to have low risk of bias (Bailey et al., 2020; Farrow et al., 2024; Froehlich-Grobe et al., 2022; Nightingale et al., 2018; Nooijen et al., 2016), while two studies were deemed high risk due to the findings being pooled from two separate trials undertaken in different settings (Piira et al., 2020) or the use of non-validated methods for outcome measurement (Martinez et al., 2025).

Four studies were assessed as low risk of bias arising from the selection of the reported outcome variables (Bailey et al., 2020; Farrow et al., 2024; Nightingale et al., 2018; Piira et al., 2020), with the remaining three studies raising some concerns as they did not follow a pre-specified data analysis plan (Froehlich-Grobe et al., 2022; Martinez et al., 2025; Nooijen et al., 2016). Overall bias was deemed low risk in three studies (Bailey et al., 2020; Farrow et al., 2024; Nightingale et al., 2018), high risk in three studies (Froehlich-Grobe et al., 2022; Martinez et al., 2025; Piira et al., 2020) and of some concern in one study (Nooijen et al., 2016).

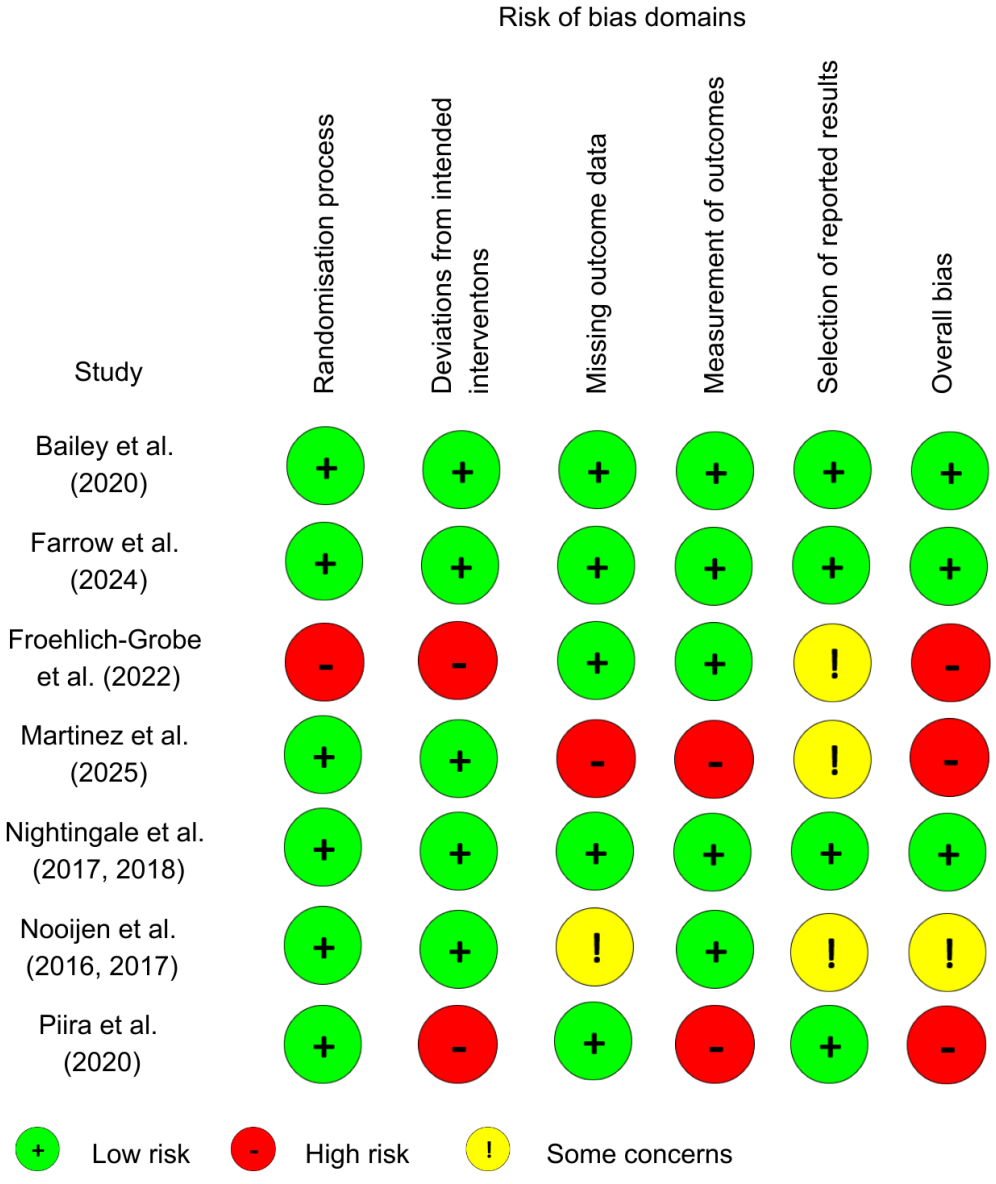

Figure 5. Risk of bias of included studies.

4.3.5 Study Outcomes

4.3.5.1 Sedentary Behaviour Outcomes

Of the seven interventions that included a measurement of sedentary behaviour (Table 3) (Farrow et al., 2024; Froehlich-Grobe et al., 2022; Martinez et al., 2025 [interventions A and B; Nightingale et al., 2018; Nooijen et al., 2016; Piira et al., 2020), two led to improvements (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention A]). In one intervention where there was an improvement (Froehlich-Grobe et al., 2022), self-reported daily sitting was the sedentary behaviour outcome, measured using the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003). The other intervention that led to a reduction in sedentary behaviour used METs derived from heart rate zones (Martinez et al., 2025 [intervention A]). The remaining interventions, in which sedentary behaviour was not reduced, employed accelerometry (Farrow et al., 2024; Nightingale et al., 2018; Nooijen et al., 2016), heart rate zones (Martinez et al., 2025 [intervention B]) and the IPAQ (Piira et al., 2020).

4.3.5.2 Cardiovascular Disease Biomarker Outcomes

Seven of eight interventions included a measurement of one or more CVD biomarkers. Thirty CVD biomarkers were assessed, with improvements in eight of these (systolic blood pressure, diastolic blood pressure, fasting insulin, postprandial glucose, insulin resistance, Matsuda insulin sensitivity index, total cholesterol and LDL cholesterol) reported in five out of seven interventions (Table 3) (Bailey et al., 2020; Farrow et al., 2024; Martinez et al., 2025 [intervention A]; Nightingale et al., 2017; Nooijen et al., 2017). In the other interventions that included CVD biomarker outcomes, there were no improvements (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention B]).

Nightingale et al. (2017, 2018) reported an improvement in insulin resistance and fasting insulin, but with no reduction in sedentary behaviour. There were no improvements in these biomarkers in one other intervention that also did not reduce sedentary behaviour (Farrow et

al., 2024), but there was an improvement in insulin sensitivity (Farrow et al., 2024). Another intervention found no improvements in fasting insulin, insulin resistance or insulin sensitivity, despite reductions in sedentary behaviour (Martinez et al., 2025 [intervention A]).

In the two interventions where postprandial glucose was evaluated, one led to an improvement following supervised breaks in sedentary behaviour (Bailey et al., 2020), whereas there was no change in postprandial glucose or sedentary behaviour in response to the other intervention (Farrow et al., 2024). One intervention led to an improvement in total cholesterol and LDL cholesterol (Nooijen et al., 2017), but with no reduction in sedentary behaviour (Nooijen et al., 2016). Lipid outcomes did not change in response to one intervention that reduced sedentary behaviour (Martinez et al., 2025 [intervention A]), nor three interventions that did not affect sedentary behaviour (Farrow et al., 2024; Martinez et al., 2025 [intervention B]; Nightingale et al., 2018).

Diastolic blood pressure was reduced in one study (Nooijen et al., 2017) in which the intervention did not affect sedentary behaviour (Nooijen et al., 2016). Six other interventions had no effect on diastolic blood pressure (Bailey et al., 2020; Farrow et al., 2024; Froehlich-Grobe et al., 2022; Martinez et al., 2025 [interventions A and B]; Nightingale et al., 2017), despite two of these reporting reductions in sedentary behaviour (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention A]), and one involving supervised breaks in sedentary behaviour (Bailey et al., 2020). There was a reduction in systolic blood pressure and sedentary behaviour in one (Martinez et al., 2025 [intervention A]) of the seven interventions measuring this outcome (Bailey et al., 2020; Farrow et al., 2024; Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention B]; Nightingale et al., 2017; Nooijen et al., 2017).

Body composition outcomes (body mass, body fat, body mass index, waist circumference and waist to hip ratio) did not improve in any of the four interventions that assessed these outcomes

(Farrow et al., 2024; Froehlich-Grobe et al., 2022; Nightingale et al., 2017; Nooijen et al., 2017).

Table 3. Outcomes of included studies.

Study, country	Sedentary behaviour outcome measures	Sedentary behaviour outcomes	Cardiovascular disease biomarker outcome measures	Cardiovascular disease biomarker outcomes
Bailey et al. (2020), United Kingdom.	N/A	N/A	Capillary blood samples at baseline, 30, 60, 90, 120, 180, 210, 240, 300, and 330 min. YSI analyser used to analyse blood glucose (mmol/L), Reflotron Plus used to measure triglycerides (mmol/L), ELISA used to measure insulin (μU/mL). Glucose, insulin and triglycerides were reported as total and incremental AUC. Blood pressure measured at baseline, 60, 120, 180, 240 and 300 min.	Data presented as mean (95% confidence intervals) for Intervention vs. Control *denotes significant difference between conditions ($p < 0.05$). **Total 5 h postprandial period:** - **Mean arterial pressure** (mmHg) 97.1 (96.7, 97.6) vs. 96.8 (96.4, 97.3) $p = 0.310$ - **Systolic blood pressure** (mmHg) 125.9 (121.5, 130.3) vs. 123.9 (119.4, 128.3) $p = 0.366$ - **Diastolic blood pressure** (mmHg) 76.6 (74.4, 78.9) vs. 76.8 (74.5, 79.0) $p = 0.934$ - **Glucose iAUC** (mmol/L·5.5 h) 5.1 (2.8, 7.4) vs. 6.5 (4.2, 8.8) $p = 0.275$ - **Glucose tAUC** (mmol/L·5.5 h) 33.7 (31.4, 36.0) vs. 35.1 (32.8, 37.4) $p = 0.276$ - **Insulin iAUC (**μU/mL·5.5 h) 217.1 (165.5, 268.8) vs. 202.9 (121.3, 284.5) $p = 0.753$ - **Insulin tAUC** (μU/mL·5.5 h) 285.4 (232.6, 338.1) vs. 262.7 (175.7, 349.8) $p = 0.980$ - **Triglycerides iAUC** (mmol/L·5.5 h) 3.5 (1.6, 5.4) vs. 2.1 (0.3, 4.0) $p = 0.194$ - **Triglycerides tAUC** (mmol/L·5.5 h) 16.2 (14.3, 18.1) 14.8 (13.0, 16.6) $p = 0.194$ **Breakfast postprandial period:** - **Glucose iAUC** (mmol/L·3 h) 4.9 (2.3, 7.5) vs. 5.0 (2.4, 7.6) $p = 0.905$ - **Glucose tAUC** (mmol/L·3 h) 19.8 (17.2, 22.4) vs. 20.0 (17.4, 22.6) $p = 0.905$ - **Insulin iAUC** (μU/mL·3 h) 129.0 (101.9, 156.3) vs. 115.8 (70.3, 161.3) $p = 0.594$

				- **Insulin tAUC** (μU/mL·3 h) 164.6 (136.4, 192.8) vs. 147.0 (98.1, 195.9) $p = 0.509$ - **Triglycerides iAUC** (mmol/L·3 h) 0.8 (-0.2, 1.7) vs. -0.01 (-0.9, 0.9) $p = 0.172$ - **Triglycerides tAUC** (mmol/L·3 h) 7.4 (6.4, 8.3) vs. 6.6 (5.7, 7.5) $p = 0.172$ **<u>Lunch postprandial period:</u>** - ***Glucose iAUC** (mmol/L·2.5 h) 1.9 (1.0, 2.7) vs. 3.0 (2.1, 3.9) ($p = 0.015$, $f = 0.34$) - ***Glucose tAUC** (mmol/L·2.5 h) 15.3 (14.4, 16.1) vs. 16.4 (15.5, 17.2) ($p = 0.015$, $f = 0.34$) - **Insulin iAUC** (μU/mL·2.5 h) 38.0 (−8.9, 84.8) vs. 57.7 (10.8, 104.5) ($p = 0.122$) - **Insulin tAUC** (μU/mL·2.5 h) 128.5 (101.4, 155.5) vs. 127.7 (100.7, 154.7) ($p = 0.949$) - **Triglycerides iAUC** (mmol/L·2.5 h) 1.1 (0.23, 2.0) vs. 1.4 (0.6, 2.3) ($p = 0.482$) - **Triglycerides tAUC** (mmol/L·2.5 h) 8.3 (7.4, 9.2) vs. 8.6 (7.8, 9.5) ($p = 0.482$).
Farrow et al. (2024), United Kingdom.	Participants wore a physical activity monitor (ActiheartTM) for 7-days after the baseline visit, and in the final week of the intervention period. Defined as <1.5 METs. Measured as min/day.	Data presented as mean (95% CI) for Intervention and Control groups pre- vs. post-intervention. **Sedentary time (min/day):** Intervention 642 (598, 687) vs. 687 (595, 780) Control 723 (628, 818) vs. 522 (404, 639) ($p = 0.040$)	Body mass was measured using platform wheelchair scales. DEXA scan was used to measure total fat mass (kg), total fat free mass (kg), and total body fat percentage. Supine length was measured using a non-elastic tape measure. Waist and hip circumferences were taken in duplicate, using a non-metallic tape measure. Resting blood pressure was measured in triplicate using an automated blood pressure monitor. Serum insulin, leptin and adiponectin were determined using ELISA. Plasma glucose and serum	Data presented as means (95% CI) or percentage change (%) for Intervention and Control groups pre- vs. post-intervention. *denotes significant difference ($p < 0.05$). - ***Matsuda ISI:** Intervention 10.3 ± 29.7% Control -12.6 ± 24.8% ($p = 0.036$) - **Systolic blood pressure (mmHg):** Intervention 125 (120, 129) vs. 118 (114, 123) Control 114 (106, 123) vs. 117 (111, 124) ($p = 0.774$) - **Diastolic blood pressure (mmHg):** Intervention 81 (78, 84) vs. 78 (75, 81) Control 77 (72, 82) vs. 78 (74, 82) ($p = 0.942$) - **Body mass (kg):** Intervention 76.5 (67.7, 85.3) vs. 74.9 (74.1, 75.7) Control 75.5 (60.8, 90.2) vs. 70.6 (59.6, 81.7)

	triglycerides, NEFA, total cholesterol, HDL cholesterol, LDL cholesterol concentrations were determined using an automated analyser. Insulin and glucose tAUC and iAUC were determined using the trapezoidal rule to characterise responses to the OGTT. The Matsuda C-ISI, HOMA2-IR and HOMA-ß were calculated to give fasting measures of insulin resistance, insulin sensitivity and pancreatic ß-cell function.	(p = 0.103) - **BMI (kg/m^2):** Intervention 26.6 (23.9, 29.3) vs. 26.1 (25.8, 26.3) Control 24.6 (21.6, 27.7) vs. 25.7 (25.2, 26.1) (p = 0.115) - **Waist circumference (cm):** Intervention 87.7 (79.7, 95.7) vs. 85.2 (83.8, 86.6) Control 83.8 (76.2, 91.4) vs. 84.8 (82.8, 86.8) (p = 0.778) - **Waist:hip ratio:** Intervention 0.85 (0.81, 0.89) vs. 0.85 (0.83, 0.86) Control 0.86 (0.81, 0.92) vs. 0.82 (0.79, 0.84) (p = 0.089) - **Fat mass (kg):** Intervention 30.2 (24.5, 36.0) vs. 29.4 (28.4, 30.3) Control 25.0 (19.7, 30.4) vs. 28.5 (27.1, 29.8) (p = 0.286) - **Body fat (%):** Intervention 39.5 (34.7, 44.2) vs. 39.3 (38.3, 40.3) Control 36.4 (29.9, 42.9) vs. 38.5 (37.0, 40.0) (p = 0.365) - **Fasting glucose** (mmol/L) Intervention 5.52 (4.23, 6.80) vs. 5.73 (5.27, 6.19) Control 4.77 (4.14, 5.40) vs. 5.80 (5.19, 6.41) (p = 0.849) - **HOMA2-IR:** Intervention 1.07 (0.54, 1.60) vs. 0.85 (0.70, 1.00) Control 0.71 (0.49, 0.94) vs. 1.00 (0.80, 1.21) (p = 0.224) - **Glucose iAUC** (mmol/L x 120 min): Intervention 433 (320, 545) vs. 411 (319, 503) Control 350 (192, 508) vs. 383 (221, 545) (p = 0.765) - **Glucose tAUC** (mmol/L x 120 min): Intervention 1096 (859, 1333) vs. 1053 (982, 1123) Control 908 (787, 1029) vs. 1028 (903, 1153) (p = 0.728) - **Insulin iAUC** (pmol/L x 120 min): Intervention 44.5 (27.1, 61.9) vs. 48.1 (40.7, 55.5)

				Control 69.4 (−5.4, 144.3) vs. 57.1 (44.0, 70.1) (p = 0.242) - **Insulin tAUC** (pmol/L x 120 min): Intervention 51.2 (33.8, 68.6) vs. 53.3 (45.7, 60.9) Control 74.9 (−1.60, 151.3) vs. 63.3 (51.0, 77.7) (p = 0.164) - **NEFA** (mmol/L): Intervention 0.61 (0.47, 0.76) vs. 0.56 (0.46, 0.66) Control 0.58 (0.35, 0.81) vs. 0.55 (0.43, 0.69) (p = 0.953) - **Leptin** (μg/L): Intervention 10.7 (6.0, 15.4) vs. 15.0 (11.3, 16.9) Control 11.4 (6.4, 16.3) vs. 11.1 (5.3, 16.9) (p = 0.264) - **Adiponectin** (μg/L): Intervention 9.21 (6.89–11.5) 9.58 (8.69–10.5) Control 10.6 (4.91–16.3) 10.1 (8.88–11.3) (p = 0.491) - **Fasting insulin** (pmol/L): (p = 0.415) - **Total cholesterol (mmol/L):** Intervention 4 5.03 (4.51, 5.56) vs. 5.47 (5.16, 5.77) Control 5.47 (4.73, 6.21) vs. 5.13 (4.72, 5.54) (p = 0.193) - **HDL cholesterol (mmol/L):** Intervention 1.12 (0.91, 1.32) vs. 1.30 (1.21, 1.39) Control 1.27 (0.99, 1.54) vs. 1.23 (1.11, 1.35) (p = 0.329) - **LDL cholesterol (mmol/L):** Intervention 3.46 (3.00, 3.92) vs. 3.71 (3.38, 4.05) Control 3.65 (2.85, 4.44) vs. 3.33 (2.88, 3.78) (p = 0.173) - **Triglycerides (mmol/L):** Intervention 1.13 (0.80, 1.46) vs. 1.04 (0.87, 1.21) Control 1.20 (0.70, 1.70) vs. 1.25 (1.02, 1.48) (p = 0.142)
Froehlich-Grobe et al.	IPAQ-SF question to assess sitting	**<u>Wait-list control:</u>** Data presented as mean ± SD for Intervention and wait-list	Resting blood pressure (mmHg) and heart rate were obtained before (0 months)	**<u>RCT:</u>** Data presented as means ± SD for Intervention and Control groups pre- vs. post-intervention.

(2022), United States.	time (hours/day).	control combined pre-post results between 0 m vs. 4 m, and 0 m vs. 6 m. *denotes significant group x time interaction effect. ***Sit time (min/day):** 0 m 616.22 ± 229.19 vs. 4 m 567.05 ± 264.86 (p = 0.076) 0 m 616.22 ± 229.19 vs. 6 m 555.13 ± 252.28 (p = 0.017)	and after (4 month) the exercise intervention. Body weight (kg) measured using a digital wheelchair scale.	- **Systolic blood pressure (mmHg):** Intervention 114.1 ± 19.6 vs. 115.5 ± 18.0 Control 109.2 ± 21.5 vs. 114.4 ± 20.1 Group x time interaction p = 0.374 - **Diastolic blood pressure (mmHg):** Intervention 73.7 ± 12.8 vs. 71.8 ± 12.9 Control 73.2 ± 11.2 vs. 71.3 ± 11.3 Group x time interaction p = 0.644 - **Body weight (kg):** Intervention 86.2 ± 22.0 vs. 85.2 ± 23.8 kg Control 81.6 ± 20.8 vs. 81 ± 21.8 kg Group x time interaction p = 0.563 - **BMI (kg/m^2):** Intervention 28.3 ± 6.2 vs. 28.4 ± 7.2 Control 27.2 ± 6.5 vs. 26.7 ± 6.9 Group x time interaction p = 0.104 **<u>Wait-list control:</u>** Data presented as means ± SD for Intervention and wait-list control combined pre-post results between 0 m vs. 4 m. - **Systolic blood pressure (mmHg):** 0 m 112.4 ± 20.3 vs. 4 m 115.0 ± 18.7 (p = 0.706) - **Diastolic blood pressure (mmHg):** 0 m 73.5 ± 12.1 vs. 4 m 71.6 ± 12.0 (p = 0.125) - **Body weight (kg):** 0 m 84.6 ± 21.5 vs. 4 m 83.3 ± 22.7 (p = 0.722) - **BMI (kg/m^2):** 0 m 27.9 ± 6.3 vs. 4 m 27.6 ± 7.0 (p = 0.475)

Martinez et al. (2025), United States.	Participants wore a Fitbit device on the wrist over 7 days to measure baseline sedentary behaviour in min/day based on heart rate zones (1 MET for > 10 min in duration). The same device was worn throughout the whole intervention, with the average daily sedentary behaviour over the final month used to determine post-intervention values.	Data presented as Δ mean difference (95% CI) for pre- vs post-intervention. * denotes significant difference. **<u>Sedentary behaviour intervention (A):</u>** ***Sedentary behaviour (min/day):** Intervention A Δ -118 (-222 to -14[a]) **<u>Physical activity intervention (B):</u>** **Sedentary behaviour (min/day):** Intervention B Δ -47 (-109 to 15[a]) Between group difference in change *p* = n.s.	Diastolic and systolic blood pressure (mmHg) were measured after a 6-minute push test. Fasted blood samples were taken to measure glucose, insulin, HOMA-%B, HOMA-%S, HOMA-IR, lipid profile and triglycerides (mg/dL).	Data presented as Δ mean difference (95% CI) for diastolic blood pressure and median (interquartile range) for triglycerides, pre- vs. post-intervention. *denotes significant difference. **<u>Sedentary behaviour intervention (A):</u>** - ***Diastolic blood pressure (mmHg):** Intervention Δ -6 (-11 to -1[a]) Between group difference in change *p* = 0.019 - **Systolic blood pressure (mmHg):** Between group difference in change *p* > 0.05. - **Glucose (mg/dL):** Between group difference in change *p* > 0.05 - **Insulin (mg/dL):** Between group difference in change *p* > 0.05 - **HOMA-%B:** Between group difference in change *p* > 0.05 - **HOMA-%S:** Between group difference in change *p* > 0.05 - **HOMA-IR:** Between group difference in change *p* > 0.05 - **Lipid profile:** Between group difference in change *p* > 0.05 - **Triglycerides (mg/dL):** Intervention Δ 7 (7, 46) Between group difference in change *p* = 0.092 **<u>Physical activity intervention (B):</u>** - **Diastolic blood pressure (mmHg):** Intervention Δ 2 (-3 to 7[a]) Between group difference in change *p* = 0.019 - **Systolic blood pressure (mmHg):** Between group difference in change *p* > 0.05. - **Glucose (mg/dL):** Between group difference in change *p* > 0.05 - **Insulin (mg/dL):** Between group difference in change *p* > 0.05

				- **HOMA-%B:** Between group difference in change $p > 0.05$ - **HOMA-%S:** Between group difference in change $p > 0.05$ - **HOMA-IR:** Between group difference in change $p > 0.05$ - **Lipid profile:** Between group difference in change $p > 0.05$ - **Triglycerides (mg/dL):** Intervention Δ -5 (-29, 9) Between group difference in change $p = 0.092$
Nightingale et al. (2017, 2018), United Kingdom.	Participants wore a chest-mounted Actiheart device to measure sedentary behaviour (< 1.5 METs) in min/day.	Data presented as means ± SD for Intervention and Control groups pre- vs. post-intervention. *denotes significant difference. **Sedentary time (min/day):** Intervention: 1232 ± 118 vs. 1179 ± 124 (Δ-53, -126 to 20[a]) Control: 1220 ± 115 vs. 1191 ± 139 (Δ-29, -136 to 78[a])	Blood pressure (mmHg), supine height (m), body mass, fat mass and lean mass (kg) were measured fasted OGTT to measure metabolic regulation, glucose, insulin (mmol/L), post-load glucose, post-load insulin (mmol/120min/L), NEFA, triacylglycerol, HOMA-2ß (%), HOMA2-IR, Matsuda C-ISI and total cholesterol, HDL cholesterol and LDL cholesterol (mmol/L).	Data presented as Δ mean difference (95% CI) for Intervention and Control groups pre- vs. post-intervention. *denotes significant difference ($p < 0.05$). - ***Insulin (pmol/L):** Intervention Δ -12.7 (-24.0, -1.4) ($p = 0.031$) Control Δ 3.1 (-5.9, 12.0) (N.S.) Between group difference in change $p \leq 0.044$ - ***HOMA2-IR:** Intervention Δ -0.24 (-0.45, -0.02) ($p < 0.035$) Control Δ 0.06 (-0.10, 0.23) (N.S.) Between group difference in change $p \leq 0.044$ - **Systolic blood pressure (mmHg):** Intervention Δ -3 (-10, 5) Control Δ -2 (-8, 2) - **Diastolic blood pressure (mmHg):** Intervention Δ -1 (-8, 6) Control Δ -4 (-9, 2) - **Body mass (kg):** Intervention Δ -1.1 (-2.1, -0.0) Control Δ -0.7 (-2.2, 1.0) Between group difference in change $p = 0.6$ - **Fat mass (kg):** Intervention Δ -0.6 (-1.4, 0.2) Control Δ -0.0 (-0.7, 0.7) - **Glucose (mmol/L):** Intervention Δ 0.0 (-0.2, 0.2) Control Δ 0.0 (-0.2, 0.2)

	Group x time interaction $p \geq 0.3$ - **HOMA2-ß (%):** Intervention Δ -14 (-26, -2) Control Δ 1 (-10, 13) Group x time interaction $p = 0.066$ - **Matsuda ISI:** Intervention Δ 0.3 (-0.7, 1.2) Control Δ -0.7 (-2.6, 1.2) Group x time interaction $p \geq 0.3$ - **Glucose response (mmol/L·120 min):** Intervention Δ 19 (-48, 86) Control Δ -25 (-153, 104) Group x time interaction $p \geq 0.3$ - **Insulin response (nmol/L·5.5 h):** Intervention Δ -4.4 (-19.0, 10.2) Control Δ 2.2 (-11.6, 16.0) Group x time interaction $p \geq 0.3$ - **NEFA (mmol/L):** Intervention Δ 0.3 (-0.2, 0.8) Control Δ -0.1 (-0.8, 0.6) Group x time interaction $p \geq 0.3$ - **Triacylglycerol (mmol/L):** Intervention Δ -0.1 (-0.2, 0.1) Control Δ 0.5 (-2.0, 1.2) Group x time interaction $p = 0.054$ - **Total cholesterol (mmol/L):** Intervention Δ -0.1 (-0.5, 0.4) Control Δ 0.1 (-0.5, 0.5) Group x time interaction $p \geq 0.3$ - **HDL cholesterol (mmol/L):** Intervention Δ 0.1 (-0.1, 0.1) Control Δ -0.0 (-0.1, 0.1) Group x time interaction $p \geq 0.3$ - **LDL cholesterol (mmol/L):** Intervention Δ -0.0 (-0.4, 0.3) Control Δ -0.2 (-0.6, 0.2) Group x time interaction $p \geq 0.3$

Nooijen et al. (2016, 2017), Netherlands.	Body-fixed accelerometers measured the total duration of sedentary daytime bouts longer than 30 minutes. Defined as sitting and lying during the day without interruption by physical activity for a minimum of 5 seconds (min/day).	Data presented as mean difference (95% CI) in change from baseline to discharge, baseline to month 6, baseline to month 12 and overall change between Intervention and Control groups. Means are adjusted for rehabilitation centre, gender and age. **Sedentary daytime (min/day):** Baseline to discharge: -14 (-69, 40) Baseline to 6 m: -50 (-134, 33) Baseline to 12 m: -21 (-119, 77) Overall intervention vs. control: -34 (-97, 29)	BMI (kg/m2) was calculated from height (m) and body mass (kg). Resting diastolic and systolic blood pressure (mmHg) were measured by a physician. Fasting blood samples were taken for total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides and glucose (mmol/L). Comparisons are "baseline vs. discharge", "baseline vs. month 6", and "baseline vs. month 12".	Data presented as mean ± SD for Intervention vs. Control groups at each timepoint: baseline, discharge, month 6 and month 12. P values are adjusted for rehabilitation centre, sex and age. *denotes significant between-group effect ($p < 0.05$). - ***Diastolic blood pressure (mmHg):** Baseline: 72 ± 9 vs. 77 ± 13 Discharge: 73 ± 9 vs. 77 ± 8 ($p = 0.52$) 6 m: 74 ± 13 vs. 84 ± 11 ($p = 0.04$) 12 m: 74 ± 12 vs. 83 ± 18 ($p = 0.01$) Overall model: ($p = 0.02$) - ***Total cholesterol (mmol/L):** Baseline: 4.47 ± 0.84 vs. 4.96 ± 1.19 Discharge: 4.47 ± 0.92 vs. 5.17 ± 1.00 ($p = 0.39$) 6 m: 4.63 ± 0.85 vs. 5.55 ± 1.29 ($p = 0.17$) 12 m: 4.17 ± 0.51 vs. 5.21 ± 0.83 ($p = 0.01$) Overall model ($p = 0.06$) - ***LDL cholesterol (mmol/L):** Baseline: 2.76 ± 0.85 vs. 3.22 ± 0.91 Discharge: 2.63 ± 0.73 vs. 3.39 ± 0.86 ($p = 0.34$) 6 m: 2.95 ± 0.54 vs. 3.46 ± 1.10 ($p = 0.40$) 12 m: 2.46 ± 0.75 vs. 3.13 ± 0.63 ($p = 0.05$) Overall model ($p = 0.08$) - **Systolic blood pressure (mmHg):** Baseline: 123 ± 19 vs. 127 ± 21 Discharge: 120 ± 15 vs. 124 ± 14 ($p = 0.75$) 6 m: 128 ± 28 vs. 132 ± 14 ($p = 0.62$) 12 m: 125 ± 19 vs. 130 ± 18 ($p = 0.36$) Overall model ($p = 0.46$) - **BMI (kg/m^2):** Baseline: 25.43 ± 5.23 vs. 23.90 ± 4.68 Discharge: 25.60 ± 5.56 vs. 24.60 ± 5.18 ($p = 0.56$) 6 m: 25.66 ± 5.53 vs. 26.00 ± 5.53 ($p = 0.41$) 12 m: 25.36 ± 5.59 vs. 27.13 ± 5.20 ($p = 0.36$) Overall model ($p = 0.29$) - **Glucose (mmol/L):** Baseline: 4.97 ± 0.69 vs. 5.52 ± 2.20 Discharge: 5.16 ± 1.28 vs. 6.61 ± 3.02 ($p = 0.06$) 6 m: 5.00 ± 0.57 vs. 6.25 ± 1.27 ($p = 0.58$)

				12 m: 5.66 ± 1.93 vs. 7.13 ± 3.55 (p = 0.38) Overall model (p = 0.05) - **HDL cholesterol (mmol/L):** Baseline: 1.37 ± 1.21 vs. 1.23 ± 1.02 Discharge: 1.02 ± 0.31 vs. 1.01 ± 0.15 (p = 0.61) 6 m: 1.08 ± 0.48 vs. 0.97 ± 0.15 (p = 0.80) 12 m: 1.09 ± 0.31 vs. 1.04 ± 0.31 (p = 0.23) Overall model (p = 0.62) - **Triglycerides (mmol/L):** Baseline: 1.40 ± 0.76 vs. 1.84 ± 0.93 Discharge: 1.50 ± 0.97 vs. 1.93 ± 0.93 (p = 0.71) 6 m: 1.80 ± 1.71 vs. 2.24 ± 1.23 (p = 0.17) 12 m: 1.12 ± 0.65 vs. 2.37 ± 1.38 (p = 0.36) Overall model (p = 0.71)
Piira et al. (2020), Norway.	Measured using the IPAQ-SF questionnaire (with no adaptation for wheelchair dependent individuals), reported in min/day.	Data presented as means ± SD for Intervention and Control groups pre- vs. post-intervention. * denotes significant difference. **Sitting time (min/day):** Intervention: 553.1 ± 265.4 vs. 457.9 ± 292.1 (Δ-95.2, -244.2 to 53.8[a]) Control: 554.3 ± 323.6 vs. 504.0 ± 229.0 (Δ-50.3, -182.5 to 81.9[a])	N/A	N/A

BMI, body mass index; CI, confidence interval; C-ISI, composite insulin sensitivity index; DEXA, Dual-energy X-ray absorptiometry; ELISA, enzyme-linked immunoassay; HDL, high density lipoprotein; HOMA-ß, homeostatic model assessment for ß cell function; HOMA-IR, homeostatic model assessment for insulin resistance; HOMA-%S, homeostatic model assessment for insulin sensitivity; iAUC, incremental area under the curve; IPAQ, international physical activity questionnaire; ISI, insulin sensitivity index; LDL, low density lipoprotein; MET, metabolic equivalent of task; NEFA, non-esterified fatty acids; N.S., non-significant; OGTT, oral glucose tolerance test; QUICKI, quantitative insulin sensitivity check index; RCT, randomised controlled trial; SD, standard deviation; tAUC, total area under the curve.

a Within-group 95% confidence interval estimated from study data to determine statistical significance.

4.3.5.3 Outcomes in the Context of Study Population

In the two interventions that led to reductions in sedentary behaviour, one included participants with paraplegia and tetraplegia (Froehlich-Grobe et al., 2022), whereas the other included participants with paraplegia only (Martinez et al., 2025 [intervention A]). Of the five interventions that had no effect on sedentary behaviour, two included participants with paraplegia and tetraplegia (Nooijen et al., 2016; Piira et al., 2020), and three included paraplegia only (Farrow et al., 2024; Martinez et al., 2025 [intervention B]; Nightingale et al., 2018). Overall, the proportion of individuals with paraplegia in the study sample did not appear to influence sedentary behaviour outcomes.

Four interventions that led to improvements in CVD biomarkers included only individuals with paraplegia (Bailey et al., 2020; Farrow et al., 2024; Martinez et al., 2025 [intervention A]; Nightingale et al., 2017), whilst one studied a sample comprising individuals with paraplegia and tetraplegia (Nooijen et al., 2017). Of the two interventions that did not improve CVD biomarkers, one included only individuals with paraplegia (Martinez et al., 2025 [intervention B]) and the other included both people with paraplegia and tetraplegia (Froehlich-Grobe et al., 2022). Intervention effects, therefore, appeared to be more consistent in studies that included only participants with paraplegia.

4.3.5.4 Outcomes in the Context of Intervention Characteristics

4.3.5.4.1 Targeting Physical Activity or Sedentary Behaviour

Of the two interventions that reduced sedentary behaviour, one targeted reductions in sedentary behaviour via a whole-day approach (Martinez et al., 2025 [intervention A]), whilst the other targeted increased physical activity using an online programme (Froehlich-Grobe et al., 2022). The five other interventions that targeted increases in physical activity (four using structured exercise training and one using motivational interviewing) found no effect (Farrow et al., 2024; Martinez et al., 2025 [intervention B]; Nightingale et al., 2018; Nooijen et al., 2016; Piira et al.,

2020). The remaining intervention included supervised breaks in sedentary behaviour and, therefore, reduced sedentary time but did not report sedentary behaviour as an outcome (Bailey et al., 2020). It appears that interventions targeting physical activity are not effective for reducing sedentary behaviour in participants with SCI.

Three of the five interventions that improved CVD biomarkers targeted increases in physical activity, but did not reduce sedentary behaviour (Farrow et al., 2024; Nightingale et al., 2017; Nooijen et al., 2016). Two interventions that reported biomarker improvements targeted sedentary behaviour (Bailey et al., 2020; Martinez et al., 2025 [intervention A]); these studies led to reduced sedentary behaviour (Martinez et al., 2025 [intervention A]) or were supervised breaks in sedentary behaviour (Bailey et al., 2020). The two interventions that did not improve any CVD biomarker both targeted physical activity (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention B]); one reduced sedentary behaviour (Froehlich-Grobe et al., 2022) and the other did not (Martinez et al., 2025 [intervention B]). One intervention that targeted physical activity did not include any CVD biomarker outcomes (Piira et al., 2020). There appears to be some evidence for CVD biomarkers being improved in interventions that target sedentary behaviour.

4.3.5.4.2 Intervention Duration

The two interventions that led to reductions in sedentary behaviour were each 16 weeks (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention A]) in duration. The interventions that had no effect on sedentary behaviour were six weeks (Farrow et al., 2024; Nightingale et al., 2018), sixteen weeks (Martinez et al., 2025 [intervention B]), six months (Piira et al., 2020) and eight months (Nooijen et al., 2016) in duration. It is unclear whether intervention duration affects sedentary behaviour outcomes.

One of the five interventions that improved CVD biomarkers lasted one day (Bailey et al., 2020), two lasted six weeks (Farrow et al., 2024; Nightingale et al., 2017), one lasted sixteen weeks (Martinez et al., 2025 [intervention A]) and one lasted eight months (Nooijen et al., 2017) (Table 2). The two interventions that had no effect on any CVD biomarker were 16 weeks in duration (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention B]). It is unclear whether intervention duration affects CVD biomarker outcomes.

4.3.5.4.3 Intervention Setting and Delivery Mode

One of the two interventions that reduced sedentary behaviour was a home-based online programme (Froehlich-Grobe et al., 2022) and one was a home- and community-based intervention targeting the whole day (Martinez et al., 2025 [intervention A]). Three of the five interventions that did not reduce sedentary behaviour were home- and community-based exercise training protocols (Farrow et al., 2024; Martinez et al., 2025 [intervention B]; Nightingale et al., 2018), whilst the others included motivational interviewing within a rehabilitation centre (Nooijen et al., 2016) and a structured exercise training protocol in a rehabilitation centre (Piira et al., 2020). It appears that structured exercise training protocols are not effective for reducing sedentary behaviour.

Two of the five interventions that improved CVD biomarkers included home-based exercise training protocols (Farrow et al., 2024; Nightingale et al., 2017), one involved a home- and community-based intervention targeting the whole day (Martinez et al., 2025 [intervention A]), one involved motivational interviewing within a rehabilitation centre (Nooijen et al., 2017) and one involved supervised breaks in sedentary behaviour in a controlled laboratory setting (Bailey et al., 2020). The two interventions that did not improve CVD biomarkers included a home-based online programme (Froehlich-Grobe et al., 2022) and a home- and community-based structured exercise training protocol (Martinez et al., 2025 [intervention B]). Cardiovascular

disease biomarker outcomes appear to be improved across a range of intervention settings and delivery modes.

4.3.5.4.4 Use of Behaviour Change Theory

Four interventions were either underpinned by, or employed, behaviour change theory (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention A]; Nooijen et al., 2016). There was no mention of behaviour change theory in the other four interventions (Bailey et al., 2020; Farrow et al., 2024; Nightingale et al., 2018; Piira et al., 2020). Both of the interventions that reduced sedentary behaviour utilised behaviour change theory (Froehlich-Grobe et al., 2022; Martinez et al., 2025). Two of the five interventions that did not affect sedentary behaviour utilised behaviour change theory (Martinez et al., 2025 [intervention B]; Nooijen et al., 2016). It is not clear whether the use of behaviour change theory was beneficial to sedentary behaviour outcomes.

Two of the five interventions that led to improvements in CVD biomarkers were informed by behaviour change theory (Martinez et al., 2025; Nooijen et al., 2017 [intervention A]), whereas the remaining three interventions were not (Bailey et al., 2020; Farrow et al., 2024; Nightingale et al., 2017). Behaviour change theory was included in both interventions that had no effect on CVD biomarkers (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention B]). It is not clear whether use of behaviour change theory influenced CVD biomarker outcomes.

4.3.5.5 Outcomes in the Context of Measurement Methods

One of the two interventions that reduced sedentary behaviour measured this outcome via self-report (Table 3) (Froehlich-Grobe et al., 2022). Metabolic equivalent of task derived from heart rate zones was used in the other intervention that reduced sedentary behaviour (Martinez et al., 2025 [intervention A]). Of the five interventions that had no effect on sedentary behaviour, three measured this outcome using accelerometry (Farrow et al., 2024; Nightingale et al., 2018;

Nooijen et al., 2016), one used the IPAQ (Piira et al., 2020) and one used heart rate zones (Martinez et al., 2025 [intervention B]). Improvements in sedentary behaviour appear to occur less consistently when measured via accelerometry.

One of the five interventions that improved CVD biomarkers found improvements in fasted outcome measures (insulin and insulin resistance), despite also measuring postprandial outcomes (Nightingale et al., 2017). Another study only measured biomarkers in a fasted state, with the intervention leading to improvements in diastolic blood pressure, LDL cholesterol and total cholesterol (Nooijen et al., 2016). One intervention reported improvements in postprandial glucose (Bailey et al., 2020), whilst another reported improvement in the Matsuda index, which is measured using fasted and postprandial measurements (Farrow et al., 2024). One intervention led to improvements in systolic blood pressure, but blood pressure was measured after a six-minute push test, not at rest (Martinez et al., 2025 [intervention A]). Other CVD biomarkers were assessed similarly across studies, making it challenging to recognise differences in outcomes according to the method of measurement. In summary, it appears that the method of measurement does not affect CVD biomarker outcomes.

4.3.5.6 Outcomes in the Context of Risk of Bias

Both interventions that led to reductions in sedentary behaviour were in studies with high risk of bias (Figure 2) (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention A]). Two of the five interventions that did not affect sedentary behaviour were in a study with low risk of bias (Farrow et al., 2024; Nightingale et al., 2018), two were in studies with high risk of bias (Martinez et al., 2025 [intervention B]; Piira et al., 2020), and one was in a study that raised some concerns (Nooijen et al., 2016). It appears that sedentary behaviour reductions were reported more frequently in studies with high risk of bias.

Three of the five interventions that improved CVD biomarkers were in studies with low risk of bias (Bailey et al., 2020; Farrow et al., 2024; Nightingale et al., 2017), one with high risk of bias (Martinez et al., 2025 [intervention A]) and one that raised some concerns (Nooijen et al., 2017). The interventions that did not report an improvement in any CVD biomarker were in studies with high risk of bias (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention B]). CVD biomarker outcomes were, therefore, improved more consistently in studies with low risk of bias.

4.3.6 Quality of Evidence

Overall quality of evidence for sedentary behaviour was deemed very low (Table 4), with quality downgraded due to risk of bias, inconsistency of results, indirectness of evidence and imprecision. Overall quality of evidence for CVD biomarkers was deemed moderate, with quality downgraded due to risk of bias and inadequate sample sizes.

Table 4. Assessment of overall quality of evidence.

Outcome		Risk of bias	Inconsistency of results	Indirectness of evidence	Imprecision	Publication bias[f]	Quality of evidence
Sedentary behaviour	Overall	-2[ab]	-1[c]	-1[d]	-1[e]	0	0 – very low
	Device-measured	0	-1[c]	0	-1[e]	0	3 – moderate
	Estimated from heart rate zone	-1[b]	0	-1[d]	-1[e]	0	2 – low
	Self-reported	-2[ab]	0	-1[d]	-1[e]	0	1 – very low
Cardiovascular disease biomarkers	Overall	-1[b]	0	0	-1[e]	0	3 – moderate
	Blood pressure	-1[b]	0	0	-1[e]	0	3 – moderate
	Body composition	-1[b]	0	0	-1[e]	0	3 – moderate
	Glycaemic biomarkers	-1[b]	0	0	-1[e]	0	3 – moderate
	Lipid biomarkers	-1[b]	0	0	-1[e]	0	3 – moderate

a – one study does not use a randomised controlled design for this outcome
b – one or more study has a high risk of bias
c – large differences in means between studies
d – one or more study uses surrogate measurements
e – one or more study has an inadequate sample size to ensure sufficient statistical power
f – Funnel plots not generated as < 10 studies included in the systematic review

4.4 Discussion

The findings of this review indicate that interventions targeting increases in physical activity are not effective for reducing sedentary behaviour in individuals with paraplegia, but show some effectiveness for improving CVD biomarkers. There was a scarcity of interventions targeting sedentary behaviour, but these interventions may have potential for improving CVD biomarkers.

The majority of interventions targeted physical activity, as opposed to sedentary behaviour, with only one leading to an improvement in the sedentary behaviour outcome. These findings suggests that physical activity interventions may not be effective for reducing sedentary behaviour in individuals with paraplegia. This is in disagreement with a meta-analysis that found interventions targeting physical activity were effective for reducing sedentary behaviour in the general population (Prince et al., 2014). The contrasting findings may be due to the majority of physical activity interventions in the present review focusing on structured exercise training, rather than non-exercise physical activity accumulated throughout the day (Prince et al., 2014), which is more likely to displace sedentary behaviour (Manns et al., 2012) and overcome physical impairments that may present a barrier to some exercise interventions in individuals with disabilities (Dogra et al., 2022). The intervention in the present review that targeted sedentary behaviour via a whole-day approach and measured sedentary behaviour as an outcome was found to be effective (Martinez et al., 2025 [intervention A]). It could be postulated that interventions targeting sedentary behaviour would be most effective as interventions focusing on physical activity may not utilise the most appropriate behaviour change techniques for sedentary behaviour (Martin et al., 2015) or appropriate activities for individuals with paraplegia. Further interventions targeting sedentary behaviour, tailored for individuals with paraplegia, require development and evaluation in order to determine their effectiveness and inform public health and clinical care guidelines.

The quality of evidence in the present review was deemed very low and, as a result, there is very little confidence with respect to sedentary behaviour outcomes (Guyatt et al., 2011a). The lack of quality is due to unexplained variability in sedentary behaviour changes across studies, small sample sizes and the measurement techniques employed (Guyatt et al., 2011b). Sedentary behaviour was assessed via self-report using the IPAQ 'time spent sitting' question in one of the two interventions that reduced sedentary behaviour. The validity of this IPAQ question has not been evaluated in individuals with SCI and may not be appropriate for wheelchair-users. One intervention that reduced sedentary behaviour measured this outcome using METs derived from heart rate zones, which is not validated (Martinez et al., 2025 [intervention A]). In addition, sample heterogeneity was high, with just one intervention that reduced sedentary behaviour including a sample comprising only individuals with paraplegia. Studies may choose to adopt broad inclusion criteria, such as including individuals with paraplegia and tetraplegia in their sample, due to difficulty recruiting and retaining individuals with SCI (Blight et al., 2019). As a result, the effects on sedentary behaviour cannot be isolated to individuals with paraplegia. The findings with respect to interventions targeting sedentary behaviour potentially being effective may, therefore, be generalisable to paraplegia and tetraplegia. However, differences in upper-limb function between individuals with paraplegia and tetraplegia means that the types of physical activities they are able to engage in differ. Interventions will, therefore, need to be tailored to different injury levels. High-quality studies that address the sources of bias and heterogeneity identified in this review are needed to inform definitive conclusions regarding sedentary behaviour intervention effectiveness.

The influence of behaviour change theory on sedentary behaviour outcomes is unclear. However, only half of included interventions employed behaviour change theory (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [interventions A and B]; Nooijen et al., 2016). Limited use of behaviour change theory has been reported in reviews of sedentary behaviour

interventions in the general population (Gardner et al., 2016; Peachey et al., 2020). The lack of behaviour change theory is partly due to the nature of some included interventions, with half employing prescribed exercise training protocols in which behaviour change theory may have limited added value (Farrow et al., 2024; Martinez et al., 2025 [intervention B]; Nightingale et al., 2018; Piira et al., 2020). Integration of theory within interventions may be important to support behaviour change via identification of precursors to behaviour and causal factors of change, which can be selectively targeted with specific behaviour change techniques (Davis et al., 2015; Michie et al., 2008). Indeed, interventions grounded in behaviour change theory yield greater improvements in physical activity in individuals with physical disabilities, such as SCI (J. K. Ma & Martin Ginis, 2018). Time spent in sedentary behaviour was more strongly correlated with engagement in light physical activity and activities of daily living than with MVPA and structured exercise (Healy et al., 2008), which could explain why sedentary behaviour was unaffected by the exercise training interventions in the current review. Therefore, the effects of sedentary behaviour interventions grounded in behaviour change theory, that utilise strategies to increase light physical activity and activities of daily living, should be evaluated in individuals with paraplegia as they are likely to be more effective.

There were mixed effects for CVD biomarkers in response to interventions that reduced sedentary behaviour. Interventions that reduced sedentary behaviour or involved supervised breaks in sedentary behaviour led to improvements in systolic blood pressure and postprandial glucose (Bailey et al., 2020; Martinez et al., 2025 [intervention A]). Previous reviews in non-disabled individuals (Hadgraft et al., 2021) and clinical populations (Nieste et al., 2021) also found that reducing sedentary behaviour improved CVD biomarkers. However, there was no change in sedentary behaviour in three interventions that improved CVD biomarkers in the present review (Farrow et al., 2024; Nightingale et al., 2017; Nooijen et al., 2017). This may indicate that improvements in cardiovascular health in these studies were due to increases in

physical activity (Farrow et al., 2024; Nightingale et al., 2018; Nooijen et al., 2016). A previous meta-analysis found that physical activity interventions improved CVD biomarkers in individuals with SCI (Itodo et al., 2022), supporting their inclusion in healthcare for this population group. Two interventions reduced sedentary behaviour and increased physical activity in the present review (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention A]), but only one of these led to improvements in CVD biomarkers (Martinez et al., 2025 [intervention A]). A combination of changes in sedentary behaviour and physical activity may, therefore, not always be necessary to achieve optimal effects (Yates et al., 2015). Targeting physical activity or sedentary behaviour separately may, therefore, yield cardiovascular benefits; this supports literature demonstrating that these are distinct behaviours related to CVD risk (Bailey et al., 2019; Wilmot et al., 2012). The quality of evidence for CVD biomarker outcomes was deemed moderate. Future studies that address limitations of the current literature and evaluate interventions targeting sedentary behaviour are needed to provide stronger evidence regarding the effects of such interventions on CVD biomarkers in individuals with paraplegia.

The majority of interventions led to an improvement in at least one CVD biomarker. Biomarkers related to glycaemia were often improved, including fasting insulin (Nightingale et al., 2017), postprandial glucose (Bailey et al., 2020), insulin resistance (Nightingale et al., 2017) and insulin sensitivity (Farrow et al., 2024). Studies with glycaemic outcomes had a moderate quality of evidence, meaning there is some confidence in these findings. However, two of these interventions had no effect on sedentary behaviour (Farrow et al., 2024; Nightingale et al., 2017). Also, both interventions that reduced sedentary behaviour did not improve glycaemic biomarkers, suggesting limited causality between these outcomes (Froehlich-Grobe et al., 2022; Martinez et al., 2025 [intervention A]). The evidence for interventions improving blood pressure and lipids in individuals with paraplegia was mixed, while there was consistent data

that body composition was unaffected. These findings extend those of previous reviews and meta-analyses in individuals with SCI, which found that physical activity interventions had no effect on blood pressure or lipids (Itodo et al., 2022). Research has also shown exercise training may not improve body composition in individuals with SCI (Bresnahan et al., 2018). Lack of improvement in these biomarkers could be a result of changes in blood pressure and body composition that occur because of SCI, limiting responsiveness to reduced sedentary behaviour and/or increased physical activity (Buchholz & Bugaresti, 2005; Claydon et al., 2006). Another plausible explanation is that intervention durations were too short (one day to sixteen weeks) (Bailey et al., 2020; Farrow et al., 2024; Froehlich-Grobe et al., 2022; Martinez et al., 2025 [interventions A and B]; Nightingale et al., 2017). The one intervention, which increased physical activity and improved lipids, was delivered over eight months (Nooijen et al., 2017). Moreover, the magnitude of change in sedentary behaviour (ranging from 118 min/day decrease to 45 min/day increase) or physical activity (8 to 97 min/day increase) across studies may have been insufficient to bring about consistent changes in blood pressure, lipid profile or body composition. Future research should assess whether interventions that target sedentary behaviour over the long-term can produce greater changes in sedentary behaviour and, subsequently, affect CVD biomarkers.

4.4.1 Strengths and Limitations

This is the first systematic review to assess the effectiveness of interventions to reduce sedentary behaviour and improve CVD biomarkers in individuals with paraplegia. Key areas for future research have been identified to improve the quality of evidence, which will benefit the development of sedentary behaviour guidelines for this population group. Further strengths include the application of frameworks to guide the reporting, risk of bias and grading of evidence to ensure rigour within the review. Potential limitations include the one-dimensional description of the use of behaviour change theory within included interventions, with no context

as to how theory was utilised. Additionally, some eligible studies had a high risk of bias and the overall quality of evidence was generally low. Three of the included studies comprised samples of individuals with paraplegia and tetraplegia, which may influence conclusions being made specifically for individuals with paraplegia. In addition, effectiveness being estimated by P-value thresholds is potentially misleading, as no studies were powered to detect changes in sedentary behaviour and only two studies were sufficiently powered to detect changes in CVD biomarkers. Also, a combination of between- and within-group comparisons was used to estimate effectiveness. It is, therefore, recommended that further high-quality studies in individuals with paraplegia are conducted with sufficient power to detect changes in sedentary behaviour and CVD biomarkers.

4.5 Conclusion

In conclusion, interventions that target increases in physical activity appear to be ineffective for reducing sedentary behaviour in individuals with paraplegia, but do have beneficial effects on CVD biomarkers. The literature examining interventions that target reductions and breaks in sedentary behaviour in individuals with paraplegia is limited, yet shows potential effectiveness for improving CVD biomarkers. Investigating interventions that focus on changing sedentary behaviour in individuals with paraplegia is an important avenue for future research to inform recommendations for public health and clinical care.

Chapter 5: Study 2. Using the Behaviour Change Wheel to Develop the REACH-SCI (Reducing sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury) Intervention

This co-design study manuscript is under review in a peer-reviewed journal:

Cooper, DL., Warland, A., Norris, E., Kilbride, C., Paddison, S., & Bailey, DP. (2025). Using the Behaviour Change Wheel to co-design a sedentary behaviour intervention in individuals with spinal cord injury. *Clinical Rehabilitation*. Under review. Preprint: https://doi.org/10.64898/2025.12.02.25338957

This study provides data around the needs, preferences and suggestions of co-design participants, researcher group discussions to guide decision making, and input from Patient and Public Involvement (PPI) into the design of the sedentary behaviour intervention. In conjunction with findings from the systematic review (Chapter 4), this study informs the development of the intervention protocol.

5.1 Introduction

A systematic review (see Chapter 4) found that interventions targeting increased physical activity were not effective for reducing sedentary behaviour in individuals with SCI (Cooper et al., 2025a). This may be due to inappropriate BCTs being used for targeting reductions in sedentary behaviour (Martin et al., 2015). Alternatively, interventions may have failed to increase non-exercise physical activity via a whole-day approach, which appears to be an important factor in achieving regular breaks in sedentary behaviour (Manns et al., 2012). In addition, there is a lack of behaviour change theory, such as the COM-B model, used in the design of the sedentary behaviour interventions in individuals with SCI (see Chapter 4). Theoretically-driven interventions are, therefore, needed in individuals with SCI to promote

their effectiveness for reducing sedentary behaviour and improving CVD biomarkers across the post-discharge rehabilitation pathway.

Embedding co-design within suitable behaviour change theory via a combined approach has been recognised as an effective method to put this intervention development process into practice (O'Cathain et al., 2019). A combination of co-production (a similar technique to co-design, discussed in Chapter 2) and the BCW was employed to develop a sedentary behaviour intervention for stroke survivors, leading to a feasible and replicable intervention (Hall et al., 2020). Co-design, and similar participatory approaches such as co-production, can be used as an adjunct to the BCW for developing interventions that are more acceptable to participants and effective for changing behaviour.

It is important that interventions are designed to support individuals at different stages of the rehabilitation journey, such as during initial inpatient rehabilitation, soon after initial discharge (e.g. the first year) and over the longer term. Physical activity levels generally increase during inpatient rehabilitation but decline after discharge into the community (van den Berg-Emons et al., 2008). This decline is likely due to lack of access to appropriate exercise facilities and the significant challenge of adapting to the home environment after SCI (Vissers et al., 2008). Although sedentary behaviour improved one year after initial inpatient discharge, levels are still significantly worse compared with non-disabled individuals (Postma et al., 2020). Thus, a community-based sedentary behaviour intervention should be designed to support individuals with SCI over the short and longer-term following inpatient rehabilitation.

This study aimed to co-design an intervention, using the BCW framework, to reduce and break up sedentary behaviour in individuals with paraplegia across different stages of the SCI rehabilitation pathway. The objectives were to (a) explore the lived experiences of people with

paraplegia regarding barriers and facilitators for breaking up and reducing sedentary behaviour, and (b) identify content and implementation options for the intervention.

5.2 Methods

5.2.1 Study Design

A qualitative workshop approach was utilised to iteratively co-design the intervention, grounded in behaviour change theory using the COM-B model, in context of the BCW framework (Michie et al., 2011). The co-design approach was used in combination with other methods to develop the intervention, which included findings from the systematic review in Chapter 4, discussions between the research team following each co-design workshop, and input from PPI. The co-design process is shown in Figure 6. A total of eight workshops were undertaken separately with participants across three groups: individuals with paraplegia (n = 4 workshops), healthcare professionals (n = 2 workshops), and community caregivers (n = 2 workshops). Workshops were undertaken either online (n = 5 workshops), in-person at Brunel University of London (n = 1 workshop) or at the Royal National Orthopaedic Hospital, London (n = 2 workshops). Activities employed in the workshops included group discussions, writing ideas on post-it notes, visualising ideas using interactive whiteboards, and appraising ideas using Likert rating scales. Figure 7 shows which aspects of the BCW were covered in each workshop. Workshops were facilitated by the PhD Researcher (MSc; Male) and each supported by one academic supervisor (n = 3; all PhD). All researchers had experience in qualitative methods. The PhD Researcher communicated with participants via email prior to the workshops to organise eligibility screening, consent, and workshop attendance. Introductions were provided by facilitators to explain their role and background at the start of each workshop. The study is reported following the COnsolidated criteria for REporting Qualitative studies (COREQ; Appendix 5).

Ethical approval was granted from the College of Health, Medicine and Life Sciences Research Ethics Committee, Brunel University of London (47898-NHS-Apr/2024-50821-2; Appendix

6) and the London - Fulham NHS Research Ethics Committee (24/PR/0621; Appendix 7). All participants provided informed consent.

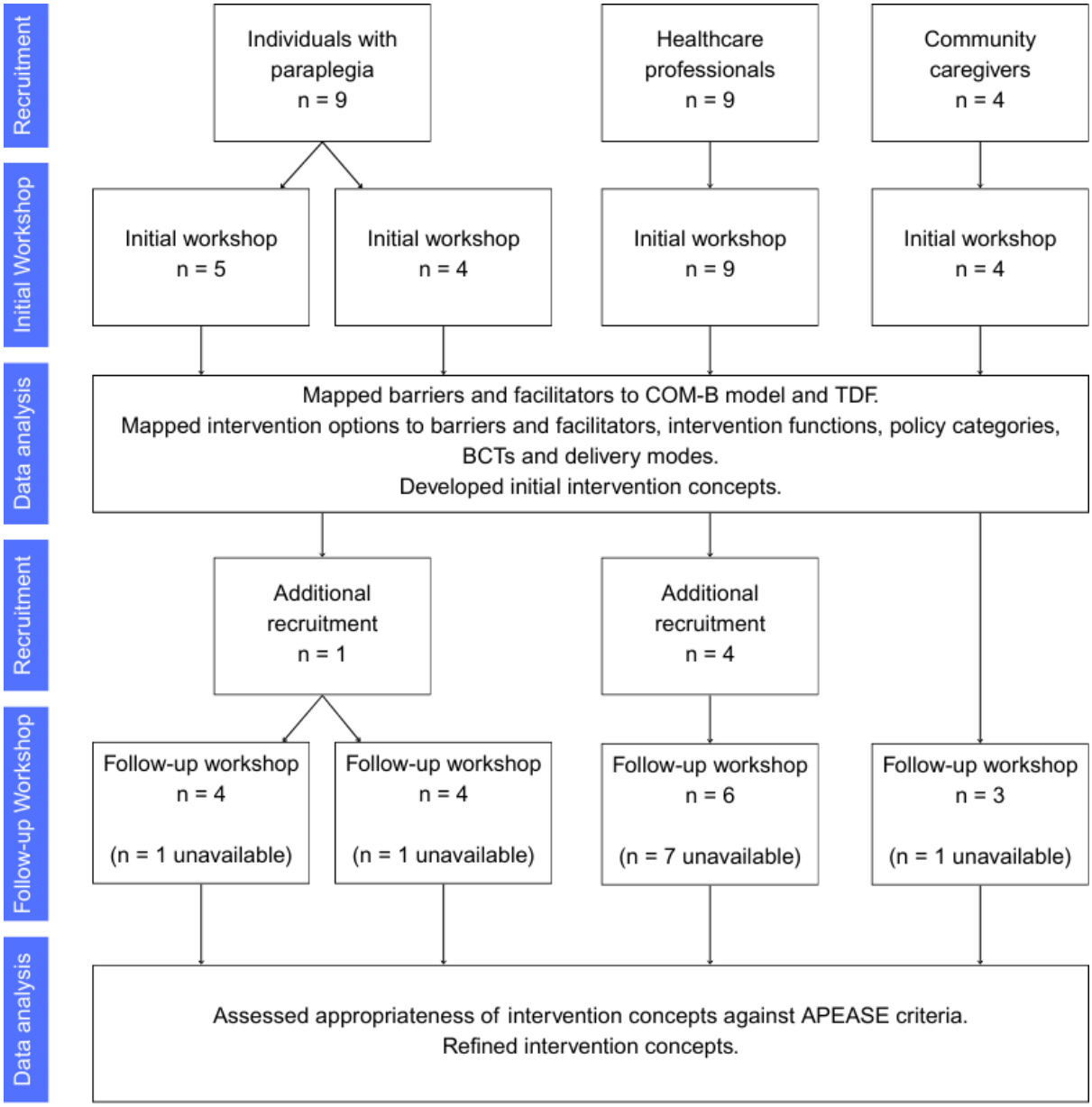

Figure 6. The study co-design process. APEASE, Acceptability, Practicability, Effectiveness, Affordability, Side-effects/safety, Equity; BCT, Behaviour Change Technique; COM-B, Capability, Opportunity and Motivation to change Behaviour; TDF, Theoretical Domains Framework.

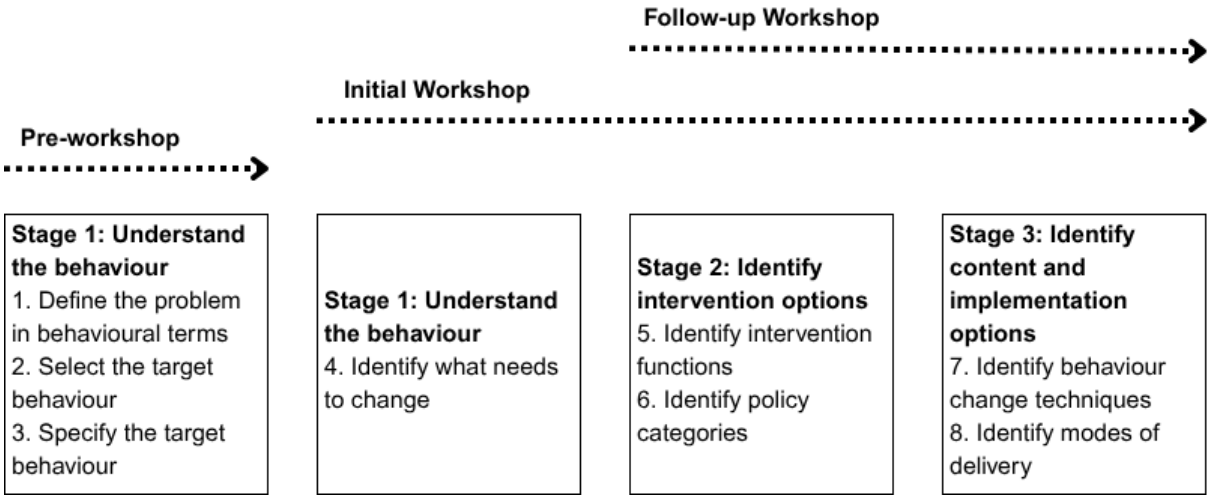

Figure 7. Data collection flowchart detailing the Behaviour Change Wheel stages addressed at each stage of the study.

5.2.2 Study Sample

Individuals with self-reported complete or incomplete paraplegia, defined as an injury to the spinal cord at T1 or below (Paddison & Hexter, 2018), were eligible. Participants also had to predominantly use a manual wheelchair for mobility, as indicated by self-report. Eligible healthcare professionals included those working full-time or part-time within a hospital or clinic for which their work primarily involves providing care or services for individuals with SCI. Community caregivers were eligible if they provided non-clinical care, services or support to individuals with SCI in the community. This included friends, family, carers, or employees or relevant organisations/charities, but did not include community healthcare professionals. All participants also needed to be able to communicate in English, participate in-person and/or online and have capacity to give full, informed consent.

5.2.3 Recruitment

Participants were recruited with the aim of achieving a sample which was representative of individuals from across the SCI care pathway after discharge from initial inpatient rehabilitation. This approach was adopted to ensure that the co-designed intervention was tailored to the needs of a diverse range of individuals with paraplegia in the community. This

included individuals at initial discharge from inpatient rehabilitation, within the first year of discharge, or more than one year after initial discharge following SCI. Individuals with paraplegia were recruited from the community via disability sport and SCI pages on social media, partner charities who provide support to this population (e.g. Spinal Injuries Association and Wheelpower), snowballing and individuals who had taken part in previous studies and had agreed to be contacted regarding future research. This participant group was also recruited through the London Spinal Cord Injury Centre, Royal National Orthopaedic Hospital NHS Trust, by which potentially eligible participants were approached by a member of the care team during routine appointments and inpatient care. Individuals were provided with a verbal explanation of the study and provided with a participant information sheet (PIS; Appendix 8) if they were interested. In addition, posters containing study information were displayed at the Centre within clinics and wards (Appendix 9).

Healthcare professionals were also recruited from the London Spinal Cord Injury Centre. Community caregivers were recruited from the community via partner charities who provide support to individuals with paraplegia and snowballing (through individuals with paraplegia who expressed interest in taking part in the study).

Individuals expressed their interest in taking part by contacting the research team via email or scanning a QR code on study recruitment materials (Appendix 9) which directed them to an online form (Jisc Online Surveys) to provide their contact details (Appendices 10 and 11). Those who expressed interest were then provided with a PIS and a link to complete an online screening questionnaire (Appendices 12 and 13). Eligibility was confirmed by the PhD researcher. Individuals had the opportunity to ask any questions via telephone or email prior to giving informed consent (form displayed in Appendices 14 and 15) to participate in the study either in writing or electronically.

Any travel expenses incurred for attendance at the workshops were reimbursed. Gift vouchers were offered to individuals with paraplegia (£30) and community caregivers (£10) for each workshop they attended as a token of appreciation.

5.2.4 Sample Size

A systematic review of studies that utilised co-design methodology in healthcare knowledge mobilisation found that sample sizes for workshops ranged from 5-18 participants (Grindell et al., 2022). Other research has suggested that 6-10 participants per group across 3-12 workshops is sufficient to consider a diverse range of viewpoints and achieve data saturation, whilst still allowing for in-depth discussion (Krueger, 2015). In keeping with both papers, a sample size of 6-8 individuals from each of the three participant groups was targeted for each workshop.

5.2.5 Intervention Development

This study followed the three stages of intervention design outlined in the BCW framework (Figure 3; page 26). Stage 1 (understanding the behaviour) was undertaken by the research team before the workshops (define the problem in behavioural terms, select and specify the target behaviour) and in the initial workshops (identify what needs to change) (Appendices 16, 17 and 18). Stage 2 (identify intervention options) and Stage 3 (identify content and implementation options) were investigated in both the initial and follow-up workshops (Appendices 19, 20 and 21).

5.2.5.1 Stage 1: Understand the Behaviour

The problem in behavioural terms (Step 1) was defined as "high volume of sedentary behaviour" by the research team before the workshops. This was based on evidence of high sedentary behaviour in individuals with SCI (Postma et al., 2020) and this behaviour being an independent risk factor for CVD (Bailey et al., 2019; Wilmot et al., 2012). The behavioural problem was discussed with participants at the start of the initial workshops in context of their

experiences around sedentary behaviour. The target behaviour was selected and specified (Steps 2 and 3) as "to reduce and break up sedentary behaviour". This target behaviour was chosen as a result of physical activity interventions not improving sedentary behaviour outcomes and sedentary behaviour interventions showing some promise in the systematic review (see Chapter 4).

Identification of what needed to change (Step 4) was achieved by exploring barriers and facilitators to achieving the target behaviour in the initial workshops using the COM-B model (See Chapter 2 for an overview) as a guide. Barriers and facilitators were mapped to the COM-B model and TDF by the PhD researcher after the initial workshops. The decision to use the COM-B model to guide this process was made because the systematic review found that interventions that improved sedentary behaviour included some form of behaviour change theory, suggesting that interventions grounded in theory could be more effective for improving this target behaviour.

5.2.5.2 Stage 2: Identify Intervention Options

Potential intervention options to address identified barriers and facilitators were proposed by participants during the initial workshops. In line with the BCW framework, each intervention option was then subsequently mapped to intervention functions (Step 5) and policy categories (Step 6) by the PhD Researcher.

5.2.5.3 Stage 3: Identify Content and Implementation Options

Proposed intervention options were mapped to the most relevant BCTs from the BCTTv1 (Michie et al., 2013) (Step 7) and modes of delivery (Step 8) by the PhD Researcher after the initial workshops. This informed the first iteration of the intervention concepts. The appropriateness of each concept was appraised against the APEASE criteria in follow-up workshops, as per BCW recommendations (Michie et al., 2014).

The content and/or delivery mode of intervention concepts were then refined through appraisal by the research team in group discussions. In these discussions, each concept was appraised for its appropriateness according to the APEASE criteria and triangulated with APEASE appraisal data gathered from participants. In addition, meetings with PPI members were carried out to finalise intervention content and develop participant-facing intervention materials.

5.2.6 Data Analysis

In-person and online workshops were audio recorded and automatically transcribed using Microsoft Teams (Microsoft Corporation, Redmond, WA, USA). Transcripts were checked for accuracy and participant ID numbers were assigned by the PhD Researcher.

Data from the initial workshops were analysed by the PhD Researcher in the context of the BCW using Framework Analysis (Gale et al., 2013). Inductive coding was undertaken using NVivo 12 (Lumivero, Burlington, MA, USA) to identify barriers, facilitators and intervention options. An inductive theme was considered as such when two or more participants mentioned it. Deductive coding followed to map the inductive codes to domains of the BCW and TDF. Credibility in the data was achieved with approximately 20% of initial workshop transcripts being deductively coded by a member of the supervisory team. As levels of agreement were generally high, and coding decisions were well-justified during discussion, the remaining transcripts were coded by the PhD Researcher. Based on the APEASE appraisal, the research team assessed whether each concept was appropriate for inclusion in the intervention via a rating matrix that determined whether intervention concepts fulfilled each individual APEASE criterion.

Peer debriefing was undertaken between the PhD researcher and PhD supervisors who were not involved in data analysis, to challenge assumptions and maintain rigour.

5.2.7 Patient and Public Involvement

Two individuals with paraplegia and a healthcare professional contributed to the development of the workshop guides, recruitment methods and the PIS for this study. After the workshops, the public contributors reviewed and provided feedback on the appropriateness of proposed intervention materials drafted by the PhD researcher. Further iterations were reviewed by PPI members to ensure that the final versions were appropriate and effective for the target population.

5.2.8 Data Management

All identifiable data collected during the study was kept strictly confidential. Electronic data were stored securely on password-protected laptops. After transcription, audio recordings were deleted. Participant screening and demographic data were collected using Jisc Online Surveys, which is a secure, password-protected platform. Paper-based documents were stored in a locked filing cabinet accessible only by the research team at Brunel University of London. Any information which leaves the University (e.g. publication of findings in an academic paper) will have any identifiable information removed, and participants will be referred to by an ID number unknown to the participant. With participant permission (as indicated via an optional question on the consent form), anonymised data were stored for use in future research studies. All research undertaken complied with the Data Protection Act (2018) and European Union General Data Protection Regulations.

5.3 Findings

5.3.1 Participant Characteristics

Twenty-seven participants took part across the workshops. This included 10 participants with paraplegia (PwP; four female), for whom descriptive statistics are shown in Table 5. There were 13 healthcare professionals (HCP; 11 female) and four community caregivers (CCG; two female). Demographic details were not given for HCPs or CCGs to maintain anonymity.

Table 5. Characteristics of individuals with paraplegia (n = 10).

Characteristic			**Data is mean ± SD or n (%)**
Sex	Female		4 (40%)
	Male		6 (60%)
Ethnicity	White British		9 (90%)
	White European		1 (10%)
Age			50 ± 10 years
Time since injury			14 ± 10 years
Lesion level	Thoracic	Total	8 (80%)
		T1	1
		T4	2
		T5	1
		T6	1
		T9	1
		T11	1
		T12	1
	Lumbar	Total	2 (20%)
		L1	2
Completeness	Complete		5 (50%)
	Incomplete		5 (50%)

L, lumbar; T, thoracic.

5.3.2 Intervention Development

Eight workshops were undertaken in total lasting 1 hour 34 minutes on average (range 1-3 hours). The co-design workshop approach employed was acceptable to participants, with high levels of engagement and retention during the study. Furthermore, individuals with paraplegia shared that the opportunity to speak with peers about common problems and potential options to overcome them within the workshops was a positive experience.

The intervention development process did not follow the BCW stages and steps linearly, instead opting for a flexible approach, but is presented as such in this section to aid interpretation. Exemplar quotes are used throughout this section to illustrate each major theme, with further quotes provided in Table 6 and Appendix 22.

5.3.2.1 BCW Stage 1: Understand the Behaviour

Barriers and facilitators to reducing and breaking up sedentary behaviour are categorised and reported according to each component of the COM-B model (Table 6).

Table 6. Barriers and facilitators for reducing and breaking up sedentary behaviour.

COM-B construct	COM-B micro-construct	TDF domain	Barrier or facilitator identified (n = number of participants that identified it)	Illustrative quotes
Capability	Physical capability	Skills	Fatigue (barrier) (n = 10)	PwP (T4 complete, male): "The other spinal cord patients I've talked to, people tend to get tired more quickly than you would be if you were not in a wheelchair". PwP (T12 incomplete, male): "I'm deliberately trying not to cram too much in, as I know it makes me tired".
			Personal care routine (barrier) (n = 10)	CCG (Charity worker, male): "When you're newly injured, predominantly a lot of your time is spent on personal care and just getting the day to day done. That can be hugely, hugely physically demanding as well as psychologically". HCP (Physiotherapist, female) "there's less flex in their day, they've got less free time available if they're also a working person to fit that in because, yeah, they're, potentially some of them [have] got longer morning routines".
			Pain (barrier) (n = 7)	PwP (T6 complete, male): "I would say the only thing that's increased my sedentary behaviour is pain". PwP (T4 complete, male): "If you sit still and don't move, then when you do move, it bloody hurts. Simple. You sit there and don't do nothing [anything] all day".
			Comorbidities (barrier) (n = 4)	HCP (Physiotherapist, female): "People have comorbidities and it's an aging population. And so you run into all the same problems with physical activity you do with anybody else". CCG (Charity worker, male): "There might be, you know, underlying health issues that are going on or which might be spinal or non- spinal… your general health can have quite a big impact on your ability to be, you know, sedentary".

		Injury (barrier) (n = 4)	PwP (L1 incomplete, male): “that happens quite frequently, you pick up injuries or stuff happens, you know, that knocks you back”. PwP (T12 incomplete, male): “When I broke my leg, that's six months in bed”.
		Pressure ulcers (barrier) (n = 4)	PwP (L1 incomplete, male): “You know, if you’re on bed rest for six months... you know, you had a sore or something” PwP (T4 complete, male): “You could be bedridden for long periods of time [if you got a pressure ulcer]. We heal a lots more slowly than able-bodied people”.
		Lack of physical function (barrier) (n = 4)	PwP (T4 complete, male): “A T12, she will have core muscles and be able to put both arms out in front of her… Whereas me, I'm at 5. If I do that, I'll fall out [of] my wheelchair”. CCG (charity worker, male): “The higher your level of injury, then obviously the lower the amount of muscle groups that you've got to use”.
		Transfers (barrier) (n = 4)	PwP (T11 incomplete, female) “I used to go the gym before my accident. I think the barrier for me mainly is the amount of transfers that you would have to do”. HCP (Physiotherapist, female): “Transfers are more difficult. All of these things, because the first chair that they get from their wheelchair service is rubbish”.
Psychological capability	Knowledge	Lack of knowledge about sedentary behaviour (barrier) (n = 15)	HCP (Physiotherapist, female): “There isn't specific guidance on sedentary behaviour. So there, if there isn't specific guidance, it's hard for people to have knowledge”. PwP (T4 complete, male): “I don’t think the word sedentary was ever said [during inpatient rehabilitation]”.
		Knowledge of pressure relief (facilitator) (n = 6)	CCG (Charity worker, male): “Something that all wheelchair users are told to do is a huge part of their education when they're in hospital is to do pressure relief to make sure every

			hour or so that they make sure they shift in their chair and lean forward in order to avoid pressure sores". PwP (T4 complete, male): "Part of my routine would then be well, I need to do pressure relief… And therefore, you know, that's exertion"
	Memory, attention, and decision processes	Reminders to be active (facilitator) (n = 5)	PwP (T12 incomplete, male): "The prompts, you know, to the alerts to say. "get moving, get moving"… alerts to say, "come on, keep going. You're nearly there", so sort of motivating alerts [would help me be less sedentary]". CCG (Family member, female): "Definitely that thing of having some kind of prompt I think would definitely be helpful for him [father with paraplegia]".
		Do not think about sedentary behaviour (barrier) (n = 4)	PwP (T6 complete, male): "I don't think about it [sedentary behaviour] during the day". CCG (Charity worker, male): "It's not really the first thing that's on their mind, you know, they've got other issues to think about".
	Behavioural regulation	Getting feedback on progress (facilitator) (n = 6)	PwP (L1 incomplete, male): "It'd be good to like, keep a log of say, whatever activities you're doing. And having like your personal best". PwP (T6 complete, male): "You can get an app for your phone, so you can actually see what [activities] you've done".
		Creating schedules around activity (facilitator) (n = 6)	CCG (Charity worker, male): "Trying to get a bit of a timetable even into your normal daily living and to and to incorporate the activity in into that". PwP (L1 incomplete, male): "Yeah, prioritising your schedule to accommodate [for physical activity and sedentary behaviour".

Opportunity	Physical opportunity	Environmental context and resources	Provision of information and/or opportunities for physical activity and exercise (facilitator) (n = 12)	HCP (Physiotherapist, female): “They'll sometimes tap into the charities as well. So they're going out and about and doing a bit more activity with some of the charities, so again, they'll start to overcome some of those barriers and see how they can plan things with the help of external sources”. CCG (Charity worker, male): “Wheelpower has probably got the best examples at the moment of showing they they've, they've got yoga, they've got people doing fitness classes and people doing different exercise activities”.
			Lack of wheelchair accessibility in and outside of the home (barrier) (n = 10)	PwP (L1 incomplete, male): “Non-accessible space, I guess. Or non-adapted space [is a barrier]”. CCG (Charity worker, male): “When they're discharged from hospital now aren't always going home because their home environments aren't accessible… So it's certainly stuff like that is going to affect their ability to be active”.
			Cost and lack of access to equipment to do physical activity or exercise (barrier) (n = 10)	CCG (Charity worker, male): “There's not a lot that you can get that is complimentary. You know, a lot of this stuff now you've got to pay for, and it's not cheap”. HCP (Physiotherapist, female): “They haven't got any finances available to purchase any extra equipment and that might be what's needed to be active”.
			Wheelchair being inappropriate for physical activity (barrier) (n = 7)	HCP (Physiotherapist, female): “They get given much heavier chairs. Harder to propel and definitely harder to do wheelchair skills in”. PwP (T4 complete, male): “At the moment kind of just moving around the house is more difficult in this wheelchair”.
			Geographical inequalities of services or opportunities relating to physical activity and exercise (barrier) (n = 5)	PwP (T11 incomplete, female): “The availability. Yeah, just the availability to services really or like the access, you know. Somebody might not live in an area that has an accessible gym”.

			PwP (L1 incomplete, female): “Yeah, there's no accessible gym where I live”.
		Support from the workplace (facilitator) (n = 4)	PwP (T4 complete, male): “I adapted my workspace and my work were very good with me in providing that sort of stuff”. PwP (T11 incomplete, female): “I think it's the type of job that you do really. I mean, I'm a nurse at a nursing home. That's my job, so I'm constantly moving”.
		Excessive planning and inability to be spontaneous (barrier) (n = 3)	PwP (T9 complete, female): “You’ve got to go through the rigmarole of, you know, what assistance do you need [when going out and about]”. PwP (T6 complete, male): “The amount of planning you have to do just to go out the door is sometimes unbelievable”.
Social opportunity	Social influences	Support from family or friends (facilitator) (n = 11)	PwP (T4 complete, male): “There's a thing, isn't there? About community, right? So doing things in a solitary capacity is often quite hard. A lot of barriers to it”. PwP (L1 incomplete, male): “Having two daughters and a wife, sedentary behaviour is just not allowed, which is good, which is good. They never allow me to wallow myself in self-pity or lay on the sofa”.
		Being deterred by family or friends (barrier) (n = 8)	CCG (Family member, female): “I find my mum does a lot for him and maybe that stops him from doing things himself”. PwP (T12 incomplete, male): “Family can put barriers up for you. But if you got your own barriers, so it's two fences to get over”.
		Peer support network (facilitator) (n = 7)	PwP (T4 complete, male): “Yeah, you know, then again, that community aspect is so encouraging, finding ways for people to connect”. CCG (Charity worker, male): “If in some way it can involve contact with others, I think that that's one of the best motivational things out there”.

Motivation	Reflective motivation	Beliefs about capabilities	Low self-esteem or self-conscious (barrier) (n = 8)	HCP (Physiotherapist, female): “People don't like being seen in a wheelchair”. CCG (Charity worker, male): “Psychological components around motivation and confidence and self-esteem, body image. That that can all contribute to just not finding that 5 minutes [to be active per day]”.
		Intentions	Building habits around activities of daily living (facilitator) (n = 7)	PwP (T1 incomplete, male): “Building [activity] into things you've got to do in the house, it gives you a sense of worth, not just for exercise and fitness”. PwP (T4 complete, male): “If you can make doing something part of your routine a habit, a good habit. Then you're more motivated to keep it up”.
			Boredom, being a chore or lack of enjoyment (barrier) (n = 6)	PwP (L1 incomplete, male): “It [physical activity] being a chore and that might break your motivation cause because it's. It’s not enjoyable”. PwP (T12 incomplete, male): “They want you in it [standing frame] for like 3 or 4 hours a day. What can you do, stood? What can you do? It’s boring”.
		Goals	Goal setting (facilitator) (n = 8)	PwP (L1 incomplete, male): “Realistic goals I guess, that's the one I mean. Because you know, if you start out thinking “Why am I not at the top of the Mount Everest, yet?””. PwP (T11 incomplete, female): “When I say objectives and goals, I mean personally I like to work towards goals and objectives”.
		Reinforcement	Rewards (facilitator) (n = 5)	PwP (L1 incomplete, female): “If I could earn a badge for doing a 5-minute exercise on a bad day that might incentivise me for doing it”. PwP (T11 incomplete, female): “The reward itself would be me completing the goal”.

	Automatic motivation	Emotions	Low mood (barrier) (n = 3)	PwP (L1 incomplete, female): “I have good days and bad days and on a good day I'm fine. I can do stuff. It's not a problem, but on a bad day it can vary between not getting out of bed or getting out of bed but not going out the house”. HCP (Physiotherapist, female): “The biggest barrier to general levels of physical activity is how you're thinking and feeling and that comes down to psychology”.

CCG, community caregiver; COM-B, Capability, Opportunity and Motivation to change Behaviour; HCP, healthcare professional; PwP, participant with paraplegia; TDF, Theoretical Domains Framework.

5.3.2.1.1 Capability

Common capability-related barriers included lack of knowledge about sedentary behaviour ("*There isn't specific guidance on sedentary behaviour [in SCI centres]. So, if there isn't specific guidance, it's hard for people to have knowledge"* [HCP, Physiotherapist]) and fatigue (*"A lot of your time is spent on personal care and just getting the day-to-days done. That can be hugely, hugely physically demanding"* [CCG, Charity worker]). Personal care routines, pain, comorbidities, injury, pressure ulcers, lack of physical function and necessity to transfer to do physical activity were also common barriers. Facilitators included knowledge of pressure relief, feedback on progress, creating schedules around activity and reminders to be active: *"The text message, with the 'get up, do something'. Yeah, it works."* (PwP, T12 incomplete, male).

5.3.2.1.2 Opportunity

Frequent opportunity-related barriers were lack of wheelchair-accessible space in and outside of the home ("*Non-adapted space is a barrier*" [PwP, L1 incomplete]), cost and lack of access to equipment to do physical activity or exercise ("*There's not a lot that you can get that is complimentary. You know, a lot of this stuff you've got to pay for and it's not cheap*" [CCG, Charity worker]), being deterred by family and friends, wheelchairs being inappropriate for physical activity, and geographical inequalities of services or opportunities relating to physical activity and exercise. Facilitators included provision of information and/or opportunities for physical activity and exercise, support from family or friends, and a peer support network: *"There's a thing, isn't there? About community, right? So doing things in a solitary capacity is often quite hard. A lot of barriers to it"* (PwP, T4 complete).

5.3.2.1.3 Motivation

Motivation-related barriers included low self-esteem or self-consciousness (*"People don't like being seen in a wheelchair"* [HCP, Physiotherapist]), boredom, being a chore or lack of enjoyment, and low mood. Facilitators included goal setting (*"I like to work towards goals and objectives. The reward itself would be me completing the goal"* [PwP, T11 incomplete]), building habits around activities of daily living (*"If you can make doing something part of your routine a habit, a good habit, then you're more motivated to keep it up"* [PwP, T4 complete]) and rewards.

5.3.2.2 BCW Stage 2: Identify Intervention Options

Ten different intervention options were identified (Table 7). Although an attempt was made to identify an intervention option for every barrier and facilitator, participants could not suggest options for some. This included injury (barrier), lack of physical function (barrier), support from work (facilitator) and being deterred by family or friends (barrier). The intervention development, therefore, focused on those for which suitable options were identified.

Intervention options that were identified include (1) receiving feedback on sedentary behaviour and physical activity, to help facilitate feedback on progress: *"[It would] be good to like, keep a log of say yeah, whatever activities you're doing. And having, like, your personal best"* (PwP, L1 incomplete). Reminders to break up sedentary behaviour (2) was commonly proposed to address not thinking about sedentary behaviour (barrier): "*Having some kind of prompt [to get moving] I think would definitely be helpful for him*" (CCG, Family member). Education (3) was suggested to address lack of knowledge about sedentary behaviour (barrier): *"People really need to be made aware of what that [reducing sedentary behaviour] looks like, what that could be, and also and also what the benefits are physiologically and psychologically"* (CCG, Charity worker). To address cost and lack of access to equipment to do physical activity or exercise (barrier), having physical activity equipment (4) was identified as an option: *"They*

haven't got any finances available to purchase any extra [exercise] equipment and that might be what's needed to be active" (HCP, Physiotherapist).

A peer support network was suggested as an option to facilitate peer support (5): *"If you're feeling a little bit demotivated, you know, maybe there's like a chat or a forum or something"* (PwP, T6 complete). Getting support from family and friends (6) was also suggested to facilitate peer support: *"I think it's good to involve family and friends. If they're up for doing it like people have already said, I think it's a good motivation"* (CCG, Charity Worker). Goal setting (7) came through as an intervention option: *"Could there be like a mentoring or coaching? It could be part of the creating targets. Maybe you can check back?"* (PwP, L1 incomplete). Creating schedules (8) was an option to support planning around activity (facilitator): *"Trying to get a bit of a timetable even into your normal daily living and to and to incorporate the activity in into that"* (CCG, Charity Worker). Signposting to relevant organisations (9) would facilitate the provision of information and/or opportunities for physical activity and exercise: "*If you have a website, you can link it to the local sports groups*" (PwP, T1 incomplete). Gaining rewards for reducing sedentary behaviour (10) could address low confidence or self-esteem (barrier): *"If I could earn a badge for doing a 5-minute exercise on a bad day that might incentivise me for doing it*" (PwP, L1 incomplete).

Table 7. Intervention options mapped to the COM-B, TDF and BCW constructs.

COM-B micro-construct	TDF domain	Barrier / facilitator being targeted	What needs to change	Proposed intervention option	Intervention function	Policy category	Behaviour change techniques	Delivery mode
Psychological capability	Behavioural regulation	Getting feedback on progress (facilitator)	Individual becomes aware of their sedentary behaviour and physical activity	Feedback on sedentary behaviour and physical activity	Enablement, Education	Guidelines, Communication/ marketing	2.2: Feedback on behaviour 2.3: Self-monitoring of behaviour 12.5: Adding objects to the environment	Wearable tracker, health and fitness app, feedback from an individual trained in motivational support
	Knowledge	Lack of knowledge about sedentary behaviour (barrier)						
Psychological capability	Memory, attention and decision processes	Reminders to be active (facilitator)	Individuals are regularly prompted to break up their sedentary behaviour	Reminders to break up sedentary behaviour	Environmental restructuring, Enablement	Environmental/ social planning	7.1: Prompts/Cues	Notifications or prompts via a wearable activity tracker or app
		Do not think about sedentary behaviour (barrier)						
Automatic motivation	Emotions	Low mood (barrier)	Individuals are given a reward for breaking up and/or reducing sedentary behaviour and increasing physical activity	Rewards for reducing and/or breaking up sedentary behaviour and engaging in physical activity	Incentivisation, persuasion	Fiscal measures	10.1: Material incentive (behaviour) 10.2: Material reward (behaviour) 10.7: Self-incentive 10.9: Self-reward	Streaks, badges, praise via an app or wearable activity tracker and praise from an individual trained in motivational support
Reflective motivation	Beliefs about capabilities	Low self-esteem or self-conscious (barrier)						
	Reinforcement	Rewards (facilitator)						
Psychological capability	Knowledge	Lack of knowledge about sedentary behaviour (barrier)	Individuals being made aware of what sedentary behaviour is and how to reduce and/or break it up, drawing similarities to existing pressure relief advice	Education around sedentary behaviour	Education, Persuasion	Guidelines, Communication/ marketing	4.1: Instruction on how to perform a behaviour 5.1: Information about health consequences 5.6: Information about emotional	Online and physical educational booklet, role models, integrate into existing pressure relief advice, integrate into activities of daily living
		Knowledge of pressure relief (facilitator)						
Physical capability	Skills	Fatigue (barrier)						

		Pain (barrier) Comorbidities (barrier)	Individuals being made aware of the physical, psychological and emotional benefits of reducing and breaking up sedentary behaviour				consequences 8.2: Behaviour substitution 8.3: Habit formation 9.1: Credible source	
Reflective motivation	Intentions	Building habits around activities of daily living (facilitator)						
Social opportunity	Social influences	Support from family or friends (facilitator)	Family members, carers and/or friends providing support to reduce sedentary behaviour	Support from family and friends to reduce sedentary behaviour	Environmental restructuring	Environmental/ social planning	3.1: Social support (unspecified) 3.2: Social support (practical) 12.2: Restructuring the social environment	Within educational resource, suggesting that participants do physical activity with family and friends, explaining the benefits of doing so and including examples of how to involve them
Reflective motivation	Intentions	Boredom, being a chore and lack of enjoyment (barrier)						
Physical opportunity	Environmental context and resources	Provision of information and/or opportunities for physical activity and exercise (facilitator) Lack of wheelchair accessibility in and outside of the home (barrier) Cost and lack of access to equipment to do physical activity or exercise (barrier)	Being signposted to national and local charities, organisations and websites that provide equipment, information and/or opportunities relating to physical activity or exercise	Signposting to charities, organisations and websites	Enablement, Education	Service provision, Communication/ marketing	3.1: Social support (unspecified)	Virtual or physical resource containing a list of links to and contact details of relevant charities, organisations and websites
Reflective motivation	Goals	Goal setting (facilitator)	Individuals setting and monitoring personalised goals related to sedentary behaviour and physical activity	Goal setting	Training, Enablement	Regulation, Guidelines, Communication/ Marketing	1.1: Goal setting (behaviour) 1.4: Action planning 1.5: Review behaviour goals	Self-selection and review of goals with support from an individual trained in motivational support, goal setting and monitoring using a

								wearable activity tracker and/or app
Psychological capability	Behavioural regulation	Creating schedules around activity (facilitator)	Creating schedules to reduce sedentary behaviour and increase physical activity that fit around fatigue, pain, personal care and other commitments	Scheduling	Environmental restructuring, Enablement	Service provision, Regulation	1.1: Goal setting (behaviour) 1.4: Action planning 1.8: Behavioural contract 1.9: Commitment	Physical or virtual calendar, support with creating schedules from an individual trained in motivational support
Physical capability	Skills	Pain (barrier)						
		Fatigue (barrier)						
		Personal care routine (barrier)						
		Pressure ulcers (barrier)						
		Comorbidities (barrier)						
Reflective motivation	Goals	Goal setting (facilitator)						
	Intentions	Building habits around activities of daily living (facilitator)						
Social opportunity	Social influences	Peer support network (facilitator)	Having access to a network of peers with a spinal cord injury to share experiences of participating in the programme, ideas to reduce sedentary behaviour and opportunities to do physical activity	Peer support network	Enablement, Environmental restructuring	Service provision, Environmental/ social planning	3.1: Social support (unspecified) 3.2: Social support (practical) 6.2: Social comparison	A group chat in a messaging app
Reflective motivation	Intentions	Boredom, being a chore or lack of enjoyment (barrier)						

							12.2: Restructuring the social environment	
Physical capability	Skills	Transfers (barrier)	Individuals being provided access to activity tools to use at home, regardless of geographical location	Providing access to activity tools	Enablement, Environmental restructuring	Service provision, Environmental/ social planning	12.1: Restructuring the physical environment 12.5: Adding objects to the environment	An equipment pack including exercise bands and a portable hand cycle to use at home
Physical opportunity	Environmental context and resources	Cost and lack of access to equipment to do physical activity or exercise (barrier)						
		Geographical inequalities of services or opportunities relating to physical activity and exercise (barrier)						
		Excessive planning and inability to be spontaneous (barrier)						
		Wheelchair being inappropriate for activity(barrier)						

Data are presented in order of final intervention components. Columns include COM-B micro-construct to provide broad categories of barriers and facilitators, TDF to provide context as to the nature of each barrier or facilitator, followed by the specific barrier or facilitator in question. The intervention option that targets each barrier/facilitator and how it maps to each BCW construct is provided in sequential order in the subsequent columns. COM-B, Capability, Opportunity and Motivation to change Behaviour; TDF, Theoretical Domains Framework.

5.3.2.2.1 Identification of Intervention Functions and Policy Categories

Six of nine BCW intervention functions were identified as relevant to the intervention options (Table 7). These were Education (n = 3 intervention options were mapped to this function), Enablement (n = 7), Environmental Restructuring (n = 5), Incentivisation (n = 1), Persuasion (n = 2) and Training (n = 1). Six of seven policy categories in the BCW guide were identified as relevant (Table 7), namely Communication/Marketing (n = 4), Environmental/Social Planning (n = 4), Fiscal Measures (n = 1), Guidelines (n = 3), Regulation (n = 2) and Service Provision (n = 4).

5.3.2.3 BCW Stage 3: Identify Content and Implementation Options

Twenty-four BCTs were mapped to the proposed intervention options (Table 7) from the BCTTv1, including Goal setting (behaviour) (1.1), Action planning (1.4), Review behaviour goals (1.5), Behavioural contract (1.8), Commitment (1.9), Feedback on behaviour (2.2), Self-monitoring of behaviour (2.3), Social support (unspecified) (3.1), Social support (practical) (3.2), Instruction on how to perform a behaviour (4.1), Information about health consequences (5.1), Information about emotional consequences (5.6), Social comparison (6.2), Prompts/Cues (7.1), Behaviour substitution (8.2), Habit formation (8.3), Credible source (9.1), Material incentive (behaviour) (10.1), Material reward (behaviour) (10.2), Self-incentive (10.7), Self-reward (10.9), Restructuring the physical environment (12.1), Restructuring the social environment (12.2) and Adding objects to the environment (12.5).

A wearable activity tracker with messaging relevant to wheelchair-users was suggested for providing feedback on physical activity, reminders to break up sedentary behaviour and virtual rewards for breaking up sedentary behaviour and engaging in physical activity. It was proposed that education around sedentary behaviour, signposting to relevant organisations, and information on support from family and friends could be delivered via an educational booklet. Proposed delivery modes for goal setting and creating schedules were a goal-setting worksheet

and one-to-one support from a person trained in motivational interviewing. A social messaging app group chat was proposed to facilitate peer support. A pack of activity tools comprising exercise bands and a portable hand cycle was proposed (access to physical activity equipment). Intervention options with overlapping modes of delivery were merged into six intervention components by the research team after the initial workshops and subsequently discussed with participants in follow-up workshops to assess appropriateness and inform refinements.

5.3.2.3.1 APEASE Assessment

A wearable activity tracker was deemed likely to be effective, with no concerns raised around acceptability, practicability, or safety (Table 8). Concerns were raised around affordability if participants were required to self-purchase the device. Equitability was questioned in relation to individuals less proficient with this type of technology, but participants indicated that this could be overcome if guidance was provided. Researcher discussion led to the Apple Watch Series 7 (Apple Inc., Cupertino, California, USA) and the Garmin Vivoactive 5 (Garmin, Olathe, Kansas, USA) being considered as potential devices, as they both have a wheelchair mode. This setting includes wheelchair-specific language and tracks daily pushes, which participants expressed a preference for over daily step count. The Garmin Vivoactive 5 was selected by researchers for inclusion in the intervention as it is compatible with both iOS and Android smartphones, therefore providing greater accessibility.

An educational booklet was deemed likely to be effective. No concerns were raised regarding practicality, affordability or safety. Printed and electronic formats were recommended for ease of access. The term ‘sedentary’ was not deemed acceptable due to the stigma attached to wheelchair use: “*Sedentary means you sit on your bum all day. We don’t have a choice. So, I would say ‘inactivity’, ‘improve activity’ or something more positive, rather than leaning on the negative*” (PwP, T1 incomplete). Therefore, the term ‘inactive’ was suggested. It was

suggested that positive messaging should be used where possible, (e.g. “break up inactivity”, “do more activity breaks”) rather than limiting sedentary behaviour (e.g. “reduce inactivity”).

Participant feedback on goal setting was generally positive with acceptability, effectiveness, affordability and safety not raising any concerns. Regarding practicability and equity, it was proposed that some participants may require more support than others. This led to the suggestion that motivational support sessions with a trained person could support goal setting through accountability and social support. Discussion between the research team led to the decision that, for pragmatic and resource-based reasons, this trained person should be the PhD Researcher for the feasibility study (Chapter 6). It was also considered that three sessions would be practicable and effective to achieve the purpose of this intervention component.

Peer support was generally deemed acceptable, practicable, effective, safe and equitable. Most participants noted a widely used app (i.e. WhatsApp) would be unlikely to exclude many participants. However, concerns about the privacy of a group chat were raised in addition to concerns about the effectiveness of such a group as some participants did not feel that they needed peer support. Social comparison of progress with the intervention was deemed less acceptable. Healthcare professionals raised concerns around the risk of undesirable behaviour in the group. To address these acceptability concerns, it was agreed amongst the research team that this component of the intervention should be optional, have ground rules for using the chosen app and social comparison should not be advocated.

The activity tools were generally considered to be effective. Some participants suggested tools could be difficult to use due to a lack of knowledge for their use or risk of injury. Therefore, subsequent researcher discussion led to a guidance document being added to this component alongside links to demonstrative videos in the educational booklet. Exercise bands, a portable hand cycle and hand weights were suggested as potential tools. Researcher discussion led to

the conclusion that hand weights would not be practicable due to issues accessing weights of multiple heaviness and transportation problems. The exercise bands and portable hand cycle were considered feasible.

Overall, there were no dissenters to the intervention components proposed in follow-up workshops. The appropriateness of particular aspects were questioned, but reasonable suggestions were made to overcome those issues identified (see Table 8).

5.3.3 Intervention Components

This study led to the development of an intervention comprising six components. The first component is a wrist-worn wearable activity tracker, the Garmin Vivoactive 5, to provide reminders to break up sedentary behaviour and feedback on physical activity with a wheelchair-mode option. The device counts the consecutive days the wearer achieves a self-directed wheelchair push count goal, as well as providing virtual badges for reaching milestones of consecutive days achieving the daily push goal and doing guided exercises.

An educational booklet will also be included in the intervention. This will include a definition of sedentary behaviour, benefits of reducing sedentary behaviour, ideas for reducing sedentary behaviour (including how to involve family and friends) and how to set and work towards goals. The booklet will also contain signposting to websites, videos, charities and opportunities related to physical activity and/or exercise. Participants will be offered the booklet in both paper and digital format.

A goal setting worksheet will also be included, in which the participants will set short- and long-term goals related to sedentary behaviour and, if they wish, physical activity. The worksheet will also involve ideas and prompts for how to strengthen commitment towards their goals. In addition, the worksheet will prompt participants to estimate their current inactivity level in the first and final week of the intervention to self-monitor progress.

Participants will receive three one-to-one motivational support sessions from an individual trained in motivational interviewing, via video call or telephone, depending on participant preference. These sessions will involve guidance around setting and working towards sedentary behaviour goals, reviewing progress and creating action plans.

A peer support group will be set up on WhatsApp for participants to join, if they wish and agree to the group rules sent by email. Participants who join the group will be encouraged to provide peer support and share ideas and advice with other participants. The PhD Researcher will send weekly messages to encourage regular interaction.

Lastly, participants will be provided activity tools to facilitate regular breaks in sedentary behaviour throughout the day. The tools include a set of exercise bands of varying intensity and a portable hand cycle. A guidance sheet around maintaining proper form, when to rest or stop and seek support, will be provided with the activity tools. In addition, links to videos providing demonstrations and ideas for using the activity tools will be provided within the educational booklet.

Table 8. Assessment of intervention components using the APEASE criteria.

Intervention component	Acceptability	Practicability	Effectiveness	Affordability	Safety/side effects	Equity	Comments
Wearable activity tracker	✓	✓	✓	X	✓	✓	It may not be affordable if participants were required to purchase wearable trackers with wheelchair mode. Concerns around the technological proficiency required are overcome by researchers providing guidance.
Educational booklet	✓	✓	✓	✓	✓	✓	Concerns around accessibility of the format are overcome by offering both printed and electronic versions. Concerns around acceptability of terminology overcome by using inclusive and positive wording in the materials.
Goal setting	✓	✓	✓	✓	✓	✓	Concerns around lack of support with creating and working towards goals are overcome by the inclusion of motivational support.
Motivational support	✓	✓	✓	✓	✓	✓	Concerns around the practicability of access to a medically qualified individual are overcome through delivery by an individual with suitable motivational support training.
Peer support group	X	✓	✓	✓	X	✓	Concerns around acceptability of social comparison are overcome by not sharing activity data between participants. Concerns around privacy are overcome by this component being optional and setting clear ground rules.
Activity tools	✓	✓	✓	✓	✓	✓	Safety concerns around injury are overcome by providing guidance for using the tools safely.

5.4 Discussion

This study has led to the development of a novel intervention targeting sedentary behaviour in individuals with paraplegia. A rigorous co-design approach embedded within the COM-B and BCW was adopted to maximise the intervention's effectiveness, feasibility and acceptability. The rigorous combined approach and the novelty of the intervention advances knowledge related to developing behavioural interventions and addressing sedentary behaviour in individuals with paraplegia.

The use of co-design may have generated greater participant engagement than traditional researcher-led methods due to a sense of ownership brought about by equal partnership in the design process. Additionally, participants expressed that taking part in the workshops was acceptable, noting that the opportunity to share their experiences was a positive aspect (Jagosh et al., 2012; Kapiszewski & Wood, 2022). Combining co-design with a workshop-based approach may have stimulated greater peer discussion and support, as well as building trust and openness between participants (Kapiszewski & Wood, 2022). These factors are integral to sharing richer and more honest insights (Kapiszewski & Wood, 2022). The co-design workshop approach, therefore, led to a rich dataset and targeted intervention components appropriate for individuals with paraplegia.

The BCW was adopted in this co-design study due to its comprehensive, theory-driven approach to intervention development (Michie et al., 2011). While the co-design workshops allowed exploration of participant insights regarding barriers and facilitators for achieving the target behaviour, the BCW facilitated a coherent behavioural diagnosis using the COM-B model (Michie et al., 2011). This facilitates the selection of appropriate BCTs that can target the behaviour more precisely. As the co-design approach facilitated discussion of preferred intervention options, the BCW allowed systematic mapping of these options to the identified barriers and facilitators, intervention functions, policy categories and BCTs (Michie et al.,

2014). This systematic mapping provides a transparent step-by-step process where decision-making can be traced. Assessing the appropriateness of the intervention options using the APEASE criteria provided a rigorous approach to ensure intervention concepts are feasible, acceptable and safe before resources are spent on testing them. An APEASE assessment also enables intervention concepts to be optimised prior to testing, meaning they are more likely to be effective for achieving the target behaviour. Indeed, use of appropriate behaviour change theory has been shown to bring about greater physical activity behaviour change in individuals with physical disabilities (Ma & Martin Ginis, 2018). Therefore, it is likely that the rigorous combined co-design and BCW approach will result in an intervention that is more acceptable and effective for reducing and breaking up sedentary behaviour.

The co-design process led to the need for a multi-component intervention to address a range of unique barriers and facilitators for individuals with paraplegia. This is in line with research demonstrating the superiority of multi-component interventions for reducing sedentary behaviour compared to single-component interventions in clinical populations (e.g. educational materials, motivational sessions, smartphone apps, reminders to break up sedentary behaviour) (Nieste et al., 2021). With regards to each intervention component, the inclusion of a wrist-worn, wearable activity tracker is consistent with interventions that have reduced sedentary behaviour in non-disabled individuals (Direito et al., 2017; Stephenson et al., 2017) and clinical populations (Nieste et al., 2021). Several BCTs identified in the present study, such as self-monitoring, social support, feedback, prompts and cues, have been effective in previous sedentary behaviour interventions (Direito et al., 2017; Nieste et al., 2021; Stephenson et al., 2017). Smartphone apps and wrist-worn activity trackers have increased physical activity in individuals with SCI, but these interventions did not target or measure sedentary behaviour (Hiremath et al., 2019; Lawrason & Martin Ginis, 2023). Therefore, previous interventions may not target appropriate BCTs to effectively reduce sedentary behaviour in individuals with

SCI (Martin et al., 2015). The technology-based component in the current study has been co-designed with a specific focus on sedentary behaviour, which is likely to lead to greater acceptability and effectiveness of the intervention.

Education is included in the present intervention, in line with an intervention co-produced with stroke survivors using the BCW (Hall et al., 2020). This highlights the importance of education around sedentary behaviour in individuals with neurological conditions, such as paraplegia (Hall et al., 2020). A systematic review found that interventions implementing education around physical activity were effective for increasing leisure-time physical activity in this population (Tomasone et al., 2018), although effects on sedentary behaviour have not been examined. Interventions utilising education have shown promise for reducing sedentary behaviour in the general population (Curran et al., 2021; Gardner et al., 2016). The present study provides novel findings that an intervention targeting reductions and breaks in sedentary behaviour should include an educational component.

Goal setting is an important intervention component for targeting sedentary behaviour in individuals with neurological conditions, as found in a co-produced intervention in stroke survivors (Hall et al., 2020). Reviews have demonstrated the effectiveness of goal setting for reducing sedentary behaviour in non-disabled individuals in workplace (Brierley et al., 2019) and non-workplace settings (Curran et al., 2021) hence it being likely that goal setting will be effective in the present intervention. Motivational support was included in the present study to aid goal setting and working towards goals. The inclusion of motivational support is backed by a meta-analysis demonstrating that motivational counselling is effective for reducing sedentary behaviour in clinical population (Nieste et al., 2021). In line with findings regarding facilitators for physical activity in individuals with SCI (Kehn & Kroll, 2009), peer support was also considered a potential strategy for reducing sedentary behaviour in the present study. Therefore, motivational support sessions and peer support may be effective for addressing

barriers and facilitators to reducing sedentary behaviour in individuals with paraplegia. Therefore, motivational support and peer support may both be effective for reducing sedentary behaviour in individuals with paraplegia.

Consistent with physical activity research, providing activity tools was identified to help overcome barriers related to affordability and access in individuals with SCI (Kehn & Kroll, 2009). Adding objects to the physical environment, such as wearable devices, sit-stand desks and exercise equipment, is an effective intervention strategy to reduce sedentary behaviour in non-SCI populations (Booth et al., 2022; Curran et al., 2021; Gardner et al., 2016). However, there is limited evidence evaluating the use of activity tools to enable regular 'activity breaks' throughout the day. The inclusion of activity tools is, therefore, a novel component for reducing sedentary behaviour.

Some participants with paraplegia raised concerns with the term "sedentary behaviour" due to the stigma attached around wheelchair use. Instead, these participants suggested referring to "inactivity", in line with findings in stroke survivors (Hall et al., 2020). This suggests that alternative terminology and/or definitions relating to sedentary behaviour should be developed for individuals with physical disabilities. Some participants with paraplegia also preferred positive messaging in relation to the target behaviour (e.g. doing *more* activity, instead of engaging in *less* sedentary behaviour), as was also expressed by stroke survivors (Hall et al., 2020). Therefore, this intervention will use positive messaging, where possible, to ensure greater acceptability.

5.4.1 Strengths and Limitations

Strengths of this study include the use of co-design methodology combined with the BCW to undertake a rigorous and systematic approach to intervention development. This combined approach of participatory methodology and behaviour change theory helps to maximise

acceptability and effectiveness of the intervention. The intervention is generalisable to a diverse range of individuals with paraplegia due to the varied sample of participants at different stages of the SCI healthcare pathway, inclusion of multiple key stakeholders and PPI. Also, the appropriateness of the intervention components as determined using the APEASE criteria was undertaken with end-users and key stakeholders, which helps to increase acceptability and relevance of the intervention.

Limitations of the study include the sample size being smaller than planned and comprising predominantly White British participants. A representative view from these participants may, therefore, have not been achieved, potentially limiting generalisability of the intervention. Not all participants were available to participate in both workshops, which is inconsistent with a traditional co-design approach (Vargas et al., 2022). However, this approach provided the opportunity to understand acceptability of intervention options from individuals who were not involved with developing the initial concepts. Additionally, stakeholder data only represents what these individuals expect to be effective for changing behaviour, rather than their actual experiences. Despite this approach potentially enhancing acceptability of the components, it is not definite that this will lead to an effective intervention.

5.5 Conclusion

This study reports on the development of a novel intervention targeting sedentary behaviour in individuals with paraplegia. The intervention was co-designed using the BCW, with input from multiple stakeholders, meaning that the developed intervention is likely to be feasible, acceptable and effective for end-users. It is recommended that future interventions are developed utilising a combined approach of participatory methodology and behaviour change theory to optimise acceptability and potential effectiveness. The feasibility, acceptability and effectiveness of the intervention is being evaluated in a further study (Chapter 6). This research could inform public health and clinical care guidelines with a focus on sedentary behaviour in individuals with paraplegia.

Chapter 6: Study 3. Acceptability, Safety, Feasibility and Preliminary Efficacy of the REACH-SCI (Reducing sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury) Intervention

The feasibility study manuscript is in preparation for submission to a peer-reviewed journal.

This study provides data around the experiences of individuals with paraplegia taking part in the developed intervention, which can inform amendments to improve acceptability, safety and feasibility in a future effectiveness trial.

6.1 Introduction

The systematic review presented in Chapter 4 found that interventions targeting physical activity in individuals with paraplegia were not effective for reducing sedentary behaviour (Cooper et al., 2025a). Although there was a lack of interventions targeting sedentary behaviour, those that did target this behaviour showed promise for improving CVD biomarkers (Bailey et al., 2020; Martinez et al., 2025). Interventions targeting sedentary behaviour require investigation to elucidate their effectiveness and consideration for management of cardiovascular health in individuals with paraplegia.

To address key gaps in the evidence, a sedentary behaviour intervention for individuals with paraplegia was developed using co-design with end-users and key stakeholders (Chapter 5) (Cooper et al., 2025b).

The primary aim of this study was to assess the acceptability, safety and feasibility of the Reducing sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury (REACH-SCI) intervention in individuals with paraplegia.

The main objectives were to (1) explore participant acceptability of the intervention by ascertaining agreement between qualitative and quantitative data using a combined mixed-methods approach, (2) assess safety of the intervention via adverse events, pain and fatigue

questionnaires, and (3) explore feasibility of the intervention in the context of intervention components being delivered as planned, as well as participant adherence and dosage. The secondary objectives were to (4) evaluate participant engagement with the intervention components, (5) explore the acceptability of data collection procedures, (6) assess the feasibility of recruiting and retaining participants in the study and (7) evaluate preliminary efficacy in the context of pre-post changes in sedentary behaviour, physical activity, CVD biomarkers, and psychosocial outcomes.

6.2 Methods

6.2.1 Study Design

This study used a mixed-methods, single-arm, pre-post design. After baseline measurements, all participants received the intervention. Measurements were repeated at eight weeks (end of intervention) following the start of the intervention period (Figure 8). Eight weeks was selected in line with sedentary behaviour interventions evaluated in individuals with other neurological conditions, in which this duration was an appropriate time period to address acceptability, safety and feasibility outcomes (English et al., 2016; Ezeugwu & Manns, 2018). Semi-structured interviews were undertaken with all participants post-intervention. Ethical approval was granted from Brunel University of London College of Health, Medicine and Life Sciences Research Ethics Committee (50038-NHS-Mar/2025- 54084-2; Appendix 23) and the National Health Service East of England - Cambridge South Research Ethics Committee (25/EE/0090; Appendix 24). The study adhered to the principles of the Declaration of Helsinki and was conducted and reported in accordance with the Consolidated Standards of Reporting Trials guidelines for feasibility and pilot trials (CONSORT; Appendix 25) (Eldridge et al., 2016). In addition, the study was reported in accordance with the Good Reporting of A Mixed-Methods Study (GRAMMS) guidelines (Appendix 26) (O'Cathain et al., 2008). The study protocol was prospectively registered with clinicaltrials.gov (NCT06957483).

6.2.2 Study Setting

The intervention was delivered remotely to individuals with paraplegia living in the community. Outcome measurements and interviews were conducted within a laboratory and private room, respectively, in the Department of Sport, Health and Exercise Sciences at Brunel University of London.

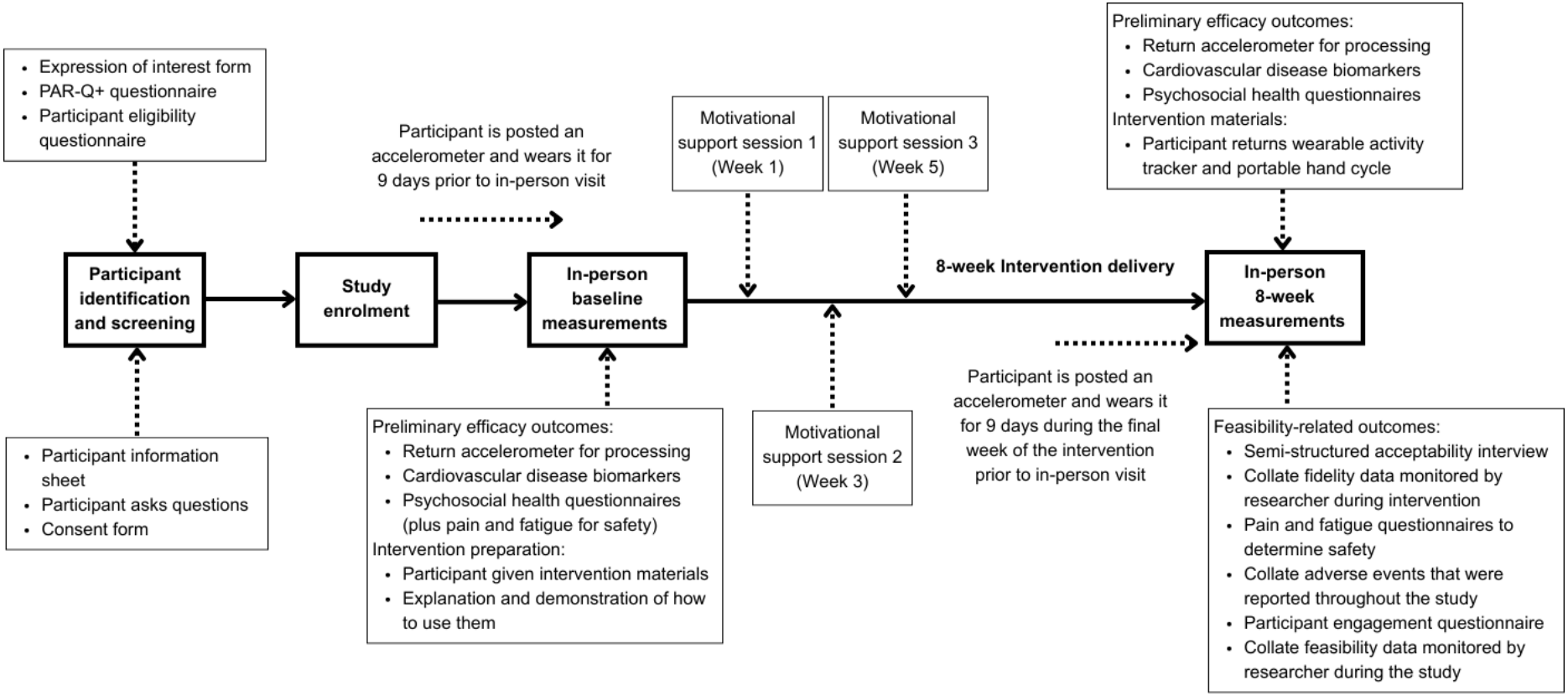

Figure 8. Intervention process flowchart.

6.2.3 Participant Eligibility Criteria

Participant inclusion criteria were adults (≥ 18 years) with self-reported paraplegia regardless of lesion completeness or cause, who use a manual wheelchair as their primary mode of mobility inside and outside of the home. Participants needed to be able to travel to Brunel University of London to undertake study measurements, have access to regular use of a smartphone or tablet with internet access, and be able to communicate in English at a level sufficient to participate in the study. Additionally, participants needed to be able to provide informed consent, willing and able to provide fingertip blood samples and fast prior to measurement sessions, and able to independently transfer to a treatment couch and lay supine to undertake anthropometric and body composition measurements.

Exclusion criteria were self-reported heart conditions, chest pain, dizziness, bone or joint problem, or any other condition that may be exacerbated by doing physical activity, as indicated via responses to the Physical Activity Readiness Questionnaire Plus (PAR-Q+; Appendices 27 and 28) (Warburton et al., 2021), history of uncontrolled autonomic dysreflexia in the past 12 months, pregnancy, or participation in another intervention study.

6.2.4 Participant Recruitment

Recruitment took place in the community via disability sport and SCI support pages on social media (e.g. X and Facebook), communication through SCI charities (e.g. Spinal Injuries Association and Back-Up Trust), snowballing and participants from previous studies (including individuals from Chapter 5) who provided consent for being contacted about future research. Recruitment also took place through the London Spinal Cord Injury Centre, Royal National Orthopaedic Hospital NHS Trust; potentially eligible patients received study information from a member of the care team during routine appointments, inpatient care and/or mail-out. Posters and leaflets containing study information were also displayed within clinics and wards (Appendix 29).

Individuals were asked to express their interest in participating by contacting the research team by email or scanning a QR code provided on study materials. The QR code took individuals to an online form (Jisc Online Surveys; Appendix 30) where they provided their contact details and consent to be contacted. For individuals who expressed an interest in taking part to a clinician, the clinician asked for verbal consent to share the individual's name and contact details (phone number and email) with the research team so they could be followed up regarding potential participation. Individuals who registered their interest were provided with a PIS (Appendix 31) if they did not already have one, and separate links to both an online screening questionnaire and the PAR-Q+ (both using Jisc Online Surveys; Appendices 32, 27 and 28, respectively). The screening questionnaire and PAR-Q+ were reviewed by the PhD researcher who followed up with individuals via email or telephone call for any clarifications regarding eligibility, if required. Individuals had the opportunity to ask the research team any questions via email or telephone call prior to giving informed consent (Appendices 33 and 34). Participants were given at least 24 hours after receiving study information to decide whether they wished to participate before choosing to provide consent either electronically or by hand.

The study aimed to include participants from across the SCI care pathway post-discharge from inpatient rehabilitation, including at initial discharge, within the first year of discharge and more than one year after initial discharge. This was operationalised by clinicians at the London Spinal Cord Injury Centre specifically identifying and providing study information to individuals who were recently discharged or soon to be discharged from inpatient rehabilitation.

6.2.5 Participant Incentives

Upon completion of eight-week study measurements, a £50 Amazon gift voucher was offered to participants as a token of appreciation. Any expenses incurred when travelling to Brunel University of London for study measurements were reimbursed.

6.2.6 Sample Size

The target sample size was 20 participants. This is greater than a previous recommendation of at least 12 participants per arm in pilot and feasibility studies (Julious, 2005) to account for difficulty recruiting and retaining individuals with SCI in clinical trials (Blight et al., 2019). A power calculation was not undertaken to inform sample size in line with recommendations for feasibility studies (Teresi et al., 2022). Instead, sample size was guided by the primary aims of the study regarding intervention acceptability, safety and feasibility (Teresi et al., 2022).

6.2.7 The REACH-SCI (Reducing sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury) Intervention

6.2.7.1 Intervention Development

The REACH-SCI intervention was developed in accordance with the MRC framework for developing complex interventions (Skivington et al., 2021) and co-designed with key stakeholders using the BCW (as described in Chapter 5).

6.2.7.2 The REACH-SCI Intervention

The REACH-SCI intervention involved a wearable activity tracker, educational resources, goal setting, motivational support from a trained researcher, peer support and activity tools. The intervention period lasted for eight weeks following baseline measures. Participants were provided with all intervention materials and given the opportunity to ask any questions regarding the intervention at the end of their baseline visit. Within the intervention materials (educational booklet and goal setting worksheet), sedentary behaviour was referred to as ‘inactivity’ in line with findings through the co-design work to reduce perceived stigma attached to wheelchair use. The term ‘sedentary behaviour’ was used to describe the intervention protocol for clarity and consistency with the aims of the study. The intervention is reported following the Template for Intervention Description and Replication checklist (Appendix 35) (Hoffmann et al., 2014).

6.2.7.2.1 Wearable Activity Tracker

Participants were provided with a Garmin Vivoactive 5 (Garmin, Olathe, Kansas, USA) to be worn on the wrist during the intervention (Figure 9). The device was set up in Wheelchair Mode, which tracks pushes instead of steps and uses wheelchair-appropriate language. Verbal guidance on how to set up, wear and use the device was provided during the baseline measurement visit. The Garmin Vivoactive 5 provides reminders to break up sedentary behaviour with a haptic alert and notification to prompt movement every hour ("Time to shift your weight"). Feedback on the number of pushes, heart rate, calories burned and minutes spent in MVPA is also provided through the wearable activity tracker interface and/or accompanying Garmin Connect smartphone app. Virtual badges are awarded to the participant for achieving personal push goals, sharing activities with friends in the app, completing challenges and doing different types of exercise. The number of consecutive days in which the personal push goal is achieved (daily streak) is also recorded within the app. Participants had the opportunity to use their own wearable activity tracker if it had wheelchair mode, inactivity prompts, physical activity tracking and rewards to ensure all planned BCTs could be delivered.

Figure 9. Garmin Vivoactive 5 wearable activity tracker (Garmin, 2023)

6.2.7.2.2 Educational Booklet

Participants were provided with an educational booklet in both electronic and hard copy format (Appendix 36). The booklet provided (1) a modified, lay version of the consensus statement definition of sedentary behaviour (Tremblay et al., 2017) with examples of sedentary activities, (2) potential health benefits of reducing and breaking up sedentary behaviour, (3) ideas and suggestions to support reducing and breaking up sedentary behaviour including examples of how to involve family and friends, (4) how to set and review sedentary behaviour and physical activity goals, and (5) a list of different charities, organisations and websites (with weblinks and contact information) who provide free or discounted exercise equipment, information and/or opportunities relating to physical activity and exercise.

6.2.7.2.3 Goal Setting

Participants set short- and long-term goals related to sedentary behaviour and physical activity using a goal-setting worksheet (Appendix 37) and guidance from a trained researcher, as described below. Goals were individualised, reflecting the amount and frequency at which participants aimed to reduce or break up sedentary behaviour and, optionally, increase physical activity. Participants were prompted and guided to estimate their sedentary behaviour during the first and final week of the intervention within the goal-setting worksheet. This was intended to aid with reviewing progress. Participants were also encouraged to set physical activity goals (e.g. daily pushes, intensity exercise minutes) within their wearable activity tracker that could help contribute to reductions in sedentary behaviour.

6.2.7.2.4 Motivational Support Sessions

The PhD researcher, who was trained in motivational interviewing, supported each participant in making behavioural changes. This included support with setting individualised goals relating to sedentary behaviour and physical activity, reviewing goals and progress, and creating action

plans. The one-to-one support sessions took place via online video call or by phone, depending on participant preference. Three sessions took place at approximately weeks 1, 3, and 5.

6.2.7.2.5 Peer Support

A peer support group was set up by the PhD researcher in WhatsApp for those participating in the study to join if they wished. Participants who opted into this component were encouraged to provide peer support and advice relating to sedentary behaviour and physical activity, in addition to sharing experiences with the intervention. The PhD researcher sent an initial email outlining the purpose of the group, ground rules and examples of what information could be shared to each participant, prior to being added to the group. When a new participant was added, the PhD researcher introduced them to the group. The PhD researcher did not monitor the group but did access the group once per week to post reminder messages to encourage use of the chat (Appendix 38 for example posts).

6.2.7.2.6 Activity Tools

Participants were provided with a pack of activity tools to use at home, which included exercise bands of varying resistance (HPYGN, Shenzhen, Guangdong, China) and a portable hand cycle (AGM, Shenzhen, Guangdong, China). Printed guidance around how and when to use the bands and hand cycle (including short, frequent bouts spread across the day to encourage breaks in sedentary behaviour) was provided within the educational booklet (Appendix 36). Additional guidance around safety precautions for maintaining good shoulder health, such as proper form and scheduling breaks, with advice to stop exercising and contacting their general practitioner if new pain or spasticity arose, or if existing pain or spasticity worsened, was provided in a separate printed document (Appendix 39).

Table 9. Study measurements at each timepoint.

Study measure	Measurement method	Measurement timepoint		
		Baseline	**Collected throughout intervention period**	**8 weeks**
Participant characteristics	Self-report questionnaire	✓		
Intervention acceptability	Semi-structured interview, intervention acceptability questionnaire			✓
Intervention feasibility	Intervention component delivery checklist		✓	
Safety (adverse events)	Ad-hoc self-report		✓	
Safety (pain and fatigue)	MPQ and MFIS questionnaires	✓		✓
Intervention engagement	Intervention engagement questionnaire			✓
Acceptability of data collection procedures	Semi-structured interview			✓
Study feasibility	Recruitment, retention and data completion rates	✓		✓
Sedentary behaviour and physical activity	Accelerometry	✓		✓
CVD biomarkers	Laboratory measurement	✓		✓
Psychosocial health	GAD-7, PHQ-9, ONS-4, SF-36ww questionnaire	✓		✓

CVD, cardiovascular disease; GAD-7, Generalized Anxiety Disorder 7-item; MFIS, Modified Fatigue Impact Scale; MPQ, McGill Pain Questionnaire; ONS-4, Office for National Statistics 4-item; PHQ-9, Patient Health Questionnaire 9-item; SF-36ww, Short Form 36-item walk-wheel.

6.2.8 Data Collection

Study measurements were collected at different timepoints and summarised in Table 9.

6.2.8.1 Demographic Data

At baseline, demographic information including participant age, sex, ethnicity, comorbidities and SCI characteristics (i.e. neurological level, completeness, years since injury) was collected via an online questionnaire (Jisc Online Surveys; Appendix 32).

6.2.8.2 Intervention Acceptability

Following completion of the intervention, acceptability was assessed via a questionnaire (Appendix 40) comprising 5-point Likert scales (Sekhon et al., 2022) and individual semi-structured interviews (Appendix 41) to explore constructs from the Theoretical Framework of Acceptability (TFA) (Sekhon et al., 2017). The TFA assesses acceptability in the context of seven components: affective attitude (how an individual feels about the intervention), burden (perceived effort required to participate in the intervention), ethicality (the extent to which the intervention fits with the individual's value system), intervention coherence (the extent to which the individual understands the intervention and how it works), opportunity costs (the extent to which the individual must give up other benefits, value or profits to engage with the intervention), perceived effectiveness (the extent to which the individual perceives the intervention as likely to achieve its purpose), and self-efficacy (the individual's confidence that they can perform the behaviour required to participate in the intervention), as well as overall intervention acceptability (Sekhon et al., 2017).

The acceptability of each intervention component was assessed in the context of perceived effectiveness from the TFA. This was ascertained via questionnaire and the aforementioned semi-structured interview.

Progression criteria for advancing to the next stage of the intervention development process were positive responses outweighing negative responses for each question within the intervention acceptability questionnaire (e.g. more participants agree or strongly agree than disagree or strongly disagree).

6.2.8.3 Intervention Safety

Safety of the intervention was evaluated through collation of adverse events experienced during the study. These were self-reported at each data collection point, during contact with the PhD

Researcher as part of the intervention, and ad-hoc throughout the study by participants contacting a member of the research team via phone or email. Safety was also evaluated via self-report of pain using the McGill Pain Questionnaire (MPQ; Appendix 44) (Melzack, 1975) and fatigue using the Modified Fatigue Impact Scale (MFIS; Appendix 45) (Fisk et al., 1994) via online questionnaires (Jisc Online Surveys) at baseline and post-intervention. Both the MPQ and MFIS are validated in individuals with SCI (Imam et al., 2012; Sawatzky et al., 2008).

6.2.8.4 Intervention Feasibility

Intervention feasibility was assessed by a researcher using a checklist (Appendix 42) to record each component being delivered as planned for each participant throughout the intervention period. This checklist included participants being provided with the wearable activity tracker, educational booklet, goal setting worksheet, exercise bands and portable hand cycle. Attendance at each motivational support session and the duration of these sessions was also recorded. This was in addition to a checklist for all planned aspects of the motivational support sessions being covered by the researcher (Appendix 43)

6.2.8.5 Intervention Engagement

Intervention engagement was assessed using an online questionnaire (Jisc Online Surveys) for participants to self-report how many days per week they used the wearable activity tracker, their use of the educational booklet, completion of the goal-setting worksheets, frequency of engagement with the peer support group chat, and frequency and average duration (min/day) of using the activity tools (Appendix 46). Open text responses in the acceptability questionnaire around reasons for engagement and non-engagement were used to contextualise quantitative engagement data.

6.2.8.6 Acceptability of Data Collection Procedures

Participant acceptability of the data collection procedures was also assessed in the semi-structured interviews (Appendix 41).

6.2.8.7 Study Feasibility

Study feasibility was determined in the context of participant recruitment and retention rates and the proportion of missing data for daily sedentary time (proposed primary outcome for a definitive trial) and secondary outcomes.

6.2.8.8 Sedentary Behaviour and Physical Activity

At baseline and during the final week of the intervention period, each participant wore an ActiGraph GT9X Link accelerometer (ActiGraph LLC, Pensacola, FL, USA) on their non-dominant wrist. The device was posted to the participant prior to each wear period and returned to the researcher during their study measurement visit. The ActiGraph GT9X Link has been validated for estimating sedentary behaviour and physical activity in manual wheelchair-users with SCI (Bailey et al., 2025). Participants were asked to wear the ActiGraph for nine consecutive days, providing seven full days of recording at each time point. The ActiGraph GT9X Link was used to provide estimates of sedentary time (min/day; proposed primary outcome for a definitive trial), number of breaks in sedentary behaviour, percentage of day spent in sedentary behaviour, number of and time spent in sedentary bouts (min/day), number of and time spent in prolonged sedentary bouts (min/day), total time spent in physical activity (min/day), time spent in light physical activity (min/day) and time spent in MVPA (min/day). The PhD researcher provided verbal guidance on proper placement of the device via telephone and in writing via a guidance sheet (Appendix 47). Participants were asked to record any non-wear periods in a diary (Appendix 48).

Raw accelerometry data were downloaded using ActiLife software v6.13.4 (ActiGraph, Pensacola, USA). Criteria for a valid day were ≥ 10 hours of waking wear time on at least four days (Migueles et al., 2017; Troiano et al., 2008; Trost et al., 2005). Raw tri-axial accelerometry data (g) across x, y and z axes at a sampling rate of 30 Hz was exported to the open-source R package GGIR (version 3.1-5; available at: www.github.com/wadpac/GGIR). Data were processed in GGIR via the inbuilt functions for sensor autocalibration using local gravity as a reference (Van Hees et al., 2014), identification of non-wear time and detection of abnormally high values. Raw signal data were aggregated into 5 second epochs and categorised as time spent in different intensities according to published cut-points for manual wheelchair-users with SCI (≤ 37 g/min for sedentary behaviour; ≥ 222 g/min for MVPA) (Bailey et al., 2025).

6.2.8.9 Cardiovascular Disease Biomarkers

After an overnight fast and being asked to only drink small sips of water, blood pressure, body composition and blood biomarker measurements were taken. Participants were asked to abstain from exercise for 24 hours prior to measurements.

6.2.8.9.1 Blood Pressure

Following five minutes of rest after first entering the laboratory, systolic and diastolic blood pressure (mmHg) of the brachial artery was measured using an automatic blood pressure monitor (A&D UA-611, Tokyo, Japan), whilst the participant sat upright in their wheelchair. This measurement was repeated three times with intervals of at least one minute between each, and the average of the two lowest readings was recorded. Mean arterial pressure (mmHg) was calculated as follows:

$$\frac{(2\ X\ Diastolic\ blood\ pressure) + Systolic\ blood\ pressure}{3}$$

6.2.8.9.2 Anthropometry and Body Composition

After measurement of blood pressure, body mass (kg) was calculated by measuring the mass of the participant in their wheelchair and the wheelchair alone (after the participant transferred to a treatment couch) using Marsden M-610 double-beam wheelchair scales (Marsden, Rotherham, UK). Supine height and waist circumference were then each measured a single time to the nearest 0.1 cm using an anatomical tape measure whilst the participant lay supine on a treatment couch. Supine height was measured in three segments and combined to attain a total value: the highest point of the skull to the great trochanter of the femur, the great trochanter of the femur to the lateral epicondyle of the knee, and the lateral epicondyle of the knee to the base of the heel (Walters et al., 2009). The circumference of the waist was measured at the centre point between the lower margin of the last rib and the top of the left iliac crest (WHO, 2000). Body mass index was calculated as: kg / m^2. Body fat mass (kg) and percentage body fat were then estimated while the participant lay supine using bioelectrical impedance analysis (Bodystat 1500; Bodystat Ltd, Isle of Man, UK), which had excellent and moderate relative agreement to dual-energy x-ray absorptiometry in individuals with SCI, respectively (Ma et al., 2022).

6.2.8.9.3 Blood Biomarkers

After measurement of body composition, participants transferred back to their wheelchair and capillary blood was drawn from the fingertip using a lancet. After wiping away the first drop of blood, 40 μL blood samples were collected into a self-wicking, non-coated capillary tube. Fasting blood glucose, total cholesterol, and HDL cholesterol (mmol/L) were measured from capillary blood samples using an automated analyser (CardioChek PA; PTS Diagnostics, Indianapolis, IN, USA), which was frequently tested for accuracy using reference solutions of a known concentration. Total cholesterol:HDL cholesterol ratio was calculated as: total

cholesterol ÷ HDL cholesterol. Non-HDL cholesterol (mmol/L) was calculated as: total cholesterol - HDL cholesterol.

6.2.8.10 Psychosocial Health Outcomes

Questionnaires were completed in a private room at Brunel University of London via Jisc Online Surveys, using a laptop. Subjective well-being was measured using the Office for National Statistics (2011) 4-item scale (ONS-4; Appendix 49). A higher score (out of 10) indicated worse wellbeing in the first three domains (life satisfaction, feel life is worthwhile, happiness), and better wellbeing in the final domain (anxiety). Anxiety and depression were measured using the Generalized Anxiety Disorder (GAD-7; Appendix 50) questionnaire (Spitzer et al., 2006) and Patient Health Questionnaire (PHQ-9; Appendix 51) (Kroenke et al., 2001), respectively. The GAD-7 is scored out of 21 and PHQ-9 out of 27. Higher scores indicate higher anxiety and depression. Health-related quality of life was measured using a modified version of the 36-item Short-Form Health Survey (Ware & Sherbourne, 1992), the SF-36 walk wheel (Appendix 52), which has been validated in individuals with SCI (Lee et al., 2009). A higher score indicates better quality of life across each of the eight domains (physical functioning, role affected by physical functioning, bodily pain, general health, vitality, social functioning, role affected by emotional functioning, and mental health), and for the physical and mental component summary scores.

6.2.9 Data Analysis

6.2.9.1 Quantitative Data

Questionnaire rating scale data relating to intervention acceptability was analysed descriptively. Trial and intervention safety were assessed via the number and type of adverse events reported during the study and change in pain and fatigue. Intervention feasibility was analysed by calculating the rate at which each intervention component was delivered to

participants as planned (e.g. number of participants provided an educational booklet / number of participants enrolled in the intervention x 100).

Self-reported questionnaire data related to intervention engagement was analysed descriptively for each intervention component. Study feasibility outcomes were analysed by calculating eligibility rate (number of eligible participants / number of participants assessed for eligibility x 100), recruitment rate (number of participants randomised / number of eligible participants screened x 100), retention rate (number of participants who completed follow up measures / number enrolled into the study x 100) and study measurement completion rate (number of complete datasets for each outcome measure / number of participants enrolled into the study x 100).

Changes from baseline to eight weeks in sedentary behaviour, physical activity, CVD biomarkers and psychosocial health outcomes were explored using descriptive statistics. Data were expressed as mean ± SD.

6.2.9.2 Qualitative Data

Semi-structured interviews were recorded and transcribed using the transcription function within Microsoft Teams. Transcripts were reviewed for accuracy and corrected where necessary, at which stage the PhD Researcher also undertook familiarisation of the data. Intervention acceptability data were analysed deductively within the context of the TFA constructs using Framework Analysis (Gale et al., 2013). Within the TFA framework, inductive coding was also undertaken to attain more detailed insights into each specific construct of acceptability. Data coding was conducted by the PhD Researcher, using NVivo 12 software to organise the data (Lumivero, Denver, CO). Data credibility was achieved via empirical and methodological triangulation by supplementing semi-structured interview data with

quantitative rating scale data. Discussions took place among the research team regarding data interpretation to challenge assumptions and ensure rigour within the analysis.

6.2.9.3 Mixed-Methods Data

Qualitative and quantitative data were collected for intervention acceptability. Via a convergent, mixed-methods approach, both data types were integrated and presented within combined tables, using a side-by-side display (Creswell, 2021). Combined tables comprised qualitative semi-structured interview data, quantitative acceptability questionnaire data, and the level of agreement between the two data types, as recommended by Creswell (2021). The qualitative data were analysed first, followed by quantitative data. Qualitative and quantitative data around intervention acceptability were reported together in the results section, with separate qualitative data available in a thematic framework (Appendix 53).

6.2.10 Data Management

All identifiable data collected during the study was treated as strictly confidential. Electronic data were kept secure on password-protected laptops. Questionnaire data were collected using Jisc Online Surveys, which is a secure, password-protected platform. Paper-based documents were and will continue to be stored in a locked filing cabinet accessible only by the research team at Brunel University of London. Any information which leaves the University (e.g. publishing the findings in a scientific paper) will have any identifiable information removed, and participants will be referred to by an ID number unknown to the participant. With participant permission (as indicated via an optional question on the consent form), anonymised data were stored for use in future research studies. All research was compliant with the Data Protection Act (2018) and European Union General Data Protection Regulations.

6.3 Results

6.3.1 Recruitment

Eighteen participants were recruited and enrolled into the study between April 2025 and September 2025. Baseline measurements were conducted between June and September 2025. Eight-week measurements took place between August and November 2025. Baseline characteristics of included participants are displayed in Table 10. Study participant flow is displayed in Figure 10.

Table 10. Participant characteristics at baseline (n = 18).

Characteristic			**Data is mean ± SD or n (%)**
Sex	Female		9 (50%)
	Male		9 (50%)
Ethnicity	Black British		1 (6%)
	White British		16 (88%)
	White European		1 (6%)
Age			51 ± 11 years
Time since injury			18 ± 13 years
Lesion level	Thoracic	Total	15 (83%)
		T3	3
		T4	1
		T4	1
		T5	2
		T8	2
		T9	3
		T10	1
		T11	1
		T12	1
	Lumbar	Total	3 (17%)
		L1	3
Completeness	Complete		9 (50%)
	Incomplete		9 (50%)
Stage of SCI rehabilitation	< 1 year since initial discharge		2 (11%)
	≥ 1 year since initial discharge		16 (89%)

L, lumbar; SCI, spinal cord injury; T, thoracic.

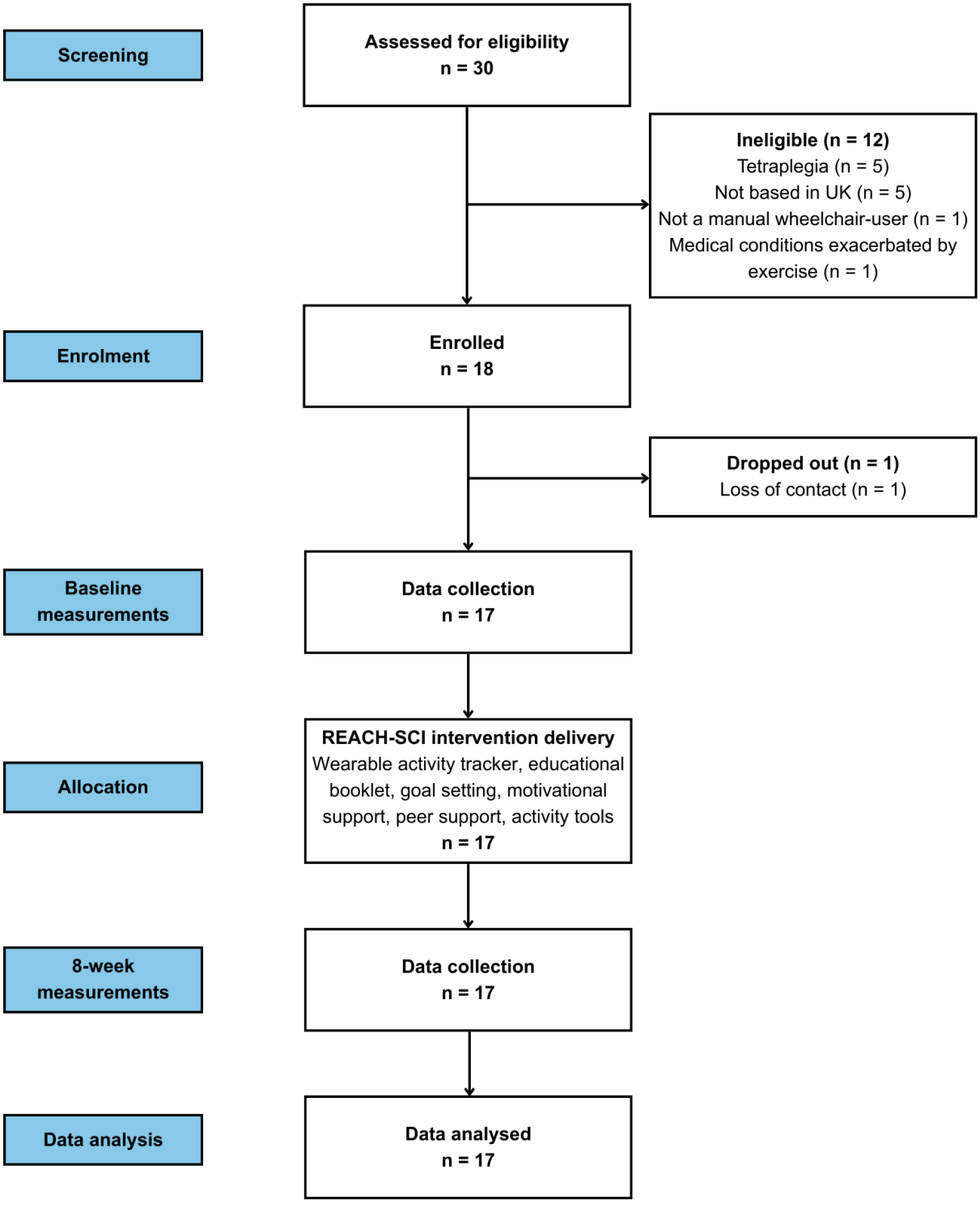

Figure 10. Study participant flow diagram

6.3.2 Intervention Acceptability

6.3.2.1 Overall Intervention Acceptability

6.3.2.1.1 Affective Attitude

There was agreement between quantitative and qualitative data that participants mostly had a positive affective attitude towards the intervention. In line with 94% of participants liking or strongly liking the intervention, participants felt that the intervention was enjoyable, they liked being made aware of inactivity and the intervention was a good challenge (Table 11). However, some participants felt there was too much paperwork, such as the educational booklet and goal setting worksheet.

6.3.2.1.2 Burden

Findings regarding the burden of participating in REACH-SCI were mixed, with both quantitative and qualitative data showing wide variation in the perceived level of effort required. Around half (47%) of participants felt that little to no effort was required to participate. Some participants felt that a low amount of effort was required to participate and that it became easier to participate over time, suggesting low burden (Table 11). However, 41% of participant felt it required a lot or a huge amount of effort to participate, with some expressing that they were too busy to engage with the intervention and that the wearable activity tracker band caused skin irritation.

6.3.2.1.3 Perceived Effectiveness

There was agreement between quantitative and qualitative data that REACH-SCI was perceived to be effective for reducing and breaking up sedentary behaviour. Consistent with 83% of participants agreeing or strongly agreeing that the intervention was effective, the qualitative data showed that the intervention increased knowledge of sedentary behaviour, helped with formation of new habits and participants felt their activity levels increased (Table 11). Another opinion identified from qualitative data was that REACH-SCI was useful for

newly injured individuals. However, some participants expressed that the intervention is less useful for individuals who are already active.

6.3.2.1.4 Ethicality

In relation to ethicality, quantitative and qualitative data were unanimous that the intervention did not raise any ethical concerns. Quantitative data found that 88% of participants felt REACH-SCI was fair for individuals with paraplegia (Table 11). As such, qualitative analysis identified that there were no ethical concerns.

6.3.2.1.5 Intervention Coherence

Both data types suggested that participants felt it was clear how the intervention was intended to reduce sedentary behaviour. Nearly all (94%) participants agreed or strongly agreed that it was clear how the intervention was intended to reduce inactivity (Table 11). This is explained by qualitative findings highlighting that there were clear explanations in the educational booklet, clear explanations by researchers and that the educational booklet improved coherence.

6.3.2.1.6 Opportunity Costs

Quantitative and qualitative data highlighted that taking part in REACH-SCI did not generally interfere with participants' other priorities or commitments. It was identified that 65% of participants disagreed or strongly disagreed that REACH-SCI interfered with other priorities or commitments (Table 11). As such, the qualitative data identified there was no interference with other commitments. However, participants' other commitments interfered with their participation in the intervention. The opposite was also true, in that the intervention interfered with their other commitments as participants could not implement activity breaks at work. These two findings suggest disagreement in the qualitative data.

6.3.2.1.7 Self-efficacy

Both quantitative and qualitative data suggested that participants felt confident participating in REACH-SCI. Quantitative data showed that 88% of participants agreed or strongly agreed that they felt confident in participating (Table 11), which was also found in the qualitative data. High levels of self-efficacy may be explained by the qualitative finding that the motivational support sessions increased confidence in participation. Although some participants noted lower self-efficacy at the beginning of the intervention, their confidence increased over time.

Table 11. Integrated mixed-methods intervention acceptability findings.

TFA domain	Acceptability questionnaire	Illustrative quotes from semi-structured interviews	Agreement between quantitative and qualitative data
Affective attitude	*Did you like or dislike REACH-SCI?* 0% strongly dislike 0% dislike 6% no opinion 59% like 35% strongly like	"Yeah, really good… So I didn't get bored. It makes me want to carry it on even after the eight weeks" (Female, L1 Incomplete) "Yes, yes [it was enjoyable]... I think being more aware of my levels of activity and kind of forcing myself to take accountability on it [was my favourite part of REACH-SCI]" (Female, T3 Incomplete) "Yes [I enjoyed doing the intervention]. The challenge was good and pushing yourself to reach those goals" (Female, T5 Complete) "It was like, "here's a watch. Just read that read that". It's like, I don't do reading, and I don't do reading, I don't do form filling. But I do like doing the practical parts" (Male, T12 Incomplete)	Agreement of participants' positive affective attitude towards the intervention.
Burden	*How much effort did it take to engage in REACH-SCI?* 6% no effort at all 41% a little effort 12% no opinion 35% a lot of effort 6% huge effort	"Not a great amount [of effort], really. It's, it's more just restructuring my hours and getting on with my life. You know" (Male, T4 Complete) "Some days a lot [of effort]. Other days, not so much and it was easier. Yeah, and it got easier as the weeks went on. I found it easier to get into the routine of get up and do it set for the days" (Female, L1 Incomplete) "I felt again, I just me personally, that I was letting you and the programme down and felt a bit guilty that I couldn't or wasn't giving the program, my full dedication. Because I just just was, yeah, too busy" (Female, T10 Complete)	Quantitative and qualitative data show perceived level of burden is inconsistent between participants.

		"I actually had to buy a different band because the band that was with it, I was allergic to" (Female, L4 Incomplete)	
Perceived effectiveness	*REACH-SCI is effective for reducing and breaking up inactivity* 6% strongly disagree 0% disagree 12% no opinion 65% agree 18% strongly agree	"Yeah, and it makes you think more about the inactivity, you know, having talked about, I'd never have thought about that in a in a negative sense. You don't think about periods of inactivity, do you? Until someone actually talks to you about it" (Male, T5 Incomplete) "Yes [intervention was effective]. Erm, definitely the idea of watching TV for 30 minutes, then doing something. Within like the first two weeks, I really got into it. But I got so into it, I went to the cinema in week 6, and without me even realising, I was kind of just wheeling around. And the person I was with was kind of like "what?", and I was like, "oh I'll sit back down". So yeah, I got so into it that" (Female, L4 Incomplete) "So, you know, so I think it's, but it's yeah, but I'm definitely, I'm definitely more active now than I was. And I've definitely got more energy now than I had when I came out when I first came onto the programme" (Female, T3 Incomplete) "It's come at the right time, because if, if you don't start now, you're just going to get lazier and lazier… remember, most of the time you're homebound, so it's good to be doing it now, so that you're not lazy… I want to be active now, rather than later" (Male, T3 Complete) "I think I think where this programme is more useful is for somebody who is perhaps not coping with their disability, or they have a lot more problems with their disability... And maybe they do spend a lot of time just sitting and watching telly or playing games on the computer or not doing very much" (Female, T10 Complete)	Agreement that the intervention is generally perceived to be effective.
Ethicality	*How fair is REACH-SCI for individuals with paraplegia?*	"No [ethical concerns], I think everything was well-organised" (Female, T5 Complete)	Agreement that the intervention

	0% very unfair 0% unfair 12% no opinion 41% fair 47% very fair	"No concerns" (Male, T9 Incomplete)	did not raise any ethical concerns.
Intervention coherence	*It is clear to me how REACH-SCI helps to reduce inactivity* 0% strongly disagree 0% disagree 6% no opinion 76% agree 18% strongly agree	"Yes. I mean, the leaflet is fairly clear on, or the booklet rather, is very clear on how it's supposed to work" (Female, T3 Incomplete) "Yeah, well you explained it initially. And then when we came for the initial testing upstairs. Yeah, erm, you said this is what this is for. And then we went away with tools that you gave us, and you explained these are what we can be using in different times each day. What we can use and more in different situations" (Male, T8 Incomplete) "Yeah [it is clear how intervention is intended to work], and it makes you think more about the inactivity, you know, I'd never have thought about that in a in a negative sense. You don't think about periods of inactivity, do you? Until someone actually talks to you about it" (Male, T5 Incomplete)	Agreement that participants understood the mechanism behind the intervention
Opportunity costs	*Taking part in REACH-SCI interfered with my other priorities or commitments* 24% strongly disagree 41% disagree 29% no opinion 6% agree 0% strongly disagree	"No, I think it was fine and fair, to be fair. I feel like it was, it was a clinical study being done in the background of my day-to-day life. It wasn't. It didn't feel like I was actually doing anything over and out of the way of my normal routines" (Female, T11 Incomplete) "I didn't give it 100%, I didn't. I should have but I didn't. But I've got other commitments. That had to come first as that's life. This is, like, you've got other participants that are gonna give you the data you need. I'm not the only one, so it's like, well, you know" (Male, T12 Incomplete)	Agreement that the intervention generally did not interfere with participants' priorities or commitments.

		Yes [taking part interfered with other priorities or commitments]. Yeah, and I did put that it did on the survey. But just because sometimes I have to focus quite hard at work. And I mean, obviously I wasn't working as much at the moment, but still trying to do things along the lines of that and it, it did make it quite tricky (Female, T3 Incomplete)	
Self-efficacy	*How confident did you feel about engaging with the REACH-SCI programme?* 0% very unconfident 0% not confident 12% no opinion 53% confident 35% very confident	"Yeah, yeah, it's pretty straightforward, and it gives you the confidence you need, and yeah" (Male, T3 Complete) Mm reasonably confident reasonably. I was a bit worried I wouldn't stick with it, but I think having that those one-to-ones during the programme gave me that accountability to say "I must do it because I'm going to talk to ", and I can't turn round and say I haven't done anything (Female, L1 Incomplete) "I wasn't sure at first, but in the end, I enjoyed it. So if you need me again, give me a shout… First week was difficult. Yeah, and then you just kind of learn what you can do, and as the weeks went, it was easier. Yeah, yeah, the first week was harder" (Female, T5 Complete)	Agreement that participants felt confident in engaging with the intervention.

L, lumbar; TFA, Theoretical Framework of Acceptability; T, thoracic.

6.3.2.2 Acceptability/Perceived Effectiveness of Each Intervention Component

6.3.2.2.1 Wearable Activity Tracker

Quantitative and qualitative data suggested that participants perceived the wearable activity tracker to be effective for reducing and breaking up sedentary behaviour. Participants rated the wearable activity tracker highly useful for breaking up sedentary behaviour (Table 12). There were findings in the qualitative data that may explain this perceived effectiveness, such as the inactivity reminders being useful and that tracking activity levels was motivational. Despite this, the accuracy of some of the wearable activity tracker's functions was questioned, with some participants suggesting that the inactivity reminders and daily push count data were inaccurate.

6.3.2.2.2 Educational Booklet

Both quantitative and qualitative data agreed that the educational booklet was generally more effective than not for reducing sedentary behaviour. The educational booklet was rated 3.8 ± 1.0 out of 5 for usefulness in reducing sedentary behaviour (Table 12). The qualitative data may explain the reasons behind the perceived effectiveness of this component, with participants expressing that the booklet contained useful ideas and information and signposted them to helpful resources. However, it was also found that some participants already knew the information.

6.3.2.2.3 Goal Setting

Goal setting was perceived to be effective for reducing sedentary behaviour, as shown in the quantitative and qualitative data. Goal setting was rated 3.5 ± 1.0 out of 5 for its usefulness (Table 12). Opinions were identified in the qualitative data that may explain this rating, including goal setting improving awareness of inactivity and that goal setting kept participants focused and on track with the intervention. Despite the positive nature of these findings, some participants expressed that the rigidity of the worksheet prevented the personalisation of goals.

6.3.2.2.4 Motivational Support

Both quantitative and qualitative data were in agreement that motivational support was perceived as highly effective for reducing sedentary behaviour. Motivational support was perceived as highly useful (4.2 ± 0.6 out of 5) (Table 12) and can be explained by qualitative findings that the motivational support sessions kept participants focused and on track, kept participants accountable and the motivational interviewer gave useful information and ideas.

6.3.2.2.5 Peer Support

It was clear from the quantitative and qualitative data that the peer support group was not perceived to be effective for reducing sedentary behaviour. This component was rated lower than the other components (2.5 ± 0.9 out of 5) (Table 12). Such a low rating is explained by qualitative findings that some individuals do not need peer support, felt uncomfortable sharing with strangers and that there was not enough engagement from others in the group chat.

6.3.2.2.6 Activity Tools

Both data types were in agreement that the activity tools were perceived to be effective. Participants rated the exercise bands as useful and the portable hand cycle slightly less (4.1 ± 1.1 and 3.4 ± 1.4, respectively) for reducing sedentary behaviour (Table 12). The relatively high rating is explained by participants expressing that it was easy to use and integrate the activity tools. Perceived effectiveness was lower for some participants who already owned similar activity tools. The lower rating for the portable hand cycle is explained by some participants having nowhere suitable to use the equipment.

Table 12. Integrated mixed-methods acceptability/perceived effectiveness findings for each intervention component, with example quotes.

Intervention component	**Perceived effectiveness rating scale data from intervention engagement questionnaire**	**Illustrative quotes from semi-structured interviews**	**Agreement between quantitative and qualitative data**
Wearable activity tracker	*On a scale of 1-5, how useful was the wearable for reminding you to break up your inactivity?* 4.0 ± 1.0	"The Garmin was very good. It was very good at reminding and prompting" (Female, T11 Incomplete) "Tracking pushes is very interesting... Yeah, it's motivational because you want to do it. You know you want to you want to try and hit those targets so absolutely" (Male, T5 Complete) "No, the watch wasn't working properly and had to start with a reprogramme, and then it started working…then went wrong again" (Male, T12 Incomplete)	Agreement that wearable was largely effective. Qualitative data helps explains quantitative data.
Educational booklet	*On a scale of 1-5, how useful was the booklet for reducing inactivity?* 3.8 ± 1.0	"Yeah, very useful yeah, it [educational booklet] was really… I really found it erm, informative about what I'm not actually doing and what I could be doing without having to go "I must go to the gym", "I must go for a walk". Small changes are good as well" (Female, L1 Incomplete) "Yeah, the links to the wheelchair workouts was also very useful for me" (Female, T3 Incomplete) "I mean, I think it's. To be honest with you, most of the information that was in there, we had already discussed prior to the booklet" (Female, T11 Incomplete)	Agreement that education was more effective than not. Qualitative data helps explains quantitative data.

Goal setting	*On a scale of 1-5, how useful did you find goal setting for reducing levels of inactivity?* 3.5 ± 1.0	"I think initially [the goal setting worksheet was] really useful to work out where my sedentary spots were. So it was useful to see the parts of the day that need to be broken up (Female, T11 Incomplete) "Yeah, it was useful ['my daily inactive time' section], again, yes, just to know where you're at, what your aims are, and where you aim to be at the end, so yeah, it's just giving an aim and staying focused" (Male, T3 Complete) "But that [my goal] doesn't fit into your goal setting, you know?" (Male, T5 Complete)	Agreement that goal setting was largely useful. Qualitative data helps explain quantitative data.
Motivational support	*On a scale of 1-5, how useful did you find the motivational support sessions for reducing levels of inactivity?* 4.2 ± 0.6	"Yes, it [motivational support] was useful yeah, to make sure everything was on track and going well" (Male, T9 Incomplete) "I found them [motivational support sessions] really useful having the accountability and knowing that I needed to have achieved something at least by such a such a date" (Female, L1 Incomplete) I'm like "What do I write?". Then when after speaking to you [motivational interviewer], you were like "you could put this on the form [goal setting worksheet]", and I was like "oh, yeah" (Male, T12 Incomplete)	Agreement that motivational support sessions were effective. Qualitative data help explain quantitative data.
Peer support	*On a scale of 1-5, how useful did you find the peer support group chat for reducing levels of inactivity?* 2.5 ± 0.9	"I saw a few things on there, but for me, I was quite happy to motivate myself... So I didn't need to refer to a third party" (Male, T8 Incomplete) "I just didn't feel like I wanted to engage with a bunch of people that don't know me and what I'm doing… I just didn't feel like sharing my information with people who I don't know" (Female, T10 Complete) "I didn't think the group chat was particularly useful. I didn't think they had enough uptake on that. Yeah, and then that, yeah, wasn't very motivational" (Female, T11 Incomplete)	Agreement that peer support was not very effective. Qualitative data help explain quantitative data.

Activity tools	*On a scale of 1-5, how useful did you find the exercise bands for reducing levels of inactivity?* 4.1 ± 1.1 *On a scale of 1-5, how useful did you find the portable hand cycle for reducing levels of inactivity?* 3.4 ± 1.4	"You can incorporate the bands easily, like I said" (Male, T5 Complete) "The hand cycle is, I think, was just easy, and it was right there. And I didn't have to think about what I was doing. It was very obvious to what you do. So I think that helps" (Female, T8 Complete) "I was lucky enough to have another piece of equipment I can use instead [of the activity tools]" (Female, T5 Complete) "Yeah, no doubt it [portable hand cycle] would have been brilliant, it's just that sort of it's just the way it was positioned on the table at home. It just wasn't comfortable" (Female, T3 Incomplete)	Agreement that activity tools were effective, although exercise bands more so than hand cycle. Qualitative data explains quantitative data.

L, lumbar; TFA, Theoretical Framework of Acceptability; T, thoracic.

6.3.3 Intervention Safety

An adverse event was reported by seven participants, who reported one each. These were skin irritation from the wearable activity tracker (n = 5, 29%) and shoulder pain (n = 2, 12%). Participants with skin irritation were advised to swap the wearable activity tracker to the opposite wrist until irritation cleared, and to regularly remove and clean the wrist strap thereafter. Participants with shoulder pain were advised to stop physical activity if new pain occurred or existing pain worsened, and to follow the advice provided in the activity tools guidance sheet regarding this (Appendix 39). These adverse events were considered mild in nature, as irritation cleared when participants swapped wrists and pain settled on rest from physical activity. Therefore, these participants continued with the intervention as planned. No serious adverse events were reported. There was a small increase in generalised pain measured using the MPQ (3.4 ± 17.9). There was a decrease in fatigue (-9.5 ± 15.4) measured using the MFIS

6.3.4 Intervention Feasibility

Intervention feasibility, in the context of each component being delivered as planned, was high, with all 17 participants who completed baseline measurements being provided with a wearable activity tracker (or given instruction on how to use necessary features on their own device; n = 3, 18%), the educational booklet, goal setting worksheet and exercise bands. One participant (6%) opted out of being provided with a portable hand cycle due to already owning and using a comparable device. One participant (6%) attended one motivational support session, four (24%) attended two sessions, and 12 participants (71%) attended all three sessions.

6.3.5 Intervention Engagement

All participants self-reported that they used the wearable activity tracker during the intervention, with 16 (94%) and 15 (88%) participants having used it 6-7 days per week in the first and second month, respectively (Table 13). The majority of participants read the whole

educational booklet (n = 15, 88%), and just one did not read it at all. Engagement with each of the booklet sections was high, but less than half of participants used the links to relevant resources. Lack of engagement with the links to relevant resources may have been due to the burden of reading the final section of the booklet (Appendix 36), with one participant noting "*[It takes too much] Time and I don't like reading*" (T12 Incomplete, Male). Despite this, those that did use the links reported finding these useful: "*Wheelchair workouts were especially useful*" (T3 Incomplete, Female). All participants used the goal setting worksheet to set goals and most participants referred back to the worksheet during REACH-SCI to review their progress. Reasons for not referring back to the worksheet included "*I didn't set long term goals*" (T9 Complete, Female) and "*It is repetitive and does not need repeating*" (T5 Complete, Male).

Engagement with the motivational support sessions was generally high, with the vast majority of participants attending two or more sessions (n = 16, 94%). Reasons for not completing all three sessions included "*I felt able to self-motivate*" (L1 Incomplete, Male) and "*I forgot about it*" (T9 Incomplete, Male). Less than half of participants opted into the peer support group chat, with reasons for non-use of this component including "*I prefer to work on my own and wasn't interested in sharing my regime with other people*" (T10 Complete, Female). Low levels of engagement amongst those that did opt into the group chat included "*Not much input from other users*" (T5 Complete, Male). All participants used the activity tools to some degree. Over half of participants used the exercise bands and portable hand cycle at least a few times per week, respectively, with the remaining participants using them once per week or less frequently.

6.3.6 Acceptability of Data Collection Procedures

Participants generally had a positive view of the data collection procedures. The burden of data collection was deemed low: "*Minimal really, there's not really a lot of effort involved [in the measurements]*" (Male, T9 Complete). Additionally, the flexibility of data collection sessions

around participants' routines was noted: "*You know, you work with me, on trying to fit it into the best time of day*" (Male, T5 Incomplete). Another positive finding identified was the accessibility of the facilities where the measurements took place: "*You've got a good set up... This height adjustable bed… it was really helpful*" (Female, T5 Complete). Some participants found that taking part in the measurements was interesting: "*I find it fascinating coming here and I like being around the academia*" (Male, L1 Incomplete).

Qualitative findings that reflected a negative view of data collection were also identified. For example, concern was raised around the burden of travel requirements: "*Only coming here and coming back [was an effort]*" (Male, T8 Incomplete). Concerns were also raised around the safety of a particular data collection procedure: "*I would say, getting on to those scales can be very yeah, a bit risky*" (Female, L4 Incomplete). In addition, some participants highlighted concerns around the sensitive nature of questions in some questionnaires: "*The PHQ and GAD I can imagine if someone were struggling with their mood, that might be tricky, because it might be difficult to, in this context, to be really honest about that stuff*" (Female, T8 Complete).

Table 13. Questionnaire responses for participant engagement with intervention components.

Intervention component	Intervention engagement	Answer	8 weeks	
			n	%
Wearable activity tracker	Which wearable did you use?	Garmin Vivoactive 5	14	82%
		Own device	3	18%
	In the first month, how often did you use the wearable?	6-7 days per week	16	94%
		3-5 days per week	1	6%
		1-2 days per week	0	0%
		Less frequently	0	0%
	In the second month, how often did you use the wearable?	6-7 days per week	15	88%
		3-5 days per week	2	12%
		1-2 days per week	0	0%
		Less frequently	0	0%
Educational booklet	Did you read through the booklet?	Yes, all of it	15	88%
		Yes, some of it	1	6%
		No	1	6%
	Did you read the “Inactivity?” section?	Yes, all of it	15	94%
		Yes, some of it	1	6%
		No	0	0%
	Did you read the “Benefits of reducing and breaking up inactivity” section?	Yes, all of it	16	100%
		Yes, some of it	0	0%
		No	0	0%
	Did you read the “Ideas to reduce and break up inactivity” section?	Yes, all of it	15	94%
		Yes, some of it	1	6%
		No	0	0%
	Did you read the “How to set and work towards goals” section?	Yes, all of it	13	81%
		Yes, some of it	3	19%
		No	0	0%
	Did you follow the links to relevant resources?	Yes, all of it	1	6%
		Yes, some of it	6	38%

		No	9	56%
Goal setting	Did you complete the worksheet?	Yes, all of it	11	65%
		Yes, some of it	6	35%
		No	0	0%
	Did you use the worksheet during the programme to review your progress?	Yes	12	71%
		No	5	29%
Motivational support	Number of one-to-one motivational support sessions attended	3 sessions	12	71%
		2 sessions	4	24%
		1 session	1	6%
	Average length of each session (minutes)		16 (mean) (range 6-48)	9 (SD)
Peer support group	Opted into peer support group chat	Yes	8	47%
		No	9	53%
	Did you make use of the peer support group chat?	Yes	4	24%
		No	13	76%
	How often did you communicate with others in the group (those who made use of it)?	Everyday	0	0%
		A few days per week	0	0%
		Once per week	0	0%
		A few times per month	1	25%
		Once per month	1	25%
		Less frequently	2	50%
Activity tools	Did you make use of the activity tools?	Yes	17	100%
		No	0	0%
	Did you read the “Activity tools guidance” document?	Yes	15	88%
		No	2	12%
	How often did you use the exercise bands?	Everyday	4	24%
		A few days per week	5	29%
		Once per week	1	6%
		A few times per month	1	6%
		Once per month	1	6%
		Less frequently	1	6%

	Never	4	24%
Did you use the exercise bands all in one go or spread across the day?	All in one go	5	38%
	Spread across the day	12	62%
How long did you spend using the exercise bands on each day you used them (minutes)?		15 (mean) (range 5-40)	10 (SD)
How often did you use the portable hand cycle?	Everyday	3	18%
	A few days per week	7	41%
	Once per week	0	0%
	A few times per month	3	18%
	Once per month	0	0%
	Less frequently	2	12%
	Never	2	12%
Did you use the portable hand cycle all in one go or spread across the day?	All in one go	7	47%
	Spread across the day	8	53%
How long did you spend using the portable hand cycle on each day you used it (minutes)?		19 (mean) (range 5-75)	18 (SD)

6.3.7 Study Feasibility

Sixty potential participants were identified through contacting previous study participants who consented to be contacted about future studies (n = 42), social media posts (n = 9), the SCI trials finder website (n = 5), a partner NHS site (n = 3) and snowballing (n = 1). Of 31 individuals who expressed interest, one lost contact before screening. A total of 30 individuals were screened for eligibility (Figure 10). Twelve participants were excluded due to not meeting the inclusion criteria. All 18 individuals deemed eligible (60% eligibility rate) were enrolled into the study (100% recruitment rate). Seventeen participants received the intervention and completed the study (94% retention rate), whilst one withdrew before baseline measurements due to loss of contact (6% attrition rate). All 17 participants who completed the study had a complete, valid data set for each outcome measure (100% data completion rate).

6.3.8 Sedentary Behaviour and Physical Activity

Sedentary behaviour and physical activity outcomes are shown in Table 14. All sedentary behaviour outcomes (sedentary time, breaks in sedentary behaviour, percentage of day spent in sedentary behaviour, time spent in prolonged sedentary behaviour bouts of > 30 and > 60 minutes, and number of prolonged sedentary bouts lasting > 30 and > 60 minutes) showed descriptive improvements in mean values. There were also descriptive increases in light intensity physical activity, total physical activity and MVPA.

6.3.9 Cardiovascular Disease Biomarkers

Cardiovascular disease biomarker outcomes are shown in Table 14. Descriptive analysis demonstrated mean reductions in systolic blood pressure, diastolic blood pressure, MAP, body mass, BMI, waist circumference, total cholesterol non-HDL cholesterol and total cholesterol:HDL cholesterol ratio. There was no change in HDL cholesterol and descriptive increases in body fat mass, body fat percentage and glucose.

6.3.10 Psychosocial Outcomes

Psychosocial health outcomes are outlined in Table 14. There were descriptive mean improvements in anxiety, depression, some wellbeing domains (life satisfaction, life being worthwhile and anxiety), all health-related quality of life domains (physical functioning, role affected by physical functioning, role affected by emotional functioning, vitality, mental health, social functioning, bodily and general health) and the health-related quality of life physical and mental component summary scores. There was a mean decrease in the 'happiness' wellbeing domain.

Table 14. Preliminary efficacy of the intervention.

Outcome	Baseline (mean ± SD)	8 weeks (mean ± SD)	Mean change (mean ± SD)
Sedentary behaviour and physical activity			
Sedentary time (min/day)	748.2 ± 175.4	717.9 ± 153.3	-30.3 ± 83.2
Breaks in sedentary behaviour (number/day)	36.1 ± 20.0	39.7 ± 27.7	3.6 ± 16.9
Percent of day in sedentary behaviour (%)	77.0 ± 11.4	75.2 ± 12.1	-1.8 ± 7.4
Time in prolonged sedentary bouts > 30 min (min/day)	561.7 ± 254.9	519.0 ± 263.1	-42.7 ± 133.2
Time in prolonged sedentary bouts > 60 min (min/day)	469.0 ± 267.9	432.8 ± 278.8	-36.3 ± 155.8
Number of prolonged sedentary bouts > 30 min	7.0 ± 2.5	5.8 ± 1.9	-1.2 ± 2.7
Number of prolonged sedentary bouts > 60 min	4.1 ± 1.5	3.4 ± 1.4	-0.7 ± 1.5
Light intensity physical activity (min/day)	205.4 ± 86.4	219.9 ± 105.7	14.5 ± 65.4
MVPA (min/day)	9.7 ± 7.5	15.2 ± 15.1	5.5 ± 10.9
Total physical activity (min/day)	215.2 ± 91.2	235.2 ±111.9	20.0 ± 69.2
Cardiovascular disease biomarkers			
Systolic blood pressure (mmHg)	122.9 ± 14.7	121.2 ± 15.4	-1.6 ± 12.9
Diastolic blood pressure (mmHg)	79.5 ± 12.2	77.2 ± 13.5	-2.3 ± 9.2
Mean arterial pressure (mmHg)	93.8 ± 12.2	91.9 ± 13.3	-1.9 ± 9.4
Body mass (kg)	83.7 ± 18.6	83.2 ± 18.8	-0.5 ± 2.2
Body mass index (kg/m^2)	28.3 ± 7.2	28.1 ± 7.0	-0.2 ± 0.8
Waist circumference (cm)	97.7 ± 14.1	96.7 ± 14.5	-1.0 ± 3.2
Body fat mass (kg)	29.4 ± 13.0	30.8 ± 13.1	1.4 ± 3.6
Body fat percentage (%)	34.2 ± 9.1	36.4 ± 8.8	2.2 ± 4.7
Total cholesterol (mmol/L)	5.2 ± 1.4	4.9 ± 1.2	-0.2 ± 0.74
HDL cholesterol (mmol/L)	1.4 ± 0.4	1.4 ± 0.4	-0.0 ± 0.2
Non-HDL cholesterol (mmol/L)	3.8 ± 1.3	3.5 ± 1.1	-0.2 ± 0.7
Total cholesterol:HDL cholesterol ratio	3.9 ± 1.4	3.7 ± 1.3	-0.1 ± 0.6
Glucose (mmol/L)	5.6 ± 0.7	5.7 ± 0.9	0.1 ± 0.6
Psychosocial outcomes			
Anxiety	4.6 ± 4.6	3.2 ± 2.9	-1.5 ± 5.0

Depression	7.5 ± 5.1	5.2 ± 4.1	-2.4 ± 6.0
Wellbeing: Life satisfaction	5.7 ± 1.9	6.3 ± 1.5	0.6 ± 2.3
Wellbeing: Life worthwhile	6.3 ± 2.0	6.8 ± 2.2	0.5 ± 3.1
Wellbeing: Happiness	6.7 ± 2.0	6.5 ± 2.1	-0.2 ± 2.7
Wellbeing: Anxiety	3.6 ± 2.4	2.6 ± 2.3	-0.9 ± 2.9
Health-related quality of life: Physical functioning	39.7 ± 22.8	42.4 ± 17.5	3.2 ± 25.5
Health-related quality of life: Physical role functioning	44.1 ± 39.1	58.8 ± 37.4	14.7 ± 45.1
Health-related quality of life: Emotional role functioning	66.7 ± 42.5	74.5 ± 34.4	7.8 ± 30.1
Health-related quality of life: Vitality	46.5 ± 14.6	54.7 ± 15.3	8.2 ± 19.4
Health-related quality of life: Mental health	69.6 ± 19.5	74.8 ± 18.5	5.2 ± 23.4
Health-related quality of life: Social functioning	64.7 ± 32.2	77.2 ± 20.8	12.5 ± 32.2
Health-related quality of life: Bodily pain	49.1 ± 25.9	67.6 ± 32.8	18.5 ± 36.0
Health-related quality of life: General health	46.2 ± 25.2	53.2 ± 23.8	7.1 ± 28.4
Health-related quality of life: Physical component summary	32.6 ± 9.4	37.0 ± 9.0	4.5 ± 11.9
Health-related quality of life: Mental component summary	50.0 ± 11.8	53.1 ± 9.2	3.1 ± 10.0
Fatigue	36.7 ± 16.6	27.2 ± 14.4	-9.5 ± 15.4
Pain	38.7 ± 16.3	42.1 ± 21.1	3.4 ± 17.9

HDL, high density lipoprotein; MVPA, moderate-to-vigorous intensity physical activity.

6.4 Discussion

This study demonstrates the acceptability, safety and feasibility of delivering and evaluating a novel co-designed sedentary behaviour intervention in individuals with paraplegia.

6.4.1 Intervention Acceptability

The quantitative data demonstrated that the intervention was acceptable to participants and met the pre-determined acceptability progression criteria. Qualitative data largely corroborated and explained these findings. The acceptability of REACH-SCI is likely due to the co-design approach taken to develop the intervention, meaning that it was tailored to individuals with paraplegia. REACH-SCI was generally acceptable in relation to affective attitude, burden, perceived effectiveness, ethicality, intervention coherence, opportunity costs and self-efficacy. These findings corroborate suggestions that starting with lower-intensity activities of daily living (such as reducing sedentary behaviour) may be an acceptable approach for long-term health behaviour change in individuals with physical impairments, such as SCI (Dogra et al., 2022). Other sedentary behaviour interventions including a wearable activity tracker, education, goal setting and one-to-one health coaching/motivational support sessions were also acceptable in individuals with neurological conditions, such as stroke survivors (Ezeugwu & Manns, 2018) and multiple sclerosis (Manns et al., 2020). These findings suggest that sedentary behaviour is an acceptable intervention target in individuals with paraplegia, and that the REACH-SCI intervention should progress to further evaluation to determine its effectiveness.

Despite a largely positive view of REACH-SCI, some negative opinions were identified from the interviews with participants. For example, some participants did not like the requirement to read and fill out paperwork. This could be overcome by including different resource formats (e.g. electronic forms, websites, videos) in future iterations of the intervention. Another recurring pattern in the data was that other commitments interfered with intervention engagement, which could be overcome by focusing more on lifestyle barriers to participation

in motivational support sessions. Lack of confidence in participating at the beginning of the intervention (self-efficacy) was also identified. Such a barrier could be solved by providing the first motivational support session at the intervention initiation point (day 1). It could be postulated that these changes would further improve the acceptability of REACH-SCI.

The intervention was deemed acceptable by participants within the first year of initial discharge from inpatient rehabilitation (n = 2), consistent with those with longer-term SCI in this study (n = 15). Acceptability for individuals earlier in the SCI rehabilitation pathway was found despite them facing challenges to adapt to their condition and the home environment (Vissers et al., 2008). High acceptability amongst individuals within the first year of initial discharge may be due to the REACH-SCI intervention bridging the gap in services between post-inpatient discharge and the commencement of community physiotherapy and occupational health services, which has been reported in SCI rehabilitation (Bray et al., 2025). Therefore, despite a limited number of participants in the first year of initial discharge, these findings suggest that the REACH-SCI intervention is acceptable to individuals across different stages of the SCI rehabilitation pathway.

Intervention components with the highest levels of perceived effectiveness included the motivational support sessions, wearable activity tracker and exercise bands (part of the activity tools). It was noted that the wearable activity tracker and activity tools worked in tandem, which may explain their high perceived effectiveness. The high perceived effectiveness of the wearable activity tracker and exercise bands supports the use of the BCT ‘adding objects to the environments’ in breaking up and reducing sedentary behaviour. Previous meta-analyses have reported this BCT as highly effective in sedentary behaviour interventions in non-disabled individuals (Booth et al., 2022; Curran et al., 2021; Gardner et al., 2016). Therefore, wearable activity trackers and exercise bands are recommended in interventions for individuals with SCI.

The perceived effectiveness of the motivational support sessions may be explained by these sessions having fulfilled the need for social support, which was identified as a facilitator in co-design workshops (Chapter 5). Providing social support within these sessions could lessen the need for the peer support group, which would explain the relatively low perceived effectiveness of that component. The lack of engagement with the peer support group is in contrast with findings from a meta-analysis showing that both motivational counselling and social facilitation are highly effective intervention components for reducing sedentary behaviour in clinical populations (Nieste et al., 2021). However, only a minority of the included studies employing social facilitation did this via an app or website that enabled virtual peer interaction with other participants, like in REACH-SCI (Nieste et al., 2021). Therefore, whilst motivational support should be included in interventions, alternative strategies should be considered for delivery of peer support.

Less favourable elements of specific intervention components that were mentioned by participants included inaccuracy of the Garmin wearable activity tracker in estimating push count and not giving appropriately-timed inactivity reminders. Participants noted that daily push tracking underestimated total daily pushes and that the inactivity reminders were not reactive to their inactive time, often prompting movement whilst they are already moving; this was because the inactivity reminders for the Garmin tracker automatically being delivered on an hourly basis. This could be overcome by using a different device, such as an Apple watch, which was used by some participants in this study (n = 3). Unlike the Garmin, the Apple watch has demonstrated acceptable validity for estimating wheelchair pushes in wheelchair-users (Karinharju et al., 2021) and sends reactive alerts to prompt movement. Alternatively, other digital health methods could be employed like smartphone apps, which have been shown to be feasible for increasing physical activity in individuals with SCI (Huang et al., 2023). Lack of engagement due to feeling uncomfortable sharing with strangers contributed to low perceived

effectiveness of the peer support group chat. The acceptability of peer support in REACH-SCI could be improved by scheduling in-person or online meetings outside of the group chat where participants can build rapport; an approach that was feasible and acceptable in a sedentary behaviour intervention in people with mental illness (Williams et al., 2019). The lower perceived effectiveness of the portable hand cycle can be explained by participants not having an appropriate place to use it. This could be overcome by using alternative activity tools that do not require mounting on a table, such as hand weights or exploring other types of arm exercises that could be acceptable. These findings highlight areas for improvement that could be implemented to further enhance the acceptability of REACH-SCI.

6.4.2 Intervention Safety

The intervention was safe with respect to no serious adverse events and a mean change decrease in fatigue. Although pain increased, as measured using the MPQ, change was small and there was a mean change decrease in the bodily pain domain of the SF-36ww health-related quality of life questionnaire. Shoulder pain was reported as an adverse effect, but this settled after rest from physical activity. Shoulder pain is a common occurrence in individuals with SCI due to overuse of the shoulder for mobility, meaning this pain may not have been attributed to the intervention. Therefore, pain may not have increased as a result on REACH-SCI, indicating that the intervention was likely safe. Safety of sedentary behaviour interventions has been reported in other neurological conditions, including stroke survivors (English et al., 2016). The intervention showed potential for reducing fatigue in the current study, which would help overcome fatigue-related barriers to reducing and breaking up sedentary behaviour as identified in Chapter 5. Although these are only preliminary findings in a small, underpowered cohort, other studies have led to improvements in fatigue as a result of sedentary behaviour interventions in individuals with chronic conditions (multiple sclerosis, cancer, chronic obstructive pulmonary disease, fibromyalgia, Parkinson's, axial spondylarthritis, bowel

syndrome, stroke, rheumatoid arthritis and kidney failure) (Barakou et al., 2023). The findings observed in the current study suggest that REACH-SCI is safe overall, although pain should be assessed as an outcome in a future definitive RCT.

6.4.3 Intervention Feasibility and Engagement

Intervention feasibility and participant engagement were high for most intervention components, indicating that the intervention was feasible to deliver as planned. All participants were either provided or used their own wearable activity tracker, with 94% and 88% of participants using the wearable 6-7 days per week in the first and second month of the intervention, respectively. This is consistent with findings from a sedentary behaviour intervention in older adults, in which 91% participants used the wearable activity tracker 6-7 days per week (McGowan et al., 2024). Every participant was provided a REACH-SCI educational booklet and goal setting worksheet, and 88% and 65% reported that they read/completed all of it, respectively. This suggests high engagement with these components, compared to 29% reading all of the psychoeducation workbook (which included goal setting) in a sedentary behaviour intervention in older adults (McGowan et al., 2024). Greater levels of engagement in REACH-SCI may be due to these resources being designed with input from end-users via co-design and PPI involvement (see Chapter 5). All participants had at least one REACH-SCI motivational support session and the majority did all three sessions, which is comparable to the sedentary behaviour intervention in older adults, in which all participants also had at least one session (McGowan et al., 2024). Every participant used the activity tools to some degree, with over half of the participants using the exercise bands and portable hand cycle at least a few times per week, indicating high engagement. The level of activity tool engagement in REACH-SCI is greater than a multi-component sedentary behaviour intervention in non-disabled individuals, in which participants self-reported using a portable pedal machine on 37% of intervention days (Carr et al., 2013). The duration of each bout using

the activity tool was comparable, lasting 16 minutes on average versus 19 minutes in REACH-SCI (Carr et al., 2013). These findings suggest that a wearable activity tracker, educational booklet, goal setting, motivational support and activity tools have high levels of engagement that are similar or greater then reported in previous interventions, suggesting a high level of acceptability and appropriateness for their inclusion in REACH-SCI.

Uptake and engagement with the peer support group chat was low, which is likely explained by the low acceptability and perceived effectiveness of this component, as discussed above. This reflects findings from a previous sedentary behaviour intervention in older adults, which also found that both a peer support group chat and scheduled peer support group meetings had low levels of engagement (McGowan et al., 2024). Low participant engagement in peer support contradicts a meta-analysis that demonstrated social facilitation was a key sedentary behaviour intervention component for clinical populations (Nieste et al., 2021). However, none of the included studies utilised a participant group chat, as used in REACH-SCI (Nieste et al., 2021). In contrast, a meta-analysis demonstrated that dyadic interventions involving setting shared goals with a peer (i.e. another participant, family member, or a peer mentor) and/or supporting each other to improve physical activity and reduce sedentary behaviour are effective for reducing sedentary time (Carr et al., 2019). A physical activity intervention in older adults with cancer involving dyadic participant-participant pairings to provide peer support had higher engagement than the present study, indicated by participants reporting that they communicated with their peer once per week for 28.9 minutes per interaction (Smith-Turchyn et al., 2024). Therefore, peer support group chats are less likely to work in sedentary behaviour interventions and other approaches to facilitating peer support should be explored.

6.4.4 Acceptability of Data Collection Procedures

Data collection procedures were deemed generally acceptable. However, there were some areas for improvement highlighted by participants. For example, one participant felt that the dual-

beam wheelchair weighing scales were unsafe, due to the beams feeling unstable when attempting to wheel onto them. This could be overcome by using a weighing platform, although this has financial and spatial implications (Sherrod et al., 2017). Some participants raised concerns around the sensitive nature of questions in the mental health questionnaires. Previous research has suggested that such sensitive questions could be distressing or cause confusion as to why they are being asked (Khaledet al., 2025). Potential distress caused by these questions could be mitigated by informing participants of the nature of the questionnaires before being completed and the reasons for them being asked. If these concerns are overcome, it is expected that all of the data collection procedures in this study would have high levels of acceptability.

6.4.5 Study Feasibility

The study had high eligibility, recruitment, retention and data completion rates, indicating that it is feasible to deliver and evaluate the REACH-SCI intervention. This is consistent with previous studies of sedentary behaviour interventions in individuals with long-term conditions such as multiple sclerosis (Manns et al., 2020), stroke survivors (Ezeugwu & Manns, 2018) and diabetes (Brierley et al., 2024), as well as in the general population (Carr et al., 2013; Edwardson et al., 2018). However, the current study lacked a control arm, meaning the feasibility and acceptability with respect to participants being randomised to a control group is unclear. Previous studies have reported favourable acceptability and had high retention and data completion rates for control groups (Bailey et al., 2024; English et al., 2016; McGowan et al., 2024), so the same could be expected in a future RCT evaluating REACH-SCI. It is recommended that a further internal pilot trial is undertaken to determine these factors before proceeding to a full, definitive RCT, as this offers a further opportunity to identify issues with study processes that can be addressed prior to the full trial (Avery et al., 2017; Herbert et al., 2019).

6.4.6 Preliminary Efficacy

The preliminary efficacy outcomes discussed below are only early data in a small cohort and are not powered to detect definitive changes. Therefore, mean changes should not be interpreted as significant outcomes or used to inform any clinical recommendations or guidelines. Instead, this discussion is intended as an initial exploration of the directions of mean change for each outcome, which could inform potential outcomes for a future effectiveness trial. This exploration is supplemented with brief comparison to mean changes in other studies, for the purpose of completion.

6.4.6.1 Sedentary Behaviour and Physical Activity

With respect to preliminary efficacy of the intervention, descriptive analysis suggested there were improvements in each sedentary behaviour outcome. Sedentary time reduced by 30.3 min/day. In comparison, a community-based, multi-component intervention in individuals with paraplegia lasting four months led to a 118 min/day reduction in sedentary time, measured using heart rate zones (Martinez et al., 2025). However, as outlined in Chapter 4, this study did not use a validated measure of sedentary behaviour, limiting certainty around this finding. A meta-analysis of sedentary behaviour interventions in non-SCI clinical populations showed a pooled reduction in accelerometer-measured sedentary time of 64 min/day (Nieste et al., 2021). The difference in magnitude of sedentary behaviour reduction in the current study compared to the meta-analysis by Nieste et al. (2021) may be due to the population being manual wheelchair-users, which may limit behavioural changes due to unique barriers (see Chapter 5) not faced by other clinical populations.

The mean number of breaks in sedentary behaviour increased by 3.6 breaks per day, suggesting that REACH-SCI has promise for improving this outcome. A scoping review of sedentary behaviour interventions in older adults found that increases in sedentary breaks ranged from 4 to 13 breaks per day (Petrusevski et al., 2021). The lesser change in breaks in the current study

could be explained by barriers to breaking up sedentary behaviour experienced by wheelchair-users (see Chapter 5). These findings indicate that REACH-SCI has potential for both reducing and breaking up sedentary behaviour, which should be further explored in a future effectiveness study.

There were improvements in each physical activity outcome in this study according to the descriptive analysis, demonstrating that REACH-SCI has potential for increasing this behaviour. Notably, there was an increase in MVPA of 5.5 min/day, which would equate to 38.5 min per week. Such an increase may not have been expected as the intervention's primary aim was to reduce and break up sedentary behaviour, rather than increase MVPA. Potential increases in MVPA may have been due to the signposting to online resources for physical activity and exercise in the educational booklet and the provision of activity tools, which had high engagement and may have encouraged higher levels of physical exertion. These preliminary findings indicate that REACH-SCI has potential for reducing and breaking up sedentary behaviour and increasing physical activity, which could help optimise cardiovascular-related benefits in a future effectiveness study (Katzmarzyk et al., 2020).

6.4.6.2 Cardiovascular Disease Biomarkers

There was preliminary efficacy of the intervention for improving a number of CVD biomarkers. Descriptive improvements were seen for systolic blood pressure, diastolic blood pressure, MAP, body mass, BMI, waist circumference, total cholesterol, non-HDL cholesterol and total cholesterol:HDL cholesterol ratio. Systolic and diastolic blood pressure were reduced by 1.6 and 2.3 mmHg, respectively, which is greater than reductions of 0.5 and 0.8 mmHg, respectively, in a meta-analysis of sedentary behaviour interventions in clinical populations (Nieste et al., 2021). Despite these findings showing some promise, the mean changes may not be great enough to account for the inherent variability in oscillometric blood pressure measurement (Stergiou et al., 2009). Waist circumference was 1.0 cm lower after eight weeks

in the current study, compared to a 1.5 cm reduction in Nieste et al. (2021). Although a 1.0 cm reduction in waist circumference could potentially be clinically relevant (Jacobs et al., 2010), any apparent improvement could be owed to the large measurement error associated with this outcome (Verweij et al., 2013). Furthermore, there was an increase in body fat mass and body fat percentage in the current study. This may be a result of continued changes in body composition following SCI, such as accumulation of body fat, but in this case, potentially not in central areas (as waist circumference decreased) (Gorgey & Dudley, 2007; Nightingale et al., 2019). Reduced adipose tissue in central areas represents a healthy body fat distribution that is related to improved cardiometabolic health (Després, 2012). However, bioelectrical impedance analysis can be greatly affected by variances in fluid intake (Schierbauer et al., 2023), which was not as tightly restricted as food intake in the current study. There was a 0.2 mmol/L decrease in total cholesterol and no change in HDL cholesterol in the current study, compared to a 1.2 mmol/L increase in total cholesterol and 0.5 mmol/L decrease in HDL cholesterol in Nieste et al. (2021). Although the lipid profile findings appear favourable compared to meta-analysis evidence, the change was relatively small. Also, the baseline lipid profile values are in the normal ranges (NHS, 2026), meaning there is limited scope for improvement in these biomarkers. Both the current study and Nieste et al. (2021) showed an increase in glucose, suggesting that sedentary behaviour interventions may not improve glycaemic biomarkers. However, the meta-analysis showed a significant improvement in HbA1C, indicating that longer-term glycaemic biomarkers could be improved through reductions in sedentary behaviour (Nieste et al., 2021). In conclusion, REACH-SCI shows some promise for improving CVD biomarkers, especially related to blood pressure and central adiposity, warranting evaluation in a future effectiveness trial. Other CVD biomarkers, such as HbA1C or CVD risk scores (such as QRISK3; Hippisley-Cox et al., 2017), could be assessed

in a future effectiveness evaluation of REACH-SCI to inform potential benefits to long-term glucose control and long-term CVD risk, respectively.

6.4.6.3 Psychosocial Outcomes

A number of psychosocial outcomes showed mean change improvements, including anxiety, depression, wellbeing (life satisfaction, life being worthwhile, anxiety) and all health-related quality of life domains (physical functioning, role affected by physical functioning, role affected by emotional functioning, vitality, mental health, social functioning, bodily pain, general health, physical and mental component summary scores). Anxiety and depression scores decreased in the current study, consistent with reductions following multi-component sedentary behaviour interventions in older adults lasting 12 weeks (Matson et al., 2019) and six months (Florez-Acevedo et al., 2025). These findings suggest that REACH-SCI has promise for improving self-reported anxiety and depression, warranting the measurement of these psychosocial health outcomes in a future evaluation of the effectiveness of the intervention. The largest descriptive change in the current study was the bodily pain domain of quality of life, which improved by 18.5 points. In comparison, a sedentary behaviour intervention in older adults led to an improvement in the bodily pain domain of 10.0 points (Barone Gibbs et al., 2017). These findings suggest that targeting sedentary behaviour could be a promising intervention for pain management for individuals with paraplegia that should be further explored in an effectiveness trial. There were also improvements in the vitality (Δ 8.2) and general health (Δ 7.1) domains of quality of life, which were larger than those seen in response to a sedentary behaviour intervention in adults with metabolic syndrome (changes of 5.3 and 3.6, respectively) (Norha et al., 2025). However, self-reported outcomes are sensitive to expectation effect, in which participants' anticipation of a positive outcome may lead to a placebo effect, potentially explaining mean improvements in psychosocial outcomes (Helfer et al., 2015). The lack of an active control group means that the impact of an expectation effect

cannot be discounted. Despite this possibility, these findings illustrate that REACH-SCI has potential efficacy for improving psychosocial health that should be further explored in a future trial.

6.4.7 Strengths and Limitations

This study followed published guidelines for conducting and reporting feasibility trials and mixed-methods studies, as well as ensuring prospective registration of the protocol to maintain rigour and reproducibility. Further strengths include the mixed-methods design to enable an in-depth understanding of acceptability, by offering insights into both the 'what' and the 'why'. In addition, the inclusion of individuals with paraplegia at different stages of the SCI care pathway helps to increase generalisability for this population group.

Limitations include the lack of a control group, meaning that the acceptability and feasibility of randomisation to usual care remains unknown. Additionally, the sample mainly consisted of White British participants (88%), which may not be generalisable to individuals with paraplegia with other ethnic backgrounds. Furthermore, the sample included a small proportion of individuals within the first year of initial discharge from inpatient SCI rehabilitation (n = 2, 11%), meaning relatively limited insight could be obtained regarding the experiences of these individuals. It is recommended that future research uses a controlled design and includes a more diverse sample to address these limitations.

6.5 Conclusion

In conclusion, the REACH-SCI intervention demonstrated high levels of acceptability, safety and feasibility. In addition, the study was feasible to deliver, in context of recruiting and retaining participants in the study. There were high levels of engagement with intervention components, suggesting that participants found them acceptable. However, the peer support group chat was less acceptable and should be further considered regarding its inclusion or delivery approach in a definitive trial. The intervention showed preliminary efficacy for improving sedentary behaviour, physical activity, CVD biomarkers and psychosocial health outcomes. The findings of this study provide novel insights regarding the acceptability of sedentary behaviour interventions in individuals with paraplegia and can be used to inform improvements to the REACH-SCI intervention to further enhance acceptability and engagement. The REACH-SCI intervention should be evaluated in a definitive RCT and may consider using an internal pilot to optimise its delivery and evaluation.

Chapter 7: General Discussion

This chapter will provide an overall discussion of the three studies that make up this PhD thesis (Chapters 4 to 6). The key findings across all three studies will be discussed and interpretated in the context of previous research. Subsequently, practical implications will be considered, alongside discussion of strengths and limitations, to inform recommendations for future research, clinical practice and policy.

7.1 Thesis Aims

The overall aim of this PhD thesis was to develop and evaluate a novel sedentary behaviour intervention to improve CVD biomarkers in individuals with paraplegia. Specific aims relating to the chapters discussed below included (1) to systematically review the effectiveness of interventions on sedentary behaviour and CVD biomarkers in individuals with paraplegia (Chapter 4), to develop a sedentary behaviour intervention to improve CVD biomarkers in individuals with paraplegia across different stages of the SCI rehabilitation pathway using the BCW (Chapter 5) and to assess the acceptability, safety, feasibility and preliminary efficacy of the co-designed sedentary behaviour intervention in individuals with paraplegia across different stages of the SCI rehabilitation pathway (Chapter 6).

7.2 Overview of Key Findings

7.2.1 Key Findings From Chapter 4 (Systematic Review)

Prior to co-designing and evaluating the REACH-SCI intervention, a systematic review was conducted to identify interventions effective for reducing sedentary behaviour and improving CVD biomarkers in individuals with paraplegia. Eight interventions were eligible, of which two targeted sedentary behaviour and six targeted physical activity. There was little promise for physical activity interventions to reduce sedentary behaviour, as only one of the six physical activity interventions reduced this outcome. Of the two interventions that targeted sedentary

behaviour, one improved this outcome and one implemented supervised breaks in sedentary behaviour; both led to improvements in one or more CVD biomarkers. These results indicate potential effectiveness of interventions specifically targeting sedentary behaviour for improving sedentary behaviour and CVD biomarkers. Half of the included interventions were evaluated in a study that had high risk of bias, and sedentary behaviour outcomes had very low quality of evidence. Also, many studies did not utilise behaviour change theory. Therefore, it was concluded that higher-quality, theoretically-driven interventions targeting sedentary behaviour should be developed and evaluated to determine their relevance in healthcare and policy for this population.

7.2.2 Key Findings From Chapter 5 (Intervention Development)

A novel sedentary behaviour intervention for individuals with paraplegia was co-designed with key stakeholders, including end-users, healthcare professional and community caregivers. The first step was to identify barriers and facilitators to reducing and breaking up sedentary behaviour, in the context of the COM-B model and TDF. Key barriers and facilitators were identified relating to Capability (Barriers: Lack of knowledge around sedentary behaviour, Fatigue, Personal care routine, Pain; Facilitators: Knowledge of pressure relief, Reminders to be active, Getting feedback on progress, Creating schedules), Opportunity (Barriers: Lack of wheelchair accessibility in and outside the home, Cost and lack of access to equipment, Wheelchair inappropriate for physical activity; Facilitators: Provision of information and/or opportunities for physical activity, Support from family or friends, Peer support network) and Motivation (Barriers: Low self-esteem or self-conscious, Boredom, Low mood; Facilitators: Goal setting, Building habits around daily activities, Rewards). Ten intervention options were proposed to target barriers and facilitators, including: Feedback on sedentary behaviour and physical activity, Reminders to break up sedentary behaviour, Rewards for reducing and/or breaking up sedentary behaviour and engaging in physical activity, Education around sedentary

behaviour, Support from family and friends to reduce sedentary behaviour, Signposting to charities, organisations and websites, Goal setting, Scheduling, Peer support network and Providing access to activity tools.

Intervention options with overlapping modes of delivery were merged to create six intervention components. The intervention components included (1) a wearable activity tracker to facilitate reminders to be active and feedback on activity, (2) an educational booklet to overcome lack of knowledge around sedentary behaviour, (3) setting goals around sedentary behaviour to target this facilitator, (4) one-to-one motivational support from a trained individual to help create schedules around sedentary behaviour, (5) a peer support group to facilitate a social network of peers and (6) activity tools, including a portable hand cycle and exercise bands, to overcome cost and lack of access to equipment to replace and break up sedentary behaviour with physical activity or exercise. The combination of co-design and use of the BCW resulted in an intervention that is more likely to be acceptable and effective. It was concluded that this intervention needed to be evaluated in terms of acceptability, safety, feasibility and preliminary efficacy, in order to determine its future evaluation in individuals with paraplegia.

7.2.3 Key Findings From Chapter 6 (Feasibility Study)

This study demonstrated that a co-designed, theoretically-driven sedentary behaviour intervention is acceptable, safe, feasible to deliver and potentially efficacious in individuals with paraplegia. The intervention was deemed generally acceptable, which was expected due to it being co-designed with key stakeholders and PPI input (see Chapter 5). Participants highlighted high levels of acceptability and perceived effectiveness of the wearable activity tracker, educational booklet, goal setting, motivational support and activity tools. Although the intervention was generally acceptable, participants recommended some areas that required improvement. Ideas for improvement outlined in Chapter 6 included replacing or supplementing the peer support group chat with a different form of peer support (e.g. dyadic

participant-participant pairing) and scheduling the first motivational support session at the intervention initiation point (day 1) to ensure confidence from the start. Participants were provided with intervention components as planned, indicating high levels of intervention feasibility. Generally, participants had high engagement with most intervention components. However, uptake and adherence to the peer support group chat was low, likely due to the low acceptability of this component. The intervention was deemed safe, with no serious adverse effects reported and no increase in pain or fatigue. The REACH-SCI intervention showed some preliminary efficacy, with mean change improvements in sedentary behaviour and physical activity outcomes, as well as some CVD biomarkers and psychosocial health outcomes. It was recommended that the REACH-SCI intervention should be assessed for its effectiveness in a future definitive RCT, with an internal pilot to determine the feasibility and acceptability of randomisation and allocation to a control arm.

7.3 Interpretation of Findings in the Context of Existing Literature

7.3.1 Sedentary Behaviour Interventions and Cardiovascular Disease Biomarkers

Previous research into sedentary behaviour in individuals with SCI is limited, with a scoping review finding a lack of interventions and cross-sectional studies (Adams et al., 2024). The studies that were identified were heterogeneous in study design, meaning no conclusions or recommendations could be drawn for this population (Adams et al., 2024).

Building on the findings from a previous scoping review in individuals with paraplegia (Adams et al., 2024), the systematic review undertaken in Chapter 4 identified that interventions targeting sedentary behaviour were scarce, limiting conclusions and recommendations, However, these sedentary behaviour interventions did show some promise for reducing sedentary behaviour and improving CVD biomarkers, congruent with research in non-SCI clinical populations (Nieste et al., 2021) and the general population (Hadgraft et al., 2021; Martin et al., 2015; Prince et al., 2014).

The systematic review undertaken in Chapter 4 demonstrated that physical activity interventions were not effective for reducing sedentary behaviour, in disagreement with previous meta-analytical evidence in the general population (Prince et al., 2014). However, the review (Chapter 4) also demonstrated that interventions targeting physical activity were effective for improving CVD biomarkers. This is in line with a review in individuals with SCI, which found that physical activity interventions were effective for improving insulin resistance (Itodo et al., 2022).

The REACH-SCI intervention demonstrated preliminary efficacy for reducing and breaking up sedentary behaviour (see Chapter 6), indicating that sedentary behaviour shows promise as an intervention target in individuals with paraplegia. Despite being underpowered for direct comparison, the 30 min/day reduction in accelerometry-derived sedentary time demonstrates preliminary efficacy, but is smaller than the 64 min/day decrease reported in a meta-analysis of sedentary behaviour interventions in non-SCI clinical populations (Nieste et al., 2021). Also, the 3.6 per day increase in sedentary breaks was smaller than the increase of 4-13 breaks per day seen in a meta-analysis of older adults (Petrusevski et al., 2021). However, smaller responses in sedentary behaviour outcomes following REACH-SCI could be due to unique barriers that wheelchair-users with paraplegia face to reducing and breaking up sedentary behaviour (see Chapter 5). The preliminary efficacy for reducing and breaking up sedentary behaviour demonstrated in this study (Chapter 6), despite facing numerous barriers (outlined in Chapter 5), could partially be owed to the theoretically-driven nature of the intervention. Interventions grounded in theory have been shown to bring about greater levels of physical activity behaviour change in individuals with physical disabilities (Ma & Martin Ginis, 2018) and non-disabled individuals (Davis et al., 2015). As previously mentioned, these are only preliminary findings in an underpowered cohort, limiting the extent of any effectiveness conclusions or use within guidelines and recommendations. Therefore, the effectiveness of the

REACH-SCI intervention to reduce and break up sedentary behaviour should be determined in a future study.

The REACH-SCI intervention showed some preliminary efficacy for improving CVD biomarkers related to blood pressure. The 1.6 and 2.3 mmHg mean reductions in systolic and diastolic blood pressure were greater than reductions (0.5 and 0.8 mmHg, respectively) reported in a meta-analysis of sedentary behaviour interventions in clinical populations (Nieste et al., 2021). Despite the inherent variability in oscillometric blood pressure measurement (Stergiou et al., 2009), the reductions in blood pressure seen following REACH-SCI suggests that these outcomes should be further explored in a larger effectiveness trial. Waist circumference showed a 1.0 cm mean reduction, which is similar to a 1.5 cm reduction in the meta-analysis by Nieste et al. (2021). Body fat mass and fat percentage both increased after REACH-SCI, however, which could suggest a healthier fat distribution (Després, 2012). An important consideration is that bioelectrical impedance, as used to assess body fat in this thesis, has greater variability in body composition outcomes than gold-standard measurements such as dual-energy x-ray absorptiometry (Lang et al., 2015). Based on these observations, dual-energy x-ray absorptiometry should be considered alongside waist circumference outcomes in a future effectiveness trial. Lipid profile was largely unchanged after REACH-SCI, similar to the meta-analysis by Nieste et al. (2021). Although this could suggest limited effects, baseline values were generally within the normal ranges, suggesting the intervention may be more useful for individuals with impaired cardiometabolic health. There was no change in fasting glucose after REACH-SCI, or as a result of the sedentary behaviour interventions in clinical populations (Nieste et al., 2021). However, the meta-analysis by Nieste et al. (2021) found an improvement in HbA1C and another meta-analysis of sedentary behaviour interventions in the general population reported reductions in fasting insulin (Hadgraft et al., 2021). Due to the

effects found in sedentary behaviour interventions in other studies, effectiveness evaluation of REACH-SCI should include assessment of glycaemic biomarkers.

7.3.2 Application of Behaviour Change Theory

The systematic review in Chapter 4 found that a low number of interventions utilise theory, in line with previous findings from the general population (Davis et al., 2015; Gardner et al., 2016) and clinical populations (Martín-Martín et al., 2021). A lack of behaviour change theory is problematic as Ma & Martin Ginis (2018) found that interventions using theory lead to greater improvements in physical activity in individuals with physical disabilities, as supported by a descriptive increase in MVPA as a result of the REACH-SCI intervention (see Chapter 6).

This PhD research demonstrates a systematic, structured, efficient and transparent method for designing sedentary behaviour interventions that may inform future intervention development studies. The use of the COM-B model and the BCW in the intervention development helped to identify a wide range of relevant intervention functions, policy categories, BCTs and delivery modes to appropriately target barriers and facilitators for achieving the target behaviour. The BCTs targeted in REACH-SCI are similar to those used in the co-production of a sedentary behaviour intervention in stroke survivors, with BCTs related to education and goal setting being used (Hall et al., 2020). In reviews of previous sedentary behaviour interventions in the general population, the most commonly-utilised BCTs were similar to those used in REACH-SCI: Goal setting, Social support, Adding objects to the environment, Instruction on how to perform the behaviour, Self-monitoring, Information about health consequences, and Prompts and cues (Curran et al., 2021; El Kirat et al., 2024; Gardner et al., 2016). This suggests that sedentary behaviour is targeted similarly across different populations, despite wheelchair users with paraplegia experiencing unique barriers and facilitators, as identified in Chapter 5. Though, the mode in which each BCT is delivered can differ widely between interventions, with the BCW not providing a pre-defined taxonomy of delivery modes to select from.

Therefore, the BCW provides flexibility in how intervention components are delivered (Michie et al., 2011). As a result, the use of the COM-B model, using the BCW as a framework, in intervention development facilitated a tailored approach to the unique needs of wheelchair-users with paraplegia. Therefore, use of the COM-B model within the BCW helped to identify and target the unique needs of individuals with paraplegia, meaning the intervention is more likely to bring about successful behaviour change. In addition, this approach was easy to use, systematic and resulted in the development of a coherent and replicable intervention, where decision making can be traced transparently.

7.3.3 Co-design and Participatory Approaches

The use of co-design methodology to develop the intervention (Chapter 5) likely led to high levels of participant engagement in the co-design workshops. This high level of engagement may be due to the sense of ownership brought about by having an active role in the design process, as suggested by Goodyear-Smith et al. (2015) and Jagosh et al. (2012). High participant engagement in the co-design workshops was demonstrated by the high levels of participant retention observed, and participants noting that the co-design process was a positive experience in which they were open to discuss their lived experiences. Positive participant experience of participatory methods is consistent with the co-production of a sedentary behaviour intervention in stroke survivors, in which participants expressed generally positive feedback about feeling valued in the intervention development process and being given the opportunity to share experiences with other stroke survivors (Hall et al., 2020). The favourable participant opinion of the co-design approach suggests that this method is effective for developing sedentary behaviour interventions in those with neurological conditions, such as paraplegia, supporting the use of co-design in the intervention development phase of the MRC framework (Skivington et al., 2021). In addition, gaining the lived experiences of end-users in intervention development is important for determining key barriers and facilitators to achieving

target behaviours, and how best to target them (Vargas et al., 2022). Therefore, it is possible that co-design may lead to more effective sedentary behaviour interventions.

Combining co-design with a workshop-based approach may have stimulated peer discussion, support, trust-building and openness between participants (Kapiszewski & Wood, 2022). Fostering openness in peer discussion has been suggested to bring about richer and more honest insights than traditional researcher-led methods (Kapiszewski & Wood, 2022). This co-design workshop approach led to an enriched understanding of the lived experience of individuals with paraplegia, with more detailed insights shared around barriers and facilitators to reducing and breaking up sedentary behaviour, as well as the potential approaches to target the behaviours. The REACH-SCI intervention was found to be acceptable to participants (Chapter 6), which is likely a result of the intervention being co-designed with key stakeholders (Chapter 5). The input from those with lived experience ensured that the intervention was relevant, engaging and appropriate throughout the design process. The acceptability of REACH-SCI is consistent with previous research finding that a co-designed sedentary behaviour interventions was acceptable (Freene et al., 2025). These findings suggests that co-design can be utilised to ensure that the reduction and breaking up of sedentary behaviour within interventions is acceptable to individuals with paraplegia.

A key potential issue with co-design methodology is whether the stated preferences of stakeholders can necessarily be interpreted as insightful. Although the intervention components suggested by these individuals may enhance acceptability, it is possible that these components are not necessarily effective for changing the target behaviour, given that these individuals are unlikely to have knowledge in behavioural science (Sumner et al., 2024). To compensate for this challenge, it is recommended that the preferences of stakeholders are triangulated with other data sources to best inform intervention development (Aguado Loi et al., 2017). Therefore, input of key stakeholders in REACH-SCI were supplemented with findings from a

systematic review (Chapter 4) and discussion amongst researchers in context of the APEASE criteria (Chapter 5).

Previous interventions in the general population were not used to inform the intervention design in this thesis. This is despite REACH-SCI employing a number of similar BCTs to those reported in previous intervention literature (Curran et al., 2021; El Kirat et al., 2024; Gardner et al., 2016), which may suggest that sedentary behaviour interventions in the general population could be suitable for individuals with paraplegia. However, the delivery modes of BCTs and types of physical activity may need to be different. For example, the need for individuals with paraplegia to break up sedentary behaviour with arm movement whilst in a seated posture. In the general population transitions from sitting to standing or walking are largely encouraged (Curran et al., 2021; El Kirat et al., 2024; Gardner et al., 2016). It could be argued that if the type of physical activity employed in the multitude of sedentary behaviour interventions in the general population could be adapted, then these interventions could be re-purposed for individuals with paraplegia. Re-purposing existing interventions would represent a large resource saving compared to developing new interventions, in terms of finances and time (Movsisyan et al., 2019). Despite this, it is still important that key stakeholders are included in this adaptation process to ensure interventions are still relevant, appropriate and engaging. As such, the ADAPT guidance has been developed to inform the adaptation of existing interventions to different target populations with a key emphasis on stakeholder involvement (Moore et al., 2021). To operationalise an intervention adaptation with sufficient stakeholder involvement, a participatory approach may be needed. Therefore, future research could consider the possibility of adapting existing sedentary behaviour interventions for individuals with paraplegia, potentially using a similar co-design workshop approach to this thesis.

7.3.4 Intervention Acceptability, Safety and Feasibility

The REACH-SCI intervention was acceptable, safe and feasible (Chapter 6). This corroborates previous research that suggested interventions targeting sedentary behaviour via a whole-day approach, comprising activities of daily living, would be an acceptable and feasible approach to health-enhancing behaviour change in individuals with physical disabilities (Dogra et al., 2022; Manns et al., 2012). The acceptability and feasibility of REACH-SCI is consistent with previous sedentary behaviour interventions that all included a wearable activity tracker, education, goal setting and one-to-one health coaching/motivational support sessions in older adults (Bailey et al., 2024; McGowan et al., 2024), stroke survivors (Ezeugwu & Manns, 2018), and individuals with multiple sclerosis (Manns et al., 2020). The safety of REACH-SCI demonstrated in Chapter 6 is consistent with findings from interventions in older adults (Bailey et al., 2024; McGowan et al., 2024), stroke survivors (English et al., 2016) and individuals with multiple sclerosis (Manns et al., 2020). These findings suggest that multi-component sedentary behaviour interventions are acceptable, safe and feasible for different populations, including individuals with paraplegia. The high levels of acceptability, perceived effectiveness and participant engagement in REACH-SCI also suggests that individuals with paraplegia value sedentary behaviour as an important target for health benefits.

Despite findings suggesting that participants with paraplegia valued reducing and breaking up sedentary behaviour, some co-design participants (Chapter 5) perceived the term sedentary behaviour to be stigmatising. This stigma was described as being due to wheelchair use restricting the user to long periods of sitting, which was perceived to be at odds with their understanding of sedentary behaviour. Negative feelings around this terminology were also experienced by stroke survivors (Hall et al., 2020) in another study. Therefore, the term "inactivity" was used throughout REACH-SCI participant-facing materials (Chapter 6), where possible. Future interventions should take caution with terms relating to "sedentary behaviour"

in wheelchair-users with SCI and future studies may use the term "inactivity" in intervention materials. These findings also indicate that the experiences and perceptions of sedentary behaviour amongst wheelchair-users with paraplegia needs to be further explored. This exploration could inform specific definitions and/or guidelines around sedentary behaviour for this population, which could also help shape future interventions and improve their acceptability.

7.4 Methodological Reflections

The use of the MRC framework for developing and evaluating complex interventions largely guided the methodological approach in this thesis (Skivington et al., 2021). The development phase of the MRC framework was carried out across two stages (Chapters 4 and 5).

A systematic review of literature was undertaken in Chapter 4 to identify which types of interventions were effective for reducing sedentary behaviour and improving CVD biomarkers in individuals with paraplegia, in order to inform intervention development. This study showed that interventions that target physical activity may not be effective for reducing sedentary behaviour, but those that specifically targeted sedentary behaviour showed promise for reducing this behaviour and improving CVD biomarkers.

The development phase of the MRC framework was also carried out via co-design workshops to develop the REACH-SCI intervention (Chapter 5). Co-design was undertaken to design the intervention in line with MRC guidance to engage diverse stakeholders in the intervention development process. Co-design was complemented by use of behaviour change theory, namely the COM-B model (Michie et al., 2011). The decision to use the COM-B model was informed by findings from the systematic review (see Chapter 4) and a different review finding that theory-driven interventions generate greater behaviour change than those not grounded in theory in individuals with physical disabilities (Ma & Martin Ginis, 2018). The COM-B model

was supplemented by use of the BCW to guide the intervention development process. The combination of co-design and the COM-B/BCW approach within an interconnected workshop design was effective for developing a multi-component intervention targeting sedentary behaviour. In addition, this process was time-efficient for participants (approximately 12 hours across all workshops) compared to previous research, that reported a participant time commitment of over 250 hours across all co-production workshops (Hall et al., 2020). Co-design workshops were also acceptable to participants, who provided positive feedback on the process. This combined approach of co-design and the COM-B/BCW contributed to the development of an intervention which is more acceptable to participants and effective for reducing and breaking up sedentary behaviour, respectively.

The feasibility phase of the MRC framework was carried out by assessing the REACH-SCI intervention within an acceptability and feasibility study in Chapter 6. The acceptability and feasibility study utilised a mixed-methods approach, in line with recommendations from the MRC Framework and previous studies using a similar approach (McGowan et al., 2024). Complex concepts such as participant acceptability and engagement cannot be fully determined using either qualitative or quantitative methods alone. Therefore, the use of mixed-methods was vital in understanding the acceptability in relation to each intervention component. The rich level of data afforded by mixed-methods research facilitated the identification of areas for improvement in the intervention protocol (outlined in Chapter 6) that can be implemented when progressing to a future definitive RCT. This acceptability and feasibility study, therefore, provided data required to be able to progress to the evaluation phase of the MRC framework. Collectively, the three studies undertaken across this PhD thesis adopted a complementary and methodologically rigorous approach, integrating qualitative and quantitative methods to ensure that the intervention was theoretically-driven, empirically grounded and robustly evaluated.

Despite the nature of the study limiting effectiveness conclusions and recommendations, the methods used to measure preliminary efficacy outcomes were largely rigorous. Firstly, the sedentary behaviour and physical activity outcomes were measured using wrist-worn accelerometers that are validated in this population group (Bailey et al., 2025), as well as employing commonly accepted valid wear criteria for inclusion in the analysis.

In terms of CVD biomarker outcomes, although automated blood pressure measurement has some inherent variability (Stergiou et al., 2009), this can be compensated for (Liu et al., 2022). For example, in the current study, there was a rest period prior to the first reading and three measurements were taken. Central obesity was estimated using waist circumference and body fat using bioelectrical impedance. Alongside a significant error rate in waist circumference measurement (Verweij et al., 2013), bioelectrical impedance is also sensitive to hydration status (Schierbauer et al., 2023), which is more difficult to control than food intake due to low participant acceptability of abstaining from fluids (Morrison et al., 2020). Although more expensive (Lang et al., 2015), measurement techniques less sensitive to hydration status, such as dual x-ray absorptiometry, should be considered in a future effectiveness evaluation of REACH-SCI.

Blood biomarkers were measured using capillary blood, which has excellent correlation with venous blood for lipid panel measurement (Hameed et al., 2025). However, these samples were analysed using an automated point of care analyser, which is less accurate than gold-standard laboratory testing (Robert Lourdes et al., 2024). Despite having higher costs, laboratory testing should be considered in any future effectiveness trial. Only a subset of lipid outcomes was assessed, as well as a single fasted glucose measure. These outcomes do not represent full lipid profile or long-term glycaemic status, respectively. Measurement of triglycerides and LDL cholesterol, in addition to the biomarkers already measured in this study, could have provided a more complete assessment of cholesterol status (Li et al., 2017). In addition, measurement of

HbA1C would provide insight of long-term glucose control (International Expert Committee, 2009). Furthermore, a future effectiveness trial of REACH-SCI could analyse a combined CVD risk score, such as QRISK3 (Hippisley-Cox et al., 2017), to give a comprehensive probability of experiencing a CVD event in the next 10 years. Such an approach can mitigate individual variability in any biomarker alone and give extra insight into multiplicative risk of elevated levels of multiple biomarkers simultaneously (Rout et al., 2024).

In relation to psychosocial outcomes, REACH-SCI demonstrated some potential for improving the bodily pain domain of quality of life and fatigue. Despite this being preliminary data, and improvement in these outcomes not being a primary focus of the study, these are important patient reported outcomes (Jensen et al., 2007) that should be considered in a future trial.

7.5 Practical Implications

7.5.1 Implications for Research and Theory

This research provides an example of how an intervention can be developed using participatory methods, such as co-design. Co-design provided the basis for understanding lived experience, and ensuring relevance of the developed intervention, making it more targeted to specific barriers and facilitators. Identification and targeting of specific barriers and facilitators are particularly important for individuals with paraplegia, as wheelchair use poses unique barriers to breaking up and reducing sedentary behaviour. Also, co-design ensures that specific intervention content is appropriate and relevant to the target population, such as avoiding stigmatising terminology around sedentary behaviour that could otherwise be overlooked in researcher-developed interventions (see Chapter 5). Therefore, researchers can use the co-design workshop approach outlined in Chapter 5 as a guide to develop targeted, relevant and acceptable interventions for individuals with paraplegia.

This PhD also highlights how intervention development can be grounded in behaviour change theory, such as the COM-B model. Utilisation of the BCW facilitated a coherent behavioural diagnosis to identify barriers and facilitators to reducing and breaking up sedentary behaviour according to a validated framework (TDF) and behavioural model (COM-B). Barriers and facilitators were then selectively targeted via identification and mapping of proposed intervention options to a taxonomy of pre-defined intervention content and implementation options (such as BCTs) (Michie et al., 2011, 2014). Therefore, the BCW represents a precise, systematic and traceable approach to intervention design. In addition, previous research suggests that interventions grounded in theory generate greater physical activity behaviour change than those not grounded in theory (Davis et al., 2015; Ma & Martin Ginis, 2018). Consequently, researchers can replicate the transparent, iterative, BCW-driven intervention design process outlined in Chapter 5 to develop future health behaviour change interventions that are more likely to be effective.

This thesis also builds on previous evidence that targeting sedentary behaviour is a meaningful health behaviour consideration in individuals with paraplegia. Cross-sectional (Bailey et al., 2019; Wilmot et al., 2012) and interventional (Hadgraft et al., 2021; Martin et al., 2015; Prince et al., 2014) data demonstrate associative and causal links, respectively, between sedentary behaviour and CVD biomarkers in the general population, but research is limited in individuals with paraplegia; hence the important contributions of this thesis to the evidence base. A scoping review stated that no conclusions or recommendations could be made pertaining to the meaningfulness of sedentary behaviour interventions in individuals with SCI due to a lack of available evidence (Adams et al., 2024). To address the limited evidence in this population, this thesis contributed a systematic review that found sedentary behaviour interventions showed promise for improving CVD biomarkers (Chapter 5), indicating some potential value of targeting this behaviour which had not previously been established. This thesis also

contributed a feasibility study, in which a sedentary behaviour intervention was acceptable and demonstrated some potential preliminary efficacy for improving sedentary behaviour CVD biomarker outcomes in individuals with paraplegia. These findings lay the foundations for a larger trial to evaluate, for the first time, the effectiveness of a sedentary behaviour intervention in individuals with paraplegia. Such research will provide data regarding causal links between reduced sedentary behaviour and improved CVD biomarkers. In conclusion, this PhD research has advanced the field of sedentary behaviour in this population and provided novel evidence of its potential use as an intervention target.

7.5.2 Implications for Clinical Policy, Care and Rehabilitation

Based on the preliminary efficacy of REACH-SCI for improving sedentary behaviour, physical activity, CVD biomarkers and psychosocial health, healthcare policy could be amended to integrate sedentary behaviour as a focus in SCI rehabilitation if these findings are replicated in an effectiveness trial. The addition of sedentary behaviour within clinical policy would be intended to build on existing advice around physical activity already in place (Martin Ginis et al., 2018). Furthermore, with further evidence, sedentary behaviour guidelines could be developed for this group. Specific sedentary behaviour guidelines could help to highlight the importance of this behaviour as a distinct, modifiable health determinant, and provide a tangible target for individuals with SCI and healthcare professionals to strive for.

Subsequently, if shown to be effective in future research, REACH-SCI could be implemented into current provisions for individuals with SCI in the rehabilitation phase after injury. Healthcare professionals could use current and future findings to implement strategies used in REACH-SCI to help reduce and break up sedentary behaviour in individuals with paraplegia. For example, providing education and information around sedentary behaviour could help to instigate behaviour change. Furthermore, undertaking relatively time- and cost-effective training in motivational interviewing could provide healthcare professionals with the skills

required to provide motivational support in reducing sedentary behaviour and assist with setting goals. Furthermore, individuals with paraplegia could be provided with or recommended to purchase a wearable activity tracker to provide reminders to break up sedentary behaviour and receive feedback on activity.

The barriers and facilitators identified in the co-design process (Chapter 5) could also be helpful for healthcare professionals to understand what the determinants of behaviour change related to sedentary behaviour are. As a result, healthcare professionals may selectively target these barriers and facilitators with strategies discussed in the paragraph above, or strategies/techniques they have been equipped with from their clinical training. However, future research is required before strategies from REACH-SCI are implemented.

7.6 Strengths and Limitations

The strengths of this thesis include strict adherence to frameworks and reporting guidelines, such as PRISMA (Page et al., 2021) and SWiM (Campbell et al., 2020) in the systematic review, COREQ (Tong et al., 2007) in the co-design study, and CONSORT (Eldridge et al., 2016) and GRAMMS (O'Cathain et al., 2008) in the feasibility study. This helped to maintain rigour throughout the research process. Furthermore, prospective registration of the systematic review protocol with PROSPERO and the feasibility study protocol with clinicaltrials.gov ensured replicability, transparency and trustworthiness.

The use of participatory methods to develop the intervention and study design such as co-design and PPI ensured that both the study procedures and intervention protocol were appropriate, useful and relevant for the target population. This contributed to the favourable levels of acceptability, safety, engagement and feasibility demonstrated in Chapter 6.

Behaviour change theory was used throughout the chapters, such as synthesising studies by use of theory in the systematic review, workshops being grounded in the COM-B model and BCW

framework during the co-design process, and the intervention protocol being mapped to the BCW constructs (Michie et al., 2011). The presence of behaviour change theory throughout the thesis means that the research is grounded in systematic, evidence-based frameworks for understanding the antecedents of behaviour and how to target them with effective intervention strategies. The theory-driven approach throughout this thesis contributed to the development of an acceptable, safe and feasible intervention.

Limitations of the thesis include a lack of meta-analysis in the systematic review that informed the intervention development (Chapter 4). A meta-analysis was not undertaken due to a small number of eligible studies and wide heterogeneity in study methods and intervention characteristics. This meant that precise, pooled estimates of effectiveness of certain intervention components could not be demonstrated to inform the development phase of the MRC framework (Skivington et al., 2021).

A smaller than anticipated number of individuals with paraplegia and community caregivers were recruited to participate in the co-design workshops than planned. Small sample size may have resulted in an insufficient range of viewpoints to answer the research question. In addition, the sample was comprised of 90% White British participants, with such homogeneity not being reflective of the ethnic makeup of this population in the UK (ONS, 2022). As a result, this reduces the probability of the intervention being generalisable to other wheelchair-users with paraplegia.

The feasibility study (Chapter 6) employed a single-arm design, meaning a control arm was not included. A control arm would provide data around the acceptability and feasibility of group allocation and randomisation procedures, as well as provide greater context around the preliminary efficacy of the intervention, which could not be determined in this study.

7.7 Conclusion

In conclusion, this thesis provides the first systematic review and co-designed, theory-driven intervention targeting sedentary behaviour in individuals with paraplegia. Through integration of the BCW, co-design and feasibility testing, this research advances both theory and practice for developing complex interventions in individuals with paraplegia who face unique barriers to reducing and breaking up sedentary behaviour. These findings highlight the acceptability, safety and feasibility of a sedentary behaviour intervention in individuals with paraplegia and provide the foundation for a definitive RCT. If found to be effective in a future trial, this research could inform future public health and healthcare policy for individuals with paraplegia, with a focus on reducing and breaking up sedentary behaviour.

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Appendices

Appendix 1. Published systematic review in Disability and Rehabilitation.

DISABILITY AND REHABILITATION
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REVIEW ARTICLE

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Effects of interventions on sedentary behaviour and cardiovascular disease biomarkers in individuals with spinal cord injury: a systematic review

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ABSTRACT

Purpose: Reducing sedentary behaviour may be an intervention target to improve cardiovascular health in individuals with spinal cord injury. The aim of this study was to systematically review the effects of interventions on sedentary behaviour and cardiovascular disease biomarkers in individuals with paraplegia.

Materials and methods: Following prospective protocol registration (CRD42023420260), eleven sources were searched to identify articles, which were screened by two reviewers. Eligible articles included participants with paraplegia, interventions targeting physical activity and/or sedentary behaviour and studies that measured sedentary behaviour and cardiovascular disease biomarkers. Quality of evidence was assessed for each outcome.

Results: Two interventions targeting sedentary behaviour and six targeting physical activity were included. One intervention targeting sedentary behaviour and one targeting physical activity reduced sedentary behaviour. Two interventions targeting sedentary behaviour and three targeting physical activity improved cardiovascular disease biomarkers. Quality of evidence was very low for sedentary behaviour and moderate for cardiovascular disease biomarker outcomes.

Conclusions: Sedentary behaviour was not improved by physical activity interventions but these interventions may improve cardiovascular disease biomarkers in individuals with paraplegia. Interventions targeting sedentary behaviour, although limited, show potential effectiveness for improving cardiovascular disease biomarkers; such interventions require further investigation to inform public health and clinical care guidelines.

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Cardiometabolic health; cardiovascular disease; spinal cord injury; paraplegia; sedentary behaviour; physical activity

> IMPLICATIONS FOR REHABILITATION

- Physical activity interventions are not effective for reducing sedentary behaviour in individuals with paraplegia
- Evidence regarding interventions targeting sedentary behaviour is limited, but such interventions show some potential effectiveness
- Interventions targeting sedentary behaviour in paraplegia should be investigated further to inform their relevance for rehabilitation

Introduction

A spinal cord injury (SCI) is a life-changing event that can cause loss of motor, sensory and autonomic function across and below the site of the injury [1]. Consequently, many individuals with SCI become manual wheelchair users [2,3]. A number of physical changes occur due to SCI, such as increased body mass and abdominal body fat [4], which are adversely associated with cardiovascular disease (CVD) biomarkers (e.g. glycaemia and lipid profile) in this population group [5]. This combination of factors makes the SCI population highly susceptible to cardiovascular disease (CVD) [6].

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Physical activity has been defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" [7]. Greater levels of physical activity are associated with a decreased risk of CVD in non-disabled individuals [8]. Evidence-based guidelines recommend 40 min of moderate-to-vigorous-intensity physical activity (MVPA) per week to improve fitness and cardiometabolic health in individuals with SCI [9]. Paraplegia is described as damage to the spinal cord at the first thoracic vertebrae (T1) or below, resulting in trunk and lower limb dysfunction [10]. Retained function in the upper limbs gives greater capability for physical activity compared to individuals with tetraplegia who additionally have loss in upper limb function [11]. The majority of physical activity interventions in individuals with SCI have involved regular arm crank ergometry exercise [12]. These interventions have generally been successful for increasing MVPA in individuals with paraplegia [13–16]. Improvements in CVD biomarkers have also been reported in such interventions [17,18], but with mixed findings [13,18,19]. However, the SCI population generally engage in low levels of physical activity, with 44% of individuals reporting no participation in MVPA whatsoever [20].

Reducing sedentary behaviour ("an energy expenditure of ≤ 1.5 metabolic equivalents (MET) while sitting, lying or reclined during waking hours") [21], could be an alternative intervention target to MVPA for improving cardiometabolic health [22]. Individuals with SCI have been reported to spend more than 11 h per day being sedentary when measured using accelerometry [23]. This population group inherently spend long periods of time sitting due to regular or complete reliance on a wheelchair for mobility. Higher levels of sedentary behaviour are associated with increased risk of CVD in the general population, independent of physical activity [24,25]. Interventions targeting sedentary behaviour have been effective in reducing daily sedentary behaviour [26] and improving CVD biomarkers [27] in non-disabled individuals. The positive effects of reducing sedentary behaviour in non-disabled individuals could be of clinical relevance in those with SCI. Reducing and breaking up sedentary behaviour may also be more achievable than MVPA for individuals with long-term conditions [28].

A systematic review is needed to understand the potential effectiveness of interventions for reducing sedentary behaviour and improving CVD biomarkers in individuals with SCI. This could help to inform sedentary behaviour guidelines. A focus on individuals with paraplegia may be particularly relevant as this type of SCI provides a greater opportunity to break up sedentary behaviour due to retained upper limb function. The aims of this study were to systematically review (1) the effects of interventions on sedentary behaviour, and (2) the effects of these interventions on CVD biomarkers, in individuals with paraplegia.

Methods

The systematic review protocol was registered prospectively on the International Prospective Register of Systematic Reviews database (CRD42023420260) and is reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines (Supplementary file 1) [29].

Eligibility criteria

The Population, Intervention, Comparators, Outcomes and Study design (PICOS) process [30] was used as the framework to guide the eligibility criteria (Table 1). Articles were excluded if the publication was not in English. Published journal articles, conference papers, theses and pre-printed papers were eligible for inclusion. Conference abstracts were only eligible if the review team could obtain the necessary data from the abstract or study authors.

Table 1. Population, intervention, comparator, outcomes, and study design criteria for the review.

PICOS component	Eligibility criteria
Population	Adult participants (≥ 18 years old) of any sex with paraplegia.
Intervention	Any intervention that targeted a reduction in sedentary behaviour, or targeted an increase in physical activity and included a measurement of sedentary behaviour as an outcome.
Comparator	Studies with or without comparators, including either passive control or active control.
Outcomes	Aim 1: Sedentary behaviour as measured by self-report or device. Aim 2: ≥ 1 cardiovascular disease biomarker.
Study design	Randomised controlled trials, uncontrolled trials, crossover trials, quasi-experimental studies, pre-post studies, pilot studies, and feasibility studies.

Population

Studies with adults (≥ 18 years old) with paraplegia were eligible. It was anticipated that articles would vary in their definition of paraplegia; therefore, this review kept the definition purposefully broad to capture all articles that may provide data relevant to the review aims. For example, studies that provided brief or detailed definitions of paraplegia, or where individual level of injury were included. Studies that included participants with paraplegia and tetraplegia were included irrespective of the proportion of the sample with paraplegia as the outcomes would be relevant to the review's target population. Studies were excluded if participants were predominantly ambulant in order to ensure a focus on the target population of this review i.e., manual wheelchair-users who have the opportunity to break up sedentary behaviour with upper-limb movement.

Intervention

Interventions that targeted a reduction in sedentary behaviour and/or an increase in physical activity (if sedentary behaviour was reported as an outcome) were eligible. As such, interventions targeting physical activity, which could lead to displacement of sedentary behaviour, were included. Interventions were not limited with respect to any characteristic, delivery mode or dose.

Comparator

Studies with or without comparators were eligible, including passive or active control.

Outcome

Interventions that specifically target sedentary behaviour and/or include a quantitative measure of sedentary behaviour (self-reported, device-assessed) (Aim 1). Interventions that are eligible for aim 1 and report outcomes for ≥ 1 CVD biomarker (Aim 2).

Study design

Randomised controlled trials, uncontrolled trials, crossover trials, quasi-experimental studies, pre-post studies, pilot studies and feasibility studies were eligible for inclusion.

Search strategy

Searches were conducted on 12 June 2023, followed by updated searches on 13 August 2024 and 2 September 2025, using the following databases: CINAHL Plus (*via* EBSCO Host), ClinicalTrials.gov, Cochrane library, ISRCTN Registry, MEDLINE (*via* EBSCO Host), PsycInfo (*via* EBSCO Host), Physiotherapy Evidence Database, PubMed, Scopus, SPORT Discus (*via* EBSCO Host), and Web of Science. There were no search restrictions on publication date or publication type. The full list of search strings is included within Supplementary File 2. Reference lists of eligible articles were searched to identify any further potential studies for inclusion.

Study selection

Identified articles were exported to an online systematic review data management system (www.covidence.org) for screening, following removal of duplicates. Two independent reviewers screened titles and abstracts. Full texts were obtained for potentially eligible studies. The same reviewers independently reviewed the full texts. The reviewers reached a consensus through discussion in cases of disagreement during each stage of screening.

Quality appraisal

Risk of bias was assessed using the Cochrane Risk of Bias 2 tool for randomised trials (RoB-2) and relates to five domains: randomisation, deviation from intended intervention, missing outcome data, measurement of the outcome and selection of the reported results [31]. Risk of bias was determined as low, high or some concerns [31].

Data extraction

Two reviewers independently extracted items into a custom data extraction spreadsheet using Microsoft Excel (Redmond, WA, USA). Extracted data included publication details, study design, participant characteristics (age, sex, and level of injury), intervention characteristics (type, duration, frequency, intensity, delivery mode, setting, provider, use of behaviour change theory), the methods used to measure outcomes, and outcome results (effects on sedentary behaviour and CVD biomarkers).

Quality of evidence

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) criteria were used to assess certainty of evidence for each outcome (sedentary behaviour and CVD biomarkers) across five domains: risk of bias, inconsistency of results, indirectness of evidence, imprecision and publication bias [32]. Overall certainty of evidence was rated as high, moderate, low or very low for each outcome [32].

Data synthesis

There was wide heterogeneity in study design and intervention characteristics. Therefore, a meta-analysis was not undertaken. Instead, a qualitative synthesis was undertaken following Synthesis Without a Meta-analysis guidelines (Supplementary File 3) [33]. Eligible studies were grouped into suitable categories to interpret the results. When neither P-values nor confidence intervals (CI) were reported in a study, 95% CIs for mean differences were calculated to enable determination of statistical significance and aid interpretation. When SD for the mean difference was not available, this was estimated following Cochrane guidelines with a conservative r correlation of 0.5 assumed between baseline and follow-up SDs [34]. The 95% CIs were then calculated using a paired-samples t distribution, with adjustment for width of the interval according to sample size [35]. Studies were synthesised in relation to:

- Nature of the intervention i.e. the target behaviour.
- Intervention characteristics (dose, setting, delivery mode, duration, use of behaviour change theory).
- Study population.
- Outcome measurement method.
- Risk of bias appraisal.

Results

Study identification

A total of 11,221 records were identified, from which 5,290 duplicates were removed (Figure 1). Titles and abstract screening of the remaining 5,931 records resulted in 5,868 exclusions. The full-text of the 63 remaining records were assessed for eligibility, resulting in the removal of 54 records. Nine articles were included in the final synthesis. Nightingale et al. [14,17] and Nooijen et al. [36,37] reported findings from a single study across two separate articles; therefore, these were each considered one single intervention. Martinez et al. [38] reported findings from two different interventions within a single article; therefore, these were considered two distinct interventions. As a result, the review comprised eight distinct interventions that were investigated in seven studies. The findings of these studies are reported across nine articles.

Study characteristics

Characteristics of the included studies are shown in Table 2. Three of the seven studies were undertaken in the United Kingdom [14,18,39], two in the United States [38,40], one in the Netherlands [37] and one in Norway [41]. Five studies were randomised controlled trials [14,18,37,40,41], one was a randomised comparative effectiveness trial [38] and one employed a randomised controlled crossover design [39].

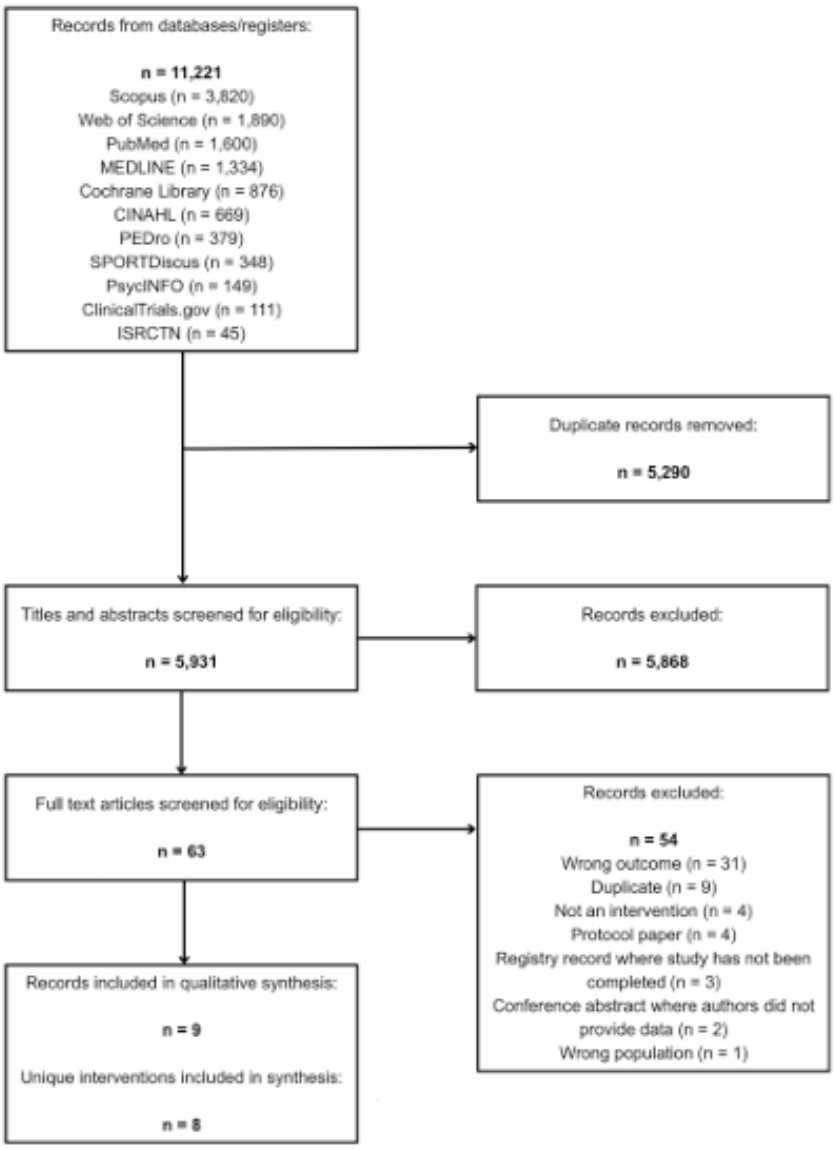

Figure 1. PRISMA flowchart for article identification.

Sample size ranged from 14 [39] to 168 [40] participants (Table 2). Four studies had a sample including only individuals with paraplegia [14,18,38,39]. Three studies included participants with paraplegia and tetraplegia, in which outcomes were reported for the whole sample [37,40,41]. None of the study sample sizes were powered a-priori to detect changes in sedentary behaviour. One study was powered a-priori to detect changes in physical activity [40], and one was underpowered for detecting changes in physical activity as the target sample size was not achieved [37]. Two studies were powered to detect changes in CVD biomarkers, namely postprandial glucose [39] and fasting insulin [17]. One study was

Table 2. Characteristics of included studies.

Study, country	Study design	Participants	Intervention and control characteristics	Intervention delivery mode and setting
Bailey et al. [39], United Kingdom.	Two-condition randomised controlled crossover design.	$N=14$ (8 F, 6 M). Mean age = 51 ± 9 years. Paraplegia between T6 - L5 (plus one participant with post-polio syndrome). Wheelchair user $N=9$. Ambulatory $N=5$.	Intervention: Participants performed moderate-intensity PA for 2 min every 20 min over 5.5 h using an arm ergometer. No behaviour change theory reported. Control: Participants remained seated and sedentary in a wheelchair over 5.5 h.	Controlled condition undertaken individually within University Sport and Exercise Science Laboratories.
Farrow et al. [18], United Kingdom.	Randomised controlled trial.	$N=27$ (14 F, 13 M). Mean age 46 ± 8 years. Paraplegia between T2 and L2. Self-reported use of a wheelchair for >75% of their waking day.	Intervention: Four intervention sessions per week for six weeks involving 10 × 60 s intervals at 80 - 90% of peak HR. Intensity increased by 5% every two weeks. No behaviour change theory reported Control: Participants were asked to maintain their habitual diet and physical activity routine.	Home-based exercise training undertaken individually.
Froehlich-Grobe et al. [40], United States.	Randomised, wait-list controlled trial.	$N=168$ (72 F, 96 M). Mean age 49.6 ± 12.3 years. Paraplegia $N=100$. Tetraplegia $N=66$. Not known $N=2$. Manual wheelchair user $N=104$. Power wheelchair user $N=60$. Scooter user $N=4$.	Intervention: 16-week programme providing participants (a) unlimited website access with exercise information, resources, and 16 skill-building modules; (b) virtual 60-minute, group-based 1x/week meetings, (c) unlimited access to a starter package of exercise equipment. The programme was founded upon Social Cognitive Theory and the Relapse Prevention model. Control: Participants underwent testing twice before being invited to participate in the intervention programme after a 4-month delay.	Home and community. Online educational resources and learning modules, group-based meetings, access to personal exercise equipment.
Martinez et al. [38], United States.	Randomised comparative effectiveness trial.	Sedentary behaviour intervention: $N=21$ (5 F, 16 M). Mean age 41 (range 27–57) years. Paraplegia between T2 and L3. All manual wheelchair users. Physical activity intervention: $N=28$ (5 F, 23 M). Mean age 41 (range 22–61) years. Paraplegia between T2 and L3. All manual wheelchair users.	Sedentary behaviour intervention: Designed to decrease sedentary time and increase overall PA by measuring and accumulating activity throughout the day. Given a wrist-worn activity monitor and phone app to view and track physical activity. Individualised goal-setting to progressively increase daily physical activity and decrease sedentary time and review of activity data with a physical therapist. Given home-based shoulder flexibility and strengthening exercises and recommendations for movement techniques that reduce shoulder demands associated with PA and daily activities. Physical activity intervention: Planned arm-crank ergometry. Individualised goal-setting to progressively increase daily physical activity and review of activity data with a physical therapist. Participants were asked to perform 3 × 15 min cycling sessions each week at 70% of maximum heart rate. Participants were encouraged to progressively increase session duration from 15 to 30 min between Weeks 2 and 4 and to 33 min by Week 5. Last, participants were instructed to exercise for 33 - 35 min per sessions, but at a higher intensity (target 85% of maximum heart rate) between week 5 and intervention end. Given home-based shoulder flexibility and strengthening exercises and recommendations for movement techniques that reduce shoulder demands associated with PA and daily activities.	Sedentary behaviour intervention: Home- and community-based. Physical activity intervention: Home- and community-based.

(*Continued*)

Table 2. Continued.

Study, country	Study design	Participants	Intervention and control characteristics	Intervention delivery mode and setting
Nightingale et al. [14, 17], United Kingdom.	Randomised controlled trial.	$N=24$ (9 F, 15 M). Mean age 47 ± 8 years. Participants had paraplegia below the T4 level. Those with an incomplete injury used a wheelchair >75% of their waking day.	Intervention: 4 × 45-minute moderate-intensity (60%–65% peak oxygen uptake) arm-crank exercise sessions per week for 6 weeks. No behaviour change theory reported. Control: Participants were asked to maintain their habitual physical activity behaviour.	Portable desktop arm-crank ergometer set up in their own home for individual exercise training.
Nooijen et al. [36, 37], Netherlands.	Single-blind, multicentre, randomised controlled trial.	$N=39$ (6 F, 33 M). Mean age 44 ± 15 years. Paraplegia $N=26$. Tetraplegia $N=13$. All wheelchair users.	Intervention: Behavioural intervention promoting an active lifestyle after discharge. Intervention involved 13 individual 1-hour sessions delivered by a coach trained in motivational interviewing beginning 2 months before and ending 6 months after discharge from inpatient rehabilitation. Motivational interviewing was based on the transtheoretical model. Control: Participants in both groups received usual care, which included a handcycle training program and advice on physical activity after discharge	Specialised rehabilitation Centres administered the rehabilitation. Face-to-face, individual sessions with a coach were planned for intervention group. Some sessions after discharge were conducted remotely by telephone.
Piira et al. [41], Norway.	Two parallel independent single-blinded randomised controlled trials.	$N=37$ (14 F, 23 M). Mean age 50 ± 13 years. Paraplegia $n=20$. Tetraplegia $n=17$. Wheelchair-dependent for ambulation $N=24$.	Intervention: 60 training days of body weight supported locomotor training, either with manual or robotic assistance 60–90 min per day, 3–5 days per week over 6 months. Telephone follow-up secured compliance. No behaviour change theory reported. Control: Usual care, typically one-on-one, by their local physical therapists 1–3 times per week (range 0–5). Telephone follow-up secured compliance.	Body weight supported locomotor training individual exercise training programme, either with manual or robotic assistance. Two inpatient rehabilitation facilities and one outpatient clinic in Norway.

Notes: F, female; HR, heart rate; L, lumbar; M, male; PA, physical activity; T, thoracic.

underpowered to detect changes in fasting insulin due to an insufficient sample size [18], whilst the remaining three studies did not conduct power calculations for CVD biomarker outcomes [36,38,40].

Intervention characteristics

Of the eight interventions identified across the seven studies, six interventions targeted increases in physical activity [14,18,37,38,40,41], whilst two targeted sedentary behaviour [38,39]. Interventions varied from one day [39] to eight months [37] in duration. Three interventions were home-based exercise training protocols [14,18,38], one was a home-based online programme [40], one used an exercise training protocol within a rehabilitation centre [41], one used motivational interviewing within a rehabilitation centre [37], one involved a whole-day approach to replace sedentary behaviour with physical activity [38], and one involved supervised breaks in sedentary behaviour within a controlled laboratory setting [39]. Four interventions were explicitly informed by behaviour change theory, including Social Cognitive Theory and the Relapse Prevention Model [40], Brief Action Planning [38] and motivational interviewing based on the Transtheoretical Model [37].

Risk of bias

Risk of bias was consistent for both sedentary behaviour and CVD biomarker outcomes across studies. Therefore, risk of bias in each domain is presented as a single judgement for each study (Figure 2). With regards to bias arising from the randomisation process, six of seven studies were deemed low risk [14,18,37–39,41], with one deemed high risk as allocation sequence was not concealed [40]. For deviations from the intended intervention protocol, five studies had a low risk of bias [14,18,37–39] and two had a high risk due to concerns around participant adherence [40,41]. Five of seven studies had a low risk of bias arising from missing outcome data [14,18,39–41], one study raised some concerns as a result of unexplained missing data points [37], and one study was high risk due to missing data points [38]. Regarding measurement of outcome variables, five of seven studies were judged to have low risk of bias [14,18,37,39,40], while two studies were deemed high risk due to the findings being pooled from two separate trials undertaken in different settings [41] or the use of non-validated methods for outcome measurement [38]. Four studies were assessed as low risk of bias arising from the selection of the reported outcome variables [14,18,39,41], with the remaining three studies raising some concerns as they did not follow a pre-specified data analysis plan [37,38,40]. Overall bias was deemed low risk in three studies [14,18,39], high risk in three studies [38,40,41] and of some concern in one study [37].

Study outcomes

Sedentary behaviour outcomes

Of the seven interventions that included a measurement of sedentary behaviour (Table 3) [14,18,37,38,40,41], two led to improvements [38,40]. In one intervention where there was an improvement [40], self-reported daily sitting was the sedentary behaviour outcome, measured using the International Physical Activity Questionnaire (IPAQ) [42]. The other intervention that led to a reduction in sedentary behaviour used METs derived from heart rate zones [38]. The remaining interventions, in which sedentary behaviour was not reduced, employed accelerometry [14,18,37], heart rate zones [38] and the IPAQ [41].

Cardiovascular disease biomarker outcomes

Seven of eight interventions included a measurement of one or more CVD biomarkers. Thirty CVD biomarkers were assessed, with improvements in eight of these (systolic blood pressure, diastolic blood pressure, fasting insulin, postprandial glucose, insulin resistance, Matsuda insulin sensitivity index, total cholesterol and low-density lipoprotein [LDL] cholesterol) reported in five out of seven interventions (Table 3) [17,18,36,38,39]. In the other interventions that included CVD biomarker outcomes, there were no improvements [38,40].

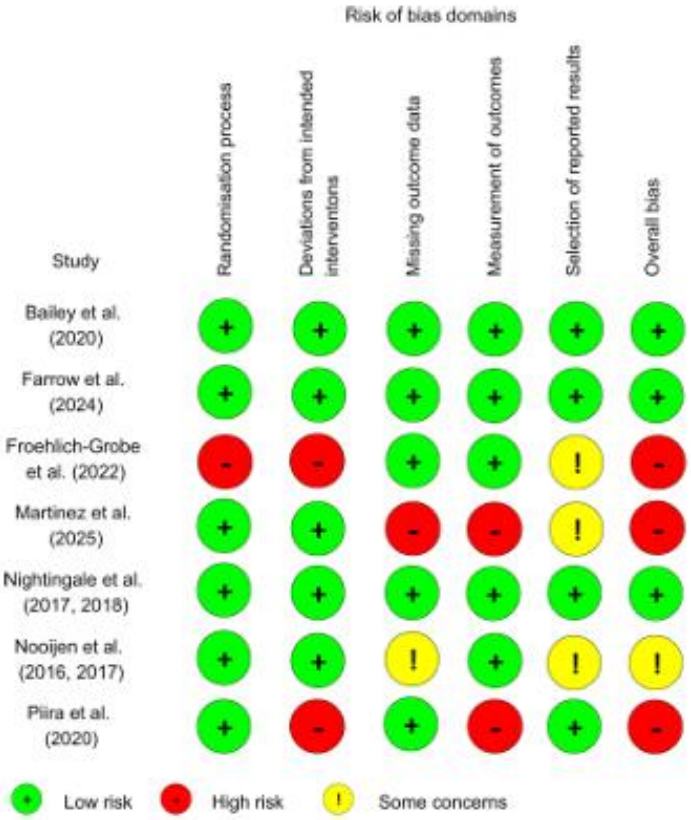

Figure 2. Risk of bias for included studies.

Nightingale et al. [13,16] reported an improvement in insulin resistance and fasting insulin, but with no reduction in sedentary behaviour. There were no improvements in these biomarkers in one other intervention that also did not reduce sedentary behaviour [18], but there was an improvement in insulin sensitivity [18]. Another intervention found no improvements in fasting insulin, insulin resistance or insulin sensitivity, despite reductions in sedentary behaviour [38].

In the two interventions where postprandial glucose was evaluated, one led to an improvement following supervised breaks in sedentary behaviour [39], whereas there was no change in postprandial glucose or sedentary behaviour in response to the other intervention [18]. One intervention led to an improvement in total cholesterol and LDL cholesterol [36], but with no reduction in sedentary behaviour [37]. Lipid outcomes did not change in response to one intervention that reduced sedentary behaviour [38], nor three interventions that did not affect sedentary behaviour [14,18,38].

Diastolic blood pressure was reduced in one study [36] in which the intervention did not affect sedentary behaviour [37]. Six other interventions had no effect on diastolic blood pressure [17,18,38–40], despite two of these reporting reductions in sedentary behaviour [38,40], and one involving supervised breaks in sedentary behaviour [39]. There was a reduction in systolic blood pressure and sedentary behaviour in one [38] of the seven interventions measuring this outcome [17,18,36,38–40].

Body composition outcomes (body mass, body fat, body mass index, waist circumference and waist to hip ratio) did not improve in any of the four interventions that assessed these outcomes [17,18,36,40].

Table 3. Outcomes of included studies.

Study, country	Sedentary behaviour outcome measures	Sedentary behaviour outcomes	Cardiovascular disease biomarker outcome measures	Cardiovascular disease biomarker outcomes
Bailey et al. [39], United Kingdom.	N/A	N/A	Capillary blood samples at baseline, 30, 60, 90, 120, 180, 210, 240, 300, and 330 min. YSI analyser used to analyse blood glucose (mmol/L), Reflotron Plus used to measure triglycerides (mmol/L), ELISA used to measure insulin (μU/mL). Glucose, insulin and triglycerides were reported as total and incremental AUC. Blood pressure measured at baseline, 60, 120, 180, 240 and 300 min.	Data presented as mean (95% confidence intervals) for Intervention vs. Control *denotes significant difference between conditions ($p<0.05$). **Total 5 h postprandial period:** • **Mean arterial pressure** (mmHg) 97.1 (96.7, 97.6) vs. 96.8 (96.4, 97.3) $p=0.310$ • **Systolic blood pressure** (mmHg) 125.9 (121.5, 130.3) vs. 123.9 (119.4, 128.5) $p=0.366$ • **Diastolic blood pressure** (mmHg) 76.6 (74.4, 78.9) vs. 76.8 (74.5, 79.0) $p=0.934$ • **Glucose iAUC** (mmol/L·5.5 h) 5.1 (2.8, 7.4) vs. 6.5 (4.2, 8.8) $p=0.275$ • **Glucose tAUC** (mmol/L·5.5 h) 33.7 (31.4, 36.0) vs. 35.1 (32.8, 37.4) $p=0.276$ • **Insulin iAUC** (μU/mL·5.5 h) 217.1 (165.5, 268.8) vs. 202.9 (121.3, 284.5) $p=0.753$ • **Insulin tAUC** (μU/mL·5.5 h) 285.4 (232.6, 338.1) vs. 262.7 (175.7, 349.8) $p=0.980$ • **Triglycerides iAUC** (mmol/L·5.5 h) 3.5 (1.6, 5.4) vs. 2.1 (0.3, 4.0) $p=0.194$ • **Triglycerides tAUC** (mmol/L·5.5 h) 16.2 (14.3, 18.1) 14.8 (13.0, 16.6) $p=0.194$ **Breakfast postprandial period:** • **Glucose iAUC** (mmol/L·3 h) 4.9 (2.3, 7.5) vs. 5.0 (2.4, 7.6) $p=0.985$ • **Glucose tAUC** (mmol/L·3 h) 19.8 (17.2, 22.4) vs. 20.0 (17.4, 22.6) $p=0.905$ • **Insulin iAUC** (μU/mL·3 h) 129.0 (101.9, 156.3) vs. 115.8 (70.3, 161.3) $p=0.594$ • **Insulin tAUC** (μU/mL·3 h) 164.6 (136.4, 192.8) vs. 147.0 (98.1, 195.9) $p=0.509$ • **Triglycerides iAUC** (mmol/L·3 h) 0.8 (−0.2, 1.7) vs. −0.01 (−0.9, 0.9) $p=0.172$ • **Triglycerides tAUC** (mmol/L·3 h) 7.4 (6.4, 8.3) vs. 6.6 (5.7, 7.5) $p=0.172$ **Lunch postprandial period:** • ***Glucose iAUC** (mmol/L·2.5 h) 1.9 (1.0, 2.7) vs. 3.0 (2.1, 3.9) ($p=0.015$, $f=0.34$) • ***Glucose tAUC** (mmol/L·2.5 h) 15.3 (14.4, 16.1) vs. 16.4 (15.5, 17.2) ($p=0.015$, $f=0.34$) • **Insulin iAUC** (μU/mL·2.5 h) 38.0 (−8.9, 84.8) vs. 57.7 (10.8, 104.5) ($p=0.122$) • **Insulin tAUC** (μU/mL·2.5 h) 128.5 (101.4, 155.5) vs. 127.7 (100.7, 154.7) ($p=0.949$) • **Triglycerides iAUC** (mmol/L·2.5 h) 1.1 (0.23, 2.0) vs. 1.4 (0.6, 2.3) ($p=0.482$) • **Triglycerides tAUC** (mmol/L·2.5 h) 8.3 (7.4, 9.2) vs. 8.6 (7.8, 9.5) ($p=0.482$).
Farrow et al. [18], United Kingdom.	Participants wore a PA monitor (ActiheartTM) for 7-days after the baseline visit, and in the final week of the intervention period. Defined as <1.5 METs. Measured as min/day.	Data presented as mean (95% CI) for Intervention and Control groups pre- vs. post-intervention. **Sedentary time (min/day):** Intervention 642 (598, 687) vs. 687 (595, 780) Control 723 (628, 818) vs. 522 (404, 639) ($p=0.040$)	Body mass was measured using platform wheelchair scales. DEXA scan was used to measure total fat mass (kg), total fat free mass (kg), and total body fat percentage. Supine length was measured using a non-elastic tape measure. Waist and hip circumferences were taken in duplicate, using a non-metallic tape measure. Resting blood pressure was measured in triplicate using an automated blood pressure monitor. Serum insulin, leptin and adiponectin were determined using ELISA. Plasma glucose and serum triglycerides, NEFA, total cholesterol, HDL cholesterol, LDL cholesterol concentrations were determined using an automated analyser. Insulin and glucose tAUC and iAUC were determined using the trapezoidal rule to characterise responses to the OGTT. The Matsuda C-ISI, HOMA2-IR and HOMA-ß were calculated to give fasting measures of insulin resistance, insulin sensitivity and pancreatic ß-cell function.	Data presented as means (95% CI) or percentage change (%) for Intervention and Control groups pre- vs. post-intervention. *denotes significant difference ($p<0.05$). • ***Matsuda ISI:** Intervention 10.3 ± 29.7% Control −12.6 ± 24.8% ($p=0.036$) • **Systolic blood pressure (mmHg):** Intervention 125 (120, 129) vs. 118 (114, 123) Control 114 (106, 123) vs. 117 (111, 124) ($p=0.774$) • **Diastolic blood pressure (mmHg):** Intervention 81 (78, 84) vs. 78 (75, 81) Control 77 (72, 82) vs. 78 (74, 82) ($p=0.942$) • **Body mass (kg):** Intervention 76.5 (67.7, 85.3) vs. 74.9 (74.1, 75.7) Control 75.5 (60.8, 90.2) vs. 70.6 (59.6, 81.7) ($p=0.103$) • **BMI (kg/m²):** Intervention 26.6 (23.9, 29.3) vs. 26.1 (25.8, 26.5) Control 24.6 (21.6, 27.7) vs. 25.7 (25.2, 26.1) ($p=0.115$) • **Waist circumference (cm):** Intervention 87.7 (79.7, 95.7) vs. 85.2 (83.8, 86.6) Control 83.8 (76.2, 91.4) vs. 84.8 (82.8, 86.8) ($p=0.778$) • **Waist:hip ratio:** Intervention 0.85 (0.81, 0.89) vs. 0.85 (0.83, 0.86) Control 0.86 (0.81, 0.92) vs. 0.82 (0.79, 0.84) ($p=0.089$) • **Fat mass (kg):** Intervention 30.2 (24.5, 36.0) vs. 29.4 (28.4, 30.5) Control 25.0 (19.7, 30.4) vs. 28.5 (27.1, 29.8) ($p=0.286$) • **Body fat (%):** Intervention 39.5 (34.7, 44.2) vs. 39.3 (38.3, 40.3) Control 36.4 (29.9, 42.9) vs. 38.5 (37.0, 40.0) ($p=0.365$)

(Continued)

Table 3. Continued.

Study, country	Sedentary behaviour outcome measures	Sedentary behaviour outcomes	Cardiovascular disease biomarker outcome measures	Cardiovascular disease biomarker outcomes
				• **Fasting glucose** (mmol/L) Intervention 5.52 (4.23, 6.80) vs. 5.73 (5.27, 6.19) Control 4.77 (4.14, 5.40) vs. 5.80 (5.19, 6.41) (p = 0.849) • **HOMA2-IR:** Intervention 1.07 (0.54, 1.60) vs. 0.85 (0.70, 1.00) Control 0.71 (0.49, 0.94) vs. 1.00 (0.80, 1.21) (p = 0.224) • **Glucose iAUC** (mmol/L x 120 min): Intervention 433 (320, 545) vs. 411 (319, 503) Control 350 (192, 508) vs. 383 (221, 545) (p = 0.765) • **Glucose tAUC** (mmol/L x 120 min): Intervention 1096 (859, 1333) vs. 1053 (982, 1123) Control 908 (787, 1029) vs. 1028 (903, 1153) (p = 0.728) • **Insulin iAUC** (pmol/L x 120 min): Intervention 44.5 (27.1, 61.9) vs. 48.1 (40.7, 55.5) Control 69.4 (−5.4, 144.3) vs. 57.1 (44.0, 70.1) (p = 0.242) • **Insulin tAUC** (pmol/L x 120 min): Intervention 51.2 (33.8, 68.6) vs. 53.3 (45.7, 60.9) Control 74.9 (−1.60, 151.3) vs. 63.3 (51.0, 77.7) (p = 0.164) • **NEFA** (mmol/L): Intervention 0.61 (0.47, 0.76) vs. 0.56 (0.46, 0.66) Control 0.58 (0.35, 0.81) vs. 0.55 (0.45, 0.69) (p = 0.953) • **Leptin** (µg/L): Intervention 10.7 (6.0, 15.4) vs. 15.0 (11.3, 16.9) Control 11.4 (6.4, 16.3) vs. 11.1 (5.3, 16.9) (p = 0.264) • **Adiponectin** (µg/L): Intervention 9.21 (6.89–11.5) 9.58 (8.69–10.5) Control 10.6 (4.91–16.3) 10.1 (8.88–11.3) (p = 0.491) **Fasting insulin** (pmol/L): • **(p = 0.415)** **Total cholesterol (mmol/L):** Intervention 4 5.03 (4.51, 5.56) vs. 5.47 (5.16, 5.77) Control 5.47 (4.73, 6.21) vs. 5.13 (4.72, 5.54) (p = 0.193) • **HDL cholesterol (mmol/L):** Intervention 1.12 (0.91, 1.32) vs. 1.30 (1.21, 1.39) Control 1.27 (0.99, 1.54) vs. 1.23 (1.11, 1.35) (p = 0.329) • **LDL cholesterol (mmol/L):** Intervention 3.46 (3.00, 3.92) vs. 3.71 (3.38, 4.05) Control 3.65 (2.85, 4.44) vs. 3.33 (2.88, 3.78) (p = 0.173) • **Triglycerides (mmol/L):** Intervention 1.13 (0.80, 1.46) vs. 1.04 (0.87, 1.21) Control 1.20 (0.70, 1.70) vs. 1.25 (1.02, 1.48) (p = 0.142)

(Continued)

Table 3. Continued.

Study, country	Sedentary behaviour outcome measures	Sedentary behaviour outcomes	Cardiovascular disease biomarker outcome measures	Cardiovascular disease biomarker outcomes
Froehlich-Grobe et al. [40], United States.	IPAQ-SF question to assess sitting time (hours/day).	**Wait-list control:** Data presented as mean ± SD for Intervention and wait-list control combined pre-post results between 0m vs. 4m, and 0m vs. 6m. *denotes significant group x time interaction effect. ***Sit time (min/day):** 0m 616.22 ± 229.19 vs. 4m 567.05 ± 264.86 (p = 0.076) 0m 616.22 ± 229.19 vs. 6m 555.13 ± 252.28 (p = 0.017)	Resting blood pressure (mmHg) and heart rate were obtained before (0 months) and after (4 month) the exercise intervention. Body weight (kg) measured using a digital wheelchair scale.	**RCT:** Data presented as means ± SD for Intervention and Control groups pre- vs. post-intervention • **Systolic blood pressure (mmHg):** Intervention 114.1 ± 19.6 vs. 115.5 ± 18.0 Control 109.2 ± 21.5 vs. 114.4 ± 20.1 Group x time interaction p = 0.374 • **Diastolic blood pressure (mmHg):** Intervention 73.7 ± 12.8 vs. 71.8 ± 12.9 Control 73.2 ± 11.2 vs. 71.3 ± 11.3 Group x time interaction p = 0.644 • **Body weight (kg):** Intervention 86.2 ± 22.0 vs. 85.2 ± 23.8 kg Control 81.6 ± 20.8 vs. 81 ± 21.8 kg Group x time interaction p = 0.563 • **BMI (kg/m^2):** Intervention 28.3 ± 6.2 vs. 28.4 ± 7.2 Control 27.2 ± 6.5 vs. 26.7 ± 6.9 Group x time interaction p = 0.104 **Wait-list control:** Data presented as means ± SD for Intervention and wait-list control combined pre-post results between 0 m vs. 4 m. • **Systolic blood pressure (mmHg):** 0m 112.4 ± 20.3 vs. 4m 115.0 ± 18.7 (p = 0.706) • **Diastolic blood pressure (mmHg):** 0m 73.5 ± 12.1 vs. 4m 71.6 ± 12.0 (p = 0.125) • **Body weight (kg):** 0m 84.6 ± 21.5 vs. 4m 83.3 ± 22.7 (p = 0.722) • **BMI (kg/m^2):** 0m 27.9 ± 6.3 vs. 4m 27.6 ± 7.0 (p = 0.475)

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Table 3. Continued.

Study, country	Sedentary behaviour outcome measures	Sedentary behaviour outcomes	Cardiovascular disease biomarker outcome measures	Cardiovascular disease biomarker outcomes
Martinez et al. [38], United States.	Participants wore a Fitbit device on the wrist over 7 days to measure baseline sedentary behaviour in min/day based on heart rate zones (1 MET for > 10 min in duration). The same device was worn throughout the whole intervention, with the average daily sedentary behaviour over the final month used to determine post-intervention values.	Data presented as Δ mean difference (95% CI) for pre- vs post-intervention. * denotes significant difference. **Sedentary behaviour intervention:** ***Sedentary behaviour (min/day):** Intervention A Δ −118 (−222 to −14*) **Physical activity intervention:** **Sedentary behaviour (min/day):** Intervention B Δ −47 (−109 to 15*) Between group difference in change p = n.s.	Diastolic and systolic blood pressure (mmHg) were measured after a 6-minute push test. Fasted blood samples were taken to measure glucose, insulin, HOMA-%B, HOMA-%S, HOMA-IR, lipid profile and triglycerides (mg/dL).	Data presented as Δ mean difference (95% CI) for diastolic blood pressure and median (interquartile range) for triglycerides, pre- vs. post-intervention. *denotes significant difference. **Sedentary behaviour intervention:** • ***Diastolic blood pressure (mmHg):** Intervention Δ −6 (−11 to −1a) Between group difference in change p = 0.019 • **Systolic blood pressure (mmHg):** Between group difference in change p > 0.05. • **Glucose (mg/dL):** Between group difference in change p > 0.05 • **Insulin (mg/dL):** Between group difference in change p > 0.05 • **HOMA-%B:** Between group difference in change p > 0.05 • **HOMA-%S:** Between group difference in change p > 0.05 • **HOMA-IR:** Between group difference in change p > 0.05 • **Lipid profile:** Between group difference in change p > 0.05 • **Triglycerides (mg/dL):** Intervention Δ 7 (7, 46) Between group difference in change p = 0.092 **Physical activity intervention:** • **Diastolic blood pressure (mmHg):** Intervention Δ 2 (−3 to 7a) Between group difference in change p = 0.019 • **Systolic blood pressure (mmHg):** Between group difference in change p > 0.05. • **Glucose (mg/dL):** Between group difference in change p > 0.05 • **Insulin (mg/dL):** Between group difference in change p > 0.05 • **HOMA-%B:** Between group difference in change p > 0.05 • **HOMA-%S:** Between group difference in change p > 0.05 • **HOMA-IR:** Between group difference in change p > 0.05 • **Lipid profile:** Between group difference in change p > 0.05 • **Triglycerides (mg/dL):** Intervention Δ −5 (−29, 9) Between group difference in change p = 0.092

(Continued)

Table 3. Continued.

Study, country	Sedentary behaviour outcome measures	Sedentary behaviour outcomes	Cardiovascular disease biomarker outcome measures	Cardiovascular disease biomarker outcomes
Nightingale et al. [14,17], United Kingdom.	Participants wore a chest-mounted Actiheart device to measure sedentary behaviour (< 1.5 METs) in min/day.	Data presented as means ± SD for Intervention and Control groups pre- vs. post-intervention. *denotes significant difference. **Sedentary time (min/day):** Intervention: 1232 ± 118 vs. 1179 ± 124 [Δ −53, −126 to 20*] Control: 1220 ± 115 vs. 1191 ± 139 [Δ −29, −136 to 78*]	Blood pressure (mmHg), supine height (m), body mass, fat mass and lean mass (kg) were measured fasted OGTT to measure metabolic regulation, glucose, insulin (mmol/L), post-load glucose, post-load insulin (mmol/120 min/L), NEFA, triacylglycerol, HOMA-2B (%), HOMA2-IR, Matsuda C-ISI and total cholesterol, HDL cholesterol and LDL cholesterol (mmol/L).	Data presented as Δ mean difference (95% CI) for Intervention and Control groups pre- vs. post-intervention. *denotes significant difference ($p < 0.05$). • ***Insulin (pmol/L):** Intervention Δ −12.7 (−24.0, −1.4) ($p = 0.031$) Control Δ 3.1 (−5.9, 12.0) (N.S.) Between group difference in change $p \leq 0.044$ • ***HOMA2-IR:** Intervention Δ −0.24 (−0.45, −0.02) ($p < 0.035$) Control Δ 0.06 (−0.10, 0.23) (N.S.) Between group difference in change $p \leq 0.044$ • **Systolic blood pressure (mmHg):** Intervention Δ −3 (−10, 5) Control Δ −2 (−8, 2) • **Diastolic blood pressure (mmHg):** Intervention Δ −1 (−8, 6) Control Δ −4 (−9, 2) • **Body mass (kg):** Intervention Δ −1.1 (−2.1, −0.0) Control Δ −0.7 (−2.2, 1.0) Between group difference in change $p = 0.6$ • **Fat mass (kg):** Intervention Δ −0.6 (−1.4, 0.2) Control Δ −0.0 (−0.7, 0.7) • **Glucose (mmol/L):** Intervention Δ 0.0 (−0.2, 0.2) Control Δ 0.0 (−0.2, 0.2) Group x time interaction $p \geq 0.3$ • **HOMA2-B (%):** Intervention Δ −14 (−26, −2) Control Δ 1 (−10, 13) Group x time interaction $p = 0.066$ • **Matsuda ISI:** Intervention Δ 0.3 (−0.7, 1.2) Control Δ −0.7 (−2.6, 1.2) Group x time interaction $p \geq 0.3$ • **Glucose response (mmol/L·120 min):** Intervention Δ 19 (−48, 86) Control Δ −25 (−153, 104) Group x time interaction $p \geq 0.3$ • **Insulin response (nmol/L·5.5 h):** Intervention Δ −4.4 (−19.0, 10.2) Control Δ 2.2 (−11.6, 16.0) Group x time interaction $p \geq 0.3$ • **NEFA (mmol/L):** Intervention Δ 0.3 (−0.2, 0.8) Control Δ −0.1 (−0.8, 0.6) Group x time interaction $p \geq 0.3$ • **Triacylglycerol (mmol/L):** Intervention Δ −0.1 (−0.2, 0.1) Control Δ 0.5 (−2.0, 1.2) Group x time interaction $p = 0.054$ • **Total cholesterol (mmol/L):** Intervention Δ −0.1 (−0.5, 0.4) Control Δ 0.1 (−0.5, 0.5) Group x time interaction $p \geq 0.3$ • **HDL cholesterol (mmol/L):** Intervention Δ 0.1 (−0.1, 0.1) Control Δ −0.0 (−0.1, 0.1) Group x time interaction $p \geq 0.3$ • **LDL cholesterol (mmol/L):** Intervention Δ −0.0 (−0.4, 0.3) Control Δ −0.2 (−0.6, 0.2) Group x time interaction $p \geq 0.3$

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Table 3. Continued.

Study, country	Sedentary behaviour outcome measures	Sedentary behaviour outcomes	Cardiovascular disease biomarker outcome measures	Cardiovascular disease biomarker outcomes
Nooijen et al. [36,37], Netherlands.	Body-fixed accelerometers measured the total duration of sedentary daytime bouts longer than 30 min. Defined as sitting and lying during the day without interruption by physical activity for a minimum of 5 s (min/day).	Data presented as mean difference (95% CI) in change from baseline to discharge, baseline to month 6, baseline to month 12 and overall change between Intervention and Control groups. Means are adjusted for rehabilitation centre, gender and age. **Sedentary daytime (min/day):** Baseline to discharge: −14 (−69, 40) Baseline to 6 m: −50 (−134, 33) Baseline to 12 m: −21 (−119, 77) Overall intervention vs. control: −34 (−97, 29)	BMI (kg/m²) was calculated from height (m) and body mass (kg). Resting diastolic and systolic blood pressure (mmHg) were measured by a physician. Fasting blood samples were taken for total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides and glucose (mmol/L). Comparisons are "baseline vs. discharge," "baseline vs. month 6," and "baseline vs. month 12."	Data presented as mean ± SD for Intervention vs. Control groups at each timepoint: baseline, discharge, month 6 and month 12. P values are adjusted for rehabilitation centre, sex and age. *denotes significant between-group effect ($p < 0.05$). • ***Diastolic blood pressure (mmHg):*** Baseline: 72 ± 9 vs. 77 ± 13 Discharge: 73 ± 9 vs. 77 ± 8 ($p = 0.52$) 6 m: 74 ± 13 vs. 84 ± 11 ($p = 0.04$) 12 m: 74 ± 12 vs. 83 ± 18 ($p = 0.01$) Overall model: ($p = 0.02$) • ***Total cholesterol (mmol/L):*** Baseline: 4.47 ± 0.84 vs. 4.96 ± 1.19 Discharge: 4.47 ± 0.92 vs. 5.17 ± 1.00 ($p = 0.39$) 6 m: 4.63 ± 0.85 vs. 5.55 ± 1.29 ($p = 0.17$) 12 m: 4.17 ± 0.51 vs. 5.21 ± 0.83 ($p = 0.01$) Overall model ($p = 0.06$) • ***LDL cholesterol (mmol/L):*** Baseline: 2.76 ± 0.85 vs. 3.22 ± 0.91 Discharge: 2.63 ± 0.73 vs. 3.39 ± 0.86 ($p = 0.34$) 6 m: 2.95 ± 0.54 vs. 3.46 ± 1.10 ($p = 0.40$) 12 m: 2.46 ± 0.75 vs. 3.13 ± 0.63 ($p = 0.05$) Overall model ($p = 0.08$) • ***Systolic blood pressure (mmHg):*** Baseline: 123 ± 19 vs. 127 ± 21 Discharge: 120 ± 15 vs. 124 ± 14 ($p = 0.75$) 6 m: 128 ± 28 vs. 132 ± 14 ($p = 0.62$) 12 m: 125 ± 19 vs. 130 ± 18 ($p = 0.36$) Overall model ($p = 0.46$) • ***BMI (kg/m²):*** Baseline: 25.43 ± 5.23 vs. 23.90 ± 4.68 Discharge: 25.60 ± 5.56 vs. 24.60 ± 5.18 ($p = 0.56$) 6 m: 25.66 ± 5.53 vs. 26.00 ± 5.53 ($p = 0.41$) 12 m: 25.36 ± 5.59 vs. 27.13 ± 5.20 ($p = 0.36$) Overall model ($p = 0.29$) • ***Glucose (mmol/L):*** Baseline: 4.97 ± 0.69 vs. 5.52 ± 2.20 Discharge: 5.16 ± 1.28 vs. 6.61 ± 3.02 ($p = 0.06$) 6 m: 5.00 ± 0.57 vs. 6.25 ± 1.27 ($p = 0.58$) 12 m: 5.66 ± 1.93 vs. 7.13 ± 3.55 ($p = 0.38$) Overall model ($p = 0.05$) • ***HDL cholesterol (mmol/L):*** Baseline: 1.37 ± 1.21 vs. 1.25 ± 1.02 Discharge: 1.02 ± 0.31 vs. 1.01 ± 0.15 ($p = 0.61$) 6 m: 1.08 ± 0.48 vs. 0.97 ± 0.15 ($p = 0.80$) 12 m: 1.09 ± 0.31 vs. 1.04 ± 0.31 ($p = 0.23$) Overall model ($p = 0.62$) • ***Triglycerides (mmol/L):*** Baseline: 1.40 ± 0.76 vs. 1.84 ± 0.93 Discharge: 1.50 ± 0.97 vs. 1.93 ± 0.93 ($p = 0.71$) 6 m: 1.80 ± 1.71 vs. 2.24 ± 1.23 ($p = 0.17$) 12 m: 1.12 ± 0.65 vs. 2.37 ± 1.38 ($p = 0.36$) Overall model ($p = 0.71$)

(*Continued*)

Table 3. Continued.

Study, country	Sedentary behaviour outcome measures	Sedentary behaviour outcomes	Cardiovascular disease biomarker outcome measures	Cardiovascular disease biomarker outcomes
Pina et al. [41], Norway.	Measured using the IPAQ-SF questionnaire (with no adaptation for wheelchair dependent individuals), reported in min/day.	Data presented as means ± SD for Intervention and Control groups pre- vs. post-intervention. * denotes significant difference. **Sitting time (min/day):** Intervention: 553.1 ± 265.4 vs. 457.9 ± 292.1 (Δ −95.2, −244.2 to 53.8*) Control: 554.3 ± 323.6 vs. 504.0 ± 229.0 (Δ −50.3, −182.5 to 81.9*)	N/A	N/A

BMI, body mass index; CI, confidence interval; C-ISI, composite insulin sensitivity index; DEXA, Dual-energy X-ray absorptiometry; ELISA, enzyme-linked immunoassay; HDL, high density lipoprotein; HOMA-B, homeostatic model assessment for B cell function; HOMA-IR, homeostatic model assessment for insulin resistance; HOMA-%S, homeostatic model assessment for insulin sensitivity; iAUC, incremental area under the curve; IPAQ, international physical activity questionnaire; LDL, low density lipoprotein; MET, metabolic equivalent of task; NEFA, non-esterified fatty acids; N.S., non-significant; OGTT, oral glucose tolerance test; PA, physical activity; QUICKI, quantitative insulin sensitivity check index; RCT, randomised controlled trial; SD, standard deviation; tAUC, total area under the curve.
*Within-group 95% confidence interval estimated from study data to determine statistical significance.

Outcomes in the context of study population

In the two interventions that led to reductions in sedentary behaviour, one included participants with paraplegia and tetraplegia [40], whereas the other included participants with paraplegia only [38]. Of the five interventions that had no effect on sedentary behaviour, two included participants with paraplegia and tetraplegia [37,41], and three included paraplegia only [14,18,38]. Overall, the proportion of individuals with paraplegia in the study sample did not appear to influence sedentary behaviour outcomes.

Four interventions that led to improvements in CVD biomarkers included only individuals with paraplegia [17,18,38,39], whilst one studied a sample comprising individuals with paraplegia and tetraplegia [36]. Of the two interventions that did not improve CVD biomarkers, one included only individuals with paraplegia [38] and the other included both people with paraplegia and tetraplegia [40]. Intervention effects, therefore, appeared to be more consistent in studies that included only participants with paraplegia.

Outcomes in the context of intervention characteristics

Targeting physical activity or sedentary behaviour. Of the two interventions that reduced sedentary behaviour, one targeted reductions in sedentary behaviour *via* a whole-day approach [38], whilst the other targeted increased physical activity using an online programme [40]. The five other interventions that targeted increases in physical activity (four using structured exercise training and one using motivational interviewing) found no effect [14,18,37,38,41]. The remaining intervention included supervised breaks in sedentary behaviour and, therefore, reduced sedentary time but did not report sedentary behaviour as an outcome [39]. It appears that interventions targeting physical activity are not effective for reducing sedentary behaviour in participants with SCI.

Three of the five interventions that improved CVD biomarkers targeted increases in physical activity, but did not reduce sedentary behaviour [17,18,37]. Two interventions that reported biomarker improvements targeted sedentary behaviour [38,39]; these studies led to reduced sedentary behaviour [38] or were supervised breaks in sedentary behaviour [39]. The two interventions that did not improve any CVD biomarker both targeted physical activity [38,40]; one reduced sedentary behaviour [40] and the other did not [38]. One intervention that targeted physical activity did not include any CVD biomarker outcomes [41]. There appears to be some evidence for CVD biomarkers being improved in interventions that target sedentary behaviour.

Intervention duration. The two interventions that led to reductions in sedentary behaviour were each 16 weeks [38,40] in duration. The interventions that had no effect on sedentary behaviour were six weeks [14,18], sixteen weeks [38], six months [41] and eight months [37] in duration. It is unclear whether intervention duration affects sedentary behaviour outcomes.

One of the five interventions that improved CVD biomarkers lasted one day [39], two lasted six weeks [17,18], one lasted one lasted sixteen weeks [38] and one lasted eight months [36] (Table 2). The two interventions that had no effect on any CVD biomarker were 16 weeks in duration [38,40]. It is unclear whether intervention duration affects CVD biomarker outcomes.

Intervention setting and delivery mode. One of the two interventions that reduced sedentary behaviour was a home-based online programme [40] and one was a home- and community-based intervention targeting the whole day [38]. Three of the five interventions that did not reduce sedentary behaviour were home- and community-based exercise training protocols [14,18,38], whilst the others included motivational interviewing within a rehabilitation centre [37] and a structured exercise training protocol in a rehabilitation centre [41]. It appears that structured exercise training protocols are not effective for reducing sedentary behaviour.

Two of the five interventions that improved CVD biomarkers included home-based exercise training protocols [17,18], one involved a home- and community-based intervention targeting the whole day [38], one involved motivational interviewing within a rehabilitation centre [36] and one involved supervised breaks in sedentary behaviour in a controlled laboratory setting [39]. The two interventions that did not improve CVD biomarkers included a home-based online programme [40] and a home- and community-based structured exercise training protocol [38]. Cardiovascular disease biomarker outcomes appear to be improved across a range of intervention settings and delivery modes.

Use of behaviour change theory. Four interventions were either underpinned by, or employed, behaviour change theory [37,38,40]. There was no mention of behaviour change theory in the other four

interventions [14,18,39,41]. Both of the interventions that reduced sedentary behaviour utilised behaviour change theory [38,40]. Two of the five interventions that did not affect sedentary behaviour utilised behaviour change theory [37,38]. It is not clear whether the use of behaviour change theory was beneficial to sedentary behaviour outcomes.

Two of the five interventions that led to improvements in CVD biomarkers were informed by behaviour change theory [36,38], whereas the remaining three interventions were not [17,18,39]. Behaviour change theory was included in both interventions that had no effect on CVD biomarkers [38,40]. It is not clear whether use of behaviour change theory influenced CVD biomarker outcomes.

Outcomes in context of measurement methods

One of the two interventions that reduced sedentary behaviour measured this outcome *via* self-report (Table 3) [40]. Metabolic equivalent of task derived from heart rate zones was used in the other intervention that reduced sedentary behaviour [38]. Of the five interventions that had no effect on sedentary behaviour, three measured this outcome using accelerometry [14,18,37], one used the IPAQ [41] and one used heart rate zones [38]. Improvements in sedentary behaviour appear to occur less consistently when measured *via* accelerometry.

One of the five interventions that improved CVD biomarkers found improvements in fasted outcome measures (insulin and insulin resistance), despite also measuring postprandial outcomes [17]. Another study only measured biomarkers in a fasted state, with the intervention leading to improvements in diastolic blood pressure, LDL cholesterol and total cholesterol [37]. One intervention reported improvements in postprandial glucose [39], whilst another reported improvement in the Matsuda index, which is measured using fasted and postprandial measurements [18]. One intervention led to improvements in systolic blood pressure [38], but blood pressure was measured after a six-minute push test, not at rest [38]. Other CVD biomarkers were assessed similarly across studies, making it challenging to recognise differences in outcomes according to the method of measurement. In summary, it appears that the method of measurement does not affect CVD biomarker outcomes.

Outcomes in context of risk of bias

Both interventions that led to reductions in sedentary behaviour were in studies with high risk of bias (Figure 2) [38,40]. Two of the five interventions that did not affect sedentary behaviour were in a study with low risk of bias [14,18], two were in studies with high risk of bias [38,41], and one was in a study that raised some concerns [37]. It appears that sedentary behaviour reductions were reported more frequently in studies with high risk of bias.

Three of the five interventions that improved CVD biomarkers were in studies with low risk of bias [17,18,39], one with high risk of bias [38] and one that raised some concerns [36]. The interventions that did not report an improvement in any CVD biomarker were in studies with high risk of bias [38,40]. CVD biomarker outcomes were, therefore, improved more consistently in studies with low risk of bias.

Quality of evidence

Overall quality of evidence for sedentary behaviour was deemed very low (Table 4), with quality downgraded due to risk of bias, inconsistency of results, indirectness of evidence and imprecision. Overall quality of evidence for CVD biomarkers was deemed moderate, with quality downgraded due to risk of bias and inadequate sample sizes.

Discussion

The findings of this review indicate that interventions targeting increases in physical activity are not effective for reducing sedentary behaviour in individuals with paraplegia, but show some effectiveness for improving CVD biomarkers. There was a scarcity of interventions targeting sedentary behaviour, but these interventions may have potential for improving CVD biomarkers.

The majority of interventions targeted physical activity, as opposed to sedentary behaviour, with only one leading to an improvement in the sedentary behaviour outcome. These findings suggests that

Table 4. Assessment of overall quality of the evidence.

Outcome		Risk of bias	Inconsistency of results	Indirectness of evidence	Imprecision	Publication bias[f]	Quality of evidence
Sedentary behaviour	Overall	−2[ab]	−1[c]	−1[d]	−1[e]	0	0 = very low
	Device-measured	0	−1[c]	0	−1[e]	0	3 = moderate
	Estimated from heart rate zone	−1[b]	0	−1[d]	−1[e]	0	2 = low
	Self-reported	−2[ab]	0	−1[d]	−1[e]	0	1 = very low
Cardiovascular disease biomarkers	Overall	−1[b]	0	0	−1[e]	0	3 = moderate
	Blood pressure	−1[b]	0	0	−1[e]	0	3 = moderate
	Body composition	−1[b]	0	0	−1[e]	0	3 = moderate
	Glycaemic biomarkers	−1[b]	0	0	−1[e]	0	3 = moderate
	Lipid biomarkers	−1[b]	0	0	−1[e]	0	3 = moderate

[a]One study does not use a randomised controlled design for this outcome.
[b]One or more study has a high risk of bias.
[c]Large differences in means between studies.
[d]One or more study uses surrogate measurements.
[e]One or more study has an inadequate sample size to ensure sufficient statistical power.
[f]Funnel plots not generated as < 10 studies included in the systematic review.

physical activity interventions may not be effective for reducing sedentary behaviour in individuals with paraplegia. This is in disagreement with a meta-analysis that found interventions targeting physical activity were effective for reducing sedentary behaviour in non-disabled individuals [26]. The contrasting findings may be due to the majority of physical activity interventions in the present review focusing on structured exercise training, rather than non-exercise physical activity accumulated throughout the day [26], which is more likely to displace sedentary behaviour [22] and overcome physical impairments that may present a barrier to some exercise interventions in individuals with disabilities [28]. The intervention in the present review that targeted sedentary behaviour *via* a whole-day approach and measured sedentary behaviour as an outcome was found to be effective [38]. It could be postulated that interventions targeting sedentary behaviour would be most effective as interventions focusing on physical activity may not utilise the most appropriate behaviour change techniques for sedentary behaviour [43] or appropriate activities for individuals with paraplegia. Further interventions targeting sedentary behaviour, tailored for individuals with paraplegia, require development and evaluation in order to determine their effectiveness and inform public health and clinical care guidelines.

The quality of evidence in the present review was deemed very low and, as a result, there is very little confidence with respect to sedentary behaviour outcomes [32]. The lack of quality is due to unexplained variability in sedentary behaviour changes across studies, small sample sizes and the measurement techniques employed [44]. Sedentary behaviour was assessed *via* self-report using the IPAQ "time spent sitting" question in one of the two interventions that reduced sedentary behaviour. The validity of this IPAQ question has not been evaluated in individuals with SCI and may not be appropriate for wheelchair-users. One intervention that reduced sedentary behaviour measured this outcome using METs derived from heart rate zones, which is not validated [38]. In addition, sample heterogeneity was high, with just one intervention that reduced sedentary behaviour including a sample comprising only individuals with paraplegia. Studies may choose to adopt broad inclusion criteria, such as including individuals with paraplegia and tetraplegia in their sample, due to difficulty recruiting and retaining individuals with SCI [45]. As a result, the effects on sedentary behaviour cannot be isolated to individuals with paraplegia. The findings with respect to interventions targeting sedentary behaviour potentially being effective may, therefore, be generalisable to paraplegia and tetraplegia. However, differences in upper-limb function between individuals with paraplegia and tetraplegia means that the types of physical activities they are able to engage in differ. Interventions will, therefore, need to be tailored to different injury levels. High-quality studies that address the sources of bias and heterogeneity identified in this review are needed to inform definitive conclusions regarding sedentary behaviour intervention effectiveness.

The influence of behaviour change theory on sedentary behaviour outcomes is unclear. However, only half of included interventions employed behaviour change theory [37,38,40]. Limited use of behaviour change theory has been reported in reviews of sedentary behaviour interventions in non-disabled individuals [46,47]. The lack of behaviour change theory is partly due to the nature of some included interventions, with half employing prescribed exercise training protocols in which behaviour change theory may have limited added value [14,18,38,41]. Integration of theory within interventions may be important to support behaviour change *via* identification of precursors to behaviour and causal factors of change,

which can be selectively targeted with specific behaviour change techniques [48,49]. Indeed, interventions grounded in behaviour change theory yield greater improvements in physical activity in individuals with physical disabilities, such as SCI [50]. Time spent in sedentary behaviour was more strongly correlated with engagement in light physical activity and activities of daily living than with MVPA and structured exercise [51], which could explain why sedentary behaviour was unaffected by the exercise training interventions in the current review. Therefore, the effects of sedentary behaviour interventions grounded in behaviour change theory, that utilise strategies to increase light physical activity and activities of daily living, should be evaluated in individuals with paraplegia as they are likely to be more effective.

There were mixed effects for CVD biomarkers in response to interventions that reduced sedentary behaviour. Interventions that reduced sedentary behaviour or involved supervised breaks in sedentary behaviour led to improvements in systolic blood pressure and postprandial glucose [38,39]. Previous reviews in non-disabled individuals [27] and clinical populations [52] also found that reducing sedentary behaviour improved CVD biomarkers. However, there was no change in sedentary behaviour in three interventions that improved CVD biomarkers in the present review [17,18,36]. This may indicate that improvements in cardiovascular health in these studies were due to increases in physical activity [14,18,37]. A previous meta-analysis found that physical activity interventions improved CVD biomarkers in individuals with SCI [53], supporting their inclusion in healthcare for this population group. Two interventions reduced sedentary behaviour and increased physical activity in the present review [38,40], but only one of these led to improvements in CVD biomarkers [38]. A combination of changes in sedentary behaviour and physical activity may, therefore, not always be necessary to achieve optimal effects [54]. Targeting physical activity or sedentary behaviour separately may, therefore, yield cardiovascular benefits; this supports literature demonstrating that these are distinct behaviours related to CVD risk [24,25]. The quality of evidence for CVD biomarker outcomes was deemed moderate. Future studies that address limitations of the current literature and evaluate interventions targeting sedentary behaviour are needed to provide stronger evidence regarding the effects of such interventions on CVD biomarkers in individuals with paraplegia.

The majority of interventions led to an improvement in at least one CVD biomarker. Biomarkers related to glycaemia were often improved, including fasting insulin [17], postprandial glucose [39], insulin resistance [17] and insulin sensitivity [18]. Studies with glycaemic outcomes had a moderate quality of evidence, meaning there is some confidence in these findings. However, two of these interventions had no effect on sedentary behaviour [17,18]. Also, both interventions that reduced sedentary behaviour did not improve glycaemic biomarkers, suggesting limited causality between these outcomes [38,40]. The evidence for interventions improving blood pressure and lipids in individuals with paraplegia was mixed, while there was consistent data that body composition was unaffected. These findings extend those of previous reviews and meta-analyses in individuals with SCI, which found that physical activity interventions had no effect on blood pressure or lipids [53]. Research has also shown exercise training may not improve body composition in individuals with SCI [55]. Lack of improvement in these biomarkers could be a result of changes in blood pressure and body composition that occur because of SCI, limiting responsiveness to reduced sedentary behaviour and/or increased physical activity [56,57]. Another plausible explanation is that intervention durations were too short (one day to sixteen weeks) [17,18,38–40]. The one intervention, which increased physical activity and improved lipids, was delivered over eight months [36]. Moreover, the magnitude of change in sedentary behaviour (ranging from 118 min/day decrease to 45 min/day increase) or physical activity (8 to 97 min/day increase) across studies may have been insufficient to bring about consistent changes in blood pressure, lipid profile or body composition. Future research should assess whether interventions that target sedentary behaviour over the long-term can produce greater changes in sedentary behaviour and, subsequently, affect CVD biomarkers.

This is the first systematic review to assess the effectiveness of interventions to reduce sedentary behaviour and improve CVD biomarkers in individuals with paraplegia. Key areas for future research have been identified to improve the quality of evidence, which will benefit the development of sedentary behaviour guidelines for this population group. Further strengths include the application of frameworks to guide the reporting, risk of bias and grading of evidence to ensure rigour within the review. Potential limitations include some eligible studies having a high risk of bias and the overall quality of evidence generally being low. Three of the included studies comprised samples of individuals with paraplegia and tetraplegia, which may influence conclusions being made specifically for individuals with paraplegia. In

addition, no studies were powered to detect changes in sedentary behaviour and only two studies were sufficiently powered to detect changes in CVD biomarkers. It is, therefore, recommended that further high-quality studies in individuals with paraplegia are conducted with sufficient power to detect changes in sedentary behaviour and CVD biomarkers.

Conclusion

In conclusion, interventions that target increases in physical activity appear to be ineffective for reducing sedentary behaviour in individuals with paraplegia, but do have beneficial effects on CVD biomarkers. The literature examining interventions that target reductions and breaks in sedentary behaviour in individuals with paraplegia is limited, yet shows potential effectiveness for improving CVD biomarkers. Investigating interventions that focus on changing sedentary behaviour in individuals with paraplegia is an important avenue for future research to inform recommendations for public health and clinical care.

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Data availability statement

All data associated with this review can be found within the included published articles.

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Appendix 2. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) checklist.

Section and Topic	Item #	Checklist item	Reported on page number
TITLE			
Title	1	Identify the report as a systematic review.	55
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	ii, iii
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	55, 56
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	56
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	57-59, Table 1
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	59
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Appendix 3
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	59, 60
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	60
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	60
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	60
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	60
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	61

Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	60, Appendix 4
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	60, Appendix 4
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	60, Appendix 4
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	60, Appendix 4
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	60, 61, Figure 5
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	60, Table 4

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	62, Figure 4
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	N/A
Study characteristics	17	Cite each included study and present its characteristics.	62, 68, 69, Table 2
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	69, 70, Figure 5
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	71-89, Table 3
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	88, 89
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g.	71-89, Table 3

		confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	69, 70, 88, 89, Figure 2
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	89, Table 4
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	91-95
	23b	Discuss any limitations of the evidence included in the review.	95, 96
	23c	Discuss any limitations of the review processes used.	95, 96, Appendix 4
	23d	Discuss implications of the results for practice, policy, and future research.	95, 97
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	57
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	57
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	N/A
Competing interests	26	Declare any competing interests of review authors.	N/A
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	57

Appendix 3. Systematic review database search strings.

EBSCO Host (MEDLINE, SPORTDiscus, CINAHL Plus, APA PsycInfo)

(MH "spinal Cord Injury") OR TI ("parapleg*" OR "spinal cord dysfunction" OR "spinal cord injur*" OR "spinal cord lesion" OR "spinal cord trauma") OR AB ("parapleg*" OR "spinal cord dysfunction" OR "spinal cord injur*" OR "spinal cord lesion" OR "spinal cord trauma")

(MH "physical activity") OR (MH "exercise") OR TI ("exercise" OR "inactivity" OR "physical activity" OR "physical exertion" OR "program*" OR "sedentar*" OR "sit" OR "sitting" OR "training" OR "wheelchair propulsion" OR "wheeling") OR AB ("exercise" OR "inactivity" OR "physical activity" OR "physical exertion" OR "program*" OR "sedentar*" OR "sit" OR "sitting" OR "training" OR "wheelchair propulsion" OR "wheeling")

(MH "cardiovascular diseases") OR TI ("anthropometr*" OR "blood pressure" OR "BMI" OR "body composition" OR "body mass index" OR "cardiometabolic" OR "cardiovascular" OR "cholesterol" OR "CRP" OR "cytokine" OR "diabet*" OR "diastolic" OR "glucose" OR "glycaemi*" OR "glycemi*" OR "hyperglyc*" OR "IL-6" OR "IL-10" OR "inflammat*" OR "insulin" OR "interleukin-6" OR "interleukin-10" OR "lipid*" OR "lipoprotein" OR "metabolic" OR "obese" OR "obesity" OR "overweight" OR "proinflammat*" OR "systolic" OR "TNF-α" OR "TNFα" OR "triglyceride*" OR "tumor necrosis factor" OR "tumour necrosis factor" OR "vascular" OR "waist" OR "weight") OR AB ("anthropometr*" OR "blood pressure" OR "BMI" OR "body composition" OR "body mass index" OR "cardiometabolic" OR "cardiovascular" OR "cholesterol" OR "CRP" OR "cytokine" OR "diabet*" OR "diastolic" OR "glucose" OR "glycaemi*" OR "glycemi*" OR "hyperglyc*" OR "IL-6" OR "IL-10" OR "inflammat*" OR "insulin" OR "interleukin-6" OR "interleukin-10" OR "lipid*" OR "lipoprotein" OR "metabolic" OR "obese" OR "obesity" OR "overweight" OR "proinflammat*" OR "systolic" OR "TNF-α" OR "TNFα" OR "triglyceride*" OR "tumor necrosis factor" OR "tumour necrosis factor" OR "vascular" OR "waist" OR "weight")

(MH "clinical trials") OR PT ("Randomized Controlled Trial" OR "Controlled Clinical Trial" OR "Pragmatic Clinical Trial" OR "Clinical Trial") OR TI ("clinical study" OR "clinical trial" OR "cohort" OR "comparative" OR "controlled" OR "crossover" OR "follow up" OR "followup" OR "follow-up" OR "intervention" OR "nonrandomised" OR "nonrandomized" OR "non-randomised" OR "non-randomized" OR "program*" OR "randomised" OR "randomized" OR "RCT" OR "therapy" OR "trial") OR AB ("clinical study" OR "clinical trial" OR "cohort" OR "comparative" OR "controlled" OR "crossover" OR "follow up" OR "followup" OR "follow-up" OR "intervention" OR "nonrandomised" OR "nonrandomized" OR "non-randomised" OR "non-randomized" OR "program*" OR "randomised" OR "randomized" OR "RCT" OR "therapy" OR "trial")

ClinicalTrials.gov

Study type: Intervention

Condition: Spinal cord injuries

Intervention/treatment: exercise OR inactivity OR physical activity OR physical exertion OR program* OR sedentar* OR sit OR sitting OR training OR wheelchair propulsion OR wheeling

Outcome Measure: blood pressure OR bmi OR body composition OR cardiometabolic OR cardiovascular OR cholesterol OR diabet* OR glucose OR glycem* OR inflammat* OR insulin OR lipid OR lipoprotein OR metabolic OR obes* OR triglycerid* OR vascular OR waist OR weight

Cochrane Library

paraplegia OR paraplegic OR spinal cord dysfunction OR spinal cord injury OR spinal cord injuries OR spinal cord injured OR spinal cord lesion OR spinal cord trauma in Title Abstract Keyword

AND exercise OR inactivity OR physical activity OR physical exertion OR program OR programme OR sedentary OR sedentariness OR sit OR sitting OR training OR wheelchair propulsion OR wheeling in Title Abstract Keyword

AND anthropometry OR anthropometric OR blood pressure OR bmi OR body composition OR body mass index OR cardiometabolic OR cardiovascular OR cholesterol OR CRP OR cytokine OR diabetes OR diabetic OR diastolic OR glucose OR glycaemic OR glycaemia OR glycemic Or glycemia OR hyperglycaemic OR hyperglycaemia OR hyperglycemic OR hyperglycemia OR IL-6 OR IL-10 OR inflammation OR inflammatory OR insulin OR interleukin-6 OR interleukin-10 OR lipid OR lipoprotein OR metabolic OR obese OR obesity OR overweight OR proinflammatory OR proinflammation OR systolic OR TNF-α OR TNFα OR triglyceride OR tumor necrosis factor OR tumour necrosis factor OR vascular OR waist OR weight in Title Abstract Keyword

AND clinical study OR clinical trial OR cohort OR comparative OR controlled OR crossover OR follow up OR followup OR follow-up OR intervention OR nonrandomised OR nonrandomized OR non-randomised OR non-randomized OR program OR programme OR randomised OR randomized OR RCT OR therapy OR trial in Title Abstract Keyword

ISRCTN Registry

Condition: spinal cord injury

PEDro

Abstract and title: spinal cord injury

Method: clinical trial

PubMed

Search: ((((spinal cord injuries[MeSH Terms]) OR (parapleg*[Title/Abstract] OR spinal cord dysfunction[Title/Abstract] OR spinal cord injur*[Title/Abstract] OR spinal cord lesion[Title/Abstract] OR spinal cord trauma[Title/Abstract]))

AND (((sedentary behaviour[MeSH Terms]) OR (exercise[MeSH Terms])) OR (exercise[Title/Abstract] OR inactivity[Title/Abstract] OR physical activity[Title/Abstract] OR physical exertion[Title/Abstract] OR program*[Title/Abstract] OR sedentar*[Title/Abstract] OR sit[Title/Abstract] OR sitting[Title/Abstract] OR training[Title/Abstract] OR wheelchair propulsion[Title/Abstract] OR wheeling[Title/Abstract])))

AND ((cardiovascular diseases[MeSH Terms]) OR (anthropometr*[Title/Abstract] OR blood pressure[Title/Abstract] OR BMI[Title/Abstract] OR body composition[Title/Abstract] OR body mass index[Title/Abstract] OR cardiometabolic[Title/Abstract] OR cardiovascular[Title/Abstract] OR cholesterol[Title/Abstract] OR CRP[Title/Abstract] OR cytokine[Title/Abstract] OR diabet*[Title/Abstract] OR diastolic[Title/Abstract] OR glucose[Title/Abstract] OR glycaemi*[Title/Abstract] OR glycemi*[Title/Abstract] OR hyperglyc*[Title/Abstract] OR IL-6[Title/Abstract] OR IL-10[Title/Abstract] OR inflammat*[Title/Abstract] OR insulin[Title/Abstract] OR interleukin-6[Title/Abstract] OR interleukin-10[Title/Abstract] OR lipid*[Title/Abstract] OR lipoprotein[Title/Abstract] OR metabolic[Title/Abstract] OR obese[Title/Abstract] OR obesity[Title/Abstract] OR overweight[Title/Abstract] OR proinflammat*[Title/Abstract] OR systolic[Title/Abstract] OR TNF-α[Title/Abstract] OR TNFα[Title/Abstract] OR triglycerid*[Title/Abstract] OR tumor necrosis factor[Title/Abstract] OR tumour necrosis factor[Title/Abstract] OR vascular[Title/Abstract] OR waist[Title/Abstract] OR weight[Title/Abstract])))

AND (((clinical trials as topic[MeSH Terms]) OR (clinical study[Publication Type] OR clinical trial[Publication Type] OR controlled clinical study[Publication Type] OR controlled clinical trial[Publication Type] OR multicenter study[Publication Type] OR pragmatic clinical trial[Publication Type] OR randomized controlled trial[Publication Type])) OR (clinical study[Title/Abstract] OR cohort[Title/Abstract] OR comparative[Title/Abstract] OR controlled[Title/Abstract] OR crossover[Title/Abstract] OR follow up[Title/Abstract] OR followup[Title/Abstract] OR follow-up[Title/Abstract] OR intervention[Title/Abstract] OR nonrandomised[Title/Abstract] OR nonrandomized[Title/Abstract] OR non-randomised[Title/Abstract] OR non-randomized[Title/Abstract] OR program*[Title/Abstract] OR randomised[Title/Abstract] OR randomized[Title/Abstract] OR RCT[Title/Abstract] OR therapy[Title/Abstract] OR trial[Title/Abstract]))

Scopus

TITLE-ABS-KEY ("parapleg*" OR "spinal cord dysfunction" OR "spinal cord injur*" OR "spinal cord lesion" OR "spinal cord trauma")

AND TITLE-ABS-KEY ("exercise" OR "inactivity" OR "physical activity" OR "physical exertion" OR "program*" OR "sedentar*" OR "sit" OR "sitting" OR "training" OR "wheelchair propulsion" OR "wheeling")

AND TITLE-ABS-KEY ("anthropometr*" OR "blood pressure" OR "BMI" OR "body composition" OR "body mass index" OR "cardiometabolic" OR "cardiovascular" OR "cholesterol" OR "CRP" OR "cytokine" OR "diabet*" OR "diastolic" OR "glucose" OR "glycaemi*" OR "glycemi*" OR "hyperglyc*" OR "IL-6" OR "IL-10" OR "inflammat*" OR "insulin" OR "interleukin-6" OR "interleukin-10" OR "lipid*" OR "lipoprotein" OR "metabolic" OR "obese" OR "obesity" OR "overweight" OR "proinflammat*" OR "systolic" OR "TNF-α" OR "TNFα" OR "triglyceride*" OR "tumor necrosis factor" OR "tumour necrosis factor" OR "vascular" OR "waist" OR "weight")

AND TITLE-ABS-KEY ("clinical study" OR "clinical trial" OR "cohort" OR "comparative" OR "controlled" OR "crossover" OR "follow up" OR "followup" OR "follow-up" OR "intervention" OR "nonrandomised" OR "nonrandomized" OR "non-randomised" OR "non-randomized" OR "program*" OR "randomised" OR "randomized" OR "RCT" OR "therapy" OR "trial")

Web of Science

(((TS=("parapleg*" OR "spinal cord dysfunction" OR "spinal cord injur*" OR "spinal cord lesion" OR "spinal cord trauma"))

AND TS=("exercise" OR "inactivity" OR "physical activity" OR "physical exertion" OR "program*" OR "sedentar*" OR "sit" OR "sitting" OR "training" OR "wheelchair propulsion" OR "wheeling"))

AND TS=("anthropometr*" OR "blood pressure" OR "BMI" OR "body composition" OR "body mass index" OR "cardiometabolic" OR "cardiovascular" OR "cholesterol" OR "CRP" OR "cytokine" OR "diabet*" OR "diastolic" OR "glucose" OR "glycaemi*" OR "glycemi*" OR "hyperglyc*" OR "IL-6" OR "IL-10" OR "inflammat*" OR "insulin" OR "interleukin-6" OR "interleukin-10" OR "lipid*" OR "lipoprotein" OR "metabolic" OR "obese" OR "obesity" OR "overweight" OR "proinflammat*" OR "systolic" OR "TNF-α" OR "TNFα" OR "triglyceride*" OR "tumor necrosis factor" OR "tumour necrosis factor" OR "vascular" OR "waist" OR "weight"))

AND TS=("clinical study" OR "clinical trial" OR "cohort" OR "comparative" OR "controlled" OR "crossover" OR "follow up" OR "followup" OR "follow-up" OR "intervention" OR "nonrandomised" OR "nonrandomized" OR "non-randomised" OR "non-randomized" OR "program*" OR "randomised" OR "randomized" OR "RCT" OR "therapy" OR "trial")

Appendix 4. Synthesis without meta-analysis (SWiM) in systematic reviews checklist

Reporting item	Item description with examples
METHODS	
1 Grouping studies for synthesis	1a) Provide a description of, and rationale for, the groups used in the synthesis (e.g. groupings of populations, interventions, outcomes, study design) We grouped studies as described below in order to analyse potential effects of these on the review outcomes: • Intervention characteristics (targeting sedentary behaviour or physical activity, use of behaviour change theory, setting, delivery mode, duration). • Study population (sample size and proportion of individuals with paraplegia in the sample). • Methods used to measure the outcome variables (e.g. self-report or devices for sedentary behaviour, fasted or postprandial CVD biomarkers). • Risk of bias (high, low or of some concern).
	1b) Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis The protocol is in line with the latest version of the review protocol published in the PROSPERO online registry (CRD42023420260).
2 Describe the standardized metric and transformation method used	Describe the standardised metric for each outcome. Explain why the metric(s) was chosen, and describe any methods used to transform the intervention effects, as reported in the study, to the standardised metric, citing any methodological guidance used We used the outcome data as it was reported in each eligible study. This consists of means, standard deviations, 95% confidence intervals (CI) and P values. We used these to determine significant effects within each study. Where neither P-values nor CIs were reported, 95% CIs were calculated to infer statistical significance. We did not transform data into a standardised metric.
3 Describe the synthesis methods	Describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis of effect estimates Wide heterogeneity in terms of study designs and interventions was observed along with a limited number of eligible studies,

	meaning a meta-analysis was not possible. Therefore, a qualitative synthesis was used. Eligible studies were grouped into suitable categories to interpret the results. Depending on the data available, this included synthesising the results in the context of sedentary behaviour and CVD biomarker effects. The number of studies that reported a significant effect was reported for each outcome and in context of each data synthesis grouping, guided by P-values or 95% CIs reported in each individual study.
4 Criteria used to prioritise results for summary and synthesis	Where applicable, provide the criteria used, with supporting justification, to select particular studies, or a particular study, for the main synthesis or to draw conclusions from the synthesis (e.g. based on study design, risk of bias assessments, directness in relation to the review question) Results were prioritised according to risk of bias appraisals using Cochrane Risk of Bias 2 [30], and quality of evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) criteria [31]. This is because higher ratings according to these appraisal tools indicates a greater certainty that the true effect is substantially similar to the estimate of effect. Therefore, greater confidence can be placed in these results.
5 Investigation of heterogeneity in reported effects	State the method(s) used to examine heterogeneity in reported effects when it is not possible to undertake a meta-analysis of effect estimates and its extensions to investigate heterogeneity Wide heterogeneity in terms of study designs and interventions was observed along with a limited number of eligible studies. Therefore, we did not calculate a quantitative measurement of heterogeneity. Differences in sample characteristics (e.g. individuals with paraplegia or tetraplegia), intervention characteristics (e.g. targeting physical activity or sedentary behaviour) and outcomes (e.g. self-reported or device-measured sedentary behaviour) variables were identified subjectively upon data extraction. These differences were discussed in the data synthesis, including the effects of these factors on review outcomes. In order to assess the quality of evidence for each study outcome, “inconsistency between studies” needs to be identified. To achieve this, large, unexplained differences in means between studies were identified and interpreted subjectively.
6 Certainty of evidence	Describe the methods used to assess certainty of the synthesis findings

	The overall certainty of evidence was assessed using the GRADE criteria for each outcome in this review [31]. These outcomes related to sedentary behaviour and CVD biomarkers. The GRADE criteria were used to assess certainty of evidence for each outcome across five domains, including risk of bias, inconsistency of results, indirectness of evidence, imprecision and publication bias. Overall certainty of evidence was rated as high, moderate, low or very low.
7 Data presentation methods	Describe the graphical and tabular methods used to present the effects (e.g. tables, forest plots, harvest plots) Specify key study characteristics (e.g. study design, risk of bias) used to order the studies, in the text and any tables or graphs, clearly referencing the studies included Eligibility criteria (Table 1), study characteristics (Table 2), study outcomes (Table 3) and GRADE recommendations (Table 4) are each displayed in tables. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart (Figure 1) and RoB-2 appraisal (Figure 2) are each displayed in figures. Results for article identification, study characteristics, sample characteristics, sedentary behaviour outcomes and CVD biomarker outcomes are displayed in text. Subsequently, sedentary behaviour and CVD biomarker outcomes are displayed in context of the data synthesis categories (as described above in section 3) in-text.
RESULTS	
8 Reporting results	For each comparison and outcome, provide a description of the synthesised findings, and the certainty of the findings. Describe the result in language that is consistent with the question the synthesis addresses, and indicate which studies contribute to the synthesis Sedentary behaviour: Two of the seven interventions which included sedentary behaviour as an outcome led to a reduction [38,40]. Overall quality of evidence was very low. Cardiovascular disease biomarkers: Five of the seven interventions which included CVD biomarkers as an outcome led to an improvement in at least one biomarker [17,18,36,38,39]. One of these also reported a reduction in sedentary behaviour [38], whilst one intervention included supervised breaks in sedentary behaviour [39]. Overall quality of evidence for CVD biomarkers was deemed moderate. Outcomes in context of study population:

	Of the five interventions with a sample comprising only individuals with paraplegia, one led to a reduction in sedentary behaviour [38], one did not include sedentary behaviour as an outcome [39] and the others had no effect on sedentary behaviour [14,18,38]. Of the three interventions with a sample comprising individuals with paraplegia and tetraplegia, one led to a reduction in sedentary behaviour [40] and the others reported no effects [37,41]. Four of five interventions with a sample comprising only individuals with paraplegia led to an improvement in one or more CVD biomarkers [17,18,38,39]. Of the three interventions with a sample comprising individuals with paraplegia and tetraplegia, one reported a reduction in CVD biomarkers [36], one did not include any CVD biomarkers as an outcome variable [41] and the other had no effect [40]. Outcomes in context of intervention characteristics: *Targeting physical activity or sedentary behaviour* Of the six interventions that targeted increases in physical activity, one led to a reduction in sedentary behaviour [40]. One intervention targeted sedentary behaviour and led to a reduction in this outcome [38], whilst another included supervised breaks in sedentary behaviour and did not include sedentary behaviour as an outcome [39]. Of the six interventions that targeted increases in physical activity, three reported an improvement in at least one CVD biomarker [17,18,36]. Both interventions that targeted sedentary behaviour reported an improvement in at least one CVD biomarker [38,39]. *Intervention duration* The two interventions that reduced sedentary behaviour were 16 weeks in duration [38,40]. The interventions that did not affect sedentary behaviour were six weeks [14,18] sixteen weeks [38], six months [41] and eight months [37] in duration. Of the five interventions that improved a CVD biomarker, one lasted one day [39], two lasted six weeks [17,18], one lasted sixteen weeks [38] and one lasted eight months [36]. The only interventions that did not lead to an improvement both lasted 16 weeks [38,40]. *Intervention setting and delivery mode* One of the two interventions that reduced sedentary behaviour was a home-based online programme [40] and one was a home- and community-based programme [38]. Three of the interventions that did not reduce sedentary behaviour were home- and community-based exercise training protocols

	[14,18,38], whilst one included motivational interviewing within a rehabilitation centre [37], and the other was an exercise training protocol within a rehabilitation centre [41]. Two of the five interventions that improved CVD biomarkers included home-based exercise training protocols [17,18], one was a home- and community-based programme [38], one involved motivational interviewing within a rehabilitation centre [36] and one involved supervised breaks in sedentary behaviour in a controlled laboratory setting [39]. The interventions that did not improve CVD biomarkers were a home-based online programme [40] and a home- and community-based exercise training protocol [38]. *Behaviour change theory* Both of the interventions that improved sedentary behaviour used behaviour change theory [38,40], whilst two of the five interventions that did not see an improvement used behaviour change theory [37,38]. Two of the five interventions to improve CVD biomarkers used behaviour change theory [36,38], whilst two interventions that did not see an improvement also used behaviour change theory [38,40]. Measurement of outcomes: One of the interventions to improve sedentary behaviour measured this outcome using self-report [40], whilst the other used heart rate zones [38]. Those that did not improve sedentary behaviour used accelerometery [14,18,37], heart rate zones [38] and self-report [41]. One of the five interventions that improved CVD biomarkers only improved biomarkers measured in a fasted state (insulin and insulin resistance) but also measured postprandial outcomes [17]. Another study only measured biomarkers in a fasted state, with the intervention leading to improvements in diastolic blood pressure, LDL cholesterol and total cholesterol [36]. One intervention reported improvements in postprandial glucose [39], whilst the other reported improvements in the Matsuda index, measured using fasted and postprandial measurements [18]. One intervention that reported an improvement in systolic blood pressure measured this after a six-minute push test, as opposed to at rest [38]. Other CVD biomarkers were assessed similarly across studies. Risk of bias: Both interventions that improved sedentary behaviour had a high risk of bias [38,40]. Interventions that did not improve sedentary

	behaviour were either low risk [14,18], high risk [38] or raised some concerns [37]. Three of the five interventions that improved CVD biomarkers were low risk of bias [17,18,39], whilst one was high risk [38] and the other raised some concerns [36]. Both interventions that did not improve any biomarkers were high risk [38,40].
Discussion	
9 Limitations of the synthesis	Report the limitations of the synthesis methods used and/or the groupings used in the synthesis, and how these affect the conclusions that can be drawn in relation to the original review question Wide heterogeneity in study characteristics and outcomes, and a low number of eligible studies, meant it was not possible to undertake a meta-analysis. Instead, we employed a subjective, qualitative synthesis comprising vote counting of significant effects versus non-significant effects. Not all studies reported P values for every outcome, meaning significance had to be inferred by 95% CIs for some outcomes in some studies.

Appendix 5. COnsolidated criteria for Reporting Qualitative studies (COREQ): 32-item checklist.

No. Item	Guide questions/description	Reported on Page #
Domain 1: Research team and reflexivity		
Personal Characteristics		
1. Interviewer/facilitator	Which author/s conducted the interview or focus group?	101
2. Credentials	What were the researcher's credentials? E.g. PhD, MD	101
3. Occupation	What was their occupation at the time of the study?	101
4. Gender	Was the researcher male or female?	101
5. Experience and training	What experience or training did the researcher have?	20, 101
Relationship with participants		
6. Relationship established	Was a relationship established prior to study commencement?	101
7. Participant knowledge of the interviewer	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	101
8. Interviewer characteristics	What characteristics were reported about the interviewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	20, 101
Domain 2: study design		
Theoretical framework		
9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	101
Participant selection		
10. Sampling	How were participants selected? e.g. purposive, convenience, consecutive, snowball	104-106
11. Method of approach	How were participants approached? e.g. face-to-face, telephone, mail, email	104-106
12. Sample size	How many participants were in the study?	106, 110, Figure 6, Table 5
13. Non-participation	How many people refused to participate	Figure 6

	or dropped out? Reasons?	
Setting		
14. Setting of data collection	Where was the data collected? e.g. home, clinic, workplace	101
15. Presence of non-participants	Was anyone else present besides the participants and researchers?	N/A
16. Description of sample	What are the important characteristics of the sample? e.g. demographic data	110, Table 5
Data collection		
17. Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	101, Appendices 16-21
18. Repeat interviews	Were repeat interviews carried out? If yes, how many?	101, Figure 1, Figure 2
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?	108
20. Field notes	Were field notes made during and/or after the interview or focus group?	N/A
21. Duration	What was the duration of the interviews or focus group?	110
22. Data saturation	Was data saturation discussed?	106
23. Transcripts returned	Were transcripts returned to participants for comment and/or correction?	N/A
Domain 3: analysis and findings		
Data analysis		
24. Number of data coders	How many data coders coded the data?	108
25. Description of the coding tree	Did authors provide a description of the coding tree?	Table 6, Table 7, Appendix 22
26. Derivation of themes	Were themes identified in advance or derived from the data?	108
27. Software	What software, if applicable, was used to manage the data?	108
28. Participant checking	Did participants provide feedback on the findings?	108, 109
Reporting		
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	119-121, Table 6, Appendix 22
30. Data and findings consistent	Was there consistency between the data presented and the findings?	119-121, Table 6, Appendix 22

31. Clarity of major themes	Were major themes clearly presented in the findings?	119-121, Table 6, Table 7 Appendix 22
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	Appendix 22

Developed from:

Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*. 2007. Volume 19, Number 6: pp. 349 – 357

Appendix 6. Brunel ethical approval for co-design study.

College of Health, Medicine and Life Sciences Research Ethics Committee (DLS)
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

29 April 2024

CONDITIONAL LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 03/05/2024 AND 31/12/2024

Applicant (s): Mr Daniel Cooper Dr Daniel Bailey, Dr Alyson Warland, Dr Emma Norris, Professor Cherry Kilbride, Ms Sue Paddison

Project Title: Designing a programme to support individuals with paraplegia to be more active

Reference: 47898-NHS-Apr/2024- 50821-2

Dear Mr Daniel Cooper

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

Please can you amend the PIS under "What will happen to the results of the research study?", to a minimum of 10 years.

- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to any conditions that may appear above.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.

Professor Louise Mansfield

Chair of the College of Health, Medicine and Life Sciences Research Ethics Committee (DLS)

Brunel University London

Appendix 7. NHS ethical approval for co-design study.

Dr Daniel Bailey
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH

Email: approvals@hra.nhs.uk
HCRW.approvals@wales.nhs.uk

10 June 2024

Dear Dr Bailey

HRA and Health and Care Research Wales (HCRW) Approval Letter

Study title:	**Designing a programme to support individuals with paraplegia to be more active**
IRAS project ID:	**339045**
Protocol number:	**1**
REC reference:	**24/PR/0621**
Sponsor	**Brunel University London**

I am pleased to confirm that **HRA and Health and Care Research Wales (HCRW) Approval** has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications received. You should not expect to receive anything further relating to this application.

Please now work with participating NHS organisations to confirm capacity and capability, in line with the instructions provided in the "Information to support study set up" section towards the end of this letter.

How should I work with participating NHS/HSC organisations in Northern Ireland and Scotland?
HRA and HCRW Approval does not apply to NHS/HSC organisations within Northern Ireland and Scotland.

If you indicated in your IRAS form that you do have participating organisations in either of these devolved administrations, the final document set and the study wide governance report (including this letter) have been sent to the coordinating centre of each participating nation. The relevant national coordinating function/s will contact you as appropriate.

Appendix 8. Co-design participant information sheet.

PARTICIPANT INFORMATION SHEET

Study title
Designing a programme to support individuals with paraplegia to be more active

Invitation Paragraph
You are being asked to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask the research team if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

How do I sign up to take part?
If you decide you want to take part, please email daniel.cooper2@brunel.ac.uk.

What is the purpose of the study?
People with paraplegia have a higher risk of heart disease and stroke. This might be because they spend a lot of time being sedentary (i.e. using low amounts of energy due to inactivity). Sedentary behaviours include things like watching TV, working on a computer or browsing social media while sitting or lying down. In non-disabled people, there have been a number of programmes to reduce sedentary behaviour that have led to improvements in heart health markers such as blood sugar, blood pressure and cholesterol levels. We don't know how well programmes to reduce sedentary behaviour work in manual wheelchair users with paraplegia.

The purpose of this research is to co-design a programme to support manual wheelchair users with paraplegia reduce their sedentary behaviour and improve their heart health.

Why have I been invited to participate?
We want to involve a range of people in designing the programme. You have been invited to participate as either:

- You have paraplegia (a spinal cord injury at T1 or below). To be eligible, you need to be 18 years or older, use a manual wheelchair as your main method of mobility during the day, and have the ability to travel to Brunel University London campus and / or take part in online video calls.

- You are a healthcare professional who works full-time or part-time in a healthcare profession within a hospital, clinic or the community for which your work mainly involves providing care or services for individuals with a spinal cord injury. This may include, but is not limited to, physiotherapists, occupational therapists, or rehabilitation assistants.

- You are an adult (aged at least 18 years old) who provides care, services or support to individuals with spinal cord injury in their home or the community. This may include friends, family, carers, or non-healthcare professionals working part-time or full-time for an organisation or charity. You must be able to take part in online video calls.

We are aiming to recruit 10 individuals from each of these three groups.

Do I have to take part?
As participation is entirely voluntary, it is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and you will be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time without having to give a reason. Data you have already provided will continue to be used in analysis of the study results.

What will happen to me if I take part?
Individuals with paraplegia:
You will take part in two workshops that are likely to last around 3 hours each. Workshops will take place at Brunel University London campus (Uxbridge) and online using Microsoft Teams video calls. We will let you know beforehand which workshops will take place in-person or online. Each workshop will include around six to eight people with paraplegia.

Healthcare professionals:
You will take part in two workshops that are likely to last around 1 ½ hours each. These will take place in a meeting room at the Royal National Orthopaedic Hospital. Each workshop will include around six to eight healthcare professionals.

People who provide support to individuals with paraplegia in the community:
You will take part in two workshops that are likely to last around 2 hours each. Workshops will take place online via Microsoft Teams video calls. Each workshop will include around six to eight people who provide support to individuals with paraplegia in the community.

All participants:
All workshops will take place on different days across a number of weeks. The first workshop will involve tasks and activities to encourage group discussions based around experiences, opinions and beliefs relating to sedentary behaviour and ideas for designing a programme for individuals with paraplegia. In the second workshop, participants will discuss and evaluate ideas for a sedentary behaviour programme. We will then test how well this programme works in a future study. During each visit to Brunel University London, lunch and refreshments will be provided.

What are the possible disadvantages and risks of taking part?

There is a small risk that talking about experiences around sedentary behaviour may cause some psychological stress. You may end your involvement in the workshop at any time without giving a reason and you will be signposted to support services such as the Samaritans, Spinal Injuries Association, Aspire, Back Up Trust or support from your GP if appropriate. You can have someone attend the workshops with you if this would make you more comfortable.

What are the possible benefits of taking part?
Whilst there are no direct benefits of taking part, you will help to design a sedentary behaviour programme that may lead to improvements in healthcare and heart health of individuals with paraplegia in the future. We will provide an Amazon gift voucher to individuals with paraplegia (£30) and people who provide support to individuals with paraplegia in the community (£10) for each workshop you attend after the study as a token of appreciation for taking part. For any in-person workshops, we will reimburse all of your travel expenses. If you wish, you will also be provided with a summary of the findings from the study after it is finished.

How will we use information about you?
We will need to use information from you for this research project.
This information will include:

- Your initials
- Name
- Contact details

People will use this information to do the research or to make sure that the research is being done properly. People who do not need to know who you are will not be able to see your name or contact details. Your data will have a code number instead. We will keep all information about you safe and secure.

What are your choices about how your information is used?
You can stop being part of the study at any time, without giving a reason, but we will keep information about you that we already have. We need to manage your records in specific ways for the research to be reliable. This means that we won't be able to let you see or change the data we hold about you. If you agree to take part in this study, you will have the option to take part in future research using your data saved from this study. This will be stored on a secure Brunel University London server.

Where can you find out more about how your information is used?
You can find out more about how we use your information:

- at www.hra.nhs.uk/information-about-patients/
- our leaflet available from www.hra.nhs.uk/patientdataandresearch
- by asking one of the research team
- by sending an email to Brunel University London's data protection team at data-protection@brunel.ac.uk

Will I be recorded, and how will the recording be used?

In-person workshops will be audio recorded on portable audio recording equipment, whilst online workshops will be audio and video recorded using the recording function on Microsoft Teams. During the workshops, you will be asked and reminded of the recording before it starts. Recording will be transcribed (written up word-for-word) and analysed by the research team for use in research papers. All names and identities will be fully anonymised. Recordings will be deleted after they have been transcribed.

What will happen to the results of the research study?
The results of the research will be written up as part of a PhD degree dissertation, as a research paper and may be presented at a conference so we can share the findings with other researchers and healthcare professionals. The PhD dissertation will be published in the Brunel University Research Archive. Selected parts of anonymised transcripts will be made publicly available online in Brunel University London's open repository if you consent to this. Participants will not be identified in any of the results we share. A summary of the results will be shared with you by email if you indicate that you want this in the consent form. Non-identifiable data will be stored on a secure University server for at least 10 years after the study has finished so they can be used for publishing and to help inform future research.

What if something goes wrong?
Given the low-risk nature of the study, it is unlikely that you will suffer any harm from participation in this study. If something goes wrong, then please contact Mr Daniel Cooper (daniel.cooper2@brunel.ac.uk) or Dr Daniel Bailey (daniel.bailey@brunel.ac.uk) as soon as possible to explain the problem or ask any questions. We will work with you to find a resolution. If you would like to make a complaint or discuss a problem with someone outside of the research team, then please contact Chair of the Research Ethics Committee: Professor Christina Victor (christina.victor@brunel.ac.uk). All contact details can be found at the bottom of this form.

Who is organising the research?
This study is being organised by researchers at Brunel University London in conjunction with the Royal National Orthopaedic Hospital NHS Trust.

What are the indemnity arrangements?
Brunel University London provides appropriate insurance cover for research which has received ethical approval. In the event of a claim where negligence cannot be demonstrated, the claimant may seek legal action, for which they would need to pay.

Who has reviewed the study?
This study has been reviewed and a favourable opinion provided by the [INSERT REC NAME] NHS Research Ethics Committee and the Brunel University London College of Health, Medicine and Life Sciences Research Ethics Committee.

Research Integrity

Brunel University London is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from the researchers during the course of this research.

Where can you find out more about how your information is used?

You can find out more about how we use your information at:

- www.hra.nhs.uk/information-about-patients/
- our leaflet available from www.hra.nhs.uk/patientdataandresearch
- by asking one of the research team
- by sending an email to data-protection@brunel.ac.uk

Contact for further information and complaints

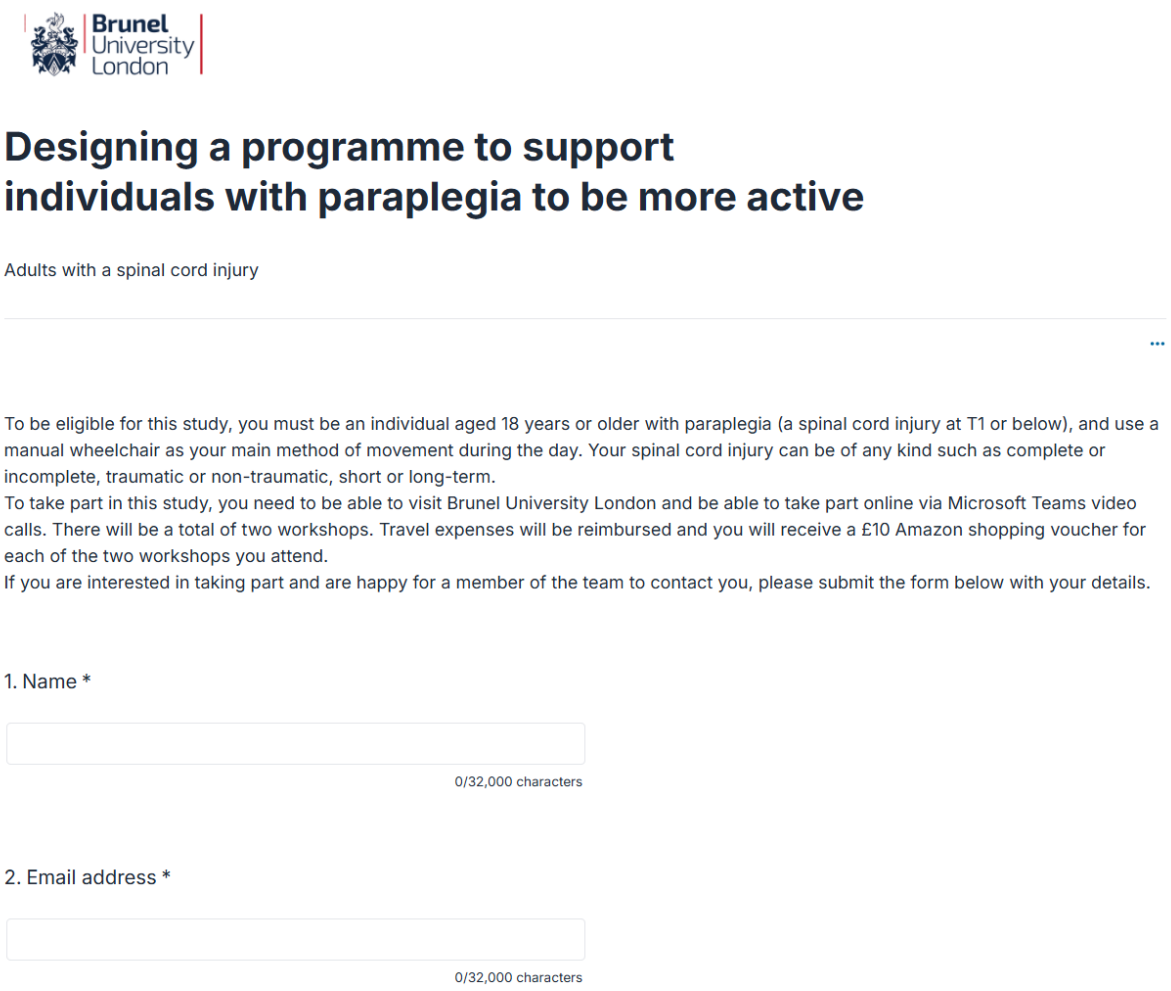
Researcher name and details:
Mr Daniel Cooper (daniel.cooper2@brunel.ac.uk)

Supervisor name and details:
Dr Daniel Bailey (daniel.bailey@brunel.ac.uk)

For complaints and questions about the conduct of the research:
Professor Christina Victor, Chair of Brunel University London Research Ethics Committee (christina.victor@brunel.ac.uk)

Appendix 9. Co-design recruitment poster.

Appendix 10. Co-design expression of interest form (individuals with paraplegia).



Brunel University London

Designing a programme to support individuals with paraplegia to be more active

Adults with a spinal cord injury

To be eligible for this study, you must be an individual aged 18 years or older with paraplegia (a spinal cord injury at T1 or below), and use a manual wheelchair as your main method of movement during the day. Your spinal cord injury can be of any kind such as complete or incomplete, traumatic or non-traumatic, short or long-term.
To take part in this study, you need to be able to visit Brunel University London and be able to take part online via Microsoft Teams video calls. There will be a total of two workshops. Travel expenses will be reimbursed and you will receive a £10 Amazon shopping voucher for each of the two workshops you attend.
If you are interested in taking part and are happy for a member of the team to contact you, please submit the form below with your details.

1. Name *

0/32,000 characters

2. Email address *

0/32,000 characters

3. Phone number *

0/32,000 characters

4. Town/city where you live (so we can check your distance from Brunel University London) *

0/32,000 characters

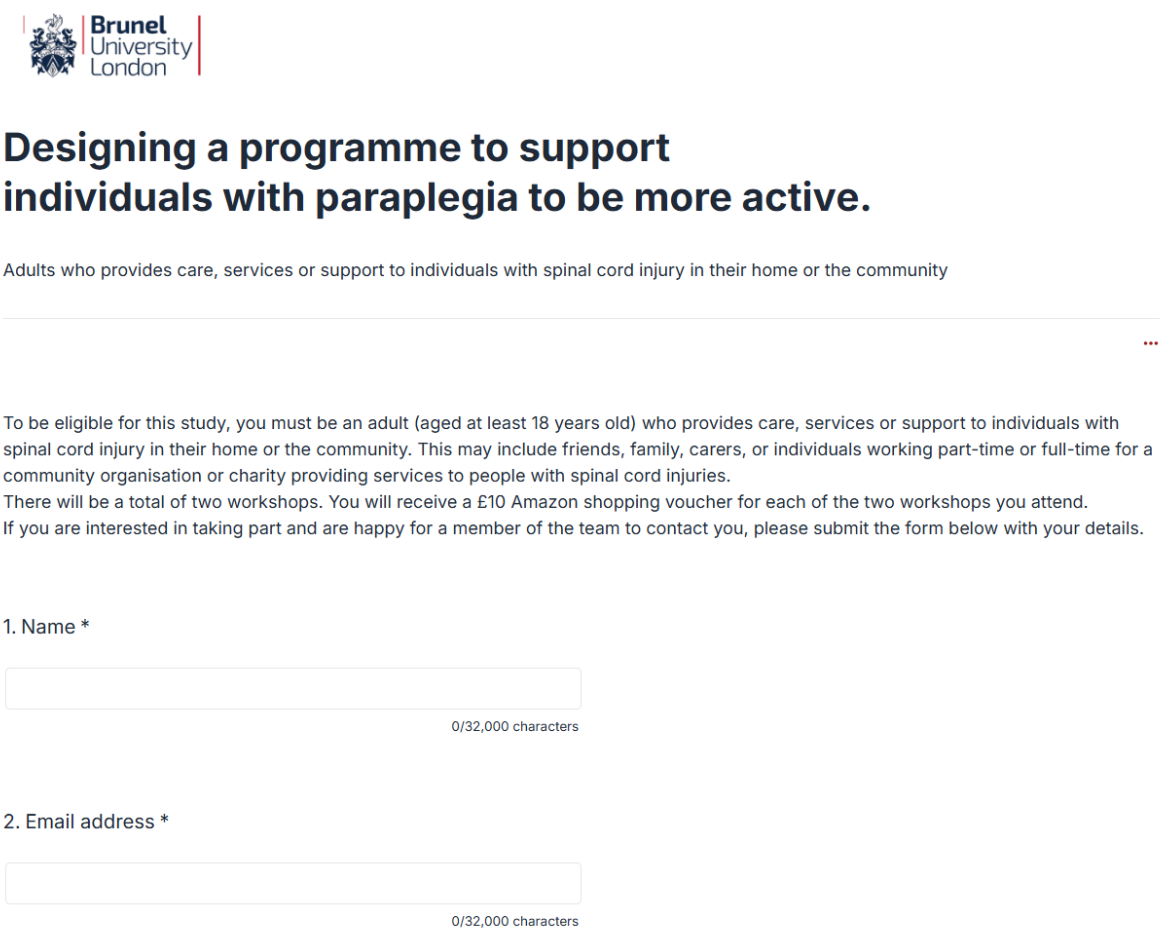
5. How did you hear about the study? (i.e. which specific social media group or website?)

0/32,000 characters

If you have any more questions, want more information about the study, or want to check if you are eligible, please contact Daniel Cooper by email at daniel.cooper2@brunel.ac.uk or by phone on [redacted]
Please press the 'Submit' button below to submit your responses.
By submitting this form I am providing my consent for the research team to contact me about participation in this study using the contact details I provided above.

Submit

Appendix 11. Co-design expression of interest form (community caregivers).



Brunel University London

Designing a programme to support individuals with paraplegia to be more active.

Adults who provides care, services or support to individuals with spinal cord injury in their home or the community

To be eligible for this study, you must be an adult (aged at least 18 years old) who provides care, services or support to individuals with spinal cord injury in their home or the community. This may include friends, family, carers, or individuals working part-time or full-time for a community organisation or charity providing services to people with spinal cord injuries.
There will be a total of two workshops. You will receive a £10 Amazon shopping voucher for each of the two workshops you attend.
If you are interested in taking part and are happy for a member of the team to contact you, please submit the form below with your details.

1. Name *

0/32,000 characters

2. Email address *

0/32,000 characters

3. Phone number *

0/32,000 characters

4. How did you hear about the study?

0/32,000 characters

If you have any more questions, want more information about the study, or want to check if you are eligible, please contact Daniel Cooper by email at **daniel.cooper2@brunel.ac.uk** or by phone on [redacted]
Please press the 'Submit' button below to submit your responses.
By submitting this form I am providing my consent for the research team to contact me about participation in this study using the contact details I provided above.

Submit

Appendix 12. Co-design participant eligibility questionnaire (individuals with paraplegia).

Study eligibility questionnaire

Thank you for your interest in participating in this research study.
In order to check your eligibility for the study, please answer the following questions:

1. What is your full name? *

0/32,000 characters

2. What is your email address? *

0/32,000 characters

3. What is the level of your spinal cord injury (e.g. T1, L4)? *

0/32,000 characters

4. What is the completeness of your spinal cord injury (e.g. complete, incomplete)? *

5. How long have you had a spinal cord injury for? *

0/32,000 characters

6. If it has been less than 2 years since your spinal cord injury, are you currently an in-patient or have you been recently discharged?

0/32,000 characters

7. Do you use a manual wheelchair as your main way of getting around throughout the day (Yes/No)? *

0/32,000 characters

8. What is your age in years? *

0/32,000 characters

9. What is your biological sex? *

0/32,000 characters

10. Can you communicate verbally using English? *

0/32,000 characters

11. Are you able to participate in an online video call using Microsoft Teams? *

0/32,000 characters

12. Are you able to travel to Brunel University London (Uxbridge, West London) to participate in an in-person workshop? *

0/32,000 characters

Please press the 'Submit' button below to submit your responses.

Submit

Appendix 13. Co-design participant eligibility questionnaire (community caregivers).

Study eligibility questionnaire.

Thank you for your interest in participating in this research study.
In order to check your eligibility for the study, please answer the following questions:

1. What is your full name?

0/32,000 characters

2. What is your email address?

0/32,000 characters

3. What is your relationship to an individual(s) with a spinal cord injury (e.g. parent, friend, carer, charity worker, community support worker)?

0/32,000 characters

4. What is your age in years?

0/32,000 characters

5. What is your biological sex?

0/32,000 characters

6. Can you communicate verbally using English?

0/32,000 characters

7. Are you able to participate in an online video call using a Microsoft Teams?

0/32,000 characters

Please press the 'Submit' button below to submit your responses.

Submit

Appendix 14. Co-design participant consent form (individuals with paraplegia and community caregivers).

CONSENT FORM

Designing a programme to support individuals with paraplegia to be more active

Principal Investigator: Dr Daniel Bailey

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 03/05/2024 AND 31/12/2024

The participant (or their legal representative) should complete the whole of this sheet.		
	YES	NO
Have you read the Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Who have you spoken to about the study?		
Do you understand that you will not be referred to by name in any report concerning this study?	☐	☐
Do you understand that:		
• You are free to withdraw from this study at any time	☐	☐
• You don't have to give any reason for withdrawing	☐	☐
• If you withdraw, data you have already provided will continue to be used in analysis of the study results	☐	☐
• Choosing not to participate or withdrawing will not affect your present or future medical care or services that you are entitled to	☐	☐
I agree to the workshops being recorded	☐	☐

I agree to the use of non-attributable (anonymous) quotes when the study is written up or published	☐	☐
The procedures regarding confidentiality have been explained to me	☐	☐
I understand that data collected during the study may be looked at by individuals from regulatory authorities, where it is relevant to my participation in this study, for auditing and monitoring purposes	☐	☐
I agree to take part in this study.	☐	☐

Additional Questions (Optional)		
	YES	NO
I agree that my anonymised data can be stored and shared with other researchers for use in future projects.	☐	☐
I agree that my contact details can be stored so that I can be contacted about taking part in future research projects	☐	☐
I agree to my spoken data (quotations) being made publicly available in an online open research repository	☐	☐
I would like to receive a summary of the results from this study by email	☐	☐

Signature of research participant:	
Print name:	Date:

Signature of person taking consent:	
Print name:	Date:

Filing arrangements: 1 copy for participant, 1 copy for site file.

Appendix 15. Co-design participant consent form (healthcare professionals).

CONSENT FORM

Designing a programme to support individuals with paraplegia to be more active

Principal Investigator: Dr Daniel Bailey

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 03/05/2024 AND 31/12/2024

The participant (or their legal representative) should complete the whole of this sheet.		
	YES	NO
Have you read the Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Who have you spoken to about the study?		
Do you understand that you will not be referred to by name in any report concerning this study?	☐	☐
Do you understand that:		
• You are free to withdraw from this study at any time	☐	☐
• You don't have to give any reason for withdrawing	☐	☐
• If you withdraw, data you have already provided will continue to be used in analysis of the study results	☐	☐
• Choosing not to participate or withdrawing will not affect your present or future medical care or services that you are entitled to	☐	☐
I agree to the workshops being recorded	☐	☐
I agree to the use of non-attributable (anonymous) quotes when the study is written up or published	☐	☐

The procedures regarding confidentiality have been explained to me	☐	☐
I understand that data collected during the study may be looked at by individuals from regulatory authorities, where it is relevant to my participation in this study, for auditing and monitoring purposes	☐	☐
I agree to take part in this study.	☐	☐

Additional Questions (Optional)		
	YES	NO
I agree that my anonymised data can be stored and shared with other researchers for use in future projects.	☐	☐
I agree that my contact details can be stored so that I can be contacted about taking part in future research projects	☐	☐
I agree to my spoken data (quotations) being made publicly available in an online open research repository	☐	☐
I would like to receive a summary of the results from this study by email	☐	☐

Signature of research participant:	
Print name:	Date:
Job title:	

Signature of person taking consent:	
Print name:	Date:

Filing arrangements: 1 copy for participant, 1 copy for site file.

Appendix 16. Co-design workshop 1 guide (individuals with paraplegia).

PwP Workshop 1 guide

Part A: Introduction (10 minutes)

Introduction

- Introduce myself as well as any other researchers facilitating the session
- Express gratitude for involvement of all the participants
- Address confidentiality - all information collected will be confidential and participant names will not be disclosed in the final report. I hope this encourages you to speak openly and freely
- Stress that there are no wrong answers - it's their opinion which counts, so don't be afraid of expressing a different view to others
- The information shared by someone else in this workshop should not be shared with anyone outside of the group
- Ground rules – please ensure mobile phones are on silent. Please ensure you speak clearly and avoid interrupting others. Please show respect for others - everyone's views are of interest.

Consent

- Please ensure you have signed the consent form and handed this to the research team
- Please be aware that in taking part in this workshop, you consent to it being audio recorded

Aims

- To understand obstacles that get in the way of breaking up and reducing sedentary behaviour
- To identify potential solutions to overcome these obstacles that could be included in an programme to support breaking up and reducing sedentary behaviour

Icebreaker

Start with a brief icebreaker to make participants comfortable and allow them to get to know each other:

- Participants and facilitators take turns to each introduce themselves by sharing their name and why they signed up to take part in this study.

Part B: Definitions (10 minutes)

Researchers will go through key definitions, with examples. Written definitions also will be provided to participants, to refer to throughout the co-design activities.

- **Sedentary behaviour**
    - Being inactive or stationary during the day, and using up small amounts of energy
    - E.g. watching TV, playing video games, sitting at work, travelling in a car
- **Break in sedentary behaviour**
    - When you interrupt being sedentary with any type of physical activity (however light)
    - E.g. After 30 minutes of watching TV, you do 5 minutes of housework

Part C: Experiences related to sedentary behaviour (10 minutes)

Participants will create post it notes answering the first question below. This will spark a group discussion guided by the responses provided to this question. After which, each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- What are your experiences related to sedentary behaviour?
    - Prompts:
        - How has this changed since your SCI?
        - How do you feel about your current sedentary behaviour levels? Positively or negatively
- Do you try to limit the amount of time you spend being sedentary? If so, how?
    - Prompts:
        - How often do you try and break up sedentary periods?
        - How much time being spent sedentary is too much?
- How do you feel when you are sedentary for long periods?
    - Prompts:
        - How does it affect things like your feelings or mood?

Part D: Capability Barriers (15 minutes)

Participants will be prompted to write post-notes to individually answer the following question. Participants will be invited to share their responses, initiating a group discussion.

What might affect your capability to break up and reduce sedentary behaviour?

Prompts

- Physical barriers, like fatigue or pain
- Skill-related barriers, like wheelchair skills
- Psychological barriers, like knowledge, memory, attention or awareness

Make notes here of the barriers/facilitators suggested:

Part E: Capability Solutions (15 minutes)

Participants will be prompted to answer the following question, guided by the barriers in the post it notes written in the previous section, initiating a group discussion.

What <u>solutions</u> do you think there could be to overcome the obstacles we just discussed?

Prompts

- Improving fitness, improving wheelchair skills, doing non-sedentary activities when you have more energy or less pain
- Including sedentary behaviour in healthcare, educational resources on sedentary behaviour
- Tracking your sedentary behaviour (wearables, apps)
- Reminders to break up sedentary behaviour (wearables, timers, apps)

Keep in mind:

- How could this be delivered or supported?
- When would it ideally happen?
- Where?
- How often?
- Supported by whom?

Part F: Opportunity Barriers (15 minutes)

Participants will be prompted to write post-notes to individually answer the following question. Participants will be invited to share their responses, initiating a group discussion.

What might affect your <u>opportunity</u> to break up and reduce sedentary behaviour?

Prompts:

- Your social circle, like friends and family
- Physical environment, like in the home, local area or workplace (time, space, facilities, services)

Make notes here of the barriers/facilitators suggested:

Part G: Opportunity Solutions (15 minutes)

Participants will be prompted to answer the following question, guided by the barriers in the post it notes written in the previous section, initiating a group discussion.

What <u>solutions</u> do you think there could be to overcome the obstacles we just discussed?

Prompts:

- Doing physical activity together, talking together about sedentary behaviour, giving you advice about sedentary behaviour, messages on social media
- Support groups / peer exercise groups
- Your house, your workplace, your local area, or the facilities/equipment you have access to. How could they be changed?

Keep in mind:

- How could this be delivered or supported?
- When would it ideally happen?
- Where?
- How often?
- Supported by whom?

Part H: Motivation Barriers (15 minutes)

Participants will be prompted to write post-notes to individually answer the following question. Participants will be invited to share their responses, initiating a group discussion.

What might affect your <u>motivation</u> to break up and reduce sedentary behaviour?

Prompts:

- Self-belief that you can do it
- Awareness of benefits
- Goals
- Being rewarded
- Mood

Make notes here of the barriers/facilitators suggested:

Part I: Motivation Solutions (15 minutes)

Participants will be prompted to answer the following question, guided by the barriers in the post it notes written in the previous section, initiating a group discussion.

What <u>solutions</u> do you think there could be to overcome the obstacles we just discussed?

Prompts:

- Goal setting (weekly challenges, changing goals, personalised goals)
- Make them more optimistic about reducing sedentary behaviour
    - including sedentary behaviour in healthcare
    - information from charities or on social media groups
- Improve your self-belief/building up confidence
    - goal setting with achievable targets
    - rewards
    - role models
    - Regular feedback on sedentary behaviour/progress
- Rewards such as praise, financial, feedback, sense of pride/accomplishment, gifts, in-app points, streaks
- Mood/emotional support
    - Mood tracking
    - When planning physical activity/exercise, being flexible around your mood
    - Referrals
    - Counselling/coaching
    - Online resources

Keep in mind:

- How could this be delivered or supported?
- When would it ideally happen?
- Where?
- How often?
- Supported by who

Part J: Conclusion (5 minutes)

- Thank participants for their time and valuable insights
- Provide information on the timeline of the study and when they can expect to see the results of their contributions
- Inform participants of time, date and location of the next workshop

Appendix 17. Co-design workshop 1 guide (healthcare professionals).

HCP Workshop 1 guide

Part A: Introduction (5 minutes)

Introduction

- Introduce myself as well as any other researchers facilitating the session
- Express gratitude for involvement of all the participants

Consent

- Please ensure you have signed the consent form and handed this to the research team
- Please ensure you have signed the consent form and handed this to the research team
- Anything you share will be completely confidential

Aims

- To understand obstacles that get in the way of breaking up and reducing sedentary behaviour in people with paraplegia
- To identify potential solutions to overcome these obstacles that could be included in an intervention to support breaking up and reducing sedentary behaviour
- We are designing a programme for when they are 'at home' and/or in the community after discharge from in-patients
- So, any insights around the inpatient to at-home transition and certainly the earlier barriers faced after discharge are welcomed

Part B: Definitions (5 minutes)

- **Sedentary behaviour**
    - Activities we do whilst sitting or lying down when we are awake, that use up small amounts of energy
    - E.g. watching TV, playing video games, sitting at work, travelling in a car
- **Break in sedentary behaviour**
    - When you interrupt being sedentary with either standing or any type of physical activity (however light)
    - E.g. After 30 minutes of watching TV you do 5 minutes of housework

Part C: Capability (12 minutes)

In individuals with paraplegia, what might affect their capability to break up and reduce sedentary behaviour?

Prompts

- Physical barriers, like fatigue or pain
- Psychological barriers, like knowledge, memory or attention

Make notes here of the barriers/solutions suggested:

Part D: Opportunity (12 minutes)

What might affect their <u>opportunity</u> to break up and reduce sedentary behaviour?

Prompts:

- Their social circle, like friends and family
- Physical environment, like in the home or workplace

Make notes here of the barriers/solutions suggested:

Part E: Motivation (12 minutes)

What might affect their <u>motivation</u> to break up and reduce sedentary behaviour?

Prompts:

- Self-belief that they can do it
- Awareness of benefits
- Goals
- Being rewarded
- Mood

Make notes here of the barriers/solutions suggested:

What <u>solutions</u> could there be to overcome the obstacles we just discussed? (12 minutes)

For each potential solution, ask:

- How could this be delivered or supported?
- When would it ideally happen?
- Where?
- How often?
- Supported by whom?

<u>Capability:</u>

Physical

- E.g. improving fitness, doing non-sedentary activities when you have more energy or less pain

Psychological (knowledge)

- E.g. Including sedentary behaviour in healthcare, information from charities or on social media groups

Psychological (memory)

- E.g. wearables, timers, apps, reminders from other people

<u>Opportunity:</u>

Social

- E.g. doing physical activity together, talking together about sedentary behaviour, giving you advice about sedentary behaviour, messages on social media

Physical (environment, resources)

- e.g. their house, their workplace, the facilities they have access to. How would they be changed?

<u>Motivation:</u>

Goals

- e.g. weekly challenges, changing goals, personalised goals

Beliefs about capabilities

- E.g. building up confidence, goal setting with achievable targets, rewards, role models (social media, online influencers etc.)

Automatic (reinforcement, reward)

- E.g. praise, financial, feedback, sense of pride/accomplishment, gifts, in-app points, streaks

Automatic (emotions)

- e.g. mood tracking, referrals, online resources

Appendix 18. Co-design workshop 1 guide (community caregivers).

CCG Workshop 1 guide

Part A: Introduction (10 minutes)

Introduction

- Introduce myself as well as any other researchers facilitating the session
- Express gratitude for involvement of all the participants
- Address confidentiality - all information collected will be confidential and participant names will not be disclosed in the final report. I hope this encourages you to speak openly and freely
- Stress that there are no wrong answers - it's their opinion which counts, so don't be afraid of expressing a different view to others
- The information shared by someone else in this workshop should not be shared with anyone outside of the group
- Ground rules – please ensure mobile phones are on silent. Please ensure you speak clearly and avoid interrupting others. Please show respect for others - everyone's views are of interest.

Consent

- Please ensure you have signed the consent form and handed this to the research team
- Please be aware that in taking part in this workshop, you consent to it being audio recorded

Icebreaker

Start with a brief icebreaker to make participants comfortable and allow them to get to know each other:

- Participants and facilitators take turns to each introduce themselves by sharing their name, and how they provide support or care for someone with a spinal cord injury.

Aims

- To understand obstacles that get in the way of breaking up and reducing sedentary behaviour
- To identify potential solutions to overcome these obstacles that could be included in an programme to support breaking up and reducing sedentary behaviour

Part B: Definitions (10 minutes)

Researchers will go through key definitions, with examples. Written definitions also will be provided to participants, to refer to throughout the co-design activities.

- **Sedentary behaviour**
    - Being inactive or stationary during the day, and using up small amounts of energy
    - E.g. watching TV, playing video games, sitting at work, travelling in a car
- **Break in sedentary behaviour**
    - When you interrupt being sedentary with any type of physical activity (however light)
    - E.g. After 30 minutes of watching TV, you do 5 minutes of housework

Part C: Capability Barriers (10 minutes)

Participants will be prompted to write post-notes to individually answer the following question. Participants will be invited to share their responses, initiating a group discussion.

What might affect their capability to break up and reduce sedentary behaviour?

Prompts

- Physical barriers, like fatigue, pain or SCI symptoms
- Skill-related barriers, like wheelchair skills
- Psychological barriers, like knowledge, memory, attention or awareness

Make notes here of the barriers/facilitators suggested:

Part D: Capability Solutions (10 minutes)

Participants will be prompted to answer the following question, guided by the barriers in the post it notes written in the previous section, initiating a group discussion.

What <u>solutions</u> do you think there could be to overcome the obstacles we just discussed?

Prompts

- Improving fitness, improving wheelchair skills, doing non-sedentary activities when you have more energy or less pain
- Including sedentary behaviour in healthcare, educational resources on sedentary behaviour
- Tracking your sedentary behaviour (wearables, apps)
- Reminders to break up sedentary behaviour (wearables, timers, apps)

Keep in mind:

- How could this be delivered or supported?
- When would it ideally happen?
- Where?
- How often?
- Supported by whom?

Part E: Opportunity Barriers (10 minutes)

Participants will be prompted to write post-notes to individually answer the following question. Participants will be invited to share their responses, initiating a group discussion.

What might affect their <u>opportunity</u> to break up and reduce sedentary behaviour?

Prompts:

- Their social circle, like friends and family
- Other stakeholders, such as charity workers, community providers, healthcare professionals
- Physical environment, like in the home, local area or workplace (time, space, facilities, services)

Make notes here of the barriers/facilitators suggested:

Part F: Opportunity Solutions (10 minutes)

Participants will be prompted to answer the following question, guided by the barriers in the post it notes written in the previous section, initiating a group discussion.

What <u>solutions</u> do you think there could be to overcome the obstacles we just discussed?

Prompts:

- Doing physical activity together, talking together about sedentary behaviour, giving advice about sedentary behaviour, messages on social media
- Support groups / peer exercise groups
- Their house, their workplace, their local area, or the facilities they have access to. How could they be changed?

Keep in mind:

- How could this be delivered or supported?
- When would it ideally happen?
- Where?
- How often?
- Supported by whom?

Part G: Motivation Barriers (10 minutes)

Participants will be prompted to write post-notes to individually answer the following question. Participants will be invited to share their responses, initiating a group discussion.

What might affect their motivation to break up and reduce sedentary behaviour?

Prompts:

- Self-belief that they can do it
- Awareness of the benefits of reducing sedentary behaviour
- Goal setting
- Being rewarded for reducing sedentary behaviour
- Mood

Make notes here of the barriers/facilitators suggested:

Part H: Motivation Solutions (10 minutes)

Participants will be prompted to answer the following question, guided by the barriers in the post it notes written in the previous section, initiating a group discussion.

What <u>solutions</u> do you think there could be to overcome the obstacles we just discussed?

Prompts:

- Goal setting (weekly challenges, changing goals, personalised goals)
- Make them more optimistic about reducing sedentary behaviour
    - including sedentary behaviour in healthcare
    - information from charities or on social media groups
- Improve your self-belief/building up confidence
    - goal setting with achievable targets
    - rewards
    - role models
    - Regular feedback on sedentary behaviour/progress
- Rewards such as praise, financial, feedback, sense of pride/accomplishment, gifts, in-app points, streaks
- Mood/emotional support
    - Mood tracking
    - When planning physical activity/exercise, being flexible around your mood
    - Referrals
    - Counselling/coaching
    - Online resources

Keep in mind:

- How could this be delivered or supported?
- When would it ideally happen?
- Where?
- How often?
- Supported by who

Part I: Conclusion (5 minutes)

- Thank participants for their time and valuable insights
- Provide information on the timeline of the study and when they can expect to see the results of their contributions
- Inform participants of time, date and location of the next workshop

Appendix 19. Co-design workshop 2 guide (individuals with paraplegia).

PwP Workshop 2 guide

Part A: Introduction (10 minutes)

Introduction

- Introduce myself as well as any other researchers facilitating the session
- Express gratitude for involvement of all the participants
- Address confidentiality - all information collected will be confidential and participant names will not be disclosed in the final report. I hope this encourages you to speak openly and freely
- Stress that there are no wrong answers - it's their opinion which counts, so don't be afraid of expressing a different view to others
- The information shared by someone else in this workshop should not be shared with anyone outside of the group
- Ground rules – please ensure mobile phones are on silent. Please ensure you speak clearly and avoid interrupting others. Please show respect for others - everyone's views are of interest.

Consent

- Please be aware that in taking part in this workshop, you consent to it being audio recorded

Aims

- To discuss and evaluate proposed ideas for an activity programme
- To discuss ways in which an idea could be changed

Icebreaker

Start with a brief icebreaker to make participants comfortable and allow them to get to know each other:

- Participants and facilitators take turns to each introduce themselves by sharing their name and why they signed up to take part in this study.

Part B: Definitions (10 minutes)

Researchers will go through key definitions, with examples. Written definitions also will be provided to participants, to refer to throughout the co-design activities.

- **Sedentary behaviour**
    - Being inactive or stationary during the day, and using up small amounts of energy
    - E.g. watching TV, playing video games, sitting at work, travelling in a car
- **Break in sedentary behaviour**
    - When you interrupt being sedentary with any type of physical activity (however light)
    - E.g. After 30 minutes of watching TV, you do 5 minutes of housework

Part C: Recap (10 minutes)

- Remind participants of the background behind the study, and what happened in workshop 1.
- Give an overview of the proposed intervention options based on their suggestions from workshop 1.

Part D: Idea appraisal

Component 1: Wearable smartwatch device (10 minutes)

Researcher will give an overview of what the intervention solution involves, and how it will be delivered in the programme.

1. Give feedback on sedentary behaviour levels (linked to app to track progress)
2. Regular prompts and reminders to break up sedentary behaviour after inactivity
3. Give rewards (e.g. praise, streaks, badges) for reducing sedentary behaviour

Researcher will then start a poll to determine the overall appropriateness of the intervention option, which will start a group discussion around the intervention solution.

The following prompts will be used for those aspects of the APEASE criteria which have not been covered in the group discussion:

- How affordable is it?
- How practical or realistic is it?
- Will it be effective to reduce sedentary behaviour?
- Do you think it is appropriate for wheelchair users?
- Does it sound safe?
- Can it be used by all? Regardless of age, fitness or motor function?

Component 2: Online resources (10 minutes)

Researcher will give an overview of what the intervention solution involves, and how it will be delivered in the programme.

1. Education on what sedentary behaviour is, ideas/strategies to reduce it, and the benefits of reducing it
2. Psychological resources
3. Signposting to different charities and organisations providing equipment, information and/or opportunities relating to physical activity and exercise
4. Delivered via online modules, videos, infographics and pamphlets

Researcher will then start a poll to determine the overall appropriateness of the intervention option, which will start a group discussion around the intervention solution.

The following prompts will be used for those aspects of the APEASE criteria which have not been covered in the group discussion:

- How affordable is it?
- How practical or realistic is it?
- Will it be effective to reduce sedentary behaviour?
- Do you think it is appropriate for wheelchair users?
- Does it sound safe?
- Can it be used by all? Regardless of age, fitness or motor function?

Component 3: One-to-one health coaching (10 minutes)

Researcher will give an overview of what the intervention solution involves, and how it will be delivered in the programme.

1. Giving feedback on sedentary behaviour levels and progress
2. Help with setting personalised goals relating to sedentary behaviour
3. Help to create daily, weekly and monthly schedules around sedentary behaviour, physical activity, personal care routines and other commitments

Researcher will then start a poll to determine the overall appropriateness of the intervention option, which will start a group discussion around the intervention solution.

The following prompts will be used for those aspects of the APEASE criteria which have not been covered in the group discussion:

- How affordable is it?
- How practical or realistic is it?
- Will it be effective to reduce sedentary behaviour?
- Do you think it is appropriate for wheelchair users?
- Does it sound safe?
- Can it be used by all? Regardless of age, fitness or motor function?

Component 4: Social support element (10 minutes)

Researcher will give an overview of what the intervention solution involves, and how it will be delivered in the programme.

1. Option to join a peer network group via a messaging app with others in the programme
2. Option to log, share and compare activities with others using an activity/exercise focused social networking app
3. Family and/or friends also receive parts of the programme (e.g. education, goal setting)

Researcher will then start a poll to determine the overall appropriateness of the intervention option, which will start a group discussion around the intervention solution.

The following prompts will be used for those aspects of the APEASE criteria which have not been covered in the group discussion:

- How affordable is it?
- How practical or realistic is it?
- Will it be effective to reduce sedentary behaviour?
- Do you think it is appropriate for wheelchair users?
- Does it sound safe?
- Can it be used by all? Regardless of age, fitness or motor function?

Component 5: Exercise equipment pack (10 minutes)

Researcher will give an overview of what the intervention solution involves, and how it will be delivered in the programme.

1. Individuals being provided access to exercise equipment to use at home
2. May include weights, exercise bands, handcycle
3. Include instructions, demonstrations and ideas for how and when to use them (links into the education module)

Researcher will then start a poll to determine the overall appropriateness of the intervention option, which will start a group discussion around the intervention solution.

The following prompts will be used for those aspects of the APEASE criteria which have not been covered in the group discussion:

- How affordable is it?
- How practical or realistic is it?
- Will it be effective to reduce sedentary behaviour?
- Do you think it is appropriate for wheelchair users?
- Does it sound safe?
- Can it be used by all? Regardless of age, fitness or motor function?

Part E: Conclusion (5 minutes)

- Thank participants for their time and valuable insights
- Provide information on the timeline of the study and when they can expect to see the results of their contributions
- Inform participants of when they can expect to receive their shopping voucher as a token of appreciation for taking part

Appendix 20. Co-design workshop 2 guide (healthcare professionals).

HCP Workshop 2 guide

Part A: Introduction (5 minutes)

Introduction

- Introduce myself as well as any other researchers facilitating the session
- Express gratitude for involvement of all the participants
- Address confidentiality - all information collected will be confidential and participant names will not be disclosed in the final report. I hope this encourages you to speak openly and freely
- Stress that there are no wrong answers - it's their opinion which counts, so don't be afraid of expressing a different view to others
- The information shared by someone else in this workshop should not be shared with anyone outside of the group
- Ground rules – please ensure mobile phones are on silent. Please ensure you speak clearly and avoid interrupting others. Please show respect for others - everyone's views are of interest.

Consent

- Please be aware that in taking part in this workshop, you consent to it being audio recorded

Aims

- To discuss and evaluate proposed ideas for an activity programme
- To discuss ways in which an idea could be changed

Icebreaker

Start with a brief icebreaker to make participants comfortable and allow them to get to know each other:

- Participants and facilitators take turns to each introduce themselves by sharing their name and their job role.

Part B: Definitions (5 minutes)

Researchers will go through key definitions, with examples. Written definitions also will be provided to participants, to refer to throughout the co-design activities.

- **Sedentary behaviour**
    - Being inactive or stationary during the day, and using up small amounts of energy
    - E.g. watching TV, playing video games, sitting at work, travelling in a car
- **Break in sedentary behaviour**
    - When you interrupt being sedentary with any type of physical activity (however light)
    - E.g. After 30 minutes of watching TV, you do 5 minutes of housework

Part C: Recap (5 minutes)

- Remind participants of the background behind the study, and what happened in workshop 1.
- List and describe to the participants the proposed intervention options based on suggestions from workshop 1.

Part D: APEASE criteria (10 minutes for each intervention option)

Affordability and cost-effectiveness

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- What do you think would be the costs involved in this delivering this intervention option?
- To what extent do you think this would be good value for money?
- Do you think that doing this will affect the participants financially?

Practicability

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- How easy or difficult do you think this solution would be to put into practice in a home environment?
- How realistic do you think it would be?
- How could this solution be made more practicable?

Effectiveness

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- How effective do you think this proposed solution could be for breaking up and reducing sedentary behaviour, and improving activity levels?
- How could its effectiveness be improved?

Acceptability

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- How appropriate do you think this proposed solution would be for a wheelchair user with paraplegia?
- To what extent do you think they would like it? And why?
- How could its acceptability be improved?

Safety and side effects

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- What safety concerns, or negative side effects could arise from this intervention option?
- How could the safety be improved?

Equity

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- How could this proposed intervention option be delivered across individuals with paraplegia who may vary in their health and symptoms?
- How could the equity be improved?

Part E: Conclusion (5 minutes)

- Thank participants for their time and valuable insights
- Provide information on the timeline of the study and when they can expect to see the results of their contributions

Appendix 21. Co-design workshop 2 guide (community caregivers).

CSH Workshop 2 guide

Part A: Introduction (10 minutes)

Introduction

- Introduce myself as well as any other researchers facilitating the session
- Express gratitude for involvement of all the participants
- Address confidentiality - all information collected will be confidential and participant names will not be disclosed in the final report. I hope this encourages you to speak openly and freely
- Stress that there are no wrong answers - it's their opinion which counts, so don't be afraid of expressing a different view to others
- The information shared by someone else in this workshop should not be shared with anyone outside of the group
- Ground rules – please ensure mobile phones are on silent. Please ensure you speak clearly and avoid interrupting others. Please show respect for others - everyone's views are of interest.

Consent

- Please be aware that in taking part in this workshop, you consent to it being audio recorded

Aims

- To discuss and evaluate proposed ideas for an activity programme
- To discuss ways in which an idea could be changed

Icebreaker

Start with a brief icebreaker to make participants comfortable and allow them to get to know each other:

- Participants and facilitators take turns to each introduce themselves by sharing their name and how they provide support or services to individuals with paraplegia.

Part B: Definitions (10 minutes)

Researchers will go through key definitions, with examples. Written definitions also will be provided to participants, to refer to throughout the co-design activities.

- **Sedentary behaviour**
    - Being inactive or stationary during the day, and using up small amounts of energy
    - E.g. watching TV, playing video games, sitting at work, travelling in a car
- **Break in sedentary behaviour**
    - When you interrupt being sedentary with any type of physical activity (however light)
    - E.g. After 30 minutes of watching TV, you do 5 minutes of housework

Part C: Recap (10 minutes)

- Remind participants of the background behind the study, and what happened in workshop 1.
- List and describe to the participants the proposed intervention options based on suggestions from workshop 1.

Part D: APEASE criteria (10 minutes for each intervention option)

Affordability and cost-effectiveness

Participants will create post it notes answering the first question below. This will spark a group discussion guided by the responses provided to this question. After which, each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- What do you think would be the costs involved in this delivering this intervention option?
- To what extent do you think this would be good value for money?
- Do you think that doing this will affect the participants financially?

Practicability

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- How easy or difficult do you think this solution would be to put into practice in a home environment?
- How realistic do you think it would be?
- How could this solution be made more practicable?

Effectiveness

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- How effective do you think this proposed solution could be for breaking up and reducing sedentary behaviour, and improving activity levels?
- How could its effectiveness be improved?

Acceptability

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- How appropriate do you think this proposed solution would be for a wheelchair user with paraplegia?
- To what extent do you think they would like it? And why?
- How could its acceptability be improved?

Safety and side effects

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- What safety concerns, or negative side effects could arise from this intervention option?
- How could the safety be improved?

Equity

Each question will be discussed verbally. This will be undertaken as a whole group, facilitated by a researcher and recorded.

- How could this proposed intervention option be delivered across individuals with paraplegia who may vary in their health and symptoms?
- How could the equity be improved?

Part E: Conclusion (5 minutes)

- Thank participants for their time and valuable insights
- Provide information on the timeline of the study and when they can expect to see the results of their contributions
- Inform participants of when they can expect to receive their shopping voucher as a token of appreciation for taking part

Appendix 22. All quotes for barriers and facilitators for reducing and breaking up sedentary behaviour.

COM-B construct	COM-B micro-construct	TDF domain	Barrier or facilitator identified (n = number of participants that identified it)	Illustrative quotes
Capability	Physical capability	Skills	Fatigue (barrier) (n = 10)	HCP (Physiotherapist, Male): "So I suppose my other thoughts is that rather than challenges more from from awareness, is that because they're using their shoulders much more often, is that we teach and advise around shoulder protection, and so therefore, if you're breaking up the sedentary behaviour actually an important part of shoulder protection is rest. And so I guess in the chair for a long bit of time, wheeling around a lot, transfers, everything like that. You're using it a lot more that it is actually designed to do" . HCP (Physiotherapist, Female): "And I guess we've talked a lot about wheelchair users, but we know that the majority of our patients come to us incomplete. So most of our patients will spend some time on their feet, umm. And. But equally, most of our patients will at best use a combination of a wheelchair and ambulation to get around. And again, the physical effort that's involved in getting up and moving about on your feet is prohibitive for lots of people". CCG (Charity worker, Male): "When you're newly injured, predominantly a lot of your time is spent on personal care and just getting the day to day done. That can be hugely, hugely physically demanding as well as psychologically". PwP (T4 Complete, Male): "I think that's similar to what I do. In my workshop, I restore things, up cycle things. Yeah. And so

	and also my wife gets to be doing the DIY jobs which, it's amazing what she'll let me do when it's a DIY thing, but if I wanted to do something, then "oh no, no, no, that's far too dangerous. No, you can't be doing that". And but I go all day. And by the evening, I'm knackered".
	PwP (T4 complete, Male): "The other spinal cord patients I've talked to, people tend to get tired more quickly than you would be if you were not in a wheelchair".
	PwP (T12 Incomplete, Male): "I'm deliberately trying not to cram too much in, as I know it makes me tired".
	PwP (T4 Complete, Male): "So I know I say it again and again, but today will be tiring for me. I was up an hour earlier than I normally am, cab journey here for 45 minutes, doing this, travelling home. I will be tired, so knowing that I was doing something equally kind of time consuming on Wednesday, I've left tomorrow to be a down day".
	PwP (T12 Incomplete, Male): "Yesterday was marked as a down day because I've been doing today. Because sitting up too long, your feet swell up, then I start throbbing like he said. Yeah, you can't feel it, but they swell up massive. You gotta put them above your head, on the bed. Look, I've got a hoist thing. That's where I put them, I lift them up and I leave them. Just hanging there all night just to drain the fluid back into my body. And it's the pain, like if I'd have done loads yesterday, I wouldn't be here today. Even driving in my van, I start getting pain. Then I start getting pain and my shoulders start and it spasms your back. Like I said to you, didn't I? My sitting down is your standing up all day".

PwP (L1 Incomplete, Male): “And I think that's the thing with a wheelchair, though, isn't it? So, like my mother said, I haven't sat down all day. And I go well I've sat down most of the day, but I'm knackered. You know, and it's, if I know I'm sort of relaxed, if I transfer to the sofa and it's evening time watching TV, or just had dinner, or having dinner or whatever”.

PwP (L1 Incomplete, Female): “I find getting in out the car tiring cause of lifting my chair in”.

PwP (T11 Incomplete, Female): “Yeah. So that was me. Just generally, you know the increased level of fatigue maybe just because I'm newly injured. But that sometimes makes it difficult. Sort of 4:00 PM for me as a cut off point to become active throughout my day. But then I'm up at 5:30, so I think it's just generally what your routine, you know, how that's it. So that is a new thing for me”.

PwP (T11 Incomplete, Female): “Not really. I mean, I'm kind of all out though, until about half four. Then that's sort of my calming down time. I would probably do less transfers, a little bit sitting in front of the television. But then putting something up. But that's the time at which I've noticed the most drawback from for being active”.

PwP (T4 Complete, Male): “Yeah, I mean, I'll get to sort of like the evening. And sometimes I'm actually fine and I'm bouncing around and some of the days we've been out and done a lot in that daytime. Yeah. You do feel tired quicker in a wheelchair than you did pre wheelchair life. Yeah. Do you know what I mean? I could do a lot more pre wheelchair life than I can now

		without feeling shattered. So yeah, fatigue is one. It is tiring being a wheelchair. And people don't seem to understand that. But it's not only physically tiring. It's mentally tiring because how you're having to flip things in your brain all day long? Have you … *inaudible* to be positive so you can do things? That gets meant. That does your head in towards the end of that and you are mentally shattered as well as physically shattered?". PwP (L1 Incomplete, Female): "Yeah, I agree. I I get tired quite easily. And I mean, I take a mid-afternoon nap 'cause. I'm awake at 4:00 in the morning. Take mid afternoon nap and then go to bed, sort of ten-ish. And I don't do much in the evening, I tend to sit and watch telly in the evenings, and I don't go out in the evening 'cause it's too much for me". PwP (L1 Incomplete, Female): "I do nothing the day before, yeah. And the day after as well".
Personal care routine (barrier) (n = 10)		HCP (Physiotherapist, Female) "There's less flex in their day, they've got less free time available if they're also a working person to fit that in because, yeah, they're, potentially some of them [have] got longer morning routines". HCP (Physiotherapist, Female): "Yeah. Or in and out of the shower in 10 minutes. You know an hour would be a speedy morning routine for somebody who needs to manage their bladder and their bowel and get washed and get dressed". CCG (Charity worker, Male): "When you're newly injured, predominantly a lot of your time is spent on personal care and just getting the day to day done. That can be hugely, hugely physically demanding as well as psychologically".

PwP (T12 Incomplete, Male): “Yeah, getting dressed, your. Yeah, cos when you get dressed you’re flipping all over the bed”.

HCP (Physiotherapist, Female): “We practice sort of out outward activities and it's it's RAs and RPs um who are more responsible for getting people out and about and having the experience of being in social environments away from the spinal cord injury centre. Other things that are really challenging is managing bowel routines, I mean bladder routines. So if people use intermittent catheterisation, they have to do that regularly. And that's not always easy in every environment, and you know, some people might need to do a catheter every four hours. People have to monitor how much they drink. So you you can't drink freely necessarily, if that's, if that's part of your caring team. So again, all of that alters how spontaneous you can be”.

PwP (T12 Incomplete, Male): “It's catheterisation. Do you catheterise? Self-catheterise? You start getting bladder infection, and then start sweating. Then most people get tremor relaxed because they get a bladder infection. Mine increases pain. If I was sat here now and my knee was resting against that, I’d know about it. Even though I can’t feel it, something in my head like is telling me something is not right”.

HCP (Physiotherapy Student): “I think also because quite a lot of the patients, because the transfer can be quite, like a lot of energy is quite challenging. But quite they’ll want to prioritise what transports they're doing during the day. For when they need them in function, so trying to reduce unnecessary transfers where you can”.

	PwP (T6 Complete, Male): “Whereas myself, I have to get a banana board, slide myself into the car. And then start dismantling the chair. I'm putting it in, but yeah. By the time you've done that, sometimes you have to sit for 5 minutes before I start. I'm knackered”. PwP (T9 Complete, Female): “Transferring to my shower chair, and then wheeling into the bathroom. So, I've got a double kind of transfer”. PwP (T6 Complete, Male): “That's just in the car. So if I was going, I mean this is gonna sound stupid. If I’m at home and I transfer on to the toilet, when I, once you come to where you’re dressing yourself again, I can't redress myself, right? So I then have to get onto the floor. Shuffle. Bum shuffle, going back to what you were saying earlier. Roll around, like a kind of beached whale, and then into my hoist, we start back into my chair again”. PwP (T4 Complete, Male): “Uh, no, so for me, to Doug’s point, to Christine’s point, so I can transfer from bed to commode or bed to chair umm, and from commode to bed. and bed to chair, and chair to bed quite quickly. Yeah, just. Yeah. Couple of minutes, no more than that umm. But then, you know, I have to, once I have a shower, I have to transfer back to bed, to get finished getting dressed, getting dressed, then sit up again. For me, it's the going from lying to sitting in bed position. It’s hard. Hardest. I have help. I've got, you know, you know, getting better at it. Umm. So in terms of kind of, you know, going for a wee, you know I don't get out my chair. I don't. I don't. Yeah, I won't go to toilet here and transfer. Yeah, I will just stay sitting in my chair”.

	PwP (T11 Incomplete, Female): “I used to go the gym before my accident. I think the barrier for me mainly is the amount of transfers that you would have to do. You know, I'm still trying to stay as active as possible, but I think. You know the barriers behind transferring, driving, whether the gyms are accessible or not. I think it just makes it an extra layer to have to contend with”. PwP (T11 Incomplete, Female): “Yeah. So I am, you know, with a spinal cord injury, you have. I have to use catheters to go to empty my bladder. So I will deliberately get up, go over to the toilet rather than using bags. That's something that we were that. That’s a way for me to be able to kind of move or make me make myself a cup of tea. I might get up out of the chair to do that, but I do a lot of transfers so I don't stay in my chair very long. I will transfer out of my wheelchair onto the sofa or, and out to the kitchen. And so I think I just. I don't sit still long enough. I also have five children so I can't sit still for very long periods of time”. PwP (T4 Complete, Male): “Well. Yes, it's the on on the on. I’m the same as you that I'm never in my wheelchair. If I've got an option to be out my wheelchair, even in a coffee shop, I'll jump into a tub chair, I'll jump into a sofa in the coffee shop, my sofa at home. I just. My wheelchair’s a pain in the neck of the morning and I hate it. Yeah. So if I if I can limit my time in there to the best I possibly can, I will. Whether I'm sitting anywhere but in my wheelchair. Transfer to the car, go down the shops, do this, do that. Yeah. I'm just bouncing around all day”.
Pain (barrier) (n = 7)	HCP (Physiotherapist, Male): “So I suppose my other thoughts is that rather than challenges more from from awareness, is that

because they're using their shoulders much more often, is that we teach and advise around shoulder protection, and so therefore, if you're breaking up the sedentary behavior actually an important part of shoulder protection is rest. And so I guess in the chair for a long bit of time, wheeling around a lot, transfers, everything like that. You're using it a lot more that it is actually designed to do".

HCP (Physiotherapist, Male): "I suppose our mindset probably goes a lot towards around how they strategically used their their energy in the day, from a pace perspective. We kind of frame sedentary behaviour as that sort of rest period. As opposed to, yeah, breaking it up per se. So when you kind of frame it in that way in order to mitigate these secondary complications such as shoulder pain et cetera".

CCG (Charity worker, Male): "I I I think the pain is such a personalised thing, some somebody just because of your level of. I mean, if you've got neurological pain or shoulder pain or you know, age-related pain, then that's going, that's going to influence it. Yeah, so so pain. So pain. So pain is a is a personal thing really".

PwP (T6 complete, male): "I would say the only thing that's increased my sedentary behaviour is pain".

PwP (L1 Incomplete, Male): "I'm not doing anything, I'm just sitting there because I have to have my legs straight to stretch my leg, and then it's my legs".

PwP (L1 Incomplete, Male): "I don't get pain just discomfort. OK, discomfort, I thought. Yes, for some people might say it's

		like always like. So it's like between nought and 10, but some people go off high level 2, but I've got quite a high pain tolerance. So for me it's like “oh it’s uncomfortable””. PwP (T12 Incomplete, Male): “Yeah, because I can't do anything when that’s. When that's when my knee starts”. PwP (T6 Complete, Male): “Pain is the main one [that affects my sedentary behaviour]”. PwP (T12 Incomplete, Male): “Pain will stop me doing anything. Wheelchair skills won’t because I'm pretty good in a wheelchair”. PwP (T1 Incomplete, Male): “Yesterday, for the last week I've been in agony and I just couldn't bother and I just didn't”. PwP (T4 Complete, Male): “If I can just say one more thing, one more thing very, very quickly, if that's OK. Is that about it is obviously the pain factor. Yeah, but I find that if I train every day, day in, day out. For the first 5 minutes, I'm not lying, it bloody hurts. Yeah, but once you get, but once you get a bit of warm, warm blood flowing around the muscles. Yeah. And warm oxygen. Yeah. It doesn't hurt anymore. Yeah. So it's getting over that. Yes, it's really hurts. This is painful. Yeah”. PwP (T4 complete, male): “If you sit still and don't move, then when you do move, it bloody hurts. Simple. You sit there and don't do nothing [anything] all day”.
	Comorbidities (barrier) (n = 4)	HCP (Physiotherapist, female): “People have comorbidities and it's an aging population. And so you run into all the same problems with physical activity you do with anybody else”.

		CCG (Charity worker, male): “There might be, you know, underlying health issues that are going on or which might be spinal or non- spinal… your general health can have quite a big impact on your ability to be, you know, sedentary”. PwP (T6 Complete, Male): “Also it’s the drugs [that I take for comorbidities that affect sedentary behaviour]”. PwP (T1 Incomplete, Male): “Well. I I laugh because I was just like PwP until three years ago when I went in for an operation in hospital. They dumped me at home on my own. I got sepsis. And you can see the size of me. But I've, I mean, you know, the sepsis down here ruined me, and it knocked all all the feeling out of me. I couldn't do anything”.
	Injury (barrier) (n = 4)	HCP (Physiotherapist, Male): “Get a shoulder injury as a wheelchair user, it’s so it's so hard to reverse, yeah”. PwP (L1 incomplete, male): “that happens quite frequently, you pick up injuries or stuff happens, you know, that knocks you back”. PwP (T9 Complete, Female): “So, yeah, just a broken leg, for instance, that would lay you out for six weeks, wouldn’t it”. PwP (T12 incomplete, male): “When I broke my leg, that's six months in bed”.
	Pressure ulcers (barrier) (n = 4)	PwP (L1 incomplete, male): “You know, if you’re on bed rest for six months... you know, you had a sore or something”. PwP (T12 Incomplete, Male): “It went right up into the bone. And it went into pelvis. My leg just swelled up. They thought it

		to cyst, so I went to the first hospital. They cut it open left the wound open. Six months in bed, still a wound open, weren't healing up". PwP (T4 complete, male): "You could be bedridden for long periods of time [if you got a pressure ulcer]. We heal a lots more slowly than able-bodied people". PwP (T12 Incomplete, Male): "Oh if I got pressure sore and I'm in bed, it annoys me. Yeah, because I'm in bed for at least six weeks". PwP (T1 Incomplete, Male): "I got a taphylococcus Auris infection and I was just stuck on my stuck on my bed. Almost immobile for six weeks and that gave me a bed sore".
	Lack of physical function (barrier) (n = 4)	HCP (Physiotherapist, Female): "They can only use their arms to do it [break up sedentary behaviour with physical activity]". CCG (charity worker, male): "The higher your level of injury, then obviously the lower the amount of muscle groups that you've got to use". CCG (Charity worker, Male): "That's going to then influence things like you know how high you can get your heart rate. It's going to, it's going to make you think, well, I don't have, you know, if you're tetraplegic. Well, I don't have much use of my arm. So how am I going to… how is that going to benefit me? Whereas if you're a lower level of injury then you're potentially going to be able to do a lot more more exercises. But I don't. So does that make sense?".

	PwP (T4 complete, male): “A T12, she will have core muscles and be able to put both arms out in front of her… Whereas me, I'm at 5. If I do that, I'll fall out [of] my wheelchair”. PwP (T1 Incomplete, Male): “So there's two aspects for my exercise thing. I mean, I don't know you can decide, but one's the mental drive to do it and some of us have had it kicked out of us. The other one is the physical ability to do stuff. And then that's it really. Pop that in your things to do”. PwP (T4 Complete, Male): “I think I think the biggest thing is is. The biggest thing about doing anything is that you've just gotta just you just gotta be able to accept that it’s bloody frustrating. Yeah. What used to take you two minutes to do or five minutes to do, might take you 15 minutes. Yeah. Silly little things like cutting things up. Yeah. Obviously. Because I'm a T5, I've got no tummy muscles, so I can't use both hands”.
Transfers (barrier) (n = 4)	HCP (Physiotherapy Student): “the transfer can be quite, like a lot of energy; it’s quite challenging. But quite they’ll want to prioritise what transfers they're doing during the day, for when they need them in function. So, trying to reduce unnecessary transfers”. HCP (Physiotherapist, female): “Transfers are more difficult. All of these things, because the first chair that they get from their wheelchair service is rubbish”. PwP (T11 incomplete, female) “I used to go the gym before my accident. I think the barrier for me mainly is the amount of transfers that you would have to do”.

			PwP (T9 Complete, Female): ”Transferring to my shower chair and then wheeling into the bathroom. So, I've got a double kind of transfer”.
Psychological capability	Knowledge	Lack of knowledge around sedentary behaviour (barrier) (n = 15)	HCP (Physiotherapist, Female): “They might be quite offended to say that sedentary behaviour is sitting down and breaking in sedentary behaviour is standing up”. HCP (Physiotherapist, female): “There isn't specific guidance on sedentary behaviour. So there, if there isn't specific guidance, it's hard for people to have knowledge”. HCP (Physiotherapist, Female): “And like I said, I think. Like we don't know how much activity in a paraplegic is the difference between being unhealthily inactive and healthily inactive. It’s very hard to make people. Um. Give good education on that front when we don't actually have an understanding of what what good looks like. So from a professional’s point of view, that's a challenge. But yeah. Go on”. HCP (Physiotherapist, Female): “Yeah, because I don't. I think people who haven't come through a spinal cord injury centre, I'm not sure they would have even the advice we give about the exercise recommendations. Certainly when I was I was working, going out to visit people in hospital when they were first injured, that is far from this sort of stuff we're discussing, it's it's much too early. And then they go somewhere else and it maybe never gets mentioned if they don't come through a spinal cord injury centre. So there may be people out there with very different knowledge depending on their their rehab pathway”.

	HCP (Physiotherapist, Female): “I also don't know if we speak about breaking up sedentary behaviour particularly well in all honesty. Thinking about it, we talk about exercise all the time and we talk about shoulder care and preservation of shoulders and we talk about transfers and pacing and exercise and going to the gym, going swimming, going out and pushing and we talk about all that. And I think we do that pretty well. But just considering what we're talking about in terms of breaking sedentary behaviour, I'm not 100% sure I actually go through that with patients”. HCP (Physiotherapist, Female): “I’m quite sure that I don't, but what I think is that asking someone to push across the room is insignificant. If you sit still and watch the telly and then you push across the room and come back again”. HCP (Physiotherapist, Female): “Yeah, completely. But I wouldn't advise people on moving about more because I I haven't got any understanding of if that is in any way worth their time and thought. And and my guess is perhaps it's really not”. HCP (Physiotherapist, Male): “Something for you guys, because I think it's it's really challenging is that when when you, when you problem solve it around what do we define as sedentary behavior for these different kinds of people”. CCG (Charity worker, Male): “That we forget the fact that any movement is good movement. Any activity is is good activity. So it's it's trying to make people aware… So I think it's just helping people to understand what do we mean by you're talking about 5 minutes of exercise. People really need to be made aware of what that looks like, what that could be, and also and

also what the benefits physiologically and psychologically are going to be".

CCG (Charity worker, Male): "Yeah. Similar to what CCG was saying that some people can feel a bit intimidated by, you know, just looking at a sport like wheelchair rugby for example, that that any kind of, you know, immediately you're you think of those sort of high end or those elite sports whereas you know I sometimes try and say to someone that, you know, exercise can be anything, it can be just walking your dog. you know, just just getting out of the house".

CCG (Family member, Female): "I think for my dad, it would be having the understanding that doing anything really would benefit him. Not in terms of sort of what you would sort of call, I guess he is not really capable of doing exercise or sport or such, but just for him to understand that to be doing anything really would be beneficial".

CCG (Charity worker, Male): "There's also an element of. If you look at sort of like what positive psychology is all about, it's it's almost recognising that, the fact that you're, you know, that you're out of bed and that you're moving around already. That's a positive starting point that you've got. So just going through your personal care every day is, you know, or you know, keeping the house tidy and all of those things, that those are all contributing to what you're doing. So, for so many people, they're already being active. We're asking them to become more active. So I think it's sort of like helping people to understand that you're already doing something. We're just kind of like wanting to help you become more aware of how much, how active you are. And then also thinking about how we can, you

	know, do, do how, how could we introduce more activity to improve your situation". PwP (T12 Incomplete, Male): "Sedentary? Like laziness?". PwP (L1 Incomplete, Male): "I'm paralyzed from here down. So yeah, a good 80% of our body doesn't work. Umm yeah, so I mean, am I sedentary now, sitting around doing this or or, not? And I think that's quite a key". PwP (L1 Incomplete, Male): "[What is] the definition of being sedentary?". PwP (T9 Complete, Female): "Yeah, but, but we don't see that as exercise, do we? It's just getting from A to B. But it is exercise". PwP (T12 Incomplete, Male): "No they don't give you [guidance on sedentary behaviour]". PwP (T12 Incomplete, Male): "There's nothing regimental, no. They just try and teach you in hospital in order to send you out". PwP (T6 Complete, Male): "I'm going to say no as well. The only time they say [to reduce sedentary behaviour] is for to stop you getting sores". PwP (T6 Complete, Male): "That that's the big word, sores. And apart from that you don't get told about movement at all". PwP (T4 complete, male): "I don't think the word sedentary was ever said [during inpatient rehabilitation]".

PwP (L1 Incomplete, Male): “Because isn’t it, what they say about something in motion stays in motion, rather than something stopped. But it's more sort of difficult. Maybe it's in branding. Whatever it is, what you're trying to achieve in a way where it, because people are right, you're right. People are like “oh exercise, God that makes me sick”, you know?”.

PwP (T1 Incomplete, Male): “OK. Could you remove? I'd be cautious about using if you're gonna spread this out. The word sedentary means you sit on your bum all day. We don't have a choice. So I would say “inactivity”, you know? Yeah. Be cautious. I I'm not offended by that. I'm used to being called a cripple. And I I know it. I don't mind. But some people get offended by someone saying you're, you know, sedentary, especially if you haven't got a choice. So I would take the word out”.

HCP (Physiotherapist, Female): “They might not wanna look at it. But, it's just there. Is it another option, potentially? Rather than just going ‘be active, you need to move’ and people go ‘don't want to’. Actually go ‘OK, you’re not moving, lets maybe think about why you are not moving, and actually this might be a good opportunity to link in with this person or talk to this person or watch this podcast or these are different options potentially that you use’. Instead of ‘move now’”.

HCP (Physiotherapy Student): “You just absolutely have to move someone from my extrinsic to intrinsic motivation. And that might start with having like having therapy sessions and then even like within those sessions, just discussing like, why

you would want to continue these after. But I'm sure that's already done".

CCG (Charity worker, Male): "Yeah. Similar to what Will was saying that some people can feel a bit intimidated by, you know, just looking at a sport like wheelchair rugby for example, that that any kind of, you know, immediately you're you think of those sort of high end or those those elite sports whereas you know I sometimes try and say to someone that, you know, exercise can be anything, it can be just walking your dog. you know, just just getting out of the house".

CCG (Family member, Female): "I think. I think it would be helpful. In the case of my dad, really, for my mum to understand that it's good for him to actually be doing as much as he can. I think as long as a family member are aware of bits of it".

PwP (T1 Incomplete, Male):
Or, you know, and then we get through the incentivizes, you get the lies for parents. So, the devil will come and get you if you pick your nose, you know, tonight, you know, whatever, you know what I mean. But you need to make me more positive. But you can do that. You can. That's one aspect from, you know your your study if that's a possible thing. You can say "reasons why not", "reasons why" and then if you can't win the people over then they go back to the the the, you know, the what do you call it, intellectual aspects rather than calling them mental, the intellectual, and then you got the physical".

PwP (T4 Complete, Male): "For me it was a bit of both really. I enjoyed standing up and having a conversation with someone at eye line, yeah, rather than looking up or looking, them looking

		down on me. And also, you know, I mean when you're standing up, yeah, it's good. It affects your blood pressure, your heart bounces more. Yeah. Do you know what I mean? To pump the blood around your body more. So I think gravity, it helps your lungs go down, digestive, and stuff like that. So I think standing is really important".
	Knowledge of pressure relief (facilitator) (n = 6)	CCG (Charity worker, male): "Something that all wheelchair users are told to do is a huge part of their education when they're in hospital is to do pressure relief to make sure every hour or so that they make sure they shift in their chair and lean forward in order to avoid pressure sores". PwP (T4 complete, male): "Part of my routine would then be well, I need to do pressure relief… And therefore, you know, that's exertion". PwP (T4 Complete, Male): "So they they recommend that every two hours sitting in your chair that you do 2 minutes of [pressure relief activities]". PwP (T12 Incomplete, Male): "They used to tell me every 20 minutes you've got to lift up just to get some blood on your bum. Otherwise you can't feel your bum. But my sitting down is not standing up. My lying down is your sitting down". PwP (T4 Complete, Male): "But let's just stay in the leaning forward. Yeah, and yeah, parts of your body which will hit the chair. to be not touching the chair". PwP (T12 Incomplete, Male): "I got told [to do pressure relief] every 20 minutes".

		PwP (L1 Incomplete, Male): “I was gonna say from what they advised you, I'm sure it's every half an hour. They said to something on those those lines”. PwP (T12 Incomplete, Male): “Even just moving in your Chair, sitting forward like that. Yeah, that’s pressure relieving”. PwP (T9 Complete, Female): “Yes, so I thought “this will clear up, this will clear up”. But actually it didn’t, so I had an operation and… Two years later, I managed to break my leg. And so it was sort of, you know, and it was full cast umm, so and I you know, I was still using the shower chair, so I put extra weight on back side. So I had to have a second operation. But yeah, just leaning forward makes a difference. So you don't physically have to lift or just won't be normal side or untouched. Good”. PwP (T1 Incomplete, Male): “One other thing for you [the researchers] is the other benefit about doing transfers, get moving, is you don't get bed sores”.
Memory, attention, and decision processes	Reminders to be active (facilitator) (n = 5)	HCP (Physiotherapist, Female): “What about like an app that beeps at them, it says ‘move now’”. CCG (Family member, Female): “Can I also add something if that's alright? So there was there was a bit of an observation from my part when my sister had her accident. She actually gave away her apple. She used to have an Apple Watch. She gave away her Apple Watch because it kept notifying her to move to stand up. So there's a little thing on the watch. It’s kind of a push, a push notification that says “stand up” and tries to keep you kind of moving. And she found that really triggering, but it's almost it's almost that kind of useful tool perhaps of, you

	know, encouraging somebody to move rather than rather than, you know, stand up as the term. But I think she would really benefit from almost, like, a smart device that is inclusive for those that are wheelchair users to be able to have that inclusivity with everybody, she would, I think she would really benefit from something similar to that". CCG (Family member, female): "Definitely that thing of having some kind of prompt I think would definitely be helpful for him [father with paraplegia]". PwP (T12 Incomplete, Male): "No, you need it. You need your bum kicking sometimes". PwP (T12 Incomplete, Male): "The text message, everyone goes "read it". You're having a chat and go "oh, my phone". With the big big "get up. Do something". Yeah, it works. It will work". PwP (L1 Incomplete, Male): "I mean you've you've basically, for having the app and signing up for it, you're accepting, right? That it's gonna beep at me, it's gonna nag me. But I want that to happen because I know sometimes I can be a bit lazy or or ignore what I should be doing, you know? And it's interesting what you were saying about the sort of misconstruing between being sedentary and exercise. You know it's more. It's not so much exercise, it's keeping in motion, isn't it? Yeah, because isn't it?". PwP (T12 incomplete, male): "The prompts, you know, to the alerts to say. "get moving, get moving"… alerts to say, "come

			on, keep going. You're nearly there", so sort of motivating alerts [would help me be less sedentary]".
		Do not think about sedentary behaviour (barrier) (n = 4)	CCG (Charity worker, male): "It's not really the first thing that's on their mind, you know, they've got other issues to think about". PwP (T12 Incomplete, Male): "I don't [think about sedentary behaviour]. I just get on my bed [at the end of the day]". PwP (T6 complete, male): "I don't think about it [sedentary behaviour] during the day". PwP (T9 Complete, Female): "Yeah, I mean, some days I don't, yeah, I'm like "I haven't left the house today", but then I know I'm going somewhere tomorrow. So like you know, I don't, I don't let it bother me".
	Behavioural regulation	Getting feedback on progress (facilitator) (n = 6)	HCP (Physiotherapist, Female): "Honestly, I think the people for whom it speaks to it would reinforce what they're doing anyway and maybe help maintain their their motivation. You know, Strava, whatever, people who love it use that as a way of communicating about things that they enjoy and that does keep their fire burning. But for the people for whom it's not interesting". CCG (Family member, Female): "My sister [with paraplegia] used to have an Apple Watch. She gave away her Apple Watch because it kept notifying her to move to stand up. So there's a little thing on the watch. It's kind of a push, a push notification that says "stand up" and tries to keep you kind of moving. And she found that really triggering, but it's almost it's almost that kind of useful tool perhaps of, you know, encouraging somebody to move rather than rather than, you know, stand up

as the term. But I think she would really benefit from almost, like, a smart device that is inclusive for those that are wheelchair users to be able to have that inclusivity with everybody, she would, I think she would really benefit from something similar to that".

CCG (Charity worker, Male): "I use a, I use a. I've got a, I've got an app which is called "High intensity interval training app". And I just I set that up and I've got sort of like, you know, 5 minutes of exercise, 8 minutes of exercise, 10 minutes of exercise. And it just does 30 seconds on 30 seconds off for like 5 reps, 8 reps, 10 reps and and that just gives me like a little calendar with a little thing that bounces up. And so if I'm doing some activity, I'll I quite like that because then it shows you like a month. It shows you for like the month of September. It's like little shapes throughout the calendar that show me I'm being active".

CCG (Charity worker, Male): "There's also an element of. If you look at sort of like what positive psychology is all about, it's it's almost recognising that, the fact that you're, you know, that you're out of bed and that you're moving around already. That's a positive starting point that you've got. So just going through your personal care every day is, you know, or you know, keeping the house tidy and all of those things, that those are all contributing to what you're doing. So, for so many people, they're already being active. We're asking them to become more active. So I think it's sort of like helping people to understand that you're already doing something. We're just kind of like wanting to help you become more aware of how much, how active you are. And then also thinking about how we can, you

		know, do, do how, how could we introduce more activity to improve your situation". PwP (L1 incomplete, male): "It'd be good to like, keep a log of say, whatever activities you're doing. And having like your personal best". PwP (L1 Incomplete, Male): "Umm, well the lack of results one, goals. It could go back to the prompts, you know, to the alerts to say. "get moving, get moving". I think it's been said before, alerts to say, "come on, keep going. You're nearly there", so sort of motivating alerts". PwP (T6 complete, male): "You can get an app for your phone, so you can actually see what [activities] you've done". PwP (T4 Complete, Male): "And yeah, I would say that at first, someone might need a need a high level of intervention. Yeah, but then that intervention might become less and less, which it should do as their mind becomes more down to them".
	Creating schedules around activity (facilitator) (n = 6)	HCP (Physiotherapist, Male): "Strategic breaks of perhaps breaking up certain behaviours, yeah". HCP (Physiotherapist, Female): "There's another thing that happens is they can have quite a routine in the morning, can take a long time, so they got to do like getting washed getting dressed, but a bladder and bowel routine that takes them often longer in the morning to get out of the door than it would take us to get out of the door to work. So if they're somebody who works, there's less flex in their day, they've got less free time available if they're also a working person to fit that in because,

yeah, they're, potentially some of them got longer morning routines".

HCP (Physiotherapist, Female): "Lots of lots of our advice will be around people making choices about how they expend their energy. And there's the difference between a blast of activity versus a more continual activity across the day, and the morning routine is really physically taxing. So that's harder work for them than it would be for us, but we might advise people to use carers to assist them with that in order to save their energy for other parts of the day. And so there's a difference between the energy in the way that we think of, like your ability to get up and go and do things versus your metabolic energy cost, which for somebody who's a wheelchair user, will have bigger peaks and troughs. But you might imagine across the day is is less. But that doesn't make it any less tiring".

HCP (Physiotherapist, Male): "What we used to kind of do is like, practice discharges, kind of do like a Monday to Sunday timetable of their life and be like 'Right, what happens in the morning for you?'. Build a 24 hour sort of plan here and get sort of as close as we can prior to discharge as to what looks optimal from a pacing perspective and so, therefore, part of the goals in say, when I used to do community referrals, was tweak their 24 hours sort of routine. To optimize it in a way where they can do a tailored exercise program alongside the rest breaks in between… Perhaps something like that again, it's really hard. As part of the reintegration phase, when patients are here and they go home, could be something to template and then tweak when they're at home, when they actually go about their daily life".

				CCG (Charity worker, male): “Trying to get a bit of a timetable even into your normal daily living and to and to incorporate the activity in into that”. CCG (Charity worker, Male): “There's something around timetabling. It's something about thinking about, again as well we're saying your personal care, so I know exactly what time I need to go up in the morning to ensure that whatever happens, I'll get out of the door at a certain time. So, these are what must be going through most people's heads when, you know, when they get up in the in the morning and have to do these things that are very different now. And and time is is is kind of key key to that”. PwP (L1 incomplete, male): “Yeah, prioritising your schedule to accommodate [for physical activity and sedentary behaviour”. PwP (L1 Incomplete, Male): “So that's what I was gonna say when we're talking about the ones above. So like, time is looking at your day to day sort of calendar and what responsibilities you've got umm and the last one which”.
Opportunity	Physical opportunity	Environmental context and resources	Provision of information and/or opportunities for physical activity and exercise (facilitator) (n = 12)	HCP (Physiotherapist, female): “They'll sometimes tap into the charities as well. So they're going out and about and doing a bit more activity with some of the charities, so again, they'll start to overcome some of those barriers and see how they can plan things with the help of external sources”. HCP (Physiotherapist, Female): “We always point them towards the charities, and the psychology team do an awful lot about pointing them towards their relevant charities and it is something we speak about. So, we do get some charities in to do

some of the Backup wheelchair skills for us as well. So, they are signposted. But again, it's it's them taking that step forwards to actually tap into some of those support networks".

HCP (Physiotherapist, Female): "They can also, Wheelpower is a charity that provides free Therabands, so any anyone who's called injured can ask for those. And they're like quite posh ones with handles on and stuff. They're they're good".

HCP (Physiotherapist, Male): "Well, I was gonna say as well, who might be pretty well-placed in primary care services is Spinal Injuries Association, Back Up. they're perfectly placed for that sort of thing [providing advice and resources related to activity]".

CCG (Charity worker, Male): "Mainly what we [Charity] do is as an information service".

CCG (Charity worker, male): "Wheelpower has probably got the best examples at the moment of showing they they've, they've got yoga, they've got people doing fitness classes and people doing different exercise activities".

PwP (T6 Complete, Male): "But, yeah. Where you are now, at [SCI centre], there's gonna be loads of that type of thing, and then you can just pick and choose. That's why [SCI centre] is so good".

PwP (T4 Complete, Male): "Not particularly no, I'm not particularly sporty. Or, having said that I'm gonna go and do the inter-spinal unit games".

PwP (T6 Complete, Male): “Yeah, yeah. Like, you were saying earlier about, was it Sportability [that provided opportunities to do physical activity and/or exercise]?”.

PwP (T12 Incomplete, Male): “Yeah, they do different areas, Sportability. Like you could run a group where go sailing. I could run a group to go shooting, you know, like target shooting”.

PwP (T12 Incomplete, Male): “You could run a good doing archery in your area. I’m in [LOCATION REMOVED]. Yours is [LOCATION REMOVED]. That's what like, everyone organises it. Like, I would organise a group like this for about 8 people to go shooting.

PwP (L1 Incomplete, Male): “So going to financial, what you're saying about equipment, I got a small grant I think it was from Wheelpower or one of the charities. And so it was to enable me to go walking with my wife with the dogs.”.

PwP (T9 Complete, Female): “Well I’ve got, from Wheelpower, I’ve got some stretchy bands”.

PwP (T1 Incomplete, Male): “You get one that holds your neck up and it holds you and you can float and then you can move your fingers or your arms or your neck or whatever. Or anything else you can, but that's what and there's a social thing there where you can get lots of other people off of Physiotherapists or retired Physiotherapists who help you. And it's peanuts. It's about £5 where it would cost you £100 to do it in a normal pool”.

		PwP (T1 Incomplete, Male): “People can go out and find stuff. And if you're prepared to go out the house, you could ask your doctor to recommend a Physiotherapist who will come to you. They do a six week. They used to do a six week course for the disabled, to rehabilitate them, and you get a membership with the gym for a huge discount”. PwP (L1 Incomplete, Female): “Well, we used to have, locally, we used to have a scheme where we had volunteer befrienders. And I had someone who used to come once a week from that [giving her social opportunity to go out and be active]. But they stopped running the scheme”.
	Lack of wheelchair accessibility in and outside of the home (barrier) (n = 10)	HCP (Physiotherapist, Female): “Sometimes people can't get out of the house as well, and I think then it's the accessibility which I'm assuming you might move on to in a minute. The accessibility of things like even just going on a pavement is extraordinarily difficult for some of our patients as well. Yeah. Ramps. Stairs. steps. Getting in and about the house sometimes”. HCP (Physiotherapist, Female): “Some patients have got the higher wheelchair skills and ability, but I think it's also the setup of the environment as well and because it may be all great that they can get up downstairs potentially in a very um, sort of protected environment here potentially. But then we all know getting in and out of that house is very different because you've got to get over the the potentially the lip of the doorframe and you’ve got the stairs outside potentially, which may be very narrow. May be very difficult to navigate”. HCP (Physiotherapist, Female): “I guess being mobile in a peer group is also more difficult. So lots of us will go out with people

who are similarly able, you know, for a walk or to a restaurant or a bar. And for lots of people who are wheelchair users, that becomes much less part of their life, but it doesn't have to be. And some people find a way to make that work, and it's fine. But for lots of people that falls out of their routine because their challenges in accessing environments are different to the rest of their peer group, and that is a barrier to them".

PwP (L1 Incomplete, Male): "Yeah, well, that mine came about, I think from shuffling on my backside as well because it was early after my injury and I was getting used to getting around and I think we were staying at mother-in-law's flat, which is upstairs. No space for a wheelchair, so I would stand and hold on to walls or furniture. But what was safe? My wife's words was, you know, "shuffle" and that. Yeah".

PwP (L1 Incomplete, Male): "It could be. I mean, we're lucky because we bought our house as we were coming back from the States and we gutted it and did what we were doing it before we moved in. And a lot in our mind was sort of open plan, or enough room for the wheelchair to work, you know. And and I had this conversation with mt wife actually just the other day and talking about going to visit other people in their houses and how difficult it is because there are thresholds, there are steps to get in. They probably don't have enough room to wheel a wheelchair around, cause some people's houses can be really old and they've got really sort of steep steps".

PwP (T12 Incomplete, Male): "You can't get in the bathroom and people's kitchens".

PwP (L1 Incomplete, Male): “Some of the bathrooms are like, you know, literally a meter squared or whatever. I get in, close the door and the toilets, like, literally whacking the knees. And it's the bits that I take for granted at home. Grab bars, you know, the toilet, which you know. Something I don’t want to talk too much about, but it's, you know. And so it's it's not that I'm trying to age myself and not go out and do things or or restrict myself, should I say. But the creature comforts at home”.

PwP (T6 Complete, Male): “Any payments. We’d be better going the road than on the pavements because it's not. Yeah. And sometimes they just drop like that and you hit them and then that's it”.

PwP (L1 Incomplete, Male): “And when you find anything like this on the road, you end up in the in the road because the pavement slopes like that *laughs*”.

PwP (T12 Incomplete, Male): “Yeah, it's solving my problem with the van. Tail lift, I'm not on a path anymore, yeah. I'm coming onto the road cause the lift comes out the back of it, right. And then I'll have to try and get up curbs. I've just had to pay £1400 to get a drop curb, which I have to pay for in the road. And you have to apply for it as well. Disgusting. And everyone else can use it. But I have to pay for it”.

PwP (T6 Complete, Male): “We weren't allowed disabled parking”.

PwP (T4 Complete, Male): “Yeah, some limitations like that, as Leon said. You go to someone else's house. Different ball game, right? Less manoeuvrability, more furniture. Layout”.

PwP (L1 incomplete, male): “Non-accessible space, I guess. Or non-adapted space [is a barrier]”.

PwP (T12 Incomplete, Male): “Going shopping, right? Can't get this one. You have to look around for a member staff, the hardly like Tesco's, there's hardly any staff and you gotta wait for someone to come down the aisle “Excuse me, I don't suppose you can get that”. I hate that. I like to do everything as much as I possibly can, but with certain jobs you can’t. You physically can’t do it”.

PwP (T9 Complete, Female): “It’s worth mentioning, you know, depends where you go, if you need to use a lift and the lift isn’t working”.

PwP (L1 Incomplete, Male): “Yeah, right. And if that's something that gets you out of your house, you can't then do anything else because you're lift is broken”.

PwP (T12 Incomplete, Male): “My sports centre as well. I joined the gym there and the lift was always broken. Got there - broken. Have to go home without it. Disappointment”.

PwP (T4 Complete, Male): “Again, it's postcode isn’t it. Where I've moved to, there’s a hotel next door to where we live, now. They've got a leisure facility. I rang them up and said “is the equipment in your gym wheelchair accessible?” and they said “of course it is, we've had a we've had a a multimillion refurbishment last year”. I went “brilliant”. So I go down there, make an appointment to see the membership manager, he takes me into the gym, and none of the equipment is accessible. So

	OK. All the machines are all fixed and he went “Oh, I know it's all fixed” and I said “well I wouldn't even bothered coming here if I was told it was not wheelchair accessible”. And the very fact that a good hotel has spent that much money recently, and not made it accessible equipment, is just”. PwP (T12 Incomplete, Male): “I’m out eating, and needed a pee. I go “where's the toilet?”, he says “upstairs”. I go “where's the lift?”, he says “we ain’t got one? They put a disabled toilet upstairs just to say they’ve got a disabled toilet. You can’t use it in a wheelchair”. PwP (T4 Complete, Male): “Just going back on to sort of like diet and stuff like that, a lot of people refer and you sort of like the Apple Watch. “We've burned this amount of calories” and stuff like that, but that's not tailored to someone just using their arms, if that makes sense. Yeah, there's nothing that sort of like tailored to a paraplegic. Like, if I cycle on my bike, yeah, my heart's running at 140 beats a minute or whatever for 2 1/2 hours, it will stay all I've burnt X amount of calories, but that's based upon the calculations that it would be for my quads and my legs drawing that energy and not my arms. So, people think, “oh, I've burnt all this energy”, whereas in fact you haven't because what you're using is nowhere near the burn. Does that make sense?”. HCP (Physiotherapist, Female): “If we also look at the capability of some of our patients being able to break some of that very static behaviour and we're not necessarily looking at exercise or intense activity, the home environment is also really key factor because a lot of our patients will sometimes get discharged to a microenvironment. So even just being able to

manoeuvre their wheelchair around will be sometimes extraordinarily difficult to do so breaking up any activity may be extraordinarily difficult because they may not be able to manoeuvre even from room to room".

HCP (Physiotherapist, Female): "Lots of people are discharged to live in one room [with little space to move around and do activity]".

CCG (Charity worker, male): "When they're discharged from hospital now aren't always going home because their home environments aren't accessible… So it's certainly stuff like that is going to affect their ability to be active".

CCG (Family member, Female): "So for example the OTs couldn't get a standing frame for over 12 months. She's only just got a standing flat frame for her to be able to use. It's taken a long time for the external community occupational health to get involved. And just mimicking what the other guys have said in regards to the home environment she was popped into a living room area with a minimal access to upstairs, in fact had no access to upstairs for obvious reasons, but she had minimal access to her bathroom. It was a case of discharge and hope for the best effectively. So she had to get a kind of a mini. Well, she had to convert part of the house, which isn't ideal, but into almost a wet room type facility for her to be able to get herself washed and dressed".

PwP (T12 Incomplete, Male): "Same as opening the fridge, you're doing so many bloody moves. Just to open the fridge door".

		PwP (L1 Incomplete, Male): “Yeah you have to get clearance or. Yeah, the dishwasher and like our units in the kitchen are kind of like this. And the dishwasher is opening here. I can I can get some stuff this way, but if I start a job on the other side, I'm kind of stuck on that other side because the door's open. So I can't get this stuff out to put in the cupboards because they're backside sort of thing”. PwP (L1 Incomplete, Male): “Yeah, space. Physical space [is a barrier]”. PwP (T12 Incomplete, Male): “And if you’ve got stuff at home, you can do it yourself. But a gym in your house, you might not have enough space. You’re doing it on your own, you don’t. You hang stuff on it. You don't even use it. It's just sat there doing nothing”.
	Cost and lack of access to equipment to do physical activity or exercise (barrier) (n = 10)	HCP (Physiotherapist, Female): “They do normally go home with an exercise plan and we can send them home with the Theraband. We wouldn't send them home with weights, they'd have to self-purchase. And the thing I suppose, all the all the the bikes or additions to their chair, they would have to self-purchase”. CCG (Charity worker, male): “There's not a lot that you can get that is complimentary. You know, a lot of this stuff now you've got to pay for, and it's not cheap”. CCG (Family member, Female): “So for example the OTs couldn't get a standing frame for over 12 months. She's only just got a standing flat frame for her to be able to use. It's taken a long time for the external community occupational health to get involved. And just mimicking what the other guys have said in

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PwP (T4 Complete, Male): "It's getting dressed. But I was also thinking more just to the exercise. You know the getting big physical, doing physical activities, being non-sedentary which, is a lot, again it's easier because it's all there. Yeah, it's like 2 minutes away rather than "oh I've gotta get to the gym" or "I've got to go for a walk" or "I've got to do something in the park" or whatever".

PwP (L1 Incomplete, Male): "It's all so defeating, isn't it? Really? I think that's what I'm saying. The hardest bit for me is getting in the car to go to the gym".

PwP (T12 Incomplete, Male): "That's the only bit of kit I got from the hospital. A rubbish wheelchair and a standing frame".

PwP (T4 Complete, Male): "I want a home bike again".

PwP (T4 Complete, Male): "Yeah, exactly. So so some stuff you know. And then I had approval for NHS funding for my standing frame. But my case manager said it's probably easier to wrap it all up in one funding claim against the, you know, the insurer. So it's all, it's complicated".

	PwP (T6 Complete, Male): “Or your equipment that you can get to [affects opportunity to break up sedentary behaviour with physical activity]”. PwP (T4 Complete, Male): “So instead of steps, it measures pushes. “Yeah. Brilliant”. Yeah, and it does, but it still doesn't track your distance. So if you go into your health app and it will say “you've done 10,000 pushes today”. And you go “Well, how far have I gone?”. It will say “you’ve gone 0” because you haven't taken a single step”. PwP (L1 Incomplete, Female): “Yeah, there's no accessible gym where I live”. PwP (T11 Incomplete, Female): “The availability. Yeah, just the availability to services really or like the the access, you know somebody might not live in an area that has an accessible gym, maybe not have access to the Internet. I mean that would be odd these days. But you know, I think just what people's, you know, availability to services or places would be”. PwP (T4 Complete, Male): “Yeah, I think if you look at them they’re all sort of like in inter-linked with each other. Yeah. And like availability, and like equipment at home that you spoke about. I'm very fortunate that I've I've retired from work and I can spend time on my body, which is my job. My job is my body and looking after myself. I've got, I've got an FES machine upstairs, which does my legs. So I put like for two hours every couple of days, I FES my legs. Yeah, to keep bulk, keep muscle, keep the pain out, keep the lactic acid out, but I’m fortunate that. That bit of kit is like 12 grand. Yeah, I’m fortunate that I've got that at home to use. Yeah. And I would do that for two hours

	every couple of days. Something like that should be given to every paraplegic person who it's suitable for, but it's not, and that's what's not right". PwP (T4 Complete, Male): "You might you might get a set of ramps on your own from your OT if you're lucky". HCP (Physiotherapist, female): "They haven't got any finance finances available to purchase any extra equipment and that might be what's needed to be active". PwP (L1 Incomplete, Male): "Yeah, exactly. Sometimes my wife gives me a once over. She.. in terms of looking for for things. It's less, you know, she's less attentive now 14 years after the accident. But the the talking about physical exercise or what have you. When I was discharged from hospital and I had my insurance covered like a physical person, trainer, whatever coming in a couple of days a week, and then it got to a point, basically the insurance was saying "you're not making anymore progress". Yeah, you are maintaining your level of exercise. Yeah. "So, we can't pay for this anymore". PwP (L1 Incomplete, Male): "So we paid for me to go and see someone a couple of days a week out of our, you know, pocket, which was great because I didn't wanna stop doing the physio or being in a good sort of routine and doing as much as I could". PwP (T6 Complete, Male): "It's not titanium [wheelchair], so I can do what you were saying. Yeah, take the wheels off when you get to the car, put the wheels in the back and then this goes in the passenger seat. So I can go out independently. Umm, but

	the more you have taken off the chair, the more the price goes north”.
	PwP (T6 Complete, Male): “14 years. Yeah, but you then have to bite the bullet if you can. If not, because luckily enough, I was lucky to get through government funding and work funding. Otherwise I'd still be in one of those [heavy wheelchairs]”.
	PwP (T4 Complete, Male): “I will have to pay for it [equipment needed to be active] myself”.
	PwP (T6 Complete, Male): “So, you know, it's what PwP is saying, if you don't have money, you are absolutely stuffed outside [of inpatient rehabilitation]”.
	PwP (T4 Complete, Male): “It's just a you have to navigate the right way. You have to get the right budget approved, some of its NHS funded. Some of it has to be privately funded”.
	PwP (T4 Complete, Male): “And one of the biggest barriers is money. Yeah. I’m fortunate that I can afford to buy a new wheelchair. I can afford to buy it and buy that and have a very active life. But some people can't. Yeah. And that's where it goes wrong. Is that people who are walkers, yeah, don't seem to understand… And that's what's that's what's wrong, about picking up what Donna said, is that you don't understand. Not you. Anyone, unless you're in this position and it's wrong that finance should be a barrier. And but it is a barrier for people. And that's not fair”.
	PwP (T4 Complete, Male): “It's in the ability that if you haven't got to work because you you can financially rely on your

		pension or retirement, yeah. Then, instead of working 9:00 till 5:00, my body's my job from 9:00 till 5:00. So when my son went to school, yeah, I'm lucky that I didn't have to go to work. So he went to school. I went to work on my body. So when he come in from school, I could do anything with him because I was physically fit enough to do that, if that makes sense. So that's a barrier for people as well". PwP (T4 Complete, Male): "Well, yeah, again that comes down back down to the old finance issues, doesn't it? Yeah. Are you able to buy a house or put an extension on or adapt your house to support the needs of a wheelchair? And that unfortunately costs money, which is wrong because you won't get nothing from the government".
	Wheelchair being inappropriate for physical activity (barrier) (n = 7)	HCP (Physiotherapist, female): "They get given much heavier chairs. Harder to propel and definitely harder to do wheelchair skills in". HCP (Physiotherapist, Female): "So there isn't a circumstance in which somebody goes home unable to mobilize. That's unthinkable to us. That's not true in all the spinal cord injury centres and in an increasingly, because of the difference between what the wheelchair services provide and what our patients need. The reality is that gets closer with every passing month. But, as HCP said before, it's not necessarily you know they'll learn to function at a really high level in an appropriate chair for their needs here. And they will almost always be discharged in something that is vastly inferior, which will mean pushing is heavier, more painful, they're sat less well, they get less, they're less comfortable in sitting, they can access the environment less well that you know, the transfers are more

difficult. All of these things, because the first chair that they get from their wheelchair service is rubbish".

PwP (T4 Complete, Male): "Yeah, I think there's there's an awful lot of problem solving that we… from dishwasher, cupboards, you know, whether it's going to the toilet camber on the pavement. Yeah. So I'm always thinking about what is that thing in front of me and how do I kind of best position myself to go around. And now I'm I'm waiting for a better wheelchair, for example. So it's really funny the NHS, brilliant. But you know".

PwP (L1 Incomplete, Male): "I'm having problems. This will chairs not been looked at, serviced, since before covid and it's falling apart".

PwP (T4 Complete, Male): "You get a super lightweight, active user wheelchair at the spinal unit, which you practice in and practice in and practice in, and then you get a going home wheelchair".

PwP (T12 Incomplete, Male): "You can't get it out of the car. When you pass your car test, yeah, you're supposed to dismantle your chair and pull it over you, right. I knackered my shoulder doing that. Now I've got van now, with a tail lift, yeah. I was supposed to drive from a wheelchair, but it's only if it's a electric wheelchair, which I can't light as well. So I said "I'll have an electric wheelchair, then". So I was gonna buy an electric wheelchair just so I could drive my van".

PwP (T4 Complete, Male): "At the moment kind of just moving around the house is more difficult in this wheelchair".

		PwP (T6 Complete, Male): “I spent ages in one of those [wheelchairs] and it nearly killed me”. PwP (L1 Incomplete, Male): “My wheelchair was looked at in February because they’re still waiting for cushions, parts. Yeah, it's all the duct tape, the little things inside are like pyramid-shaped with air. But last time I looked, because I've washed them all, most of them are flat. Uh, I took the breaks off as they were hitting my hands”. PwP (T4 Complete, Male): “And this, just to pick up what PwP just said there about picking the chair up. This comes back to that we've got to fight for everything. Yeah. So, for instance, my wheelchair. I'm very active. I'm in my own wheelchair that I've bought. Wheelchair services, yeah, wanted to give me an Argon 2 wheelchair that weighs a bloody tonne, yeah, and lifting that in and out of my car with my shoulder is no good whatsoever. Yeah. So it's just pointless. I can't use it”.
	Geographical inequalities to services or opportunities relating to physical activity and exercise (barrier) (n = 5)	PwP (L1 Incomplete, Male): “I think financial, but also geographic. Yeah, I think probably, yeah. Postcode kind of lottery. Yeah, you might get better care in certain places”. PwP (T6 Complete, Male): “It depends on the hospital you end up under as well. The hospital you end up under, because I wasn’t under that spinal unit [that was previously mentioned]. And then listening to what you lot have been given coming out that spinal unit. And I was in another spinal unit”. PwP (T6 Complete, Male): “With a sub group because as we said postcode lottery was that it. If you get too big and too, then you're like, some people will be like “well, why they getting that? We're not getting that” and vice versa”.

	PwP (T9 Complete, Female): “Perhaps distance. Because you know, because I want to take up fencing. But it's far too far away”. PwP (L1 Incomplete, Male): “Yeah, yeah. Location of the activities [is a barrier], you know”. PwP (L1 Incomplete, Female): “Yeah, there's no accessible gym where I live”. PwP (T11 incomplete, female): “The availability. Yeah, just the availability to services really or like the access, you know. Somebody might not live in an area that has an accessible gym”.
Support from the workplace (facilitator) (n = 4)	PwP (T6 Complete, Male): “I was fortunate enough to get obviously a donation through whatever they are, the government thing and then work pay for this chair”. PwP (T12 Incomplete, Male): “Actually they do, don’t they? If you work, they pay for loads of stuff.” PwP (T11 Incomplete, Female): “I think it's the type of job that you do really. I mean, I'm a nurse at a nursing home. That's my job, so I'm constantly moving”. PwP (T11 Incomplete, Female): “Not really. I mean, I'm. I'm going across the nursing home. I'm either in meetings, you know, meetings, but I'll be wheeling myself to and from external buildings. Yeah. Transferring in and out. Transfers onto the toilet and back off again”.

			PwP (T4 Complete, Male): “I adapted my workspace and my work were very good with me in providing that sort of stuff”. PwP (T4 Complete, Male): “100% we have. So you got you get an assessment, an independent assessment and you say what you need and they [your workplace] have to supply these things”.
		Excessive planning and inability to be spontaneous (barrier) (n = 3)	HCP (Physiotherapist, Female): “Or the uncertainty. So, everything has to be planned very differently from most most people who have different levels of mobility. So you can't be, you have to be very brave and very able to be spontaneous. And so if you're with a group who where normally it would be completely spontaneous where you ended up, there are some people who are chair users or who are ambulant post their cord injury, who are really comfortable with that, but it's a tiny minority. Because you have to, you know, you plan where you're going, you know if you can access it, you know if you if there's enough room”. PwP (T6 Complete, Male): “The amount of planning you have to do just to go out the door is sometimes unbelievable”. PwP (T9 Complete, Female): “You’ve got to go through the rigmarole of, you know, what assistance do you need [when going out and about]”. PwP (T9 Complete, Female): “Oh well I got on a tube to come off at this stube station, and they asked “do you need a ramp to come off at Uxbridge?”, so “yes”, somebody phoned ahead. [I arrived and] it wasn’t there”.
Social opportunity	Social influences	Support from family or friends (facilitator) (n = 11)	HCP (Physiotherapist, Female): “Yeah, we occasionally see some families that are very much facilitators though as well in terms of let’s do your exercises, let’s do your standing frame

and they do, it's it's probably less, but they do push potentially, so they they could be classed as a facilitator as well as a barrier".

HCP (Physiotherapist, Female): "In my experience, my patients I see as outpatients that have got that support network definitely go out and about an awful lot more than the ones that potentially don't. Or have a close family unit that will support them. It does make a big difference in in my experience".

CCG (Charity worker, Male): "Well, if you're a parent with young kids, it's gonna be. It might be, I suppose you're not likely to be that sedentary in some in some respects, but but again, if you've got, you know, home commitments and things that you need to be doing in that respect. Then it can be a a distraction, I suppose from focusing on on being active in in some ways. Yeah, but there's. It depends, I suppose, whether or not. Yeah. You know, you might be a mother with young kids or, yeah, the people have different family commitments, don't they, which can be a distraction from from engaging in some kind of exercise or activity".

CCG (Family member, Female): "I think the kids, my sister [with paraplegia] has got two, in fact she's got four children, but two younger children and she's she, it keeps her quite busy".

CCG (Family member, Female): "I think you know I I try and encourage her to go out for some we call it wheels but walks effectively. So we'll go out for a walk and a wheel together".

PwP (L1 Incomplete, Male): "Having two daughters and a wife, sedentary behaviour is just not allowed, which is good, which is

good. They never allow me to wallow myself in self-pity or lay on the sofa".

PwP (T12 Incomplete, Male): "I get on the bed at night. Yeah, and just watch film after film after film after film. Get up, have a bit of supper. Go to bed, go to sleep. Wake up in the morning. Busy, busy, busy, round my mum's sorting her house out, cos my daughter's gonna get it eventually. So we're trying to decorate it, plasterboard it, and do everything. which I take part in. I do all that sanding and stuff like that. But then at night when I get home, after my tea I get on the bed and couch".

PwP (T4 Complete, Male): "I think that's similar to what I do. In my workshop, I restore things, up cycle things. Yeah. And so and also my wife gets me doing the DIY jobs which, it's amazing what she'll let me do when it's a DIY thing".

PwP (T12 Incomplete, Male): "No, I love staying in, if that mean's I have to stay in. On a Sunday, if I don't go to my mum's, that's it. My day is literally on bed all day".

PwP (L1 Incomplete, Male): "Yeah, because they're cause. You're you're. Yeah, you're stopping them [children] from rolling away that way. Or toddling".

PwP (L1 Incomplete, Male): "Right, but it, but if it's getting up a ladder or going up into the loft. Yeah, to help my wife organize it, she's alright with that. My wife is happy for me to climb up a step ladder to get into the loft to help her organise the loft. It's cause she wants that job done".

PwP (L1 Incomplete, Male): “Yeah. And I and I guess that's that's what you sign up to as a parent. So you know. They they do sort of distract me from whatever I'm doing for whatever they need to get done, and I'm not complaining about it because I love my daughter, I love my wife”.

PwP (T6 Complete, Male): “Yeah, I guess family depending on who they were, going back to my last lot, whether it's parents or whatever. It's dependent and you go from chalk to cheese. My son would just say “get on with it”. And others would not let you get anywhere near it”.

PwP (T4 complete, Male): “There's a thing, isn't there? About community, right? So doing things in a solitary capacity is often quite hard. A lot of barriers to it”.

PwP (T4 Complete, Male): “Yeah, you know, then again, that community aspect is so encouraging, finding ways for people to connect, cause that”.

PwP (T1 Incomplete, Male): “My sons are as like I used to be as a teenager, they're 15 and you're going on the bench press going “I did 50 kilos yesterday” and there's twins, so the other one is going “well, I benched 55”. So just yesterday they both bench pressed 55 and and that's wonderful. But you see what I mean? You got to start. I said, why don't you do reps and then build your way up and, you know, don't go for the powerlifting 100 kilos. You can see what I mean? So you know it's it depends on the person's incentive”.

PwP (L1 Incomplete, Female): “Well, I don't do the cleaning. I have someone comes in, does the cleaning for me. And while

		they're there, they supervise me, doing like a batch cook for the week, and then I just reheat in the microwave every day for what I'm eating once a day. And then I do the washing when they're there as well, 'cause. Then they can get the stuff in and out the washing machine for me". PwP (T11 Incomplete, Female): "I don't sit still long enough. I also have five children so I can't sit still for very long periods of time". PwP (T1 Incomplete, Male): "Yeah, actually, friends and family, it'd be a good idea to help build to motivate them". PwP (L1 Incomplete, Female): "Yes, because [having someone to do activity with] it would encourage me to go out more". PwP (T4 Complete, Male): "I think that's very unique to the specific person and what that person needs are me personally, I wouldn't need that. Some people might need that and therefore I can be a friend, a sponsor or something like that, and they can help together to do it until that person can do it on their own, if that makes sense. So have someone to support you to do it until you can do it on your own".
	Being deterred by family or friends (barrier) (n = 8)	HCP (Physiotherapist, Female): "I think it depends on like where they're discharged to as well and how much support they have at home, because like even those insignificant movements, a lot of patients won't do them because they have other people there to do them for them. And I think like a natural human response to someone who's less able than you are, is to help them. And so family and other people around would tend to just do small things like going out to get a cup of tea instead of them moving into another room to do it themselves. Things like that.

So it depends on if someone is living on their or if they're living with four other people that can help".

CCG (Charity worker, Male): "Well, if you're a parent with young kids, it's gonna be. It might be, I suppose you're not likely to be that sedentary in some in some respects, but but again, if you've got, you know, home commitments and things that you need to be doing in that respect. Then it can be a a distraction, I suppose from focusing on on being active in in some ways. Yeah, but there's. It depends, I suppose, whether or not. Yeah. You know, you might be a mother with young kids or, yeah, the people have different family commitments, don't they, which can be a distraction from from engaging in some kind of exercise or activity".

CCG (Family member, female): "I find my mum does a lot for him and maybe that stops him from doing things himself".

PwP (T4 Complete, Male): "I think that's similar to what I do. In my workshop, I restore things, up cycle things. Yeah. And so and also my wife gets to be doing the DIY jobs which, it's amazing what she'll let me do when it's a DIY thing, but if I wanted to do something, then "oh no, no, no, that's far too dangerous. No, you can't be doing that"".

PwP (L1 Incomplete, Male): "Yeah, definitely. Because I gave the example. And like is, is this sort of hypocrisy that my wife shows that like, if I said "well, I wanna go watch [football team]" she would say "well, how you going to get there? Is there parking?"".

	PwP (T12 Incomplete, Male): “Yeah, they [family] put barriers up”. PwP (L1 Incomplete, Male): “No, and I I have always appreciated that. There's not, because that's the flip side to it. You go to people's houses or other relatives that don't see your day to day, so they don't really know what you're capable of and not capable of. And they sort of try and wrap you in cotton wool”. PwP (L1 Incomplete, Male): “You know, it's like: “Ohh can you do that? Can I get that for you?”. Sometimes I quite like it, like please do grab me that and do that. Yeah, yeah, yeah. I'm like “this is fantastic”, but equally it can annoy you”. PwP (T12 incomplete, Male): “Family can put barriers up for you. But if you got your own barriers, so it's two fences to get over”. PwP (L1 Incomplete, Male): “You want them to be going “This is a fantastic opportunity. Can you imagine how you'd feel if you've got this done?”. It'd have been six weeks since [country]… you'd have your pilots thing. And for anyone that's a massive achievement, you know, and you sort of think “you should be behind me, guys, not sort of pointing out all the potential dangers”” PwP (T4 Complete, Male): “So for example, and again it's a relatively new and I new for my wife as well. I don't forget, but yeah, we just moved to a new area. New-ish as in sort of quite quite close to where we used to live, but it's still a new town. And she was like “oh well before we go to that pub, let me go

		first and check it out. Make sure it's all OK". And yet she was quite happy for me to come to [Removed] University on my own, you know, and just getting a cab and come here and find my way to the right building and find my way in. And then yet the pub that's two doors down to where we live, whereas I was saying to her "Well, let's just go and yeah"". PwP (T6 Complete, Male): "Yeah, I guess family depending on who they were, going back to my last lot, whether it's parents or whatever. It's dependent and you go from chalk to cheese. My son would just say "get on with it". And others would not let you get anywhere near it". PwP (T4 Complete, Male): "There's a thing, isn't there? About community, right? So doing things in a solitary capacity is often quite hard. A lot of barriers to it. PwP (L1 Incomplete, Female): "Umm. Well, I don't have much contact with my family. I mean, I go for dinner with my parents once a week. And that's it. And I've only got 2 friends and I see them once a month, so I don't have that support there to give me the incentive".
	Peer support network (facilitator) (n = 7)	HCP (Physiotherapist, Female): "But also this might be quite interesting in terms of the difference between a spinal unit and being treated somewhere else in a non-specialist centre, because of a lot of our patients will develop relationships with people that are on the ward themselves. And again, not always, and I'm generalizing a little bit. But then the patients will go out and do things together. So again, they've got those peer support networks to ultimately, again, together overcome some of these barriers".

HCP (Physiotherapist, Female): “And they'll exchange numbers et cetera. So, so it depends who's on the ward at the time as well. Some of them develop really close friendship groups that last a very long time”.

HCP (Physiotherapist, Female): “In my experience, my patients I see as outpatients that have got that support network definitely go out and about an awful lot more than the ones that potentially don’t. Or have a close family unit that will support them. It does make a big difference in in my experience”.

CCG (Family member, Female): “I think for my dad, he doesn't really, you know, sport has never been part of his life. He doesn't really have contact with other people with a similar injury. I think he just feels quite isolated. I think to have something like that where he could see other people actually are able to have some level of activity. I think really benefit him”.

CCG (Charity worker, Male): “If in some way it can involve contact with others, I think that that's one of the best motivational things out there”.

CCG (Family member, Female): “I was just thinking, you know, I could be added benefits as in sort of social, psychological, I think definitely for my dad. Because of his age, he does feel quite isolated with with his injury. And yeah, I just it could have. Yeah, more than just physical benefit for him. I think it could. Yeah, actually, something like that could actually really improve his life in lots of ways”.

PwP (T4 Complete, Male): “There's a thing, isn't there? About community, right? So doing things in a solitary capacity is often

	quite hard. A lot of barriers to it. You know, whereas, you know, if you're doing it with a buddy, or better still, with like, you talk about your walking could group or standing group”. PwP (T4 complete, Male): “Yeah, you know, then again, that community aspect is so encouraging, finding ways for people to connect”. PwP (T6 Complete, Male): “Along those lines. At rugby, 15 of us, however, many of us, 16. And someone said like quite a while ago, “there's sixteen of us here and we're all talking to each other now. If it wasn't the fact that we were sitting in this chair, we wouldn't be talking to each other”. We would probably have nothing to do with each other. Walk past each other on the street because our interests probably lay in different ways. But the fact that we're in this chair brings us together and gets us going, doing different things. Yeah, so that kind of makes it”. PwP (L1 Incomplete, Male): “And it's funny because isn't it? It's still the people say that in the negative way, so it's like just because I'm in a wheelchair doesn't mean I'll get on with like the person who's in the wheelchair. But having that common bond and under. It's an understanding which you don't need to describe to another person in the chair because they know exactly what you're talking about. Yeah, the the different things, it's just sort of a telepathic understanding”. PwP (T6 Complete, Male): “the pros and cons, and whatever you wanna call it. Yeah, the natural side of it just comes out and I mean, if you look at the five of us sitting here now, never met each other, but yet we’re properly just bleating our hearts out. Get what I mean?”.

PwP (T4 Complete, Male): “It’s what. It's not. So this is, socialization, right? Which is usually helpful, but I think it's more that like the spinal charities try to organise this. It’s kind of community. It's about. But I've only been in my new town for two- and a-bit weeks. I've not seen a single other wheelchair user”.

PwP (T4 Complete, Male): “I would like a way to be able to connect with other, you know, wheelchair, or, even better, spinal patients”.

PwP (L1 Incomplete, Male): “So if all of these users are on this app, they're all spinal cord injury patients. They're all trying to be more active and less sedentary, and I don't know if, it's not like goal setting, or it's like “Mark's smashed this target” or “he's achieved this this week” and “so and so on has achieved””.

PwP (T6 Complete, Male): “Or there's a. I mean, for, depending on what state you’re at. So for somebody like PwP, obviously everything's very new. So for something like, if you have a group, if need be, and if he, is obviously different ones wants to do it in different ways, but he would learn so much for. Obviously everyone that’s been there for a year, six months or 15 years, because everyone's at different stages and everyone tackles things in different ways. So what works right for PwP, and what works right for PwP, and what works right for me… [might be different].

PwP (T4 Complete, Male): “But you did say that meeting your wheelchair rugby buddies is hugely helpful”.

				PwP (T4 Complete, Male): “No, I was thinking more of it, in my local communities like you know. Tt's like having a running buddy or a gym buddy. You know, it's just somebody you go “You know what? Let's go. Let's go and do that together””. PwP (T6 Complete, Male): “I was more curious as to going back to the rugby, I've never done anything like that before. It was more curiosity to me that got me doing that type of thing. And then it led into the.. we go training once a week. So it's the physical side of it, but. Yeah, and then the community side of it and there's. And then you might stay behind after and just have a cup of tea or something and just a yarn. It's just silly little things, and then”. PwP (T6 Complete, Male): “The enjoyment bit umm, I was thinking maybe that would be linked to community, in terms of if you're feeling a little bit demotivated, you know, maybe there's like a chat or a forum or something. Maybe. You could go “I’m feeling a bit low about this or that”. I don't know. It's not something I would probably do”. PwP (L1 Incomplete, Female): “Yeah, that would be good. I use WhatsApp. If there was a WhatsApp group [with other individuals with a spinal cord injury] that would work”.
Motivation	Reflective motivation	Beliefs about capabilities	Low self-esteem or self-conscious (barrier) (n = 8)	HCP (Physiotherapist, Female): “Yeah, just a couple of other bits on that. Another thing is confident, so feeling confident to get out and about. And again, if you for us, we're talking about a population from people who are babies to people who are first injured in the 80s, so their needs from an activity point of view are different um and, but their ability to get out of the front door and access outside space and and be happy moving around is really variable. So confidence to access business”.

HCP (Physiotherapist, female): “People don't like being seen in a wheelchair”.

CCG (Charity worker, male): “Psychological components around motivation and confidence and self-esteem, body image. That that can all contribute to just not finding that 5 minutes [to be active per day]”.

CCG (Charity worker, Male): “Yeah, I I think that. I think that's a huge thing. For a lot of people a big issue for them is is being seen as being disabled. You know, being. The chairs are a very visible cue, obviously, and some people find it, yeah, really, really hard to adjust to that”.

PwP (T12 Incomplete, Male): “People staring at you sometimes puts you off as well doing anything”.

PwP (T12 Incomplete, Male): “People talk about you, nudging, winking, everything, pointing [when going out and about]”.

PwP (T6 Complete, Male): “Or it’s easier because I’m in the chair and when they come out with me and I've got the dog and the chair, they say “I don't know how you managed to get round the park”. Because everyone wants to stop and talk to you, or help you, or wipe your backside for you, so to speak, because you're in the chair. It's just, I don’t know. Leave me alone”.

PwP (T6 Complete, Male): “You feel like a three-year-old going shopping because you can't reach above that level”.

			PwP (L1 Incomplete, Male): “Yeah definitely, like lack of self-esteem or something that could come from the injury, illness”. PwP (T6 Complete, Male): “Yeah if you think you can't do it, you don't. Some people won't even try it”. PwP (L1 Incomplete, Male): “And yeah, with that, it could be other people's opinions on what you're doing and criticism. People might be criticising what they see is a pathetic attempt to to do whatever”.
	Intentions	Building habits around activities of daily living (facilitator) (n = 7)	HCP (Physiotherapist, Female): “Most paraplegics will be physically able to do that [do activities of daily living]. In fact, I mean almost all paraplegics, well there might be if they had something else wrong with them, then maybe that would mean that that was technically not possible, but with a paraplegic level of injury in a reasonable environment you should be able to independently get out and about. It's the environment that prevents you doing it, not your intrinsic skills. PwP (T11 Incomplete, Female): “Yeah. So I am, you know, with a spinal cord injury, you have. I have to use catheters to go to empty my bladder. So I will deliberately get up, go over to the toilet rather than using bags. That's something that we were that. That’s a way for me to be able to kind of move or make me make myself a cup of tea. I might get up out of the chair to do that, but I do a lot of transfers so I don't stay in my chair very long. I will transfer out of my wheelchair onto the sofa or, and out to the kitchen. And so I think I just. I don't sit still long enough. I also have five children so I can't sit still for very long periods of time”.

	PwP (T1 Incomplete, Male): “And you can't be embarrassed about your own incompetence. I'll be on that after this. But that's the truth of it. So yeah, building it in and building it up at home, piece by piece, that's a good idea. You're like lifting tins or lifting coffees and things, and that simple stuff. Sitting on the sofa squeezing those”. PwP (T1 incomplete, Male): “Building [activity] into things you've got to do in the house, it gives you a sense of worth, not just for exercise and fitness”. PwP (T1 Incomplete, Male): “But the. But lifting the tin of beans there, just doing what you can, you know, get hoovering or something. That's a good idea [to build activity into daily life]”. PwP (T1 Incomplete, Male): “And so there's, you know, so there's the things you gotta get the I think the intellectual problems, you know that the the thought process then the physical aspects and then slowly but surely you you knock every little brick down and work on it. And you know, then there's it's just, I think. I really like your idea about the exercising at home. Just build it into your lifestyle because unless you're just going to let, and even if you're laying in bed, I have got grab rails at the side because I have no stability, and I I actually have very strong arm, but I I grab them and I pull myself across the bed. And then I use gravity to put me in the wheelchair. I've had my bed raised above the wheelchair to just fall into it. It's a little more fun getting back in again. But if that happens, I just end up lying on the sofa all night. You know that's it's the way. But you see what I mean. There's always

ways of building some form of exercise into your, into everything".

CCG (Charity worker, Male): "If I if I'm watching TV now, I will. I won't sit there for, I'll make sure I'm not sat sedentary for more than an hour. For example. You know, if I've seen an hour come up, I'll make sure I get up. Even if it's just to go to the toilet or go and just do something else and then sit there. It means having to transfer back into my chair and to move. But but. But things like that. I think in some ways getting a bit of a trying to get a bit of a timetable even into your normal daily living and to and to incorporate the activity in into into that".

PwP (L1 Incomplete, Male): "Because, I mean, you think most of the time you've been totally motivated to get back to it, but then the length of time that you've left it, it's sort of a distant memory because you've not kept on it. And I think that's some of the thing with good habits is you've really gotta keep working at it and not letting it slip".

PwP (T4 complete, male): "If you can make doing something part of your routine a habit, a good habit. Then you're more motivated to keep it up".

PwP (T1 Incomplete, Male): "But I liked your idea about building exercise into the things you can do in your life rather than going down the gym. Cause also you're gonna stand out in the gym. "What? What?" You know, there'll be all these pumping people, do you know, pumping iron, and they just look at you and you might upset them".

		PwP (T1 Incomplete, Male): “Now, this meeting has suddenly made me think “there are things I could do”. So, the researchers, you've done it. I’m thinking “Hang on a minute. I could pick some bottles up, pick up a can of beans up, do a bit of work while sitting on the sofa””. PwP (T4 Complete, Male): “And yeah, I would say that at first, someone might need a need a high level of intervention. Yeah, but then that intervention might become less and less, which it should do as their mind becomes more down to them”.
	Boredom, being a chore or lack of enjoyment (barrier) (n = 6)	HCP (Physiotherapist, Female): “I think it's really boring and very few of them do it [their prescribed exercise programme] in spite of very specific recommendations and advice around it. But that's exercising rather than not being sedentary”. HCP (Physiotherapist, Female): “Yeah, just another idea. I've no idea if that's even possible, but just another potential option, leading on from the things that we've said in terms of mood and psychology and exercise and activity, and individualising it as much as possible. Potentially, if you've got different options for different people, they can choose what works for them”. PwP (T6 Complete, Male): “I think something. Yeah. Yeah, I get told to do something. Sitting and start off from day one, you do, like, as a regime. Day two is still that. Day 3. And by day 25 you're thinking “I'm doing this, this and this” and it all goes out the window. So a year down the line after being told to do this every day”. PwP (T4 Complete, Male): “There's a thing, isn't it? So, you know, I've got a pill reminder app, right? So it's just says, yeah, “time to take your meds”. And it reminds me every like 5

	minutes, like “you haven’t taken them” and then you go “Oh yeah”, and it's actually turned that notification off, where you go “great I've done it now” and it's off. It's not gonna remind me again. Same with exercise”. PwP (T12 incomplete, Male): “They want you in it [standing frame] for like 3 or 4 hours a day. What can you do, stood? What can you do? It’s boring”. PwP (L1 Incomplete, Male): “Or time slash boredom. As in duration of how long you’re motivated. Because it goes back to what we were saying about doing exercises or doing doing things as you probably should when you've left rehab, and then over time you've got a bit more lackadaisical about it and bad habits creep in and slip. And we just think “oh I don’t need to do that anymore””. PwP (L1 incomplete, male): “It [physical activity] being a chore and that might break your motivation cause because it's. It’s not enjoyable”. PwP (T4 Complete, Male): “But there’s the thing that cuts across time and boredom, it’s enjoyment isn't it. It has to be fun. If it’s fun, then all of those things kind of fall into place”. PwP (T6 Complete, Male): “Otherwise it just becomes the repetitive and that's when you kick it into touch because you can’t be bothered [if there isn’t choice or variety in an activity routine]”. PwP (T4 Complete, Male): “There's a balance isn’t there. You’ve got to have enough choice to mix things up”.

		PwP (T4 Complete, Male): “Fun, fun tackles prioritising it, other commitments, boredom, time, becoming a chore. And if something is fun to do, you'll do it more often”.
Goals	Goal setting (facilitator) (n = 8)	HCP (Physiotherapist, Female): “It’s timing it right, because I think just working out how to live when you first get home, is enough without a goal, because it's such a big shock to the system. But maybe there's a time point after getting home when you want to have goals again. But I don't. If if you said ‘you're going home and here are your goals’, they might be like ‘hold on. I just need to get into my house and work out how to be in my house and doing my routine at home’. It might not fit early in that”. HCP (Physiotherapist, Female): “The the readmissions, the readmissions, often, so, we see people across the course of their lives. But first episode of rehab. So the people that are having an inpatient rehab cycle for the first time following their spinal cord injury, I, like, there is no, there is no service level mechanism for setting goals for post-discharge because, and there might be the odd occasions where you and your patient would talk about something that you thought you know. In fact, no, that's not true”. PwP (L1 Incomplete, Male): “So if all of these users are on this app, they're all spinal cord injury patients. They're all trying to be more active and less sedentary, and I don't know if, it's not like goal setting, or it's like “Mark's smashed this target” or “he's achieved this this week” and “so and so on has achieved””.

PwP (L1 incomplete, male): “Realistic goals I guess, that's the one I mean. Because you know, if you start out thinking “Why am I not at the top of the Mount Everest, yet?””.”

PwP (T6 Complete, Male): “It goes to the old thing about having a beginners, intermediate and an advanced thing”.

PwP (L1 Incomplete, Male): “Is it? I mean, would there be like a mentoring or coaching? It could be cut part of the creating targets. Maybe you can check back or um. Adjustable”.

PwP (T1 Incomplete, Male): “The other thing is maybe you could do like they have in the scouts you could have little badges for can you move your hands? Yes, or no? and then you could do little grip exercises and start from the bottom and work way up. Now, people like Tony who have got a bit more go in them can work their way up to the top. If you start at the bottom and say, little, you know, little bit, baby steps. You start your way at the bottom and work your way up. That's a good training exercise”.

PwP (L1 Incomplete, Female): “Hmm. Yeah. And I mean, Fitbit does the opportunity that you can, when you're tracking your steps, you can do challenges like the number of steps to climb Kilimanjaro, for example, or go from one place to another place. So that's another opportunity. The number of calories you've burnt is enough calories to have done this thing”.

PwP (T11 incomplete, female): “When I say objectives and goals, I mean personally I like to work towards goals and objectives”.

		PwP (T4 Complete, Male): “I think that's very unique to the specific person and what that person needs are me personally, I wouldn't need that. Some people might need that and therefore I can be a friend, a sponsor or something like that, and they can help together to do it until that person can do it on their own, if that makes sense. So have someone to support you to do it until you can do it on your own”.
Reinforcement	Rewards (facilitator) (n = 5)	PwP (T12 Incomplete, Male): “Money or vouchers would be wicked [as an incentive for breaking up sedentary behaviour with physical activity]”. PwP (L1 Incomplete, Male): I was gonna say a tie in with sponsors. You know, I mean sports shops or sports brands or something, because it's exercise equipment. Or just, yeah, discount, or if you, I don't know”. PwP (L1 Incomplete, Male): “Self-esteem. The self-esteem thing might come, you know, if you've readjusted the goals and they’re more realistic you, you're gonna feel a boost. That you're trying again, or you're trying in a different way. So, I don’t know if that answers that one or not”. PwP (T4 Complete, Male): “Oh yeah, I think. Anyway, for me personally, I certainly have to reduce and watch what I eat. And I mean, I cycle every day on a day for an hour and a half. Yeah. And things like that. Just so I can basically eat cake and go out of coffee shops. Yeah. I mean, I like eating cake and chocolate, but I do that and the trade-off for me in that is I do three hours of exercise every day, day in, day out. So I can get away with eating, coffee and walnut cake. Because if I did do the exercise, I wouldn't be able to do it. Well, I could”.

			PwP (L1 incomplete, female): “If I could earn a badge for doing a 5-minute exercise on a bad day that might incentivise me for doing it”. PwP (L1 Incomplete, Female): “Yeah, I usually do so like, if I go down to the hospital because I've been out for the day and I've done a lot during the day, I'll come back by McDonald's and have a Mcflurry. That's my reward”. PwP (T4 Complete, Male): “Well, if if I'm going out seeing friends in coffee shops and now I'd like to have a cake. So you can either have a slab of cake and put a fair bit of weight on, or you can say, you know what? I'm gonna have that cake. So therefore I've burnt the calories and now and exercise just becomes a routine”. PwP (L1 Incomplete, Female): “Gems kind of things and you when you get so many gems you get a badge. So it's like a reward that you, “oh, I've. I've got so many. So many from doing so many lessons”. So it kind of motivates you to do that number of lessons because then you've got another reward and it's not much, but it's something”. PwP (T11 incomplete, female): “The reward itself would be me completing the goal”.
Automatic motivation	Emotions	Low mood (barrier) (n = 3)	HCP (Physiotherapist, Female): “I think some people think they've got enough on, you know, like we're all aware of the recommendations with regards to levels of activity that we should have in order to be healthy, but that that advice is even harder to make stick for a population with disabilities sometimes, because they feel like they've been served enough challenge”.

		HCP (Physiotherapist, female): “The biggest barrier to general levels of physical activity is how you're thinking and feeling and that comes down to psychology”. PwP (L1 Incomplete, Male): “Having two daughters and a wife, sedentary behavior is just not allowed, which is good, which is good. They they never allow me to wallow myself in self-pity or lay on the sofa”. PwP (L1 incomplete, female): “I have good days and bad days and on a good day I'm fine. I can do stuff. It's not a problem, but on a bad day it can vary between not getting out of bed or getting out of bed but not going out the house”.

CCG, Community Caregiver; COM-B, Capability, Opportunity and Motivation to change Behaviour; HCP, Healthcare Professional; PwP, Participant with Paraplegia; TDF, Theoretical Domains Framework.

Appendix 23. Brunel ethical approval for feasibility study.

College of Health, Medicine and Life Sciences Research Ethics Committee (DLS)
Brunel University of London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

27 March 2025

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 27/03/2025 AND 31/12/2025

Applicant (s): Mr Daniel Cooper Dr Daniel Bailey, Dr Alyson Warland, Dr Emma Norris, Professor Cherry Kilbride, Ms Sue Paddison, Dr Benjamin Maylor, Dr Louise Ferrandino, Dr Katherine Finlay

Project Title: Acceptability, fidelity, safety and preliminary efficacy of a sedentary behaviour intervention in individuals with spinal cord injury: a pilot study

Reference: 50038-NHS-Mar/2025- 54084-2

Dear Mr Daniel Cooper

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

Please ensure tracked changes and comments are removed before submitting to NHS REC

- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to any conditions that may appear above.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Louise Mansfield

Chair of the College of Health, Medicine and Life Sciences Research Ethics Committee (DLS)

Brunel University London

Appendix 24. NHS ethical approval for feasibility study.

Ymchwil Iechyd a Gofal Cymru
Health and Care Research Wales

NHS
Health Research Authority

Dr Daniel Bailey
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH

Email: approvals@hra.nhs.uk
HCRW.approvals@wales.nhs.uk

09 May 2025

Dear Dr Bailey

HRA and Health and Care Research Wales (HCRW) Approval Letter

Study title:	**Acceptability, fidelity, safety and preliminary efficacy of a sedentary behaviour intervention in individuals with spinal cord injury: a pilot study**
IRAS project ID:	**345324**
Protocol number:	**1**
REC reference:	**25/EE/0090**
Sponsor	**Brunel University of London**

I am pleased to confirm that **HRA and Health and Care Research Wales (HCRW) Approval** has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications received. You should not expect to receive anything further relating to this application.

Please now work with participating NHS organisations to confirm capacity and capability, in line with the instructions provided in the "Information to support study set up" section towards the end of this letter.

How should I work with participating NHS/HSC organisations in Northern Ireland and Scotland?
HRA and HCRW Approval does not apply to NHS/HSC organisations within Northern Ireland and Scotland.

If you indicated in your IRAS form that you do have participating organisations in either of these devolved administrations, the final document set and the study wide governance report (including this letter) have been sent to the coordinating centre of each participating nation. The relevant national coordinating function/s will contact you as appropriate.

Appendix 25. Consolidated Standards of Reporting Trials (CONSORT) guidelines for feasibility and pilot trials.

CONSORT 2010 checklist of information to include when reporting a pilot or feasibility trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a pilot or feasibility randomised trial in the title	138
	1b	Structured summary of pilot trial design, methods, results, and conclusions (for specific guidance see CONSORT abstract extension for pilot trials)	ii, iii
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale for future definitive trial, and reasons for randomised pilot trial	138, 139
	2b	Specific objectives or research questions for pilot trial	138, 139
Methods			
Trial design	3a	Description of pilot trial design (such as parallel, factorial) including allocation ratio	140
	3b	Important changes to methods after pilot trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	142
	4b	Settings and locations where the data were collected	140
	4c	How participants were identified and consented	142, 143

Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	144-147
Outcomes	6a	Completely defined prespecified assessments or measurements to address each pilot trial objective specified in 2b, including how and when they were assessed	148-154
	6b	Any changes to pilot trial assessments or measurements after the pilot trial commenced, with reasons	N/A
	6c	If applicable, prespecified criteria used to judge whether, or how, to proceed with future definitive trial	149
Sample size	7a	Rationale for numbers in the pilot trial	144
	7b	When applicable, explanation of any interim analyses and stopping guidelines	144
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	N/A
	8b	Type of randomisation(s); details of any restriction (such as blocking and block size)	N/A
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	N/A
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	143
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	N/A
	11b	If relevant, description of the similarity of interventions	N/A

Statistical methods	12	Methods used to address each pilot trial objective whether qualitative or quantitative	154-156
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were approached and/or assessed for eligibility, randomly assigned, received intended treatment, and were assessed for each objective	157, 172, Table 10, Figure 10
	13b	For each group, losses and exclusions after randomisation, together with reasons	Figure 10
Recruitment	14a	Dates defining the periods of recruitment and follow-up	157
	14b	Why the pilot trial ended or was stopped	144
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 10
Numbers analysed	16	For each objective, number of participants (denominator) included in each analysis. If relevant, these numbers should be by randomised group	Figure 10, Table 13, Table 14
Outcomes and estimation	17	For each objective, results including expressions of uncertainty (such as 95% confidence interval) for any estimates. If relevant, these results should be by randomised group	159-179, Tables 11-14
Ancillary analyses	18	Results of any other analyses performed that could be used to inform the future definitive trial	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	172
	19a	If relevant, other important unintended consequences	N/A
Discussion			

Limitations	20	Pilot trial limitations, addressing sources of potential bias and remaining uncertainty about feasibility	193
Generalisability	21	Generalisability (applicability) of pilot trial methods and findings to future definitive trial and other studies	193
Interpretation	22	Interpretation consistent with pilot trial objectives and findings, balancing potential benefits and harms, and considering other relevant evidence	182-193
	22a	Implications for progression from pilot to future definitive trial, including any proposed amendments	182-193
Other information			
Registration	23	Registration number for pilot trial and name of trial registry	140
Protocol	24	Where the pilot trial protocol can be accessed, if available	140
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	N/A
	26	Ethical approval or approval by research review committee, confirmed with reference number	140

*We strongly recommend reading this statement in conjunction with the CONSORT 2010, extension to randomised pilot and feasibility trials, Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up-to-date references relevant to this checklist, see www.consort-statement.org.

Appendix 26. Good reporting of a mixed-methods study (GRAMMS) checklist.

Guideline	Page number
1. Describe the justification for using a mixed methods approach to the research question	138
2. Describe the design in terms of the purpose, priority and sequence of methods	140, Figure 8
3. Describe each method in terms of sampling, data collection and analysis	142-144, 148-156
4. Describe where integration has occurred, how it has occurred and who has participated in it	156
5. Describe any limitation of one method associated with the present of the other method	156, 193
6. Describe any insights gained from mixing or integrating methods	193

Reference: O'Cathain, A., Murphy, E., Nicholl, J. (2008). The quality of mixed methods studies in health services research. *Journal of Health Services Research and Policy, 13*, 92-98.

Appendix 27. Physical Activity Readiness Questionnaire + (Part 1).

Brunel University of London

Physical Activity Readiness Questionnaire

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.

1. Has your doctor ever said that you have a heart condition **OR** high blood pressure? *

- ◯ Yes - heart condition
- ◯ Yes - high blood pressure
- ◯ Yes - both
- ◯ No

2. Do you feel pain in your chest at rest, during your daily activities of living **OR** when you do physical activity? *

- ◯ Yes
- ◯ No

3. Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? *

- ◯ Yes
- ◯ No

4. Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? *

- ◯ Yes
- ◯ No

6. Are you currently taking prescribed medications for a chronic medical condition? *

- ◯ Yes
- ◯ No

8. Do you currently have (or have had within the past 12 months), a bone, joint or soft tissue (muscle, ligament or tendon) problem that could be made worse by becoming more physically active?

[please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active] *

- ◯ Yes
- ◯ No

10. Has your doctor ever said that you should only do medically supervised physical activity? *

- ◯ Yes
- ◯ No

11. What is your full name? *

0/32,000 characters

PARTICIPANT DECLARATION

By pressing 'Submit', I am confirming that I have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the researchers at Brunel University of London may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

Submit

Appendix 28. Physical Activity Readiness Questionnaire + (Part 2).

Physical Activity Readiness Questionnaire - extended

You are completing this form because you answered YES to one or more of the seven questions in the Physical Activity Readiness Questionnaire. As a result, we need to ask you some more follow-up questions about your medical condition to check your readiness to do physical activity.

Please read the questions below carefully and answer each one honestly: check YES or NO.

1. Do you have Arthritis, Osteoporosis, or Back Problems?

- (●) Yes
- ( ) No

2. Do you have difficulty controlling your Arthritis, Osteoporosis or Back Problems with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)

- ( ) Yes
- ( ) No

3. Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?

- ◯ Yes
- ◯ No

4. Have you had steroid injections or taken steroid tablets regularly for more than 3 months for your Arthritis, Osteoporosis or Back Problems?

- ◯ Yes
- ◯ No

5. Do you currently have Cancer of any kind?

- ◉ Yes
- ◯ No

6. Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?

- ◯ Yes
- ◯ No

7. Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?

- ◯ Yes
- ◯ No

8. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

- (●) Yes
- ( ) No

9. Do you have difficulty controlling your Heart or Cardiovascular Condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)

- ( ) Yes
- ( ) No

10. Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)

- ( ) Yes
- ( ) No

11. Do you have chronic heart failure?

- ( ) Yes
- ( ) No

12. Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?

- ( ) Yes
- ( ) No

13. Do you currently have High Blood Pressure?

- (●) Yes
- ( ) No

14. Do you have difficulty controlling your High Blood Pressure with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)

- ( ) Yes
- ( ) No

15. Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)

- ( ) Yes
- ( ) No

16. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

- (●) Yes
- ( ) No

17. Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician- prescribed therapies?

- ( ) Yes
- ( ) No

18. Do you often suffer from signs and symptoms of low blood sugar (hypoglycaemia) following exercise and/or during activities of daily living? Signs of hypoglycaemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.

- ◯ Yes
- ◯ No

19. Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes **OR** kidneys?

- ◯ Yes
- ◯ No

20. Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?

- ◯ Yes
- ◯ No

21. Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?

- ◯ Yes
- ◯ No

22. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

- ◉ Yes
- ◯ No

23. Do you have difficulty controlling your Mental Health Problem or Learning Difficulty with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

- ◯ Yes
- ◯ No

24. Do you have Down Syndrome **AND** back problems affecting nerves or muscles?

- ◯ Yes
- ◯ No

25. Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

- ◉ Yes
- ◯ No

26. Do you have difficulty controlling your Respiratory condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)

- ◯ Yes
- ◯ No

27. Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?

- ◯ Yes
- ◯ No

28. If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?

- ◯ Yes
- ◯ No

29. Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?

- ◯ Yes
- ◯ No

30. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia

- ◉ Yes
- ◯ No

31. Do you have difficulty controlling your Spinal Cord Injury with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

- ◯ Yes
- ◯ No

32. Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?

- ◯ Yes
- ◯ No

33. Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?

- ◯ Yes
- ◯ No

34. Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event

- ◉ Yes
- ◯ No

35. Do you have difficulty controlling your Stroke-related condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

- ◯ Yes
- ◯ No

36. Do you have any impairment in walking or mobility caused by a stroke?

- ◯ Yes
- ◯ No

37. Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?

- ◯ Yes
- ◯ No

38. Do you have any other medical condition not listed above or do you have two or more medical conditions?

- (●) Yes
- ( ) No

39. Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?

- ( ) Yes
- ( ) No

40. Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?

- ( ) Yes
- ( ) No

41. Do you currently live with two or more medical conditions?

- ( ) Yes
- ( ) No

43. What is your full name? *

0/32,000 characters

PARTICIPANT DECLARATION

By pressing 'Submit', I am confirming that I have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the researchers at Brunel University of London may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

Submit

Appendix 29. Feasibility study recruitment poster.

Brunel University of London

ARE YOU A MANUAL WHEELCHAIR USER WITH A SPINAL CORD INJURY WANTING TO GET MORE ACTIVE?

Join our study to test a new physical activity programme to improve heart health in people with paraplegia

What will it involve?

- An 8-week programme to increase your activity throughout the day
- Using a Smartwatch with wheelchair mode to track activity
- Using exercise bands and a portable hand cycle
- Measurements of health, like body fat and blood sugar

Am I eligible?

- 18 + years old with paraplegia
- Use a manual wheelchair
- Able to travel to Brunel University of London

£50
SHOPPING VOUCHER
& travel expenses covered

Approved by Brunel's College of Health, Medicine & Life Sciences Research Ethics Committee and NHS Research Ethics Committee (27/3/2025 to 31/12/2025) Version 2.5 (16/01/2025)

If you're interested and want to learn more, scan the QR code or email: daniel.cooper2@brunel.ac.uk

Appendix 30. Feasibility study expression of interest form.

Expression of interest form

The REACH-SCI (Reduction of sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury) study

To be eligible for this study, you need to:

- Be aged 18 years or older with paraplegia (a spinal cord injury at T1 or below).
- Use a manual wheelchair as your main way of getting around during the day.
- Have a spinal cord injury of any kind such as complete or incomplete, traumatic or non-traumatic, short or long-term.
- Be able to visit Brunel University of London twice to take part in measurements.

Travel expenses will be reimbursed and you will receive a £50 Amazon shopping voucher after completing the study.

If you are interested in taking part and are happy for a member of the team to contact you, please submit the form below with your details.

1. Name

0/32,000 characters

2. Email address

3. Phone number

0/32,000 characters

4. Your postcode (so we can check your distance from Brunel University of London)

0/32,000 characters

5. How did you hear about the study? (e.g. social media group or website)

0/32,000 characters

If you have any questions about the study, or want to check if you are eligible, please contact Daniel Cooper by email at daniel.cooper2@brunel.ac.uk.

Please press the 'Submit' button below to submit your responses.

By submitting this form I am providing my consent for the research team to contact me about participation in this study using the contact details I provided above.

Submit

Appendix 31. Feasibility study participant information sheet.

PARTICIPANT INFORMATION SHEET

Study title

The REACH-SCI study: Reduction of sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury

Invitation Paragraph

You are being asked to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask the research team if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the study?

People with paraplegia have a high risk of heart disease and stroke. Reducing inactivity could help to lower these risks. Inactivity is when you do sedentary activities that don't use up much energy, like watching TV, working on a computer or browsing social media. In non-disabled people, there have been a number of programmes to reduce inactivity that have led to improvements in markers of heart health such as blood sugar, blood pressure and cholesterol levels. We don't know how well programmes to reduce inactivity work in manual wheelchair users with paraplegia.

The purpose of this research is to test a new programme, REACH-SCI, to support manual wheelchair users with paraplegia to reduce inactivity and improve heart health.

Why have I been invited to participate?

You have been invited to participate as you have paraplegia (a spinal cord injury at T1 or below). To be eligible, you need to be 18 years or older, use a manual

wheelchair as your main way of getting around during the day, and be able to travel to Brunel University of London, Uxbridge, on two occasions to complete study measurements.

How do I sign up to take part?

If you decide you want to take part, please email daniel.cooper2@brunel.ac.uk or scan the QR code.

Do I have to take part?

As participation is entirely voluntary, it is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and you will be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time without having to give a reason, and without this affecting any care you may be receiving or will receive in the future. Data you have already provided will continue to be used in analysis of the study results.

What will happen to me if I take part?

At the start of the study you will visit Brunel University of London campus to have a set of measurements taken. This will include using wheelchair scales to measure your body weight and a tape measure to measure your height and waist size. The amount of muscle in your body will be measured by placing four sticky electrode pads to your hand and foot. Muscle levels will be worked out by sending a small, safe electric current through your body, which will not cause any pain. Your blood pressure will be measured by inflating a blood pressure cuff around your upper arm. A small amount of blood will be taken from your fingertip using a lancet (a small needle), so we can measure blood sugar and cholesterol levels. The blood sample will be analysed using a handheld analyser and then disposed of. If any abnormal results arise from your blood sample, we will advise you to contact your GP to discuss this with them. You will need to fast overnight, and not consume any caffeine or alcohol for 24 hours before these measurements are taken to make sure they are accurate.

You will also be asked to complete some questionnaires to ask about your wellbeing, mood and quality of life. We will then ask you to wear an activity monitor, called an ActiGraph (see Image 1) on your wrist for 7 full days to record your normal day-to-day levels of inactivity and physical activity. During these 7 days of monitoring, you will be asked to keep a diary to note times you slept and if you removed the activity monitor.

Image 1. ActiGraph activity monitor

Once the measurements have been completed, you will then receive the REACH-SCI programme for eight weeks.

REACH-SCI will involve:

- Using a Garmin Vivoactive 5 smartwatch (Image 2) or your own similar device (if you prefer and it has wheelchair mode)
- An educational booklet including information and worksheets about inactivity and goal setting
- Three one-to-one motivational support sessions with a trained researcher who will support you with goal setting, reviewing progress and creating action plans to achieve your goals
- The option to join a WhatsApp peer support group chat that will include other participants in the programme
- Activity tools including exercise bands and a portable hand cycle so you can do light activity during the day

Image 2. Garmin Vivoactive smartwatch

As your first visit to Brunel will involve the above measurements and a researcher getting you started with the REACH-SCI programme, the visit is likely to take around 3 hours in total.

During the last seven days of the programme, you will be asked to wear the ActiGraph monitor again for 7 full days to see if there have been any changes in your inactivity and physical activity levels. You will need to wear both the ActiGraph and Smartwatch (Garmin Vivoactive or your own device) during this time, as you will still be doing the REACH-SCI programme. After this, you will be invited back to Brunel University of London to complete the exact same measurements as you did at the start of the study, and return the ActiGraph, Garmin smartwatch and portable hand cycle. We will also ask you to complete some questionnaires and you may be asked to take part in a one-to-one interview to find out about your experiences with the REACH-SCI study. Your second visit is expected to last around 2 hours.

You will receive a £50 Amazon gift voucher after you complete the final set of measurements at the end of the study as a thank you for taking part. We will reimburse your travel expenses for any visits to Brunel University of London.

What are the possible disadvantages and risks of taking part?

There is a very small risk of cross infection when providing a fingertip blood sample. This risk will be minimised by blood samples being taken by a trained researcher following best practice guidelines. There is a small risk that providing a blood sample could make you feel dizzy or faint. If this happens, we will monitor you until you feel better and, if necessary, help will be sought from on-site first aiders. For those taking part in the interview about your experience in the study, there is a small risk that you could feel upset when answering some of the questions. Please let the researcher know if this is the case and the interview can be paused or stopped. Remember that you do not have to answer any questions that you do not want to and you are free to withdraw from the study at any point without giving a reason and without this affecting any care you are receiving or will receive in the future.

There is a possibility of muscle soreness, pain or discomfort as a result of doing physical activity, although this risk is low as we are not asking you to do any intense exercise. You will be provided with instructions on how to use the activity tools we provide you with in a proper and safe way. If you experience new or worsening symptoms such as pain, a sudden dangerous rise in blood pressure (autonomic dysreflexia) or involuntary muscle stiffness (spasticity) during the course of the study,

you should stop any exercise and contact a member of the research team on the email address provided at the end of this form. Autonomic dysreflexia is a serious medical condition that can lead to severe complications. If symptoms such as a pounding headache, sweating, and a flushed appearance happen you should stop any physical you may be doing and contact your GP if the symptoms remain.

What are the possible benefits of taking part?

We hope the findings of this study could lead to improvements in healthcare for individuals with paraplegia in the future. You will be contributing to this by taking part. If you wish, you will also be provided with a summary of the findings from the study after it is finished.

Will my taking part in this study be kept confidential?

All information which is collected about you during the research will be kept strictly confidential. Responsible members of Brunel University of London and regulatory authorities may be given access to data for monitoring and/or audit of the study to ensure the study is being carried out correctly and complies with regulations. These people will have a duty of confidentiality to you as a research participant. If, during the course of the research, evidence of harm or misconduct come to light, then it may be necessary to break confidentiality. We will tell you at the time if we think we need to do this, and let you know what will happen next.

Will I be recorded, and how will the recording be used?

If you take part in an interview, this will be audio recorded using the recording function on Microsoft Teams. The recording will be saved on a password-protected laptop and then transcribed (written up word-for-word) and analysed by the research team for use in research papers. We will use an ID number instead of your name and any identifying information will be removed from published materials to protect your identity. Recordings will be deleted after they have been transcribed.

How will we use information about you?

Personal information about you collected during the study will be kept securely for up to 12 months after the study has ended. This information will include your name, sex, age, phone number, email and details of your spinal cord injury. Data we collect from

you will only be used to inform the findings of this study. Responsible people at Brunel University London will use this information to do the research or to make sure that the research is being done properly. People who do not need to know who you are will not be able to see your name or contact details. Your data will have a code number instead. We will keep all information about you safe and secure.

Study data including direct quotes from the interview, questionnaire responses and physical measurements (e.g. height, weight, blood pressure) will be anonymised, meaning that it won't be possible to identify you in any part of the study that is written up for publication or presented. After the study has ended, non-identifiable study data will be stored on a secure University server for 10 years so they can be used for publishing and to help inform future research if you give your permission in the consent form. Published reports will be written up in a way that you cannot be identified.

What are your choices about how your information is used?

You can stop being part of the study at any time, without giving a reason, and without this affecting any care you are receiving or will receive in the future. We need to manage your records in specific ways for the research to be reliable. This means that we won't be able to let you see or change the data we hold about you. With your permission, anonymised data will be stored that may be used in future research – you can indicate whether or not you give permission for this by way of the Consent Form. With your consent, we will also store your contact details so we can contact you to take part in future studies.

What will happen to the results of the research study?

The results of the research will be written up as part of a PhD degree dissertation, as a research paper and may be presented at conferences and academic meetings so we can share the findings with other researchers and healthcare professionals. The PhD dissertation will be published in the Brunel University Research Archive. Selected parts of anonymised transcripts will be made publicly available online in Brunel University of London's open repository if you agree to this in the consent form.

What if something goes wrong?

If something goes wrong, then please contact:

Mr Daniel Cooper (daniel.cooper2@brunel.ac.uk; [redacted telephone no.]), or

Dr Daniel Bailey (daniel.bailey@brunel.ac.uk)

We will work with you to find a resolution. If you would like to make a complaint or discuss a problem with someone outside of the research team, then please contact Chair of the Research Ethics Committee: Professor Christina Victor (christina.victor@brunel.ac.uk).

Who is organising the research?

This study is being organised by researchers at Brunel University of London and the Royal National Orthopaedic Hospital NHS Trust. Brunel University of London is the study sponsor.

What are the indemnity arrangements?

Brunel University of London provides appropriate insurance cover for research which has received ethical approval. In the event of a claim where negligence cannot be demonstrated, the claimant may seek legal action, for which they would need to pay.

Who has reviewed the study?

This study has been reviewed and a favourable opinion provided by the NHS East of England – Cambridge South Research Ethics Committee and the Brunel University of London College of Health, Medicine and Life Sciences Research Ethics Committee. Approval has been granted for this study to be carried out between 27/03/2025 and 31/12/2025.

Research Integrity

Brunel University of London is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from the researchers during the course of this research.

Where can you find out more about how your information is used?

You can find out more about how we use your information:

- our leaflet available from www.hra.nhs.uk/patientdataandresearch
- by asking one of the research team
- by sending an email to Brunel University of London's data protection team at data-protection@brunel.ac.uk

Contact for further information and complaints

Researcher name and details: Mr Daniel Cooper (daniel.cooper2@brunel.ac.uk; [redacted telephone no.])

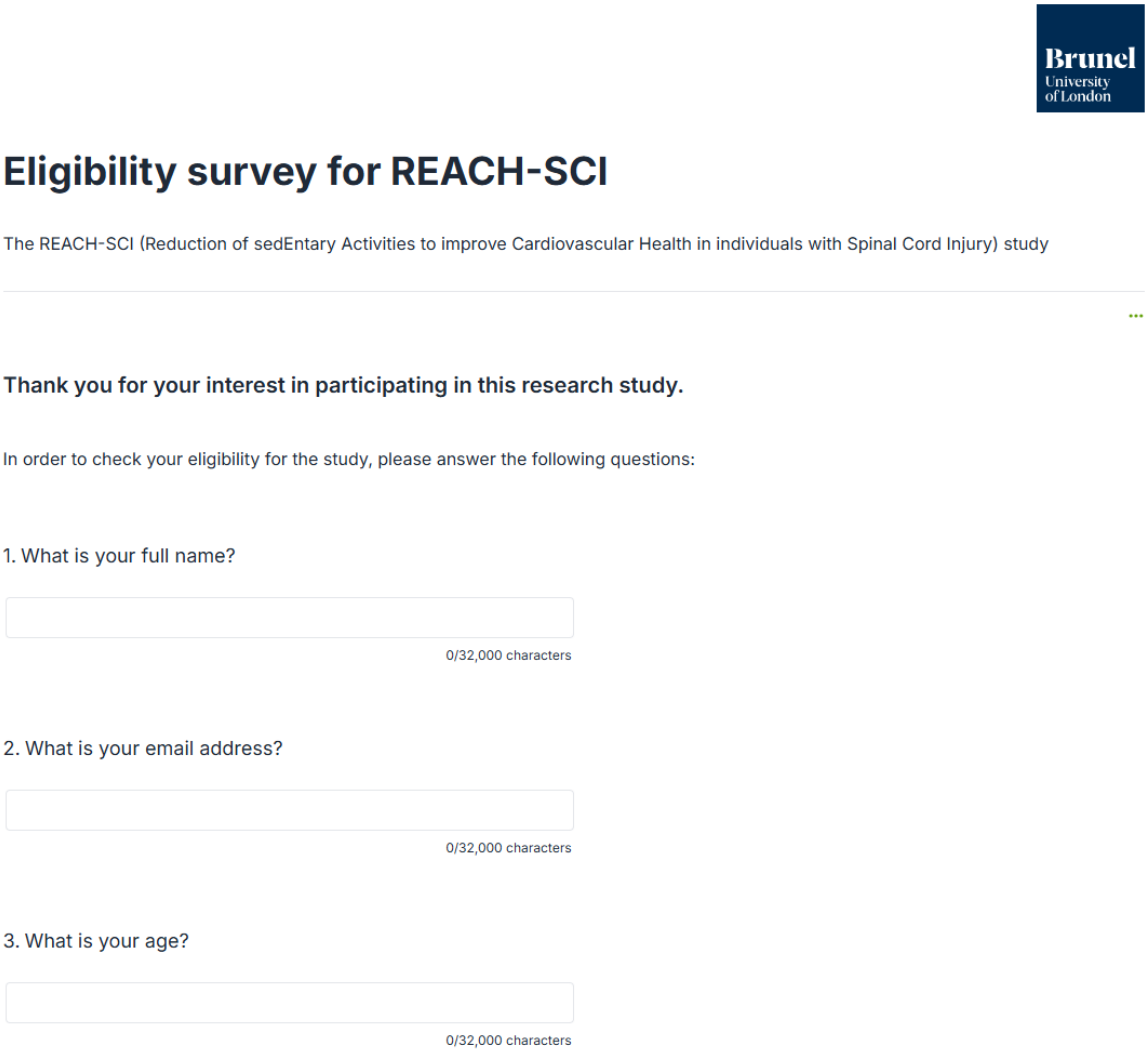
Supervisor name and details: Dr Daniel Bailey (daniel.bailey@brunel.ac.uk)

For complaints and questions about the conduct of the research:

Professor Christina Victor, Chair of Brunel University of London Research Ethics Committee (christina.victor@brunel.ac.uk)

Thank you for taking the time to read this form.

Appendix 32. Feasibility study participant eligibility questionnaire.



Brunel University of London

Eligibility survey for REACH-SCI

The REACH-SCI (Reduction of sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury) study

Thank you for your interest in participating in this research study.

In order to check your eligibility for the study, please answer the following questions:

1. What is your full name?

0/32,000 characters

2. What is your email address?

0/32,000 characters

3. What is your age?

0/32,000 characters

4. What is your biological sex?

0/32,000 characters

5. What is your ethnicity?

0/32,000 characters

6. What is the neurological level of your spinal cord injury? (e.g. T1, L4)

0/32,000 characters

7. What is the completeness of your spinal cord injury? (e.g. complete, incomplete)

0/32,000 characters

8. Is your spinal cord injury traumatic or non-traumatic?

0/32,000 characters

9. How long have you had a spinal cord injury?

0/32,000 characters

10. If it has been less than 2 years since your spinal cord injury, are you:
    - Currently an in-patient?
    - Recently discharged from in-patient care?

    If you answered yes to either of the above, please give more details about when you were admitted to in-patient care, and if you have been discharged, how long ago this was.

0/32,000 characters

11. Do you use a manual wheelchair as your main way of getting out and about during the day?

0/32,000 characters

12. Do you have a history of autonomic dysreflexia (any incidents in the last 2 years)?

0/32,000 characters

13. Are you able to independently transfer to a treatment couch and lie flat, so a trained researcher can take height and waist size measurements?

0/32,000 characters

14. Are you able and willing to fast overnight before having your measurements taken in the morning at Brunel University of London?

15. Are you able and willing for a trained researcher to take a small blood sample from your fingertip, taken with a lancet (a small needle)?

0/32,000 characters

16. Are you currently involved in any other research studies, or are planning to do so soon? If so, please provide details of what this involves

0/32,000 characters

17. Are you able to communicate in both written and spoken English?

0/32,000 characters

18. Are you able to travel to Brunel University of London campus in Uxbridge, West London on two occasions to have study measurements taken?

0/32,000 characters

Please press the 'Submit' button below to submit your responses.

Submit

Appendix 33. Feasibility study participant consent form (main study).

CONSENT FORM

The REACH-SCI study: Reduction of sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury

Principal Investigator: Dr Daniel Bailey

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 27/03/2025 AND 31/12/2025

The participant should complete the whole of this sheet.		
	YES	NO
Have you read the Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Who have you spoken to about the study?		
Do you understand that you will not be referred to by name in any report concerning this study?	☐	☐
Do you understand that:		
• You are free to withdraw from this study at any time	☐	☐
• You don't have to give any reason for withdrawing	☐	☐
• If you withdraw, data you have already provided will continue to be used in analysis of the study results	☐	☐
• Choosing not to participate or withdrawing will not affect your present or future medical care or services that you are entitled to	☐	☐
The procedures regarding confidentiality have been explained to me	☐	☐
I understand that data collected during the study may be looked at by individuals from regulatory authorities, where it is relevant to my participation in this study, for auditing and monitoring purposes	☐	☐
I agree to take part in this study.	☐	☐
Additional Questions (Optional)		

	YES	NO
I agree that my contact details can be stored so that I can be contacted about taking part in future research projects	☐	☐
I agree that my anonymised data can be stored and shared with other researchers for use in future projects	☐	☐
I would like to receive a summary of the results from this study by email	☐	☐

PLEASE TURN OVER

Signature of research participant:	
Print name:	Date:

Signature of person taking consent:	
Print name:	Date:

Filing arrangements: 1 copy for participant, 1 copy for site file.

Appendix 34. Feasibility study participant consent form (semi-structured interview).

INTERVIEW CONSENT FORM

The REACH-SCI study: Reduction of sedEntary Activities to improve Cardiovascular Health in individuals with Spinal Cord Injury

Principal Investigator: Dr Daniel Bailey

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 27/03/2025 AND 31/12/2025

The participant should complete the whole of this sheet.		
	YES	NO
Have you read the Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss taking part in the interview as part of this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Who have you spoken to about the interview?		
Do you understand that you will not be referred to by name in any report concerning this study?	☐	☐
Do you understand that:		
• You are free to withdraw from this interview at any time	☐	☐
• You don't have to give any reason for withdrawing	☐	☐
• If you withdraw, data you have already provided will continue to be used in analysis of the study results	☐	☐
• Choosing not to participate or withdrawing will not affect your present or future medical care or services that you are entitled to	☐	☐
I agree to this interview being recorded	☐	☐
I agree to the use of non-attributable (anonymous) quotes from my interview responses when the study is written up or published	☐	☐
The procedures regarding confidentiality have been explained to me	☐	☐

I understand that data collected during the interview may be looked at by individuals from regulatory authorities, where it is relevant to my participation in this study, for auditing and monitoring purposes	☐	☐
I agree to take part in this interview	☐	☐
Additional Questions (Optional)		
	YES	NO
I agree to my spoken data (written quotations from my interview responses) being made publicly available in an online open research repository	☐	☐
I agree that my anonymised data can be stored and shared with other researchers for use in future projects	☐	☐

PLEASE TURN OVER

Signature of research participant:	
Print name:	Date:

Signature of person taking consent:	
Print name:	Date:

Filing arrangements: 1 copy for participant, 1 copy for site file.

Appendix 35. Template for Intervention Description and Replication (TIDieR) checklist.

TIDieR
Template for Intervention Description and Replication

The TIDieR (Template for Intervention Description and Replication) Checklist*:

Information to include when describing an intervention and the location of the information

Item number	Item	Where located **	
		Primary paper (page or appendix number)	Other † (details)
	BRIEF NAME		
1.	Provide the name or a phrase that describes the intervention.	138, 144	
	WHY		
2.	Describe any rationale, theory, or goal of the elements essential to the intervention.	138, 139	
	WHAT		
3.	Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).	144-147, Appendices 36-39	
4.	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.	144-147, Appendices 36-39	
	WHO PROVIDED		

5.	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	144, 146	_____
	HOW		
6.	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	144-147	_____
	WHERE		
7.	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	144-147	_____
	WHEN and HOW MUCH		
8.	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.	144-147	_____
	TAILORING		
9.	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.	144-146	_____
	MODIFICATIONS		
10.‡	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	N/A	_____
	HOW WELL		
11.	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	150, Table 10	_____

12.‡	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	172, 173, Table 13	_____

** **Authors** - use N/A if an item is not applicable for the intervention being described. **Reviewers** – use '?' if information about the element is not reported/not sufficiently reported.

† If the information is not provided in the primary paper, give details of where this information is available. This may include locations such as a published protocol or other published papers (provide citation details) or a website (provide the URL).

‡ If completing the TIDieR checklist for a protocol, these items are not relevant to the protocol and cannot be described until the study is complete.

* We strongly recommend using this checklist in conjunction with the TIDieR guide (see *BMJ* 2014;348:g1687) which contains an explanation and elaboration for each item.

* The focus of TIDieR is on reporting details of the intervention elements (and where relevant, comparison elements) of a study. Other elements and methodological features of studies are covered by other reporting statements and checklists and have not been duplicated as part of the TIDieR checklist. When a **randomised trial** is being reported, the TIDieR checklist should be used in conjunction with the CONSORT statement (see www.consort-statement.org) as an extension of **Item 5 of the CONSORT 2010 Statement.** When a **clinical trial protocol** is being reported, the TIDieR checklist should be used in conjunction with the SPIRIT statement as an extension of **Item 11 of the SPIRIT 2013 Statement** (see www.spirit-statement.org). For alternate study designs, TIDieR can be used in conjunction with the appropriate checklist for that study design (see www.equator-network.org).

Appendix 36. REACH-SCI educational booklet.

REACH SCI

Reducing SedEntary Activities to improve Cardiovascular Health in individuals with a Spinal Cord Injury

Brunel University of London

NHS Royal National Orthopaedic Hospital NHS Trust

REACH SCI

Welcome to the REACH-SCI programme. Limiting the amount of time spent being inactive can improve health in many ways.

The purpose of this booklet is to support people with paraplegia with reducing the time they spend being inactive.

It provides information about what we mean by inactivity, why it is important to limit long periods of inactivity and tips and ideas to help with this.

2

Contents

Part 1: Inactivity

What is inactivity?

Inactivity is when you do sedentary activities that use up very small amounts of energy while you are awake.

Examples of common sedentary activities include:
- Watching TV
- Working on a computer
- Work meetings
- Scrolling on social media
- Reading
- Socialising with friends and family
- Relaxing in a chair

In modern times, many people spend a lot of their day being inactive due to advancements in technology. This means we do not have to use up much energy to do the majority of our daily tasks and activities.

Being a wheelchair user with a spinal cord injury may make it even more challenging to avoid long periods of inactivity.

Why is it important to limit time spent being inactive?

Being inactive for long periods during the day can lead to higher levels of blood sugar, blood pressure, cholesterol and body fat.

This can increase the risk of heart disease and diabetes, which are some of the leading causes of death worldwide and in people with a spinal cord injury.

Even doing purposeful exercise like sport or wheeling workouts does not protect people from the health risks that come with long periods of inactivity.

5

What are the guidelines?

The UK Chief Medical Officer's guidelines recommend that people in the general population and those with a disability should should (a) limit the amount of time spent being inactive during the day, and (b) regularly break up periods of inactivity, to lower their risk of health problems like heart disease.

What can I do?

There are plenty of ways for wheelchair users to keep moving and avoid long periods of inactivity.

The REACH-SCI programme has been designed with input from individuals with paraplegia and healthcare professionals to help you achieve this.

6

Part 2: Benefits of reducing and breaking up inactivity

Reducing the amount of time spent being inactive each day and avoiding long periods of inactivity can benefit physical and mental health.

Introducing regular, short bursts of movement into your daily life is a great way to achieve this!

Every movement counts, small or large. Whether pushing around the house, doing arm exercise or household chores, these all help in reducing time spent being inactive and can benefit health.

7

Heart health

Doing activity breaks across the day has been shown to reduce blood sugar, blood pressure, and cholesterol, which can help lower the risk of health conditions like heart disease, stroke and diabetes.

Weight management

Research has also shown that breaking up periods of inactivity can help burn calories, reduce body fat and maintain a healthy weight.

These are important for better heart health and reducing the risk of diabetes.

8

Pain and fatigue

Limiting inactivity and encouraging regular movement throughout the day can help to manage pain and fatigue and also improve strength, flexibility, mobility and energy levels.

Mental health

Doing physical activity helps to release 'feel-good' chemicals in the brain called endorphins, which can boost mood and lower anxiety.

Less time spent being inactive is linked to better mood and improved overall quality of life.

Sleep

More movement across the day can help to improve the body's internal clock, which can help with feeling awake and sleepy at the right times of the day.

Research also shows that reducing inactivity and moving more during the day helps with better quality of sleep.

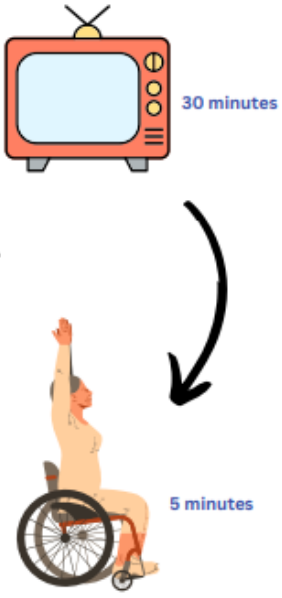
9

Part 3: Ideas to reduce and break up inactivity

It is important to break up periods of inactivity with short bursts of physical activity, no matter how light the activity is.

This might mean interrupting a sedentary activity with a few minutes of wheeling around or arm exercises. We call these 'activity breaks'.

For example, doing 5 minutes of light arm exercise after watching TV for half an hour.



10

What activities could I do?

You could try some of the activities listed below and do them little and often throughout the day, to limit long periods of inactivity.

Wheeling in your wheelchair

- Moving around the house, in the garden or out and about

Hand cycling (with the hand cycle provided to you)

- You can cycle at the resistance and speed that you feel comfortable with
- Alternatively, you could follow one of the pre-set hand cycle workouts on your smartwatch

Exercise band exercises (with the bands provided to you)

- Wrap it around a stable object or hold in both hands
- Follow the exercise band workouts on your smartwatch
- You could also find a YouTube video to follow a routine. There are some examples provided in 'Part 5: REACH-SCI Additional Resources' on page 24

11

Lifting objects

- You can use tins or fill bottles with different amounts of water to adjust the weight and use them for your short activity breaks
- You could also use these whilst following a strength training workout on your smartwatch
- There are YouTube videos with weight training routines you can follow. See some examples provided in 'Part 5: REACH-SCI Additional Resources' on page 25

Yoga, Pilates or tai-chi

- Follow pre-loaded yoga or Pilates routines on your smartwatch or follow a YouTube video (for examples see page 25)
- You could do these spread across the day as your 'activity breaks'

Housework and gardening

- You could break up periods of inactivity with household chores or gardening
- This could be a great way to get your activity breaks in whilst getting jobs done at the same time!

12

Personal care routine

- Personal care routines including showering and dressing can require a lot of physical effort due to the wheelchair transfers required
- So, like housework, you are being active whilst also doing an essential job at the same time

Shoulder protection activities

- You can follow the shoulder protection advice you have already received from your healthcare team, which could also help to break up periods of inactivity
- This might include shoulder strengthening exercises or static stretches

Active video games (Nintendo Wii/Switch, virtual reality)

- If you have access to active video games, this could be a useful and fun way to break up periods of inactivity by getting you moving whilst playing

13

How often should I break up periods of inactivity?

Breaking up periods of inactivity every 20 to 30 minutes can be beneficial. You should aim to break up your inactive time as often as you feel is manageable and achievable.

You can start with small, infrequent breaks in inactivity (e.g. 2 minutes of exercise band activities every 1 or 2 hours), and then gradually increase this to longer and more frequent breaks (e.g. 5 minutes of arm cycling every half an hour).

If you are more confident in making these changes, you could start with longer and more frequent activity breaks straight away (e.g. 10 minutes of housework every hour).

14

Remembering to take activity breaks

If you struggle to remember to do activity breaks, you can use everyday cues around you to act as reminders.

For example, you could do a 2-minute activity break during TV adverts, while waiting for the kettle to boil, at the end of a book chapter or during a phone call.

DON'T FORGET

Your smartwatch will also give you alerts and notifications to remind you to get moving if you have been inactive for too long.

You could also set calendar reminders or set timers on your smartphone.

15

Activity breaks vs. exercise

Doing these activity breaks little and often throughout the day is not designed to tire you out like exercise does.

Instead, you should try to avoid feeling signs of fatigue, such as a racing heart rate or heavy breathing.

You can do this by changing the duration (e.g. do an activity for only 5 minutes) or the intensity (e.g. lowering the resistance or speed of your hand cycling).

This will make sure that you still have the energy to keep doing activity breaks regularly throughout the day.

You might also like to think about doing more exercise, like half an hour of dancing, swimming or a sport. This can be great for your health, but it doesn't make up for long periods of inactivity for the rest of the day.

So, even if you do exercise, doing activities little and often throughout the day is still important.

16

Could my family and friends get involved?

Doing activities with other people such as your family and friends is a good way to increase motivation and enjoyment.

You could tell family and friends about the REACH-SCI programme that you are taking part in. They could read this educational booklet and might want to make changes to their own behaviour.

You could do your activity breaks with someone else or go out and about doing activity together.

The app that connects to the Smartwatch you are using for REACH-SCI also allows you to compare your activity levels to family or friends by linking your accounts so you might want to think about pairing up like this too.

Part 4: How to set and work towards goals

A goal is an aim or result that a person wants to work towards. The best way to start working towards a goal is to make a plan of how you are going to get there.

Your goal-setting plan should include where you are starting from, a long-term goal, and some short-term goals.

Understanding where you are starting from

The first step towards reducing your inactivity is to understand where you are starting from. To do this, work out how much time you spend being inactive.

This can be done by thinking about how much time you spend doing sedentary activities during a normal day, and how long each sedentary activity lasts for each time.

The 'REACH-SCI Goal setting worksheet' provided as part of the programme will help you work this out.

My current time spent doing sedentary activities:____ hours and _____ minutes per day.

Now think about one of the sedentary activities you spend the most time doing:

How long you typically spend doing this sedentary activity each time: _____ minutes.

19

Goals should follow the SMART approach

1. **Specific:** Clear and easy to understand
2. **Measurable:** You can track your progress towards achieving the goal
3. **Achievable:** Challenging but realistic
4. **Relevant:** Line up with what **you** want to achieve from the programme
5. **Time-oriented:** A deadline for completion

20

Long-term goals:

These are your destination or the big picture for what you want to achieve in relation to inactivity.

For example, "I want to reduce my time spent being inactive by 1 hour per day".

Long-term goals give you a sense of purpose and direction, help you stay focused and remind you why you're doing all those short-term steps.

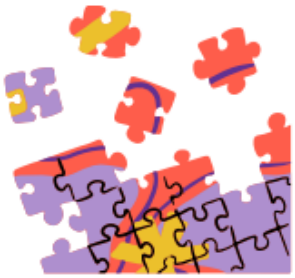
Have a go at setting your long-term goals in the 'REACH-SCI Goal setting worksheet'.

21

Short-term goals

Think of these as small milestones towards reducing your inactivity. They help you focus on what you can do today, this week, or this month to move forward.

Short-term goals keep you motivated because you can see quicker progress than with long-term goals. Achieving these goals can help to build confidence and momentum.



A good way of doing this is by using an '**If-then' plan.** For example: 'If' there is a TV ad break, 'then' I will do 2 minutes of hand cycling.

Have a go at setting your short-terms goals in the 'REACH-SCI Goal setting worksheet'.

22

Part 5: REACH-SCI Additional Resources

Below is a list of charities, organisations and websites that offer videos, advice, information and equipment to help with doing physical activity.

You can also find out about opportunities to join physical activity and exercise sessions through some of these organisations.

Remember, even if you do exercise, it is still important to do regular activity breaks so that you limit the amount of time you spend being inactive for the rest of the day. This will help you to get the best health benefit.

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YouTube videos

Hand cycle videos
Videos including useful demonstrations of how to use the portable hand cycle provided in REACH-SCI with good form:

HeadNorth Video: Jas Arnold demonstrates using a handcycle (HeadNorth San Diego): https://tinyurl.com/hand-cycle-1

Handcycle (wheeln00): https://tinyurl.com/hand-cycle-2

Wheelie Good Tips Episode #8 - STATIONARY HAND CYCLES FOR SPINAL CORD INJURY (New Zealand Spinal Trust): https://tinyurl.com/hand-cycle-3

Exercise bands videos
Videos including useful demonstrations and ideas of how to use the exercise bands provided in REACH-SCI with good form:

Wheelchair Workout with Ade Adepitan | Workout 3: Resistance Bands | Joe Wicks Workouts (The Body Coach TV with Joe Wicks): https://tinyurl.com/exercise-bands-1

A Resistance Band Workout!- Video 70 (Ella's Wheelchair Workouts!): https://tinyurl.com/exercise-bands-2

Wheelchair Resistance Band Workout (Adapt to Perform): https://tinyurl.com/exercise-bands-3

YouTube Channels

Adapt To Perform - guided physical activity routines

Adapt To Perform offers tailored workouts and motivation for all situations designed specifically for wheelchair users. This includes guided yoga, Pilates, weight training and aerobic exercises.

Link: https://www.youtube.com/@AdaptToPerform

Powered to Move - workouts for Wheelchair Users

The mission of Powered to Move is to provide people with disabilities opportunities for physical fitness. Includes guided videos for workouts without equipment, stretching routines, strength training, wheelchair skills and fitness equipment instructions.

Link: https://tinyurl.com/Powered-To-Move

Gym Possible - adapted fitness videos

Gym Possible are the North East of England's first dedicated gym for wheelchair users. They also provide accessible online exercise opportunities and adapted guided fitness videos via their YouTube channel, including aerobics, shadow boxing, dancing, wheelchair pushes and shoulder strength.

Link: https://www.youtube.com/@gympossibleUK

Ella's Wheelchair Workouts!

Guided exercise videos by an online disabled fitness instructor who is a fully qualified Level 3 personal trainer. Includes strength training using household items, shadow boxing, floor workouts and exercise band workouts.

Link: https://www.youtube.com/@ellabeept

Wheelpower – home exercise videos

Ideas for doing exercise at home with their latest Online Resources and Free Online Classes from home.

Link: https://www.youtube.com/@WheelPowerVideos/videos

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Advice and information around physical activity and exercise

Every Body Moves

Every Body Moves is a UK-wide initiative by the Activity Alliance aimed at promoting physical activity among disabled people. It serves as a national movement to encourage inclusivity and ensure that everyone, regardless of ability, has the opportunity to be active. The website includes programmes, events, and resources to help people find accessible ways to be active, provides advice and ideas about exercise and physical activity.

Contact details: 020 3965 4124 info@everybodymoves.org.uk
Link: https://everybodymoves.org.uk/

The Wheelchair Skills College

The Wheelchair Skills College is an organisation that provides training and education to help wheelchair users develop essential skills for navigating their daily lives independently and confidently. Wheelchair skills training, tailored programmes, group and individual sessions and online educational resources are available on their website.

Contact details: learn@wheelchairskills.org
Link: https://www.wheelchairskills.org/ https://www.youtube.com/@wheelchairskills

Better Inclusive Gyms

Better Inclusive Gyms is an initiative by Better, a UK-based leisure and community fitness provider, aimed at making gyms more accessible and inclusive for individuals with disabilities. The website includes a database of inclusive gyms nationwide and the option to sign up for a paid membership to access these gyms.

Contact details: customerservices@gll.org
Link: https://www.better.org.uk/monthly-membership/better-hf-inclusive

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Opportunities for scheduled physical activity and exercise sessions

Wheelpower

A charity focused on wheelchair sport, exercise and physical activity. Wheelpower provide free exercise equipment, physical activity and exercise advice and scheduled exercise sessions (in-person and online).

Contact: 01296 395995 info@wheelpower.org.uk https://www.wheelpower.org.uk/

Sportability

A charity dedicated to helping individuals with physical disabilities engage in free sports and recreational activities through advice and scheduled sessions. Includes wheelchair basketball, archery, cycling and skiing.

Contact details: 07305 047 533 info@sportability.org.uk https://www.sportability.org.uk/

Disability Sports Coach

A charity that provides physical activity opportunities for disabled individuals of all ages and abilities. They organise community sport clubs, social activities and provide activity sessions in-person and online.

Contact: 020 7928 4267 DSC@disabilitysportscoach.org.uk https://disabilitysportscoach.org.uk/

SportsAble

A charity that provides sport opportunities for people with disabilities. Includes swimming, boccia, wheelchair basketball, exercise and dance classes, sailing, power-boating, cycling and online social activities.

Contact: https://tinyurl.com/Facebook-SportsAble https://aftersportsable.org.uk/

Gym Possible

A charity that aims to make exercise both physically and financially accessible to people with disabilities providing accessible in-person and online exercise opportunities and adapted fitness videos.

Contact: 0191 406 2421 contact@gympossible.org https://www.gympossible.co.uk/online-sessions/

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Thank you for taking the time to go through the REACH-SCI educational booklet. We hope you found it useful!

If you have any questions about this booklet or any of the information included, please contact Dan:

daniel.cooper2@brunel.ac.uk

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Appendix 37. REACH-SCI goal setting worksheet.

Goal setting worksheet

Date:_____

Welcome to the REACH-SCI goal setting worksheet. This resource will help you to work out your current time spent being inactive per day and set long- and short-term goals related to inactivity.

If you have any questions about this worksheet or about goal setting in general, please contact Dan on daniel.cooper2@brunel.ac.uk.

MY CURRENT INACTIVE TIME

The first step towards reducing your inactivity is to understand where you are starting from. To do this, work out how much time you spend doing sedentary activities during a normal day.

Complete this sheet by:

1. Listing all the sedentary activities you did throughout a typical the day in the first column (don't include sleep).
2. Estimate how much time (in minutes or hours) you spend doing that activity.

Sedentary activity = Being stationary and using up very small amounts of energy

What activity did you do? (e.g. using a computer, listening to music, watching TV, relaxing in a chair)	**How long did you spend doing this activity across the whole day and night?**
Example: Scrolling social media in bed	*30 minutes*
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
Total time spent being inactive:	**Hours:_____**

	Minutes:_____

Now think about the sedentary activities you spend the most amount of time doing and how long you usually do them each time. To do this, list the top 3 longest sedentary activities you did in the table below.

Which sedentary activities do you spend the most time in? (e.g. using a computer, listening to music, watching TV, relaxing in a chair)	**How long do you typically spend doing this activity each time?**
Example: Scrolling social media in bed	*30 minutes*
1.	
2.	
3.	

MY GOAL SETTING

My current daily time spent being inactive:____ hours and _____ minutes per day.

My long-term goals:

Your long-term goals are up to you and should be personalised to your needs and what you want to get from the programme. You can set one or more long-term goals by filling in any number of the rows below.

My goals are to:

1. Reduce my overall daily time spent being inactive by:____ hours and ____ minutes per day

2. Limit each sedentary activity to: ____ minutes at a time

I plan to achieve this by the date:_____

MY GOAL SETTING

My short-term goals (over the next 2 weeks):

Short term goal: 1. Reduce inactivity by: ____ hours and _____ minutes per day 2. Break up periods of inactivity every ____ minutes 3. Break up periods of inactivity with ____ minutes of physical activity each time	
What am I going to do to achieve this?	
Daily changes	**Weekly changes**

MY GOAL SETTING

Things to consider:

1. Making a change can be difficult. What could support me with making this change?

2. What might be a barrier to making a change?

3. What steps will I take to overcome these barriers?

4. How confident do I feel that I can do this, on a scale of 1 to 10:

1	2	3	4	5	6	7	8	9	10

5. What can I do to increase my confidence?

6. When will I review this plan?

Date:_____

MY EVALUATION

Now you are approaching the end of the REACH-SCI programme, it is time to work out whether you have achieved your long-term goal, or how close you have got to achieving it.

You may want to work out again how much time you now spend doing sedentary activities during a typical day, and compare it to when you started the programme.

Complete this sheet by:

1. Listing all the sedentary activities you did throughout the day in the first column (don't include sleep).
2. Estimate how much time (in minutes or hours) you spend doing that activity.

Sedentary activity = Being stationary and using very low amounts of energy

What activity did you do? **(e.g. using a computer, listening to music, watching TV)**	**How long did you spend doing this activity?**
Example: Scrolling social media in bed	*30 minutes*
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
Total inactivity:	**Hours:_____** **Minutes:_____**

Now think about the sedentary activities you spend the most amount of time doing and how long you usually do them each time. To do this, list the top 3 longest sedentary activities you did in the table below.

What were your longest sedentary activities? (e.g. using a computer, listening to music, watching TV, relaxing in a chair)	**How long did you spend doing this activity across the whole day and night?**
Example: Scrolling social media in bed	*30 minutes*
1.	
2.	
3.	

Appendix 38. REACH-SCI group chat example facilitator messages.

Peer support group facilitator messages

Initial message:

An initial message will be posted to the group by the facilitator to outline the purpose of the group, the ground rules and examples of what information could be shared by the participants. This message will be reposted as a reminder when new participants are added to the group.

"Hello all, welcome to our REACH-SCI group chat!

This group should be a space where we can stay connected and support each other during the programme"

"The purpose of the group chat is to:

- Share experiences, tips, and progress on reducing sedentary activities and increasing physical activity
- Encourage and motivate each other
- Ask questions and provide general support to each other to help with taking part in REACH-SCI

Feel free to introduce yourself to the group and chat with others in REACH-SCI."

A document including the group rules and expectations will be sent to each participant individually prior to being added to the group.

"The rules of the group are as follows:

- Kindness and respect: Be kind and considerate when speaking with others.
- Confidentiality: What's shared in the group stays in the group
- No Judgement: We're all here to support each other, no matter where we are on our journey
- Relevance: Keep messages related to the group's purpose (e.g., physical activity, sedentary activities, goals, challenges, motivation, opportunities)"

"Things you could share with the group might include:

- Progress updates: "I managed to hit my daily push target for the first time today!"

- Your experiences with REACH-SCI: “I am finding the goal setting really useful. How is everyone else finding it?”
- Questions: “Struggling to find the motivation today - any tips?”
- Motivation: “I found this quote inspiring: ‘It’s not about being the best, it’s about being better than you were yesterday!’”
- Ideas or resources: “I discovered this stretching app - it’s been really helpful!””

The research team will help to manage the group and provide weekly reminders to encourage chat, but we will not be monitoring the content or communicate with participants in the chat. If you want to ask us anything about the group chat, please email Daniel.cooper2@brunel.ac.uk.”

We will continue to add more participants as they start the programme. You can continue to stay in the group even after you finish the programme, if you wish.

Reminder messages:

Reminder messages will be posted to the group by the facilitator each week to encourage continuous use of the chat.

“Hi all! This group can be a great place to find motivation or share your progress. What’s one thing that worked well for you this week?” Sharing your wins might help inspire someone else!”

"Hope everyone is enjoying the programme! How are you all doing with your activity goals? Don’t hesitate to share any updates or ask for advice if you’re facing any challenges”

"Hello again! Let’s keep the momentum going. What’s one small goal you’re setting yourself this week? Sharing it here can help to keep you accountable!”

"Hi! What’s a challenge you’ve faced recently, and how did you overcome it? Hearing your creative solutions might be helpful for someone else to follow!”

"Hello again! Let’s keep the momentum going. What’s one small goal you’re setting yourself this week? Sharing it here can help to keep you accountable!”

“Me again! From your experience in REACH-SCI so far, what is one piece of advice you would give to someone starting the programme?”

"Hello all! Some of you might be nearly at the end of REACH-SCI. What’s one thing you’re proud of achieving so far? Let’s celebrate our success together!”

Appendix 39. REACH-SCI activity tools guidance document.

Activity tools guidance

As part of the REACH-SCI programme you have been provided with activity tools to help reduce inactivity throughout the day, including exercise bands and a portable hand cycle.

This document provides guidance on how to properly and safely use the tools.

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More information around ideas for different ways to use the activity tools, how and when you can use them throughout the day can be found within Part 3 of the REACH-SCI educational booklet.

Links to guided workout videos using these tools can be found within part 5 of the REACH-SCI educational booklet.

1

Proper form and technique

Proper form and technique refer to the correct way to perform an activity.

It is important to use proper form whilst doing activity breaks with the activity tools.

Proper form and and technique will help to ensure that:

- The right muscles are being used for the activity or exercise you are doing
- You are not putting unnecessary strain on your joints – this will help prevent injuries

2

Tips for proper form when using the *exercise bands*

1. Make sure the band is anchored safely (either held firmly using your other hand, or tied securely to a stable base such as your chair)

2. Keep your shoulders down (away from your ears) throughout the exercise

3. Use slow controlled movements throughout the exercise

4. Let the band relax back slowly - do not let it go when it is under tension

3

Tips for proper form when using the *portable hand cycle*

1. Make sure the hand cycle is on a flat surface and the anti-slip mat is being used

2. Adjust the distance of the arm cycle from your body until it feels comfortable

3. Adjust the resistance to avoid feeling fatigued, such as a racing heart rate or shortness of breath

4. Hold the handles firmly

5. Maintain a smooth, consistent pace or rhythm

4

Some general tips to ensure good form when using *either* activity tool

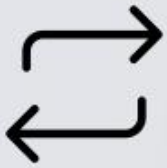
- Follow the links to YouTube videos demonstrating the use of each activity tool in the REACH-SCI Additional Resources
- Try to sit upright with shoulders relaxed and not hunched
- Start with a slower speed or resistance and build up gradually
- Try using a mirror to see if your form looks right



5

Top tip 1: Changing the routine

- When using the exercise bands, try out different exercises that target different muscles.
- This will help avoid any muscles getting over-used



Top tip 2: Keep an eye on the length and intensity of your activity breaks to avoid fatigue

- When using the exercise bands, don't do too many repetitions at once (stop when you start to feel muscle soreness or difficulty completing the activity)
- When using the hand cycle, don't cycle too hard or for too long (activity breaks are not designed to make your heart race or cause shortness of breath)

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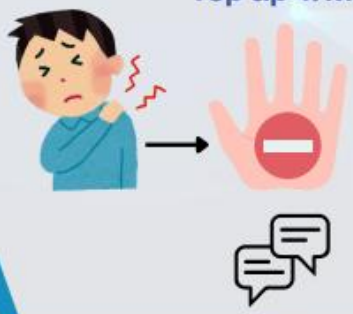
Top tip 3: Monitor your tiredness

- If you feel very fatigued, shaky or cannot maintain good form any longer whilst using the activity tools, then listen to your body and slow down or stop
- If you feel muscle soreness from a previous activity break, wait until it has cleared, and you feel ready before using the activity tools again

Top tip 4: Monitor any changes in pain or spasticity



- If new pain or spasticity starts, or if any existing pain or spasticity gets worse, stop the activity until you have spoken to a member of the research team
- Contact a member of the research team (daniel.cooper2@brunel.ac.uk) and your GP if you are concerned about any pain or spasticity

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REACH SCI

Thank you for taking the time to go through the REACH-SCI activity tools guidance. We hope that you found it useful.

If you have any questions about this guidance or the activity tools themselves, please contact Dan:

daniel.cooper2@brunel.ac.uk

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Appendix 40. Intervention acceptability questionnaire.

TFA questionnaire

This questionnaire is designed to work out how acceptable you found the REACH-SCI programme

Please tick the appropriate box to indicate your answer to each question

1. Did you like or dislike REACH-SCI? *

- ◯ Strongly dislike
- ◯ Dislike
- ◯ No opinion
- ◯ Like
- ◯ Strongly like

2. How much effort did it take to engage in REACH-SCI? *

- ◯ No effort at all
- ◯ A little effort
- ◯ No opinion
- ◯ A lot of effort
- ◯ Huge effort

3. How fair is REACH-SCI for individuals with paraplegia? *

- ◯ Very unfair
- ◯ Unfair
- ◯ No opinion
- ◯ Fair
- ◯ Very fair

4. REACH-SCI is effective for reducing and breaking up inactivity *

- ◯ Strongly disagree
- ◯ Disagree
- ◯ No opinion
- ◯ Agree
- ◯ Strongly agree

5. It is clear to me *how* REACH-SCI helps to reduce inactivity *

- ◯ Strongly disagree
- ◯ Disagree
- ◯ No opinion
- ◯ Agree
- ◯ Strongly agree

6. How confident did you feel about engaging with the REACH-SCI programme? *

- ◯ Very unconfident
- ◯ Not confident
- ◯ No opinion
- ◯ Confident
- ◯ Very confident

7. Taking part in REACH-SCI interfered with my other priorities or commitments *

- ◯ Strongly disagree
- ◯ Disagree
- ◯ No opinion
- ◯ Agree
- ◯ Strongly agree

8. Overall, how acceptable was REACH-SCI to you? *

- ◯ Completely unacceptable
- ◯ Unacceptable
- ◯ No opinion
- ◯ Acceptable
- ◯ Completely acceptable

9. What is your participant ID number (PP...)? *

0/32,000 characters

Submit

Appendix 41. Acceptability semi-structured interview guide.

REACH-SCI acceptability indicative interview guide

The aim of this interview is to discuss your experiences of the REACH-SCI programme, and any feedback you may have. The interview will last approximately 45 minutes. There are no right or wrong answers, it is just your opinions that count. We would like to know what worked well and what did not work well, so we can make improvements to the programme So, please feel free to speak as honestly and openly as possible. Please remember that you can stop or pause the interview at any time or chose not to answer any questions you don't wish to. This will not affect the care you are having nor the care you receive in the future.

Just to remind you, this interview will be recorded. This is so I don't have to write everything down, meaning I can give you my full attention. The recording will be written up word-for-word by the research team with your details anonymised. The audio file will be deleted at this point. Thanks for taking part.

Taking part in the REACH-SCI programme

1. Did you enjoy taking part in the programme?

    a. What part did you find most enjoyable, if any?
    b. What part did you find least enjoyable, if any?
    c. What would you suggest for making the programme more enjoyable?

2. How much effort was needed to take part in the programme?

    a. Which part was the easiest or hardest to engage with and why?
    b. How could we make it easier to take part in REACH-SCI?

3. Did taking part in the programme raise any ethical concerns such as privacy or safety?

    a. Were any specific parts of the programme more or less concerning than others?
    b. How could these be changed to avoid any concerns in the future?

4. Was the programme effective for reducing and breaking up inactivity? Why?

    a. Which features of the programme were most or least effective and why?
    b. How could the effectiveness of the programme be improved?

5. Was it clear to you *how* the programme was meant to help reduce and break up inactivity?

    a. If it was clearer, how would it have affected your behaviour and engagement with the programme?
    b. How could we make it clearer to participants?

6. How confident did you feel about taking part in the programme?

    a. Were there any features of the programme you felt more or less confident about interacting with?
    b. How could confidence in engaging with the programme be improved?

7. Did using the programme interfere with your other priorities or commitments?

a. E.g. length of programme, amount of content, time taken to do each one
b. Were there any parts of the programme you felt were more or less of an interference?
c. What could be changed to minimise this interference?

Wearable activity tracker

Now I am going to ask some questions about your experience with using the wearable activity tracker.

Prompts:

1. Did you use the wearable activity tracker, and if not, why?

2. If so, was there anything you liked or disliked about it, and why?

    a. What did you like or dislike about:
        i. Reminders to break up inactivity?
        ii. Tracking activity levels (wheelchair pushes, intensity minutes)?
        iii. Rewards (streaks, badges, praise)?
        iv. E.g. Ease of use, comfort, features

3. What about the wearable activity tracker would you change, and why?

Educational resource

Now I am going to ask for your thoughts on the educational booklet.

Prompts:

1. Did you use the educational resource, and if not, why?

2. If so, how useful was the content?

    a. Related to:
        i. Inactivity
        ii. Goal setting
        iii. Techniques to maintain good health and well-being
        iv. Links and contact details of relevant charities, organisations and websites
        v. E.g. Amount of content, easy to understand, easy to navigate, use of written text, graphics, worksheets

3. What would you change about it and why?

Goal setting

Now I am going to ask you about the goal setting part of the programme.

Prompts:

1. Did you use the goal setting worksheet, and if not, why?

2. If so, how useful was the goal setting worksheet?

    a. Related to:
        i. The “my inactivity” section
        ii. The “my goal setting" section
        iii. The “things to consider" section
        iv. The “my evaluation" section
    b. E.g. Content, length, format, ease of use, instructions

3. Is there anything you would change about this part of the programme?

Motivational support sessions

Now I am going to ask about your experiences of the motivational support sessions.

Prompts:

1. Did you do all three sessions, and if not, why?

2. How did you get on with the following aspects?
    a. Topics covered
    b. Regularity/length of sessions
    c. Usefulness of advice/support

3. How could motivational support be improved, if at all, if REACH-SCI was to happen again?

Peer support group chat

Now I am going to ask about your experience of the peer support group chat.

Prompts:

1. Did you opt into the group chat, and if not, why?

2. If so, how did you find specific aspects?
    a. Comfort with sharing experiences within the group
    b. Ease of use

c. Regularity of messages/notifications
d. Usefulness of posts/content

3. How could the peer support be improved going forward?

Activity tools

Now I am going to ask how you found using the activity tools.

Prompts:

1. Did you use the activity tools, and if not, why?

2. If so, when did you use the activity tools and why?

3. Were there any parts of the activity tools that you particularly liked or disliked?

    a. Specific piece of equipment
    b. Instructions

4. Would you suggest anything different about the activity tools to improve it in the future?

Measurement sessions

At the start and the end of the study, you took part in a series of measurements, including wearing an activity tracker, laboratory measurements, questionnaires and this interview. We would like to hear about your experiences of taking part in these measurements, so we know what worked well and what did not, so we can make improvements in the future.

Now I am going to ask about your thoughts around the measurements that were taken as part of the study.

Prompts:

1. Were there any specific measurements that you have any particular thoughts on, either positively or negatively?

2. How much effort did it take to take part in the measurement sessions?

    a. Did any measurements take a lot more or less effort than the others?

3. Were there any measurements taken that you felt were problematic or unethical in any way?
    a. E.g. Painful or unsafe physical measurements, distressing questions or topics, privacy concerns

4. Do you understand why we are taking these measurements from you, and how they are useful?

5. Was taking part in the measurement sessions too much of a burden?
    a. Did taking part in these sessions affect you financially? How?
    b. What did you think about how long the measurement sessions took?
    c. Were there any issues with attendance requirements (travel and/or parking)?

Conclusion

1. Is there anything else you would like to add?

Check participant is feeling OK at the end of this and signpost them to support services if needed (Support groups or GP).

Thank the participant again.

Appendix 42. Intervention fidelity checklist.

Intervention fidelity checklist

ID number:	Date checked:
Assessor initials:	

Intervention provisions (completed by researcher):

Provision	**Provided to participant (yes/no)**	**Date provided to participant**	**Comment**
Wearable activity tracker Device used:_____ _____			
Educational booklet			
Goal setting worksheet			
Added to WhatsApp group chat			
Exercise bands			
Portable hand cycle			

Goal setting worksheet (checked by researcher during motivational support sessions):

Section	**Completed by participant?**			**Comment**
	Yes	**Partially**	**No**	

My current inactivity				
Long-term goal(s)				
Short-term goal(s)				

Motivational support sessions (completed by researcher):

Session number	**Session organised (yes/no)**	**Session attended (yes/no)**	**Session date**	**Comment**
Session 1				
Session 2				
Session 3				

Appendix 43. Motivational interviewing checklist.

Session 1: Starting out

Participant ID:_____

Task	Completed (Y/N)	Date completed
Complete motivational support session 1 (refer to Motivational support session checklist below)		
Book in date for session 2 with participant		

Checklist	
Content of session (45 minutes)	**Completed?**
1. Introductions, setting expectations and ground rules	
2. Check that they have been set up with all the other parts of the intervention	
3. Discuss current levels of inactivity and physical activity from their smartwatch – and prompt completion of "My current inactive time" within the goal setting worksheet	
4. Discuss long-term goals for reducing inactivity and increasing physical activity – an 8-week goal – and prompt completion of the goal setting worksheet	
5. Discuss short-term goals for reducing inactivity and increasing physical activity – smaller goals on a daily or weekly basis	
6. Support with creating an action plan – how we are going to get there, what tools are available to support, and how we are going to monitor progress	
7. Signpost to educational booklet and goal-setting worksheet for further support	
8. Planning next session	

Session 2: Staying on track

Participant ID:_____

Task	Completed (Y/N)	Date completed
Complete motivational support session 2 (refer to Motivational support session checklist below)		
Book in date for session 3 with participant		

Checklist	
Content of session (30 minutes)	**Completed?**
1. Reviewing progress towards goals set in session 1, and giving encouragement and motivational support	
2. Review use of all aspects of the programme (e.g. wearable activity tracker, educational resource, activity tools)	
3. Exploring barriers and facilitators they have experienced so far	
4. Discuss potentially adjusting goals	
5. Discuss their current strategies implemented to reduce inactivity	
6. Discuss their current strategies for monitoring progress	
7. Explore what challenges could occur, and strategies we could use to overcome them	
8. Planning next session	

Session 3: Maintain progress

Participant ID:_____

Task	Completed (Y/N)	Date completed
Complete motivational support session 3 (refer to Motivational support session checklist below)		

Checklist	
Content of session (30 minutes)	**Completed?**
1. Reviewing progress since previous sessions and celebrating wins to maintain motivation	
2. Review use of all aspects of the programme (e.g. wearable activity tracker, educational resource, activity tools)	
3. Exploring if previous barriers and facilitators are still there, or if any new ones have appeared	
4. Discuss goals with potential to adjust goals again until the end of the programme – prompt to complete “My evaluation” section of the goal-setting worksheet	
5. Action plan how they are going to keep this up for the rest of the programme independently without the support sessions (signpost to resources, peer support, friends and family)	
6. Opportunity for self-reflection of how they have found being in the programme and how they have benefitted from making changes	
7. Discuss how they are going to carry the changes made in REACH-SCI into their everyday life after the study (still have access to education, goal setting worksheet and group chat)	
8. Closing - acknowledgement participants’ hard work towards progress and final encouragement for the rest of the programme	

Appendix 44. McGill Pain Questionnaire (MPQ).

MPQ

The McGill Pain Questionnaire can be used to evaluate a person experiencing pain. It is divided into three sections: (1) What Does Your Pain Feel Like? (2) How Does Your Pain Change with Time? (3) How Strong is Your Pain?

1. What Does Your Pain Feel Like?

Please tick any of the following words below that may describe your **present/current** pain. Tick ONLY those words that best describe it. Leave out any category that is not suitable. Use only a single word in each appropriate category. If you **do not** feel any pain, then you may leave the boxes **unticked.**

1. Temporal (tick one or none of the options if they don't apply)

- ◯ Flickering
- ◯ Quivering
- ◯ Pulsing
- ◯ Throbbing
- ◯ Beating
- ◯ Pounding

2. Spatial (tick one or none of the options if they don't apply)

- ◯ Jumping
- ◯ Flashing
- ◯ Shooting

3. Punctuate pressure (tick one or none of the options if they don't apply)

- ◯ Pricking
- ◯ Boring
- ◯ Drilling
- ◯ Stabbing
- ◯ Lancinating

4. Incisive pressure (tick one or none of the options if they don't apply)

- ◯ Sharp
- ◯ Cutting
- ◯ Lacerating

5. Constrictive pressure (tick one or none of the options if they don't apply)

- ◯ Pinching
- ◯ Pressing
- ◯ Gnawing
- ◯ Cramping
- ◯ Crushing

6. Traction pressure (tick one or none of the options if they don't apply)

- ◯ Tugging
- ◯ Pulling
- ◯ Wrenching

7. Thermal (tick one or none of the options if they don't apply)

- ◯ Hot
- ◯ Boring
- ◯ Scalding
- ◯ Searing

8. Brightness (tick one or none of the options if they don't apply)

- ◯ Tingling
- ◯ Itching
- ◯ Smarting
- ◯ Stinging

9. Dullness (tick one or none of the options if they don't apply)

- ◯ Dull
- ◯ Sore
- ◯ Hurting
- ◯ Aching
- ◯ Heavy

10. Sensory miscellaneous (tick one or none of the options if they don't apply)

- ◯ Tender
- ◯ Taut
- ◯ Rasping
- ◯ Splitting

11. Tension (tick one or none of the options if they don't apply)

- ◯ Tiring
- ◯ Exhausting

12. Automatic (tick one or none of the options if they don't apply)

- ◯ Sickening
- ◯ Suffocating

13. Fear (tick one or none of the options if they don't apply)

- ◯ Fearful
- ◯ Frightful
- ◯ Terrifying

14. Punishment (tick one or none of the options if they don't apply)

- ◯ Punishing
- ◯ Gruelling
- ◯ Cruel
- ◯ Vicious
- ◯ Killing

15. Affective-evaluative-sensory: miscellaneous (tick one or none of the options if they don't apply)

- ◯ Wretched
- ◯ Blinding

16. Evaluative (tick one or none of the options if they don't apply)

- ◯ Annoying
- ◯ Troublesome
- ◯ Miserable
- ◯ Intense
- ◯ Unbearable

17. Sensory: miscellaneous (tick one or none of the options if they don't apply)

- ◯ Spreading
- ◯ Radiating
- ◯ Penetrating
- ◯ Piercing

18. Sensory: miscellaneous (tick one or none of the options if they don't apply)

- ◯ Tight
- ◯ Numb
- ◯ Drawing
- ◯ Squeezing
- ◯ Tearing

19. Sensory (tick one or none of the options if they don't apply)

- ◯ Cool
- ◯ Cold
- ◯ Freezing

20. Affective-evaluative: miscellaneous (tick one or none of the options if they don't apply)

- ◯ Nagging
- ◯ Nauseating
- ◯ Agonising
- ◯ Dreadful
- ◯ Torturing

2. How Does Your Pain Change with Time?

Please tick the box that best indicates your **current/present** pain. If you **do not** feel any pain, you can leave the boxes **unticked**.

21. Which word or words would you use to describe the pattern of your pain?

- ◯ Continuous, steady, constant
- ◯ Rhythmic, periodic, intermittent
- ◯ Brief, momentary, transient

22. Do the following items increase or decrease your pain?

- [ ] Liquor
- [ ] Stimulants such as coffee
- [ ] Eating
- [ ] Heat
- [ ] Cold
- [ ] Damp
- [ ] Weather changes
- [ ] Massage
- [ ] Pressure
- [ ] No movement
- [ ] Movement
- [ ] Sleep or rest
- [ ] Lying down
- [ ] Distraction (TV reading etc.)
- [ ] Urination or defecation
- [ ] Tension
- [ ] Bright lights
- [ ] Loud noises
- [ ] Going to work
- [ ] Intercourse
- [ ] Mild exercise
- [ ] Fatigue

3. How Strong is Your Pain?

Unless instructed otherwise, please tick the box that best represents your **current/present pain** level. If you **do not** feel any pain, then you can leave the boxes **unticked**.

23. Which word describes your pain right now?

- ◯ Mild
- ◯ Discomforting
- ◯ Distressing
- ◯ Horrible
- ◯ Excruciating

3. How Strong is Your Pain?

Unless instructed otherwise, please tick the box that best represents your **current/present pain** level. If you **do not** feel any pain, then you can leave the boxes **unticked**.

23. Which word describes your pain right now?

- ◯ Mild
- ◯ Discomforting
- ◯ Distressing
- ◯ Horrible
- ◯ Excruciating

24. Which word describes it at its worst?

- ◯ Mild
- ◯ Discomforting
- ◯ Distressing
- ◯ Horrible
- ◯ Excruciating

25. Which word describes it when it is least?

- ◯ Mild
- ◯ Discomforting
- ◯ Distressing
- ◯ Horrible
- ◯ Excruciating

26. Which word describes the worst toothache you ever had? *

- ◯ Mild
- ◯ Discomforting
- ◯ Distressing
- ◯ Horrible
- ◯ Excruciating

27. Which word describes the worst headache you ever had? *

- ◯ Mild
- ◯ Discomforting
- ◯ Distressing
- ◯ Horrible
- ◯ Excruciating

28. Which word describes the worst stomach ache you ever had? *

- ◯ Mild
- ◯ Discomforting
- ◯ Distressing
- ◯ Horrible
- ◯ Excruciating

29. Please write your **ID number (PP...)**, and whether you are answering **before** or **after** completing the programme *

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Submit

Appendix 45. Modified Fatigue Impact Scale (MFIS) questionnaire.

MFIS

Following is a list of statements that describe the effects of fatigue. Please read each statement carefully, then tick the one answer that best indicates how often fatigue has affected you in this way during the past 4 weeks.

Because of my fatigue during the past 4 weeks:

1. I have been less alert *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

2. I have had difficulty paying attention for long periods of time *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

3. I have been unable to think clearly *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

4. I have been clumsy and uncoordinated *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

5. I have been forgetful *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

6. I have had to pace myself in my physical activities *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

7. I have been less motivated to do anything that requires physical effort *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

8. I have been less motivated to participate in social activities *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

9. I have been limited in my ability to do things away from home *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

10. I have trouble maintaining physical effort for long periods *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

11. I have had difficulty making decisions *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

12. I have been less motivated to do anything that requires thinking *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

13. My muscles have felt weak *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

14. I have been physically uncomfortable *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

15. I have had trouble finishing tasks that require thinking *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

16. I have had difficulty organizing my thoughts when doing things at home or at work *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

17. I have been less able to complete tasks that require physical effort *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

18. My thinking has been slowed down *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

19. I have had trouble concentrating *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

20. I have limited my physical activities *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

21. I have needed to rest more often or for longer periods *

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Almost always

22. Please write your **ID number (PP...)**, and whether you are answering **before** or **after** completing the programme *

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Submit

Appendix 46. Intervention engagement questionnaire.

Participant engagement questionnaire

This questionnaire is designed to work out how much you engaged with each part of the REACH-SCI programme

Please tick the appropriate box to indicate your answer to each question

Part 1: Smartwatch

As part of the REACH-SCI programme, you were given a smartwatch.

1. Were you given a Garmin Vivoactive smartwatch, or did you use your own device? *

- ◯ Garmin Vivoactive 5
- ◯ I used my own device

2. Did you use the smartwatch? *

- ◉ Yes
- ◯ No

4. In the first month, how often did you use the smartwatch? *

- ◯ 6-7 days a week
- ◯ 3-5 days a week
- ◯ 1-2 days a week
- ◯ Less frequently

5. In the second month, how often did you use the smartwatch? *

- ◯ 6-7 days a week
- ◯ 3-5 days a week
- ◯ 1-2 days a week
- ◯ Less frequently

6. On a scale of 1 to 5, (1 being not at all useful, 5 being extremely useful) how useful was the smartwatch for reminding you to break up your inactivity? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

Part 2: Educational booklet

As part of the REACH-SCI programme, you were provided with an educational booklet with information about inactivity, ideas to keep active, setting goals, and information about physical activity provided by charities, organisations and websites.

7. Did you read through the booklet? *

- ◉ Yes, all of it
- ◯ Yes, some of it
- ◯ No

9. Did you read the "Inactivity?" section? *

- ◯ Yes, all of it
- ◯ Some of it
- ◯ No

10. Did you read the "Benefits of reducing and breaking up inactivity" section? *

- ◯ Yes, all of it
- ◯ Some of it
- ◯ No

11. Did you read the "Ideas to reduce and break up inactivity" section? *

- ◯ Yes, all of it
- ◯ Some of it
- ◯ No

12. Did you read the "How to set and work towards goals" section? *

- ◯ Yes, all of it
- ◯ Some of it
- ◯ No

13. Did you follow any links to relevant charities, organisations or websites to find out information about how they can support with physical activity? *

- (●) Yes, all of them
- ( ) Some of them
- ( ) No

14. If yes to question 13, which of these resources did you find useful and why? *

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15. On a scale of 1 to 5, (1 being not at all useful, 5 being extremely useful) how useful did you find the REACH-SCI educational resource for reducing inactivity? *

- ( ) 1
- ( ) 2
- ( ) 3
- ( ) 4
- ( ) 5

Section 3: Goal setting

As part of the REACH-SCI programme, you were provided with a goal setting worksheet to set short- and long-term goals related to inactivity

16. Did you complete the worksheet? *

- (●) Yes, all of it
- ( ) Some of it
- ( ) No

18. Did you use the worksheet during the programme to review your progress? *

- ( ) Yes
- ( ) No

19. On a scale of 1 to 5, (1 being not at all useful, 5 being extremely useful) how useful did you find goal setting for reducing levels of inactivity? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

Section 4: Motivational support

As part of the REACH-SCI programme, you were offered one-to-one motivational support sessions with a researcher to help set goals, review progress and give motivation (check-in phone calls).

20. Did you make use of the one-to-one motivational support sessions? *

- ◉ Yes
- ◯ No

22. How many one-to-one motivational support sessions did you have? *

- ◯ 1
- ◯ 2
- ◯ 3

23. On a scale of 1 to 5, (1 being not at all useful, 5 being extremely useful) how useful did you find the motivational support sessions for reducing your levels of inactivity? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

Section 5: Peer support

As part of the REACH-SCI programme, you were given access to a WhatsApp peer support group chat with other participants in the programme.

24. Did you make use of the peer support group chat? *

- ◉ Yes
- ◯ No

26. On average, how often did you communicate with others in the group chat? *

- ◯ Everyday
- ◯ A few times per week
- ◯ Once a week
- ◯ A few times a month
- ◯ Once a month
- ◯ Less frequently

27. On a scale of 1 to 5, (1 being not at all useful, 5 being extremely useful) how useful did you find the peer support group chat for reducing levels of inactivity? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

Section 6: Activity tools

As part of the REACH-SCI programme, you were provided with activity tools including exercise bands and a portable hand cycle, to help reduce and break up periods of inactivity throughout the day.

28. Did you make use of the activity tools? *

- ◉ Yes
- ◯ No

30. Did you read the "Activity tools guidance" document? *

- ◯ Yes
- ◯ No

31. How often did you use the exercise bands? *

- ◉ Everyday
- ◯ A few times per week
- ◯ Once a week
- ◯ A few times a month
- ◯ Once a month
- ◯ Less frequently
- ◯ Never

32. On average, how much time did you spend using the exercise bands on each day that you used them?

Minutes per day: *

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33. Did you do physical activity using the exercise bands all in one go or spread across the day? *

- ◯ All in one go
- ◯ Spread across the day

34. On a scale of 1 to 5, (1 being not at all useful, 5 being extremely useful) how useful did you find the exercise bands for reducing inactivity? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

35. How often did you use the portable hand cycle? *

- ◉ Everyday
- ◯ A few times per week
- ◯ Once a week
- ◯ A few times a month
- ◯ Once a month
- ◯ Less frequently
- ◯ Never

36. On average, how much time did you spend using the portable hand cycle on each day that you used it?

Minutes per day: *

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37. Did you do physical activity using the portable hand cycle all in one go or spread across the day? *

- ◯ All in one go
- ◯ Spread across the day

38. On a scale of 1 to 5, (1 being not at all useful, 5 being extremely useful) how useful did you find the portable hand cycle for reducing inactivity? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

39. What is your participant ID number (PP...)? *

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Appendix 47. ActiGraph accelerometer instructions.

ActiGraph watch instructions

What does the ActiGraph watch measure?

- The ActiGraph measures how much the wearer moves during the day.
- It can track how long the wearer spends:
    - **Sleeping**
    - **Being inactive** (like sitting or lying still, watching TV or working on a computer).
    - **Doing light physical activities** (e.g. wheeling, housework).
    - **Doing more intense activities** (e.g. exercise, playing a sport, heavy housework).

How do I wear the ActiGraph watch?

- Strap it to the **wrist** of your **weaker arm** (e.g. if you are left-handed, you should wear it on your right wrist) (see Image 1).
- Make sure the logo is facing the right way round when held up to tell the time like a normal watch (see Image 1).
- Please wear the watch **continuously** (24 hours per day).
- The watch is fully waterproof. It only needs to be removed if using a sauna, steam room (due to the high temperature). **Please continue wearing it whilst swimming and showering/bathing**.

Image 3. How to wear the ActiGraph watch

What do the symbols mean?

- The picture of a man running (Image 2) means that the device is working fine and measuring your activities.

Image 4. Measuring mode

- We will give you the device with full battery which should last a full week (Image 3). If the device is showing a low battery symbol (Image 4), please let us know by email: daniel.cooper2@brunel.ac.uk.

Image 5. Full battery

How do I complete the ActiGraph diary?

- It is important that you **fill in the Daily Diary** on the following pages **every day** for the **8 days** while you are wearing the monitor. This helps us to look specifically at the data from when you were awake.

Image 6. Low battery

- Record the **time that you woke up** AND the **time that you got out of bed**. This is because the device cannot tell the difference between lying down whilst asleep and lying down whilst awake. So, we need this information to work out how long you were awake during the day.

- Record the **time that you got into bed** AND the **time you actually fell asleep** (or your best estimate). We need this information for the same reasons stated above.

- Please write **AM** or **PM** next to your times.

- If you removed the device, please write down **the time you removed the device**, **how long** it was removed for and **the reason why**. We need this information because the device cannot tell the difference between whether you are lying down or whether you removed it.

What else do I need to do?

You will already have received the ActiGraph and this instruction manual in the post. The device will already be set up to start monitoring your activity, so you can simply start wearing it immediately. Please return your monitor to us when you visit Brunel University of London campus for your study measurement visit. Contact Dan on daniel.cooper2@brunel.ac.uk or [redacted telephone no.] if you have any questions.

Appendix 48. ActiGraph accelerometer sleep and wake time diary.

Day and date	**Wake up** *Time you woke up for the day*	**Got out of bed** *When you physically got out of bed*	**Got into bed** *When you physically got into bed*	**Fell asleep** *Time you turned the lights off to sleep*	**Any naps during the day**	**Times during the day when you took off the activity monitor and why**	**Any other comments**
Example: Monday 2nd June	*07:00 AM*	*07:30 AM*	*10:00 PM*	*10:30 PM*	*1:00 PM for 20 minutes*	*6:00 PM for 30 minutes for a CT scan during a hospital appointment*	
Date:							
Date:							
Date:							
Date:							
Date:							
Date:							
Date:							
Date:							
Date:	***The watch will stop recording on this day. Please bring the watch with you to your measurement visit***						

Appendix 49. Office for National Statistics 4-item (ONS-4) subjective wellbeing questionnaire.

ONS-4

...

Below are some questions about feelings. Please give a score of 0 to 10 for each statement:

Please tick the appropriate box to indicate your answer

1. Overall, how satisfied are you with your life nowadays? (0 is not at all, 10 is completely) *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10

2. Overall, to what extent do you feel that the things you do in your life are worthwhile? (0 is not at all worthwhile, 10 is completely worthwhile) *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10

3. Overall, how happy did you feel yesterday? (0 is not at all happy, 10 is completely happy) *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10

4. Overall, how anxious did you feel yesterday? (0 is not at all anxious, 10 is completely anxious) *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10

5. Please write your **ID number (PP...)**, and whether you are answering **before** or **after** completing the programme *

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Submit

Appendix 50. Generalized Anxiety Disorder 7-item (GAD-7) questionnaire.

GAD-7

...

Over the last 2 weeks, how often have you been bothered by the following problems?

Please tick the appropriate option to indicate your answer

1. Feeling nervous, anxious or on edge *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

2. Not being able to stop or control worrying *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

3. Worrying too much about different things *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

4. Having trouble relaxing *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

5. Being so restless that it is hard to sit still *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

6. Becoming easily annoyed or irritable *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

7. Feeling afraid, as if something awful might happen *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

8. Please write your **ID number (PP...)**, and whether you are answering **before** or **after** completing the programme *

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Submit

Appendix 51. Patient Health 9-item Questionnaire (PHQ-9) (depression).

PHQ-9

...

Over the last 2 weeks, how often have you been bothered by any of the following problems?

Please tick the appropriate box to indicate your answer

1. Little interest or pleasure in doing things *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

2. Feeling down, depressed, or hopeless *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

3. Trouble falling or staying asleep, or sleeping too much *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

4. Feeling tired or having little energy *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

5. Poor appetite or overeating *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

6. Feeling bad about yourself - or that you are a failure or have let yourself or your family down *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

7. Trouble concentrating on things, such as reading the newspaper or watching television *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

8. Moving or speaking so slowly that other people could have noticed. Or the opposite - being so fidgety or restless that you have been moving around a lot more than usual *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

9. Thoughts that you would be better off dead or of hurting yourself in some way *

- ◯ Not at all
- ◯ Several days
- ◯ More than half the days
- ◯ Nearly every day

10. Please write your **ID number**, and whether you are answering **before** or **after** completing the programme *

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Submit

Appendix 52. Short-Form 36-item walk-wheel (SF-36ww) health-related quality of life questionnaire.

SF-36 ww

...

This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Thank you for completing this survey!

For each of the following questions, please tick the box that best describes your answer.

1. In general, would you say your health is: *

- ◯ Excellent
- ◯ Very good
- ◯ Good
- ◯ Fair
- ◯ Poor

2. Compared to one year ago, would you say your health is: *

- ◯ Much better now than one year ago
- ◯ Somewhat better now than one year ago
- ◯ About the same
- ◯ Somewhat worse now than one year ago
- ◯ Much worse now than one year ago

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much? *

Clear selected

	Yes, limited a lot	Yes, limited a little	No, not limited at all
Vigorous activities, such as lifting heavy objects, participating in strenuous sports	◯	◯	◯
Moderate activities, such as moving a table, pushing a vacuum cleaner, or bowling	◯	◯	◯
Lifting or carrying groceries	◯	◯	◯
Climbing several flights of stairs	◯	◯	◯
Climbing one flight of stairs	◯	◯	◯
Bending, kneeling, or stooping	◯	◯	◯
Wheeling more than a mile	◯	◯	◯
Wheeling several blocks	◯	◯	◯
Wheeling one block	◯	◯	◯
Bathing or dressing yourself	◯	◯	◯

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health? *

Clear selected

	Yes	No
Cut down the amount of time you spent on work or other activities	◯	◯
Accomplished less than you would like	◯	◯
Were limited in the kind of work or other activities	◯	◯
Had difficulty performing the work or other activities (for example, it took extra effort)	◯	◯

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)? *

Clear selected

	Yes	No
Cut down the amount of time you spent on work or other activities	◯	◯
Accomplished less than you would like	◯	◯
Didn't do work or other activities as carefully as usual	◯	◯

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups? *

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Quite a bit
- ◯ Extremely

7. How much bodily pain have you had during the past 4 weeks? *

- ◯ None
- ◯ Very mild
- ◯ Mild
- ◯ Moderate
- ◯ Severe
- ◯ Very severe

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)? *

- ◯ Not at all
- ◯ A little bit
- ◯ Moderately
- ◯ Quite a bit
- ◯ Extremely

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the past 4 weeks . . . *

Clear selected

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
Did you feel full of pep?	○	○	○	○	○	○
Have you been a very nervous person?	○	○	○	○	○	○
Have you felt so down in the dumps that nothing could cheer you up?	○	○	○	○	○	○
Have you felt calm and peaceful?	○	○	○	○	○	○
Did you have a lot of energy?	○	○	○	○	○	○
Have you felt downhearted and blue?	○	○	○	○	○	○
Did you feel worn out?	○	○	○	○	○	○
Have you been a happy person?	○	○	○	○	○	○
Did you feel tired?	○	○	○	○	○	○

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)? *

- ◯ All of the time
- ◯ Most of the time
- ◯ Some of the time
- ◯ A little of the time
- ◯ None of the time

11. How TRUE or FALSE is each of the following statements for you? *

Clear selected

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false
I seem to get sick a little easier than other people	◯	◯	◯	◯	◯
I am as healthy as anybody I know	◯	◯	◯	◯	◯
I expect my health to get worse	◯	◯	◯	◯	◯
My health is excellent	◯	◯	◯	◯	◯

12. Please write your **ID number (PP...)**, and whether you are answering **before** or **after** completing the programme *

0/32,000 characters

Submit

Appendix 53. Intervention acceptability qualitative analysis with all quotations.

TFA domain	Inductive code	Illustrative quote from semi-structured interview
Affective attitude	The intervention was enjoyable	L1 Incomplete, Female: “So I didn't get bored”. L1 Incomplete, Female: “It makes me wanna carry it on even after the eight weeks”. T11 Incomplete, Female: “I did enjoy taking part in the program”. L1 Incomplete, Male: “Yeah, absolutely. Yeah, enjoyed it, yeah, definitely”. T8 Incomplete, Male: “I was quite happy with all of it. It's a good idea, and yeah”. T5 Complete, Male: “Yes [enjoyed taking part]”. T9 Complete, Male: “I did. Yeah, did [enjoy the intervention]”. T9 Complete, Female: “Yes, [taking part in the intervention was] enjoyable and educational”. T9 Complete, Female: “No. It’s a bit of a trek, but it’s fine. No, I've enjoyed being part of the programme”. T3 Incomplete, Female:

	"Yes, yes [it was enjoyable]... I think being more aware of my levels of activity and kind of forcing myself to take accountability on it [I liked]". T5 Complete, Female: "Yes [I enjoyed doing the intervention]. The challenge was good and pushing yourself to reach those goals". T4 Complete, Male: "Um, enjoy it. I suppose yeah, because it's been it's for a worthwhile, hopefully, outcome. So yeah, I'm quite happy to contribute my little bit so yeah, I'm pleased I've done it as well. Yeah". T3 Incomplete, Female: "Yeah, yes, I did [enjoy the intervention]. I mean, I think I said to you on one of our calls. I had a little bit of a, you know, a bit of a challenge in terms of, you know, my shoulder's not been quite right. But it was, it was really good to have something to make me mindful of the importance of activity". T9 Incomplete, Male: "Yeah, yeah, I did [enjoy participating]. Yeah". T8 Complete, Female: "Yeah, I think so, I think it's something. Yeah, yes, I would say it's… well, it's not *not* enjoyable. But yeah, yeah, I think so".
Increased awareness of inactivity	L1 Incomplete, Male: "No, not really. I mean, I think one of the things that I had to be erm, conscious of is making sure that I'd written stuff down so obviously, for the black watch kind of stuff, but also writing things down and Sort of coming up with the words that I want to use to make sense for what we were doing. Yeah, but, yeah, I mean, I think that's just because it's a bit more school-like". T3 Incomplete, Female:

	"Yes, yes [it was enjoyable]... I think being more aware of my levels of activity and kind of forcing myself to take accountability on it". T3 Incomplete, Female: "It was really good to have something to make me mindful of the importance of activity".
The intervention was a good challenge	T5 Complete, Female: "Yes [I enjoyed doing the intervention]. The challenge was good and pushing yourself to reach those goals". T5 Complete, Female: "But no, it was, it was good. It was good providing, like also I had a piece of equipment to challenge myself and push myself, but the fact that you provided things like the watch the bands, the bike, that was helpful". T3 Incomplete, Female: "Yeah, yes, I did [enjoy the intervention]. I mean, I think I said to you on one of our calls. I had a little bit of a, you know, a bit of a challenge in terms of, you know, my shoulder's not been quite right. But it was, it was really good to have something to make me mindful of the importance of activity". T8 Complete, Female: "I guess the kind of challenge and thinking, I suppose, because I think I said to you before that I've wanted to be more active, and so actually it's quite nice to have that sort of structure around thinking, 'oh okay, well, I need to do this now because I've set a goal around it'. So, yeah, that aspect of it".
There was too much paperwork	T11 Incomplete, Female: "Uh the paperwork aspect, paperwork. I'm not really a paperwork person, so I just felt like that was an extra thing. It's good to be able to look back and reflect, and to see what you've done for two weeks and sort of in the increments, but yeah, the actual writing of it is".

		L1 Incomplete, Male: “No, not really. I mean, I think one of the things that I had to be erm, conscious of is making sure that I'd written stuff down so obviously, for the black watch kind of stuff, but also writing things down and Sort of coming up with the words that I want to use to make sense for what we were doing. Yeah, but, yeah, I mean, I think that's just because it's a bit more school-like”. T12 Incomplete, Male: “If it was like, “just a watch. Just read that read that” it's like I don't do reading, and I don't do reading, I don’t do form filling. But I do like doing the practical parts. If I've got something to do or go to the shop or I'd do it, yeah. Otherwise, I'd put it in with my gardening, helping people do stuff”.
Burden	Low effort required to participate	T11 Incomplete, Female: “Not a lot [of effort]”. T8 Incomplete, Male: “Because you can set things up as and how you feel you want to do it, and then if you want to do something you can do it, if you don't, you don't. You know”. T5 Complete, Male: “None [burden in participating]. No worry. No problem at all”. T12 Incomplete, Male: “It was just more or less going in the background for me, because I just carried on with my life. A busy busy bee doing stuff for everyone else, and the watch was just on my wrist. It wasn't like right, it was on my wrist this morning. I'm gonna do this gonna do that”. T10 Complete, Female: “Erm. Wasn't so much effort, it's more it was more commitment and motivation, I suppose, but Effort, because it's easy to do. It's easy to fit in. It was just a case of making that commitment to following it through”.

T10 Complete, Female:
“I think no. No time at all. No time at all [appropriateness of time taken to engage with each component]. So I think one of the, one of the really good things that you said to me is like when you when you are boiling the kettle, don't just stand there and wait for the kettled to boil, you know, do something and move. So it's really easy”.

T9 Complete, Male:
“A little bit [of effort was required to do the intervention], but I expected that. I think it would have been unreasonable to sign up for a programme like this and thought this not gonna require any effort, because just the general nature of what it was about. Yeah, but I didn't think the amount of effort that was expected was at all unreasonable”.

T9 Complete, Female:
“None [effort needed to participate]”.

T3 Incomplete, Female:
“I think it was fairly easy to engage with. So, medium? Medium effort”.

T5 Complete, Female:
“It wasn't effortless, it was not effortless, but it was doable. It was, it was, there were days where I had to, I really needed to push myself, but it wasn't unachievable. It was, it was good”.

T4 Complete, Male:
“Not a great amount [of effort], really. It's, it's more just restructuring my hours and getting on with my life. You know”.

T3 Complete, Male:
“Not too much [effort] at all”.

		T9 Incomplete, Male: “I think out of 5 I think I would put about a 2 on that [effort required to participate]”. T8 Complete, Female: “Not really, because it didn't feel like a big ask, it wasn't like I was gonna, I was having to do, you know, an hour's physical exercise every day or anything like that. So not really, I think it was OK”. T8 Complete, Female: “It's some because you have to think about it, and you know, you have to sort of make, but it actually didn't feel that effortful, I think it was okay”.
	It became easier to participate over time	L1 Incomplete, Female: “Some days a lot. Other days, not so much and it was easier. Yeah, and it got easier as the weeks went on. I found it easier to get into the routine of get up and do it set for the days. Yeah, a lot”. L4 Incomplete, Female: “In the beginning [there was too much content and time required to do each one], I would say yes”.
	Too busy to engage	T12 Incomplete, Male: “No, the watch wasn’t working properly and had to start with a reprogramme, and then it started working. It was going alright then went wrong again, and that was it then, I just lost interest, like I was too busy with my stuff that I have to do”. T10 Complete, Female: “I felt again, I just me personally. That I was letting you and the program down and felt a bit guilty that I couldn't or wasn't giving the program, my full dedication. Because I just just was, yeah, too busy”.
	Wearable activity tracker band caused skin irritation	L1 Incomplete, Female: “I had to change the strap because I found it really, it's not good for your skin, so I bought a really cheap leather one, but otherwise, it sits really nicely on your wrist. It's a good size”.

		T12 Incomplete, Male: “No, cause it really messed my wrist up.... It was literally it hurt me there and there, and it was because I didn't take it off to wash it”. T3 Incomplete, Female: “It's not so bad now, but I got er, like a rash from wearing it. Apparently when it's wet, you have to be really careful to make sure that you're not wearing it with wet skin and stuff, it's just a rubber”.
Perceived effectiveness	Intervention increased knowledge of sedentary behaviour	L1 Incomplete, Male: “Yes [the intervention was effective]. Oh, absolutely yeah. No, without a doubt. It's it's even if you think you cover things, it's definitely worth the refresher or reminder to carry on with what you are doing”. T5 Complete, Male: 2Yeah, and it makes you think more about the inactivity, you know, having talked about, I'd never have thought about that in a in a negative sense. You don't think about periods of inactivity, do you? Until someone actually talks to you about it”. T10 Complete, Female: “Yeah, exactly. So for example, on my dancing days, my exercise days, I'm doing I'm doing 4 hours of exercise, and so it was easy to achieve those 4000 pushes. And so it was, it was good for me to know how much I actually need to do in order to be able to achieve that 4000 so even without the watch now, I kind of I've got a good idea of what I need to be doing to get the 4000 pushes”. T9 Complete, Male: “Erm, it made me start to sort of, I re-evaluated is the right word, but think about just how inactive I'd become... So, but no, it did, it did. It did get me thinking. And it did also make me realise just how easy, it is to get into some bad habits and be aware of the importance of having plenty of physical activity”.

	T3 Incomplete, Female: “Yeah, yes, I did [enjoy the intervention]. I mean, I think I said to you on one of our calls. I had a little bit of a, you know, a bit of a challenge in terms of, you know, my shoulder's not been quite right. But it was, it was really good to have something to make me mindful of the importance of activity”. T8 Complete, Female: “Yes, definitely. I think, I mean, there were days when it was less easy for me to do so. So I probably didn’t break up my inactivity on some days, but mostly, yes, I think it is because it just gets you thinking about it, and I think, yeah, I think that's helpful”.
Formation of new habits	L1 Incomplete, Female: “Yeah, it definitely got me doing more even to the point that like, if I knew I was gonna brush my hair in the evening, I'd leave my hairbrush in the bedroom until part way through the evening and then I'd go and get it so that I was getting up”. T10 Complete, Female: “So for example, when we were on holiday, we were going just for a little recce. And uh, my husband got my bike out of the car, and I said, ‘oh, no, I'm gonna do it manually. I'm gonna push’. I'd never have made that decision had it not been for this programme. So for me. It that was a really positive aspect of it”. T9 Complete, Male: “Erm, it made me start to sort of, I re-evaluated is the right word, but think about just how inactive I'd become... So, but no, it did, it did. It did get me thinking. And it did also make me realise just how easy, it is to get into some bad habits and be aware of the importance of having plenty of physical activity”. L4 Incomplete, Female: “Yes [intervention was effective]. Erm, definitely the idea of watching TV for 30 minutes, then doing something. Within like the first two weeks, I really got into it. But I got so into it. I watched, I went to the cinema week 6, and without me even realising I was kind of just wheeling around. And the person I was with was kind of

	like “what?”, and I was like, “oh I’ll sit back down”. So yeah, I got so into it that yeah”. T3 Complete, Male: “Yeah, yeah, again as I said, it don't make you lazy isn’t it? So, if you're watching TV for a few hours, you just stop, because, you know, you have to do that, and then you can go back to the TV. So yeah, it gives it gives you a little break and it's good. Doing activity between relaxing, basically”. T8 Complete, Female: “Yeah, yeah, definitely. Oh being able to kind of see when I had hit them [daily targets]. Then thinking ‘oh, what did I do?’, because I didn't really do lots of additional exercise. It was more kind of because I just never find the time for that. And also because my shoulders get very sore. It's not that there's not that much more I can do. So it was really nice to see and I definitely found that I would do things like I'd go the long way round to the canteen, a lunchtime or something like that. So I knew that, and I could see that on the watch. So that was yeah, that was good”.
Activity levels increased	L1 Incomplete, Female: “Yeah, it definitely got me doing more even to the point that like, if I knew I was gonna brush my hair in the evening, I'd leave my hairbrush in the bedroom until part way through the evening and then I'd go and get it so that I was getting up”. T5 Complete, Female: “It [the intervention] did, it did [manage to reduce and break up sedentary behaviour]”. T3 Incomplete, Female: “They're [activity levels] definitely more now than they were when I started the programme across the week, I would say, more than perhaps on a particular day, because I've got different things. I’ve got commitments for across the week. So some days, some days it can be more than others”.

		T3 Incomplete, Female: “So, you know, so I think it's, but it's yeah, but I'm definitely, I'm definitely more active now than I was. And I've definitely got more energy now, as than I had when I came out when I first came onto the program”. T8 Complete, Female: “Yeah, definitely. Well, I think I just noticed that I was doing more. I probably am more active than I would have said before. So, I probably do move more often than I think I do, and I did wear a smart watch before but I would ignore it. I didn’t use it. So I suppose tuning into that was really helpful”.
	Useful for newly injured individuals	T3 Incomplete, Female: “Having been discharged from hospital, my community physio still hasn't started yet, I'm still on the waiting list. I'm lucky that I've been able to do my own physio, you know, privately, but I just think if I hadn't have done that, then I would have needed something to keep my activity levels going. So for me, if we remove the fact that I've been able to fund my own physio, and if I was in a, I'm still sitting waiting for the community physio, then being on the [REACH-SCI] programme would have been, you know, would have been absolutely the right time. Well, it is the right time for me. But equally, you know, if I'd have been in a different situation, it would have been the right time, because it would have kept that momentum going of doing something physical”. T3 Complete, Male: “It's [REACH-SCI] come at the right time, because if, if you don't start now, you’re just going to get lazier and lazier, and it's going to just… remember, most of the time you're homebound, so it's good to be doing it now, so that you’re not lazy. Otherwise, if you leave things late, it just gets too late and you get lazy, so I want to be active now, rather than later”.
	Less useful for individuals who are already active	T11 Incomplete, Female: “Yeah, I mean, I'm already taking an exercise programme. So I've already got that aspect of it done. Yeah, I've got a personal trainer, so I don't necessarily need to have any of that [links to online resources]”.

		T10 Complete, Female: “I think I think where this programme is more useful is for somebody who is perhaps not coping with their disability, or they have a lot more problems with their disability. They don't work, they don't have, maybe a family or friends or children to look after, or people to cook for. Maybe they live on their own. And maybe they do spend a lot of time just sitting and watching telly, or playing games on the computer or not doing very, very much”. T3 Incomplete, Female: “I think if I was somebody that didn't, you know, hadn't sort of exercised and hadn't incorporated exercise into daily life previously, I think the watch probably would have been more beneficial”.
Ethicality	No ethical concerns	L1 Incomplete, Female: “Nothing like that [ethically concerning]”. L1 Incomplete, Male: “No, none at all. Nothing like that [ethical concerns]”. T5 Complete, Male: “No [ethical concerns], none at all”. T10 Complete, Female: “Not at all [ethical concerns]”. T9 Complete, Male: “No, nothing [unethical about the intervention] at all in that regard”. T5 Complete, Female: “No [ethical concerns], I think everything was well-organised”. T4 Complete, Male:

		"Nothing like that [ethical concerns]". T3 Incomplete, Female: "Nothing like that [ethical concerns]". T9 Incomplete, Male: "No concerns".
Intervention coherence	Clear explanation in educational booklet	T9 Complete, Female: "Yes, it [how the intervention was intended to achieve its aim] was explained verbally and in the booklet". T3 Incomplete, Female: "Yes. I mean, the leaflet is fairly clear on, or the booklet rather, is very clear on how it's supposed to work". T5 Complete, Female: "Yeah [it was clear how the intervention was meant to achieve its aim]. And as well [it was clear] on the leaflet, there was a list of the links to follow-up and engage with. That was also useful". T4 Complete, Male: "Well, it's in front of you, isn't it? And it sort of emphasises it, and then reemphasises it, yeah in the booklet, so as long as you read that, you can get it, it's fine".
	Clear explanation by researchers	L1 Incomplete, Female: "No, I think that was pretty much. That was very clear. You [PhD researcher] went through that really well". T8 Incomplete, Male: "Yeah, well you [PhD researcher] explained it initially. And then when we came for the initial testing upstairs. Yeah, erm, you said this is what this is for. And then we went away with tools that you gave us, and you explained these are what we can be using in different times each day. What we can use and more in different situations".

		T9 Complete, Male: “No, I don't think so [need more explanation as to how the intervention was meant to achieve its aim], I think it was all explained well”. T9 Complete, Female: “Yes, it [how the intervention was intended to achieve its aim] was explained verbally and in the booklet”.
	Educational booklet improved coherence	T5 Complete, Male: “Yeah, and it makes you think more about the inactivity, you know, having talked about, I'd never have thought about that in a in a negative sense. You don't think about periods of inactivity, do you? Until someone actually talks to you about it”. T12 Incomplete, Male: “And yeah, it's all about your heart. Yeah, Cos every time you're inactive for 20 minutes or something, it affects your heart. I think you said or 40 minutes, so you gotta keep doing a little bit rather than not do it at all. You gotta like pace yourself like light things”. T3 Incomplete, Female: “Absolutely, yeah, yeah, I'm actually, that I suppose was another reason for being a part of it was actually understanding the impact that can, you know, that it can have, because you don't normally do that in, you know, normal life”. T8 Complete, Female: “Yes, definitely. I think, I mean, there were days when it was less easy for me to do so. So I probably didn’t break up my inactivity on some days, but mostly, yes, I think it is because it just gets you thinking about it, and I think, yeah, I think that's helpful”.
Opportunity costs	No interference with other commitments	T11 Incomplete, Female: “No, I think it was fine and fair to be fair. I feel like it was, it was a clinical study being done in the background of my day-to-day life. It wasn't. It didn't feel like I was actually doing anything over and out of the way of my normal routines”.

L1 Incomplete, Male:
“No, I mean, I'm, I'm lucky enough that, you know, I sort of factor my timetable out for the day, and everything. I mean, obviously I have a couple of teenage daughters and a wife, because, and they sort of dictate quite a lot of stuff. So from my perspective I can accommodate, but then I did. There are these factors that influence it. So, but no, it was, it was enough and slotted in when, you know, I felt like doing so yeah”.

T8 Incomplete, Male:
“Yeah, no I mean. You can’t do something necessarily within a week. Some things take this amount to get embedded, mentally into you, and other things take. But I think it was a quite a nice amount of time. It gave you the chance to have a go at different activities and try and build those into your life. So definitely”.

T9 Complete, Male:
“I think if I felt it was it [REACH-SCI intervention] was interfering with other things. I think I would let you know yeah, but again I can't speak for other people obviously down but obviously everybody's got different lifestyles haven't they? So but for me personally, it didn't”.

T5 Complete, Female:
“No [intervention did not interfere with other priorities or commitments]. Time spent on the sofa has been jeopardised. Oh, but it's okay, okay”.

T5 Complete, Female:
“Oh it was it was easy, it didn't interfere with anything”.

T4 Complete, Male:
“It just stopped me sitting on a computer so yeah, not really a sort of commitment, but it wasn't a problem”.

		T3 Incomplete, Female: “What I would say, because I, you know, I'd be going to go and do physio and things across the course of the week it was it was that thinking, ‘okay, I've got a couple of hours now where I'm gonna be in the car’, ‘I've got an hour where I'm gonna be in physio. I'm not gonna be able to do too much in that time either side of the physio session’. So, it didn't interfere, but it was just more that I had to adapt on a day-to-day basis”.
	Life interfered with participation in the intervention	T12 Incomplete, Male: “Thing is my life came before the programme, which it should have come the other way. I'm doing the programme for the eight weeks. I know that my other commitments like my neighbours now dying of cancer. She fell over, I had to go round there, she had a fit epileptic fit, I had to get the ambulance first. That took precedence over what this is. This is research. This is real life”. T10 Complete, Female: “It didn't interfere, but there were there were there were definite times that I couldn't do what I needed to do so say, for example, again see, I think I think getting this job really changed the the way that I was able to engage with the programme and had I just been at home doing my normal stuff, I would have been able to have done more, and I would have done more. But for example, the day that I have to go to… I think we had this conversation on the phone. The days that I had to go to to the office, I've got the car journey all the way there, then you're committed to working in the office. I can't. I couldn't just suddenly, you know, everytime my watch just go off and do something so it was really difficult to commit and engage to the programme”. T8 Complete, Female: “No, not really. I mean, there were, you know, there were meetings where I couldn't do it because, you know, I was in a 2 or a 1 hour meeting or something and I couldn't. I was on screen and couldn't couldn't move. But it didn't, I mean, those had to take precedence, so it didn't. It didn't interfere with anything like that. It was more that work interfered with doing it. So it was the other way around, yeah”.

	Intervention interfered with other commitments	T10 Complete, Female: “You're committed to working in the office. I can't. I couldn't just suddenly, you know, every time my watch just go off and do something, so it was really difficult”. L4 Incomplete, Female: “Especially in the beginning [there was too much content and time required to do each one], I would say yes”. T3 Incomplete, Female: “Yes [taking part interfered with other priorities or commitments]. Yeah, and I did put that it did on the survey. But just because sometimes I have to focus quite hard at work. And I mean, obviously I wasn't working as much at the moment, but still trying to do things in the line of that and it, it viewed it did make it quite tricky”.
Self-efficacy	Confident in participating	T11 Incomplete, Female: “Confident, no issues”. L1 Incomplete, Male: “Confident, yeah, yeah, I mean, I have obviously done a few things here and so on. So I knew the sort of way these things go about. It’s familiar to me, so it's it's… I don't, I don't feel apprehensive, and also I feel confident that things are, you know, gonna be, as I expect, they're gonna be something”. T8 Incomplete, Male: “No, I mean I felt very confident doing it. Yeah, after obviously we'd had the initial emails going backwards and forwards, and then you'd you explained it at the start, as I said when we first came here? No, I felt very confident in where we were going or what was expected of us, erm, what we were being looked at for, yeah, so to speak. And there was nothing that we had to do or nothing that we didn't have to do”. T9 Complete, Male:

		"Yeah. Confident, yeah, confident. I think I think if had I not felt confident, I probably would have been on the phone to you erm or emailing you a fair bit, but I was confident. Yeah, so yeah". T9 Complete, Female: "Yeah, totally confident [in doing the intervention]". T4 Complete, Male: "Yeah, I wasn't fazed by it at all". T3 Incomplete, Female: "Yeah, I didn't even question, I didn't question it. It was just, I felt it was a good thing to be a part of and I wanted to be a part of it. So I didn't even question whether, I don't even think confidence came into it. I think I just thought I, you know, I can do this, and I said, I did have to adapt it to suit myself, but it was, it wasn't something I had a question that I wouldn't be able to do". T3 Complete, Male: "Yeah, yeah, it's pretty straightforward, and it gives you the confidence you need, and yeah". T9 Incomplete, Male: "Yeah, very confident [about participating]". T8 Complete, Female: "No but I guess it depends on where people are starting from. I guess if people were less confident generally then they might need more support with that, and I think it probably depends how active people are to start with. So for me, it was just building on probably what I was already doing, whereas I think if you got someone who's very sedentary, I can imagine that that would be difficult".
	Motivational sessions increased confidence	L1 Incomplete, Female:

		“Mm reasonably confident reasonably. Okay. I was a bit worried I wouldn't stick with it, but I think having that those one to ones during the programme gave me that accountability to say “I must do it because I'm going to talk to ”, and I can't turn round and say I haven't done anything”. L1 Incomplete, Female: “I found them really useful having the accountability and knowing that I needed to have achieved something at least by such a such a date. Yeah, it kept me on track with doing the work. And where I had those couple of weeks where I wasn't able to do anything, because I was doing an intensive study course, you made me feel less bad about that, yeah, so then I didn't feel like, “oh, I've not done anything. I'll just give up completely”, so that was really helpful. And that kept me on track to then go back to it and go back to doing the exercise and carry on again. Those sessions really helped”. T9 Complete, Male: “Yeah. Confident, yeah, confident. I think I think if had I not felt confident, I probably would have been on the phone to you erm or emailing you a fair bit, but I was confident. Yeah, so yeah”.
	Confidence increased over time	L1 Incomplete, Female: “Mm reasonably confident reasonably. Okay. I was a bit worried I wouldn't stick with it, but I think having that those one to ones during the programme gave me that accountability to say “I must do it because I'm going to talk to ”, and I can't turn round and say I haven't done anything”. T5 Complete, Male: “Yeah, given the first few days where I was reading it all and getting familiar with it and getting it straight in my head what I wanted to do with it, how I wanted to interpret it. Then [I felt confident], yeah, absolutely”. T3 Incomplete, Female: “Er not super confident at the start. I think I said I am not intentionally a couch potato, but I like long periods of doing something which is sedentary. Yes, so I was

	not particularly confident in how well I was gonna take this on, but I set very low goals at the start to try and make sure I didn't get discouraged, maybe they were too low. I'm not sure, but it meant that I was still engaging with it, rather than getting old as it's on a TV kind of thing, so, yeah". T5 Complete, Female: "I wasn't sure at first, but in the end, I enjoyed it. So if you need me again, give me a shout". T5 Complete, Female: "First week was difficult. Yeah, and then you just kind of learn what you can do, and as the weeks went, it was easier. Yeah, yeah, the first week was harder".

L, lumbar; TFA, Theoretical Framework of Acceptability; T, thoracic.