Utility cycling as a public health strategy to integrate physical activity into everyday life: a systematic enquiry

A thesis submitted for the Degree of Doctor of Public Health (DrPH)

by

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List of Abbreviations

AOR - Adjusted odds ratio

APS – Active People Survey

BMA – British Medical Association

BMI – Body Mass Index

BTW – Bike to work

CATI – Computer-assisted telephone interviewing

CCG – Clinical Commissioning Group

CE – Cycle England

CMO – Chief Medical Officer

CDT – Cycling Demonstration Town

CCTs – Cycling Cities and Towns; Blackpool, Bristol, Cambridge, Chester, Colchester, Leighton, Shrewsbury, Southend, Southport, Stoke, Woking and York.

DALY – Disability Adjusted Life Year

DCMS – Department for Culture, Media and Sport

DfT – Department for Transport

DH – Department of Health

DID – difference in differences

DrPH – Doctorate in Public Health

EBM – Evidence based medicine

EPIC – European Prospective Investigation into Cancer (validated questionnaire including questions into physical activity

ESRC – Economic and Social Research Council

FPH – Faculty of Public Health

GLA – Greater London Assembly

HEPA – Health Enhancing Physical Activity

HHASC – Health, Housing and Adult Social Care (a directorate of the London Borough of Enfield)

HSE – Heath Survey for England

KPI – Key performance indicator

LTC – Long term condition

MET – Metabolic equivalent

MRC – Medical Research Council

NCD – Non-communicable disease

NICE – National Institute for Health and Care Excellence

OR – Odds Ratio

PA – physical activity

PAGAC – Physical Activity Guidelines Advisory Committee

PCT – Primary Care Trust

PHE – Public Health England

PHOF – Public Health Outcomes Framework

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

RCGP – Royal College of General Practitioners

RCT – randomised controlled trial

RCP – Royal College of Physicians

RTWD – Ride to Work day

RDD – random digit dialling

TfL – Transport for London

WHO – World Health Organisation

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List of publications

The methods and main findings of the systematic review of this thesis (chapter three) have been published as:

STEWART, G., ANOKYE, N.K. and POKHREL, S. (2015). What interventions increase commuter cycling? A systematic review. *BMJ Open 2015 doi:10.1136/bmjopen-2015- 007945,* .

The evaluation of the Cycling City and Town (CCT) programme has been accepted as an abstract.

STEWART, G., ANOKYE, N.K. and POKHREL, S. (2016). Improving population levels of physical activity through integration into everyday life: a pre-post analysis of the Cycling Cities and Towns (CCTs) programme (abstract, The Lancet, in press)

The quantitative analysis of the potential for utility cycling to support meeting recommended levels of physical activity (chapter six) has been published as

STEWART, G., ANOKYE, N.K. and POKHREL, S. (2015). Quantifying the contribution of utility cycling to population levels of physical activity: An analysis of the Active People Survey. *Journal of Public Health (Oxford, England),* doi:10.1093/pubmed/fdv182.

ABSRACT

A lack of physical activity (PA) s the fourth leading cause of mortality worldwide. Reasons for physical inactivity include the increasing electrification, mechanisation and motorisation of everyday life which has excluded PA from everyday life. Building PA back into life therefore may be one means of raising population levels of PA. One way of achieving this may be through utility (non-sporting) cycling.

The overarching aim of this thesis was to explore utility cycling as a public health strategy to integrate physical activity into everyday life.

A systematic review showed that there is little evidence of what interventions might increase population levels of commuter cycling though population level interventions may be most effective. An example of such interventions identified was the Cycling City and Towns (CCT) programme.

A search of the UK dataservice found that the Active People Survey was appropriate for the evaluation of CCTs for their effect upon utility cycling and PA in other life domains. CCTs were found associated with a greater probability of utility cycling than their matched controls (AOR 1.48, 95% CI 1.14 - 1.94). Those most likely to have cycled were male, aged 16-34, and those in the ONS socio-economic category NS SEC 9. Those least likely were those in NS SEC 5-8 and of Asian ethnicity. A second analysis of the effect of utility cycling showed that there was a greater probability of meeting PA recommendations in those who undertook utility cycling compared to those who did not (AOR 4.08 (95% CI 3.88 – 4.29). Those most likely to meet PA recommendations were male, aged 16-34, of mixed ethnicity, without children and living in London.

This thesis concludes that programmes such as the CCTs may offer one means through which population levels of PA can be increased through its integration into everyday life.

Ethics

All data used in the writing of this thesis is anonymous and publicly accessible through registration with the UK dataservice (https://www.ukdataservice.ac.uk/) https://www.ukdataservice.ac.uk/ and agreement to use any data obtained in accordance with special licenses (appendix 1). Agreement to conditions contained in the licenses is a pre-requisite to being able to download data and was in accordance with best practice at Brunel University at the time.

CHAPTER 1: Introduction

A lack of physical activity (PA) is increasingly recognised as a major global public health issue. The World Health Organisation (WHO) together with at least 20 countries have issued guidelines (IHRSA undated) intended to address this 'pandemic'; the fourth leading cause of death worldwide (Kohl, Craig et al. 2012). Conditions related to physical inactivity include all-cause mortality, cardiorespiratory, metabolic and musculoskeletal health, mental health and cancer, collectively referred to as long-term conditions (LTCs) and which account for 70% of the NHS budget (NHS 2014). Meeting physical activity guidelines is associated with a 20 – 40% risk reduction in all LTC's as well as improved energy balance and functional health (Department of Health 2011). WHO has therefore launched a physical activity strategy for the European region (2016 – 2025) (World Health Organisation 2016) and The Royal College of General Practitioners (RCGP) has made physical activity a priority for the next three years (2016 – 2019) (Royal College of Physicians 2016).

As a result a number of Government, Department of Health and NHS policies and frameworks have recognised the need to raise levels of physical activity (NHS 2014, Department of Health 2004, Department of Health 2005, Cabinet Office / Department for Culture, Media and Sport 2002, Department of Health 2011, Department of Culture, Media and Sport 2008). Whilst having a mandate for sport the Department for Culture, Media and Sport (DCMS) has recognised that 'simply stepping out of the front door can provide opportunities for physical activity, most obviously through walking and cycling' (Department of Culture, Media and Sport 2008, p.27). This echoes the Chief Medical Officer (CMO); 'for most people, the easiest and most acceptable forms of physical activity are those that can be incorporated into everyday life' for which walking and cycling are highlighted as being 'the easiest and most acceptable forms' (Department of Health 2011, p.34). Whilst no evidence is cited for this assertion it remains that PA undertaken through choosing to participate in sport or active recreation has remained remarkably constant since 2005 including no apparent increase even after the 2012 London Olympics (Sport England, 2016). Plagued by the financial costs of physical inactivity across the population the NHS has adopted a leadership role through its healthy new towns programme which seeks 'to develop new and more effective ways of shaping new towns, neighbourhoods and strong communities that promote health and wellbeing, prevent illness and keep people independent' (NHS 2015, p.2). This includes working with other agencies 'to develop radical new approaches to shaping the built environment' and 'delivering radically improved infrastructure for safe active travel' (NHS 2015, p.3).

For active transport to be promoted at a national level however policy makers are likely to require at least two further pieces of evidence. Firstly that an increase in physical activity achieved through active transport is not accompanied by a subsequent decrease in physical activity in other life-domains resulting in a neutral or even negative effect upon levels of physical activity. Secondly, they are likely to require evidence of 'what works'; what are those interventions that will increase physical activity at a population level.

In 2005 the Department for Transport (DfT) established Cycling England (CE) to work with Local Authorities with the aim to get 'more people cycling, more safely, more often'. The cycling demonstration towns (CDT) programme was subsequently established to determine the effect of raising funding for cycle initiatives from the typical average in English local authorities of approximately £0.70 per capita per year to more European levels of approximately £10 (Cycling England 2009). The CDT programme was considered a 'major success' with cycle counts across all six towns increasing by 27% (Cycling England 2009). Further analysis indicated that the proportion of people classified as inactive had fallen by 2.6% (95% CI 3.7% to 1.5%) whilst those classified as moderately inactive had increased by 3.2% (95% CI 2.2% to 4.2%) and those classified as moderately active by 1.3% (95% CI 0.3% to 2.3%) (Cavill, Muller et al. 2009). However, lack of funding meant that no survey data was collected in control towns indicating that these conclusions may not be robust.

In 2008, the DfT and Department of Health (DH) jointly made a further £43 million available to be awarded through CE to one new city and 11 towns; the Cycling City and Towns (CCT) programme, the successor to the CDT programme. The aim of this programme was to promote cycling and to address a decline in cycling (AECOM January 2011). A common concern for public health is that changes in one area of physical activity may result in changes in another, that is to say there may be a substitution effect (Sloman, Cavill et al. 2009). Although the CCTs were co-funded by the DH it was therefore unknown what might be the potential effect of this or other utility cycling interventions on either likelihood of utility cycling or physical activity.

This thesis therefore set out to answer each of these questions explicitly:

- What interventions increase commuter cycling?
- What was the effect of the CCTs on population commuter cycling?
- Was there a change in PA in other life-domains associated with any change in PA through any increase in commuter cycling?
- If CCTs were effective in increasing PA what might be the contribution of this to meeting PA guidelines?

To answer these questions a literature review was undertaken to identify what interventions may increase commuter cycling. Empirical data was then used to assess both the effect size of the CCTs on both utility cycling and subsequently physical activity in other life-domains. A further analysis was undertaken to determine the effect of utility cycling on meeting recommended PA guidelines of 150 minutes a week.

This thesis is therefore organised as follows:

Chapter 2 examines, based on existing literature, the importance of physical activity for health, current estimated levels of physical (in)activity in the population, the economic costs of this for both health and healthcare and reasons for physical inactivity. It then outlines why the focus of this thesis is cycling rather than walking, cycling for transport rather than sport and adults rather than children. It also outlines the potential benefits of utility cycling to the individual beyond PA and to society beyond potentially increasing PA.

Chapter 3 is a systematic literature review (Stewart, Anokye et al. 2015b) which sought to identify what interventions have been successful in increasing commuter cycling either nationally or internationally. This was considered one means by which physical activity might be integrated into everyday life rather than becoming something that people need to make a conscious effort to plan and do. This chapter has already been cited in the academic literature as highlighting the need to understand how population levels of cycling might be increased to achieve health benefits (Panter, Ogilvie 2016).

Chapter 4 provides an evaluation framework for this thesis. It shows that the use of methodologies used to evaluate interventions aimed at individuals may be inappropriate for those aimed at populations but that CCTs not only meet Medical Research Council (MRC) criteria to be evaluated as a natural experiment but that the use of a routinely collected dataset allows this to happen both for the CCTs impact on utility cycling and, ultimately, on physical activity.

Chapter 5 is an empirical analysis that estimates quantitatively the effect of CCTs on a) probability of utility cycling and b) the probability of physical activity in other life-domains (e.g. sport and active recreation). This chapter shows whether or not CCTs produced a substitution effect in which any positive effect of the CCTS on increased PA through utility cycling were displaced by a negative effect on PA in other life-domains. Adjustment is made for covariates of PA.

Chapter 6 quantifies the contribution of utility cycling to meeting recommended levels of physical activity (Stewart, Anokye et al. 2015a). Again adjustment is made for covariates of PA. Results are shown nationally and for geographical areas noted for high commuter cycling prevalence.

Chapter 7 is the discussion chapter and pulls together the findings from the systematic review, theoretical framework and two empirical analyses presented earlier to provide a succinct discussion as to what implications this thesis as a whole has for physical activity, public health policy and practice. While doing so, the chapter comments on the strengths and weaknesses of the thesis and its study design, makes comparisons with relevant literature and makes recommendations for future research.

Chapter 8 is the concluding chapter drawing together the main themes of this thesis and outlines its conclusions.

Chapter 9 is a final reflective chapter describing key challenges encountered while undertaking this thesis with a view to learning as to how they might be addressed in similar future work.

CHAPTER 2: Impact of physical activity upon health, the need to increase its prevalence and possible way forward

Introduction

This chapter sets out the context within which this thesis is set, the health effects of a lack of PA and prevalence of PA in England, what current recommendations for PA are and reasons for any lack of PA. It then sets out Government approaches to increasing PA and the reasons for promoting PA through non-sporting cycling. UK transport policy towards transport cycling is outlined as well as potential benefits to the individual and society beyond those of PA. The reasons for focusing on cycling are outlined as is the focus on both non-sporting cycling and adults rather than sport and / or children. Implications of this thesis are outlined and recommendations made.

Context

The UK is a developed country. It has good medical care, low levels of infant mortality, high levels of vaccination and an ageing population. As such, it is at the forefront of the 'risk transition' whereby the major burden of disease has moved from infectious to non-communicable disease (NCD) (World Health Organisation 2009). Physical inactivity now accounts for some one million deaths (10% of the total) and 8.3 million disability-adjusted life years lost per year in the WHO European region (World Health Organisation 2016). An unintended consequence of the proliferation of labour saving devices including motor vehicles has been to reduce the minimum daily expenditure necessary for living (Hallal, Bauman et al. 2012) with severe consequences for health, even after accounting for social class.

In 1953, Morris et.al showed that bus conductors undertook more physical activity[1] through ascending and descending stairs on double decker buses, than their occupationally sedentary bus driving colleagues and had approximately half the rate of coronary heart disease (CHD) (Morris, Heady et al. 1953). This study was the first to outline the health benefits of PA and has been followed by numerous others that have confirmed strong evidence for a clear inverse relationship between PA and all-

[1] PA is described as any body movement produced by the skeletal muscles that results in a substantial increase over resting energy expenditure (Bouchard, Shephard 1994).

cause mortality, cardiorespiratory health, metabolic health including Type 2 diabetes, muscle mass and function, breast and colon cancer and poor mental health including depression and cognitive decline (Department of Health 2011). There is further limited, moderate or weak evidence for a positive effect of PA on weight loss, musculo-skeletal health including hip and vertebrae fracture and osteoporosis (Department of Health 2011). Precise effects are dependent upon the type, intensity and duration of activity as well as biological factors (e.g. age, gender, ethnicity) but risk reduction is approximately 30% for all-cause mortality, 20-35% for cardiovascular disease, 30-40% for metabolic syndrome and type 2 diabetes, 36-68% for hip fracture, 22-83% for osteoarthritis, 30% for prevention / delay in decline of physical functional health, 30% for risk reduction of falls, 30% for colon cancer, 20% for breast cancer and 20-30% risk reduction of depression and dementia (Department of Health 2011). Appendix 2 outlines the effect of PA on various health outcomes.

Worldwide, a lack of PA is the fourth leading global risk factor for mortality accounting for approximately 3.2 million deaths and 32.1 million DALYs[2] each year (World Health Organisation 2011). Physical inactivity[3] is estimated to cause 16.9% (95% CI 13.6 to 20.3) of premature mortality including 10.5% (95% CI 4.0 to 17.3) of CHD, 13% (95% CI 6.4 to 20.2) of type 2 diabetes, 17.9% (95% CI 8.5 to 27.8) of breast cancer and 18.7% (95% CI 10.5 to 27.1) of colon cancer (Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. 2012). This relationship is not linear but rather the greatest benefits accrue to those moving from least or no activity to some activity (Department of Health 2011).

As evidence has steadily accumulated that physical inactivity is increasingly a primary and independent risk factor for both morbidity and mortality so WHO has set a target of a 10% reduction in the prevalence of insufficient physical activity by 2025 (World Health Organisation 2013). This was reiterated in the WHO 2016 physical activity strategy for the European region (World Health Organisation 2016).

[2] Disability adjusted life years.

[3] Physical inactivity is described as doing no or very little PA at work, at home, for transport or during discretionary time and not meeting the PA guidelines deemed necessary to benefit public health (Bull, Armstrong et al. 2004).

Economic costs of physical inactivity

The economic costs of physical inactivity will vary depending on methodology, conditions included, whether or not complications of those conditions are included (for example amputations resultant from diabetes) and if direct and indirect costs are included. Based on coronary heart disease, Type 2 diabetes, breast and colon cancer and stroke the direct global healthcare costs of inactivity are estimated to be INT $53.8 billion[4] (equivalent to the GDP of Costa Rica) and indirect costs a further INT $13.7 billion per year. In the UK direct costs are estimated to be INT $1.8 billion (0.87% of healthcare costs) and indirect costs INT $558m (Ding, Lawson et al. 2016). This reflects the conclusions of two earlier papers based on ischaemic heart disease, ischaemic stroke, diabetes, colorectal cancer and breast cancer which estimated the direct costs of inactivity to the NHS to be £0.9 billion (Scarborough, Bhatnagar et al. 2011) and £1.06 billion a year (Department of Health 2011) respectively. Lost productivity through sickness is estimated to cost £5.5 billion a year and the premature death of people of working age a further £1 billion (Department of Health 2011).

Despite the above there does not seem to be consensus of the healthcare costs of physical inactivity. Whilst the UK costs above are reasonably similar the DH has also indicated that physical inactivity reduces all long-term conditions by some 20 – 40% whilst the NHS has stated that these account for approximately 70% of its budget (NHS 2014). As the NHS budget is £105.8 billion (NHS England 2016) this would imply that physical inactivity actually costs the NHS between £14.8 – 29.6 billion. Others have estimated physical inactivity accounts for 11.1% of healthcare expenditure in the US (Carlson, Fulton et al. 2015). As their healthcare systems differ so markedly direct comparisons between the US and UK are difficult but this would imply a cost of some £11.7 billion to the NHS. There would not therefore appear to be any clear consensus of the direct costs of physical inactivity to the NHS with potential estimates ranging from approximately £1 billion to £30 billion.

[4] An international dollar would buy in the cited country a comparable amount of goods and services a US dollar would buy in the United States. https://datahelpdesk.worldbank.org/knowledgebase/articles/114944-what-is-an-international-dollar. Site accessed 30th July 2016

Prevalence of physical (in)activity

The Health Survey for England (HSE) collects information from a representative sample of the English population including adults and children (Craig, Mindell 2014). It is an annual survey designed to measure both health and health related behaviours in adults and children in private households that has been undertaken since 1991[5] and is regarded as the 'main source of information for the Government about the nation's health'[6]. The most recent HSE to include PA collected data in 2012. This showed 34% of males and 44% of females aged 19 and over reported that they did not meet current PA guidelines of 150 minutes a week in bouts of 10 minutes or more. HSE 2008 similarly focused on PA but with the outcome variable of five sessions of 30 minutes PA per week in those aged 16 and over. A reanalysis of the 2008 data against current guidelines showed that 35% of males and 46% of females would not have met current guidelines in 2008 (Scholes, Mindell 2013a). Although PA guidance has changed prevalence does not seem to have changed in recent years (see appendix 3 for a comparison of 2008 and 2012 data). In both surveys the probability of meeting guidelines declined with age.

This change in recording highlights a problem noted as consistent throughout the UK's policy towards PA, namely that over time there have been multiple changes in recording (Milton, Bauman 2015). This may be understandable in that recording and monitoring practice has sought to reflect changing guidelines but equally it has meant that understanding time-trends in PA is difficult.

Physical activity guidelines

PA guidelines have been issued by at least 20 countries (IHRSA undated) including the World Health Organisation (WHO) (World Health Organisation 2010), the US Department of Health and Human Sciences (U.S. Department of Health and Human Services 2008) and the four Home Countries of England, Scotland, Wales and Northern Ireland (Department of Health 2011).

[5] https://www.noo.org.uk/data_sources/child/health_survey_england Site accessed 28th March 2016.
[6] http://www.natcen.ac.uk/taking-part/studies-in-field/health-survey-for-england/about-health-survey-for-england/ site accessed 18th July 2016.

The above guidelines echo and reinforce each other differing only in the definition of child (aged 5 – 17 following WHO and the US but 5 – 18 in the UK) but agreeing in the following:

- ‘children’ should do at least 60 minutes moderate – vigorous PA per day;
- adults should do at least 150 minutes (2½ hours) of moderate intensity or 75 minutes vigorous intensity activity in bouts of 10 minutes or more per week;
- older adults (65+) should do 150 minutes moderate intensity activity per week and more if possible (health allowing).

In the UK vigorous activity for 5 – 18 year olds should also include activities to strengthen muscle and bone on three days a week and adults and older adults (19 – 64 and 65+) are advised to undertake activities to strengthen muscles on 2 days a week. The major difference between WHO, US and UK guidance is that in the UK it is also recommended that sedentary time is minimised for those aged under 5 as well as those who are meeting recommended levels of PA. Sedentary is defined as not simply a lack of PA but a cluster of behaviours where sitting or lying is the dominant mode of posture and energy expenditure is very low. Light activity does not count towards the PA guidelines it is useful for reducing time spent being sedentary (Department of Health 2011).

Guidance recognises that differences between individuals may mean that the same activity may be perceived as light, moderate or vigorous (Department of Health 2011). Moderate intensity activity is therefore defined as the individual experiencing faster breath, increased heart rate, feeling warmer and potentially perspiration on hot or humid days. Vigorous intensity will entail rapid respiration, shortness of breath, rapid heartbeat and the inability to carry on a conversation comfortably (Department of Health 2011). Appendix 4 contains the Home Countries’ guidance for all age groups.

Reasons for lack of physical activity

The primary focus for HSE 2007 was to understand knowledge and attitudes towards a healthy lifestyle; smoking, alcohol consumption, eating and physical activity. Within this 66% of men and 69% of women indicated that they would like to do more physical activity but were constrained by the following:

- work commitments (45% males, 34% females);
- lack of leisure time (38% males, 37% females);
- lack of motivation (21% males, 25%females);
- care commitments (13% males, 25% females);

Other reasons included a lack of money (particularly the young and those in the lowest quintile of income groups), not being the 'sporty type', worries about injury, not enjoying PA, too shy / embarrassed / old / overweight and thinking that 'exercise was a waste of time (Craig, Shelton 2008). A lack of knowledge was also evident; only 6% of men and 9% of women correctly cited the (then) minimum recommendations of 5 bouts of 30 minutes a week, a quarter of described standards that were higher than recommended and approximately 70% described recommendations lower than recommended (British Heart Foundation 2013).

Some of the above figures may require further understanding; the British Audience Research Bureau (BARB) estimates that some 40 million people watch over 20 hours of television a week[7], a figure that may indicate that factors other than work commitments or lack of time are more influential on physical activity uptake. An evolutionary perspective offers an alternative view of that whilst that the human body needs a certain amount of stress in order to develop and function it is generally much more comfortable to be physically inactive e.g. sitting or lying is much more pleasant than physical labour so that comfort is 'mistaken' for well-being (Lieberman 2013). More environmental reasons are 'systemic and environmental factors, which have made daily living and working environments increasingly sedentary' (World Health Organisation 2016). This includes the increasing primacy given to the car to

[7] British Audience Research Bureau (BARB). http://www.barb.co.uk/viewing-data/monthly-viewing-summary/ Site accessed 6th September 2016.

the exclusion of other modes of transport (walking, cycling, motorcycles, buses) following the 1963 Buchannan Report ‘Traffic in Towns’ (Gunn 2011).

Approaches to increasing population levels of physical activity

In the UK, Government approaches to PA have been traditionally associated with sport and / or active recreation. Active transport has not been considered as a prime means of improving levels of PA. Reasons for this are unclear but a recent critical analysis of PA policy in England focused ‘mainly’ on the DH and Department for Culture, Media and Sport (DCMS) with only one mention of transport and even that only in the context of the Sport England ‘Active People Survey’ (Milton, Bauman 2015).

In England guidance and recommendations have been published by the CMO through the DH and strategy documents by the DCMS and Cabinet Office. The first national policy document to set quantifiable targets for PA was ‘Game Plan’, published by the DCMS (Milton, Bauman 2015) as was ‘Before, during and After: Making the Most of the London 2012 Games’ (commonly referred to as the Legacy Action Plan). This set out the Government’s intention to make Britain a ‘world leading sporting nation’ and to get two million more people active by 2012 (defined as three sessions of 30 minutes moderate activity a week). Increased PA was to be achieved through ‘focused investment in our sporting infrastructure and better support and information for people wanting to be active’ (Department of Culture, Media and Sport 2008). One of the legacy aspirations of the London 2012 Olympic Games was for a step change in sports participation by the public ‘promising nothing less than a healthier and more sporting nation’. However, even at the time it was argued that those who are inactive are unlikely to identify with elite athletes and that efforts to promote physical activity rather than sport might be more successful (Weed, Coren et al. 2012).

The publication of the consultation document ‘Moving more, living more. The physical activity Olympic and Paralympic legacy for the nation’ (Cabinet Office 2014) indicated a potential change in strategic direction in the achievement of physical activity. The 150 minutes a week target was retained but recognised that reducing inactivity will require ‘right physical environment for people, so embracing physical activity becomes a natural part of their daily life’ (p.4) and stated that never again will we allow physical activity occupy a silo in any one department' (p.5). The publication of 'Everybody active, every day' by Public Health England (PHE) seemed to cement this policy change citing Finland, The Netherlands and Germany as examples of where change has been achieved, that over-reliance on motorised transport is a factor in physical inactivity and that being active is 'about weaving incidental activity into our daily lives' (Public Health England 2014 p.7). Despite this, the subsequent 'Towards an active nation' (May 2016) (Sport England 2016) seems to indicate a retrenchment into the achievement of physical activity through sport; it is fronted by the Minister for Sport, Tourism and Heritage and cycling is not mentioned except to explicitly state that interventions to promote walking and cycling as forms of transport will not be eligible for funding. Whilst it is welcomed that two key performance indicators (KPIs) of the strategy are to increase the percentage of the population taking part in 'sport and PA[8] at least twice in the last month' and to 'decrease the percentage of people physically inactive' (Sport England 2016) it seems perverse to specifically exclude the two mechanisms most accessible to most of the population (walking and cycling). This really would seem to be skewing physical activity to those who can afford it (Lane 2016). The potential artefactual effects of changes in the survey instrument are unlikely known until January 2017 at the earliest when 12 months of data collection of both APS and Active Lives will be available (Helen Bibby, Sport England, personal communication, July 2016). The effects of changes to Sport England funding streams may take longer still to become apparent.

Whilst the new emphasis in 'Towards an active nation' of targeting the inactive (defined as less than 30 minutes moderate intensity activity per week) is welcomed arguably the approach outlined of encouraging people into sport may have fulfilled its potential for increasing PA, at least using current strategies. Whilst the London 2012 Olympics cost some £9.3 billion (AMION Consulting Limited 2015) and was described by Prime Minister David Cameron as having given the country a 'tremendous lift' and the 'best ever'[9] no increase in sports participation was observed after the London 2012 Olympics (Sport England undatedb). As noted by the House of Lords Select Committee on the Olympic and Paralympic Legacy 'the evidence

[8] This seems to imply that sport and PA are different concepts and that sport is not part of PA.

[9] David Cameron hails London 2012 as 'best ever' Olympics and Paralympics. The Daily Telegraph. 10th September 2012. http://www.telegraph.co.uk/news/politics/david-cameron/9533105/David-Cameron-hails-London-2012-as-best-ever-Olympics-and-Paralympics.html Site accessed 29th February 2016.

does not support a surge in participation in the immediate wake of the Games across the population as a whole' (House of Lords Select Committee on Olympic and Paralympic Legacy 2013). Rather, integrating PA into the fabric of everyday life may be more effective (Public Health England 2014), a perspective echoed in the Australian 'tips and ideas' for adults to become more active that emphasise walking and cycling for transport reasons (Australian Government Department of Health 2014).

Physical activity through non-sporting cycling

A number of bodies including the WHO, the British Medical Association (BMA) and the Faculty of Public Health (FPH), the CMOs of the four Home Countries and the Department of Health (DH) have advocated active transport as a means of increasing PA and increasing health (Department of Health 2011, Faculty of Public Health , British Medical Association 2010, World Health Organisation 2004). This is largely because for most people the 'easiest and most acceptable forms of PA are those that can be incorporated into everyday life' of which cycling instead of travelling by car, bus or train is one example (Department of Health 2011). It is notable that the prevalence of commuter cycling in the Netherlands is approximately 10 times that of England (Pucher, J. and Buehler, R. 2008) and that the population attributable fraction of mortality is approximately half that of the UK (Lee, Shiroma et al. 2012). The Faculty of Public Health therefore states that 'the underpinning principle of a public health approach to tackling the complex health issues relating to transport should be a modal shift away from cars and towards walking, cycling and public transport' (Faculty of Public Health undated). There is perhaps a further advantage in seeking to understand transport cycling, in that, whilst it is known that self-reported measures of PA may over-estimate actual activity (Craig, Mindell et al. 2009) substantial agreement has been found between questionnaire and objective measures of time spent commuter cycling in free-living individuals (Panter, Costa et al. 2014). CCTs, jointly funded by the DfT and DH, with the aim of getting 'more people cycling, more safely, more often' (AECOM January 2011) may therefore be seen as part of this movement to encourage active transport. Indeed, this is exactly what the Faculty of Public Health is calling for (Faculty of Public Health 2016). Equally, whilst researchers have called for urban planning and transport policies that prioritise environmentally friendly active mobility as two of the seven best investments for increasing PA there is a lack of evidence for how this might be 'scaled up' (Reis, Salvo et al. 2016).

UK transport policy

In the 1960's The Netherlands appeared to be pursuing similar 'car-centric' policies as the UK[10]. Indeed, cycle modal share was only approximately equal to, or even less than that of England (Ministerie van Verkeer en Waterstaat (Transport, Public Works and Water Management) 2009). However, from the 1960's onwards transport policies seem to have divided; in 1960 the House of Commons was told 'we must rebuild our whole environment of living and working in terms of the motor car' (Gunn 2013), in continental Europe there was at least some successful opposition to this movement (De Jong, Rouwette 2010, Aldred 2012). In the UK 'Traffic in Towns' (1963) (the Buchannan report) ushered in a 'car system' which denoted not only the mass ownership of motor vehicles but the reorganisation of social life and infrastructure to support vehicle usage (Gunn 2013). Cycling as a means of transport fell from 11% in 1952 to 1% of journeys in 1973 (Aldred 2012). Modal share of journeys has subsequently not changed substantively; in 2015 approximately 2% of journeys for any purpose were by bicycle (Department for Transport 2015c). Current and future investment is unlikely to raise this figure substantially; the Government has committed £300 million to support walking and cycling in this Parliament (Department for Transport 2016), some 0.03% of the Highways England budget for the same period (Highways England 2015). As a comparator it is estimated that the current (September 2016) redevelopment of London Bridge rail station will cost £500 million[11].

Potential benefits of cycling beyond physical activity

In addition to the above, cycling as a means of transport has a number of further advantages to the individual beyond those conferred by PA. Primarily, these relate to the reduction of transport costs and therefore an individual's financial resilience and mobility for those who do not own motorised transport. Savings are unlikely to

[10] How Amsterdam became the bicycle capital of the world. The Guardian. https://www.theguardian.com/cities/2015/may/05/amsterdam-bicycle-capital-world-transport-cycling-kindermoord. Site accessed 8th September 2016.

[11] London Bridge Station Redevelopment, England, United Kingdom. http://www.railway-technology.com/projects/london-bridge-station-redevelopment/ Site accessed 8th September 2016.

be either unrealistic or insubstantial; in 2012 in the UK the average person made 954 trips of an average length of 7.0 miles. Of these 20% of journeys were less than one mile and 66% less than 5 miles (Office for National Statistics 26th March 2014), the distance that the BMA states a person cycling ‘can easily cover’ (British Medical Association 2010).

It has yet to be developed but a concept of ‘transport poverty’ can be seen to be analogous to that of fuel poverty. There is a consensus that fuel poverty is defined as households needing to spend more than 10% of their income to keep living areas heated to 20°C and other household areas to 18°C (Boardman 2010). No such consensus exists for transport, partly because of the difficulty of defining the need for travel. However, expenditure on travel by income quintile in urban, small town and rural settlements indicates that those in the lowest quintile spend approximately 30% of their income on transport (Stokes, Lucas 2011). This would indicate that transport costs are an issue for a number of people and presumably more adversely affecting those on a lower income.

Cycling as (virtually) free mobility, the movement of people (or objects) from one place to another giving access to employment, education, shops, recreation, health and other service and the countryside can, in and of itself, improve health in its widest sense of well-being (Mindell, Watkins et al. 2011). Whilst the benefits listed here of mobility cover much of what is needed for living it should be noted that a bicycle will give many a geographical and temporal flexibility that a public transport system is unlikely ever to achieve.

Potential benefits of cycling to the wider society

Whilst the benefits of cycling accruing to the individual relate to PA, finance and access to services the benefits of cycling to wider society largely relate to the avoidance of harm caused by motorised transport to health and the environment. These have been well-documented by the Transport and Health Study Group and include, pollution (particulates, carbon monoxide, nitrogen oxides, hydrocarbons, ozone, carbon dioxide, lead, benzene), noise, vibration, odour, climate change, stress / anxiety, danger, loss of land and planning blight, and community severance and injuries[12] (Mindell, Watkins et al. 2011). There is also a non-linear relationship between numbers of cyclists and the risk of collision so that a 'safety in numbers' effect is observed (Elvik 2009). Congestion is further estimated to cost the country £10 billion per year (The Cabinet Office 2009). As these are costs avoided rather than directly related to physical inactivity they are not included in the CMOs' estimates above. In the UK, it is estimated that 40,000 deaths per year are attributable to outdoor air pollution that mainly emanates from factories and traffic (Royal College of Physicians 2016b). Climate change itself has been described as the biggest single threat to global health in the 21st century (Costello 2009). Ironically it is anticipated that a heating planet may mean that people will be less inclined to undertake physical activity (Stamatakis, Nnoaham et al. 2013) and therefore cycling. The shift in the use of human-energy to fossil-fuel energy for transportation over the past half-century has been argued to be not only a cause of rise in prevalence of obesity but equally part of a self-reinforcing cycle whereby obesity disinclines people to undertake active transport which itself drives obesity (Roberts, Edwards 2010). The cost to the UK as a whole of obesity has been estimated as £73 billion a year or 3% of GDP (Dobbs, Sawers et al. November 2014).

Whilst the impact of pollution and injuries are readily understood the impact of motorised transport on community severance is perhaps less so. The seminal study impact documenting this impact was set in San Francisco where Appleyard and Lintell showed that increasing traffic was associated with diminishing social contact (Appleyard, Lintell 1972). This study has since been repeated in the UK which again found that lower levels of social contact were reported by residents living on streets with higher volumes of motor traffic (Hart, Parkhurst 2011).

Why cycling and not walking?

Both walking and cycling will confer the individual and society level the benefits outlined above. There is some debate of which is likely to be the most beneficial to health. Whereas commuting by walking has been found to be of borderline intensity to be physiologically beneficial, cycling was found to be of sufficiently high intensity

[12] The Transport and Health Study Group uses the term injuries as opposed to accidents as accident is seen as implying the collision was unavoidable whereas injury highlights predictability and therefore that is might be avoided.

to be effective as well as being associated with being regular, frequent, brisk and year-round and therefore likely to meet the criteria for Health Enhancing Physical Activity (HEPA) (Oja, Vuori et al. 1998). Although exact energy expenditure is difficult to predict in different urban environments it may be that achieving a recommended weekly gross energy expenditure of 4 mega joules would require a journey of only 11 minutes each way by bicycle compared to 44 minutes walking. Even this may not be vigorous enough to be health-enhancing in young adults (Shephard 2008). The CMO defines walking as either ‘light’ or ‘moderate’ and cycling as either ‘moderate’ or ‘vigorous’. A systematic review of both walking and cycling accounting for other physical activity found that walking reduced all-cause mortality by 11% and cycling by 10% in groups that achieved 11.25 MET hours a week. That this would be more quickly achieved by cycling than walking as perhaps shown by cycling rather than walking that is associated with preventing weight gain or weight loss (Mytton, Panter et al. 2016).

Both modes of transport are likely to be advantageous to the individual and society with pedestrians in particular being associated with vitality in urban environments (Pucher, Dijkstra 2000). However, due to its range and load-bearing capacity it is cycling that has the potential account for more journeys.

Why commuter cycling?

Commuter cycling is associated with being a ‘regular, frequent, brisk and year-round’ activity (Oja, Vuori et al. 1998). Census data also indicates that there are 26.5 million people who work and are and resident in England and Wales and that 81.2% of these commute to a fixed onshore location within in the UK with an average commuting distance of 15 km (Office for National Statistics 26th March 2014). 64.2% of these journeys are under 10 km and 42.9% under 5 km e.g. considerably less than the 8 km noted by the BMA that a ‘person can easily cover’ (British Medical Association 2010). Mean cycling distance in Tampere, Finland has been shown to be 9.7 km (6 miles)(Oja, Vuori et al. 1998) and in Holland cycling accounts for some 34% of journeys up to 7.5km (4.6 miles) (Ministerie van Verkeer en Waterstaat (Transport, Public Works and Water Management) 2009). Survey data indicates that most people leave the house most days, at least in London (Fairnie, Wilby et al.

2016). There is therefore a tremendous potential for commuter cycling to contribute to contribute significantly to the population levels of PA.

There is therefore broad consensus therefore that

- PA is a 'good thing';
- population levels of PA are insufficient to confer maximal health;
- a modal shift towards cycling away from motorised transport will confer both individual and societal health benefits and
- this has been achieved elsewhere in developed nations, notably the Netherlands, Denmark and Germany where the difference may be due to alternate transport infrastructure design and implementation.

In 2008 the Department for Transport (DfT) and Department of Health (DH) jointly funded the Cycling City and Towns (CCT) programme with the aim of getting 'more people cycling, more safely, more often' (AECOM January 2011).

Why adults and not children?

In May 2015, the Secretary of State for Health (Jeremy Hunt) vowed to make the 'great scandal' of childhood obesity one of the main priorities of this Parliament. There was an 'absolute need' to do something about having 1 in 5 children in primary school being clinically obese[13]. More cynically the focus on children may reflect how difficult it has proven to control obesity in the adult population. The White Paper 'The Health of the Nation (1992) set targets that by 2005 fewer than 6% of males and 8% of females were to be obese (House of Commons Health Committee 2004), a target that was missed by some 400% (National Obesity Forum 2014). Focusing on a less powerful demographic may show 'something is being done' whilst not losing votes. However, as obesity prevalence is higher in adults than in children it is difficult to understand why children are the target group. Apart from the apparent hypocrisy therefore and that it is adults who develop long-term conditions there are at least two reasons why it would be useful to focus on adults rather than children.

[13] 'Great scandal' of childhood obesity to be top NHS target. The Telegraph, 21st May 2016. http://www.telegraph.co.uk/news/health/news/11619735/Great-scandal-of-childhood-obesity-to-be-top-NHS-target.html Site accessed 9th September 2016

Firstly, parents are noted as influencing health behaviours in children including obesity (Lindsay, Sussner et al. 2006), smoking (Vuolo, Staff 2013) and physical activity (Craig, Cameron et al. 2013). It would therefore seem that if a lifestyle behaviour can be provoked in adults there is a greater likelihood that it will become embedded across society for all. Secondly, focusing on children may imply that cycling is something that is done in childhood and promote the perception that a cycle is a toy rather than a serious means of transport and therefore to be left behind as part of a rite of passage for attaining adulthood (Aldred 2012). If the benefits of cycling are to be realised across society then this a perception to be avoided.

Conclusion

This chapter illustrates and reflects on why it might be useful to consider integrating PA into everyday life as a means of increasing population PA rather than focusing on activities that people may need to think about and plan in order to participate. This includes an overview of Government policy towards physical activity and how participation in sporting activity, without new directions, may have reached a peak. The economic costs of physical inactivity were shown with the rejoinder that healthcare costs may be many times higher than currently estimated. Although not quantified it is shown that the benefits of utility cycling potentially extend far beyond individual and population physical health through the avoidance of the external costs of motorised transport and further include the potential alleviation 'transport poverty', a concept for which there is no accepted definition but which is analogous to 'fuel poverty'. It is clarified that it is cycling rather than walking that is likely to be sufficiently vigorous to meet the threshold of health enhancing physical activity (HEPA) and that commuter cycling is both more likely to be both year-round as well as feasible for much of the UK population. Finally the focus on adults rather than children is clarified in that if it is desirable that a behaviour is to become embedded across a population then it should become a habit of the adult population rather than a behaviour expected of children (and therefore left behind as part of the rite of passage from child to adulthood).

Recommendations

- The potential of transport and therefore the DfT, to influence the health of the public should be considered and highlighted to policy makers. There should include areas that are not usually associated with the DfT such as PA;
- The potential for transport systems to increase both the probability of PA and the probability of meeting recommended levels of PA should be considered;
- If an accurate understanding of population level PA over time is to be achieved then some consistency of recording measures needs to be implemented. If recommended levels of PA change following scientific consensus thought should be given to how any new recording practice can be related to previous collections so that some understanding of time trends in PA could be achieved;
- The UK is a 'data-rich' country; it would be useful to show examples how routinely collected data-sets can be used to highlight and analyse a public health issue;
- The potential for sectors outside health to increase healthy behaviours should be illustrated.

Thesis implications

This thesis will have a number of important public health implications. Firstly, the above implies that increasing the modal share of cycling as a means of transport from its current 2% of trips (Department for Transport 2015c) would have important health implications for both the individual through physical activity and wider society largely, but not exclusively, through the avoidance of the external costs of motorised transport. It will therefore be useful for policy makers to understand what effects the CCT programme had. Secondly, the UK is a 'data-rich' country and this thesis will help to illustrate how a routinely collected dataset might be used to understand the effect of a large-scale intervention upon life-style and consequently health. Thirdly it will make explicit that the health of the public is very often affected by factors outside of the 'health sector' and that improvement in health, as opposed to healthcare, may be most effectively addressed by tackling the 'wider determinants of health'. This has already been recognised; Simon Stevens (Chief Executive of the NHS) has called for the NHS to be more proactive in preventing mortality and morbidity including in working more closely with Local Authorities (NHS 2014). Fourthly, it will demonstrate how, if different sectors of the economy work together so PA might be built into everyday life so making ‘the healthy choice the easy choice’ (World Health Organisation 1986).

This thesis has already begun to influence the understanding and practice of public health through the publication of chapter three as a systematic review in August 2015 (Stewart, Anokye et al. 2015b), the publication of chapter six in December 2015 (Stewart, Anokye et al. 2015a), an abstract in The Lancet (Stewart, Anokye et al. In press) and a poster presentation at the Public Health England national conference in September 2014. It has also influenced my work as the Assistant Director of Public Health in a Local Authority where I am the public health lead for the implementation of a £30 million cycling programme.

CHAPTER 3: What interventions increase commuter cycling? A systematic literature review[14]

Chapter 2 showed that population levels of PA in England are below those requisite for maximal health and that physical inactivity not only has severe implications for individual health but also for the NHS. The chapter went further and suggested that reasons for a lack of PA may include the replacement of human physical activity previously undertaken as part of the tasks of everyday life with electrical or mechanical power. Commuting was highlighted as an activity that approximately half the population potentially undertakes most days and that if motorised journeys were replaced with physically active journeys there would be health benefits to society as a whole as well to the individual. It was recognised that walking as well as cycling would avoid the external costs of motorised transport but shown that cycling, rather than walking, is more likely to be of sufficient effort to meet the threshold of being a 'health-enhancing physical activity' (HEPA). Finally it was argued that if an activity is to become embedded across society it cannot be framed as an activity of children to be left behind as a rite of passage into adulthood. The challenge therefore is to find interventions that will increase this type of cycling.

A number of reviews have sought to examine the evidence of how the prevalence of PA can be increased through cycling (Pucher, Dill et al. 2010, Yang, Sahlqvist et al. 2010, Fraser, Lock 2011, Ogilvie, Egan et al. 2004). However, where these reviews seek to identify how to increase the prevalence of cycling in general this may include cycling for transport, leisure, recreation, health or sport. It may be that commuter cycling — defined following the European Network for Cycling Expertise as journeying for the sake of completing a journey as opposed to a journey that is an end in itself (Aldred 2015) — is more likely to be continued and to have sustainable health gains. From these reviews however, the evidence of this, both nationally and internationally is sparse.

[14] A summarised version of this chapter has been published as a journal article: STEWART, G., ANOKYE, N.K. and POKHREL, S. (2015). What interventions increase commuter cycling? A systematic review. BMJ Open 2015 doi:10.1136/bmjopen-2015- 007945.

This chapter seeks to identify interventions that would increase commuter cycling, as this is considered to be more likely to be 'weaved into our daily lives' (Public Health England 2014) and therefore have sustainable health gains as well the additional health benefits of avoiding the external costs of motorised transport (Mindell, Watkins et al. 2011). There is also a reasonably good correlation of 0.77 between cycling as a commuting transport and cycling for all purposes (Goodman 2013) with implications therefore far beyond the working population.

Methods

Search strategy

Between October and November 2014, eight databases were searched including Scopus, ERIC, CINAHL, the Cochrane library, Digital Dissertations, Sports Discus, PsychInfo and Web of Science. Scopus is the largest ever bibliographic database and indexes over 20 000 titles from science, technology, medicine and the social sciences, is updated daily and contains both Medline and EMBASE databases (Brunel University 2014).

In each database a core set of words were used; cycl* OR bik* OR cycle AND hire OR active and commut* OR active AND travel* OR green AND commut* OR green AND transport* OR green AND travel* OR ecological AND commut* OR ecological AND transport* OR non-motor* OR non-auto. These drew on earlier reviews to increase either cycling (Yang, Sahlqvist et al. 2010) or walking and cycling (Ogilvie, Egan et al. 2004).

As a large number of hits were often returned database-specific filters were applied to all databases except Scopus. Table 1 gives an overview of the searches performed, hits and remaining hits following the application of filters:

Table 1: Database search

Database	Initial hits	Hits following application of database specific filters	Final number of hits
Scopus	845	Filter not used	845
ERIC	11,847	Limit to: academic journals - 4879 Limit to: higher education, postsecondary education, case studies, intervention, program effectiveness - 1789	1789
CINAL plus	43,324	Limit to: academic journals – 37,745 Limit to: cycling - 2414 Limit to: adult - 1359	1359
Cochrane library	39,218	Limit to: reviews – 377	377
Digital Dissertations	>1,000,000	Limit to: scholarly journals – 326,607 Limit to American Journal of Public Health, Social Research, Health Affairs -2938	2938
PsycINFO	56,448	Limit to: academic journals – 47, 213 Limit to: population (human) – 11,366 Limit to: subject (health, PA) - 196	196
Sports Discus	95, 808	Limit to: academic journals – 47, 213 Subject thesaurus term – cycling, exercise, physical fitness, cyclists, prevention – 1494 Subject: males, comparative studies, young adults, evaluation, adulthood, women, teenagers,	615

		research, middle age, case studies – 615	
Web of science	>1,000,000	Limit to: engineering, behavioural sciences, public environmental occupational health, sports sciences, healthcare sciences services, sociology - 371 085 Research domains: restrict to behavioural sciences, public environmental occupational health, sports sciences, healthcare sciences services, sociology, life sciences, biomedicine other topics, social issues, social sciences other types - 194 675 Research areas—restrict to behavioural sciences, public environmental occupational health, engineering, social sciences other topics, urban studies, transportation - 144 459 Limit to: articles - 125, 612 Limit to: English - 114 955 Limit to: transportation, urban studies—827	827
Total databases searched = 8	Total initial hits =>2,000,000	Total after applying filters = 9,825	Total imported to RefWorks = 9825

9,825 titles were imported into Refworks reference software manager. 492 duplicates were removed to leave 9,333 titles to screen.

Although commuting is largely non-discretionary the mode of commuting itself may be affected by a large number of influences including incentives / disincentives for other forms of transport (for example business mileage allowances). Influences upon cycle commuting have been divided into five categories (Heinen, Van Bee et al. 2010)

- The built environment; distance between destinations, network layout, mixture of functions, bicycle infrastructure, incentives / disincentives for motorised transport, general traffic infrastructure including traffic lights / stop signs etc., surface quality), work facilities (parking, changing and storage facilities, showers),
- The natural environment; landscape, hilliness, weather, climate,
- Socio-economic characteristics (gender, age, income, bicycle and car ownership, employment status, having children, being physically active, educational status
- Psychological factors; attitudes, social norms and habits
- Cost, travel time, effort and safety

To these might be added perceptions of cycling as a normal means of transport (Steinbach, Green et al. 2011) as might other factors that could potentially impact upon commuter cycling prevalence indirectly such as congestion charging, petrol taxation, parking policies and perceptions of the cost of private / public transport (Pucher, Dill et al. 2010). This quantity of variables indicates that commuter cycling may be argued to be an example of the 'inverse evidence law' in that we have the least evidence about those interventions which are most likely to have most effect on population health (Ogilvie, Egan et al. 2005). In relation to the hierarchy of evidence therefore and the 'gold standard' of the randomised controlled trial (RCT) population level interventions in particular may be unlikely to be allocated randomly and it may be impractical or impossible to 'blind' the population to the intervention.

For this review therefore the standards of evidence generally applied to clinical interventions were frequently found to be inappropriate so that the application of strict inclusion criteria by Ogilvie et.al (Ogilvie, Egan et al. 2005) or Yang et.al (Yang, Sahlqvist et al. 2010) was rejected in favour of the more pragmatic approach adopted by Pucher (Pucher, Dill et al. 2010). This was intended to avoid narrowing the search unnecessarily to a small number of high quality studies or reviews that would be similarly limited. Alternatively, it was not intended that the review would include Government or municipal publications or studies without any controls / comparative data. As cycling is more likely to reach the threshold of HEPA this review also specifically excluded data relating to 'active travel / transport' where walking and cycling data was combined. To be included studies therefore studies needed to:

- report specifically on commuter cycling as a dependent variable (rather than walking and cycling combined)
- include comparison groups and/or pre-intervention and post-intervention data
- include adults rather than schoolchildren
- include data relating to commuting to work
- be written in English

Table 2 shows the inclusion and exclusion criteria of the search:

Table 2: Eligibility criteria for literature search

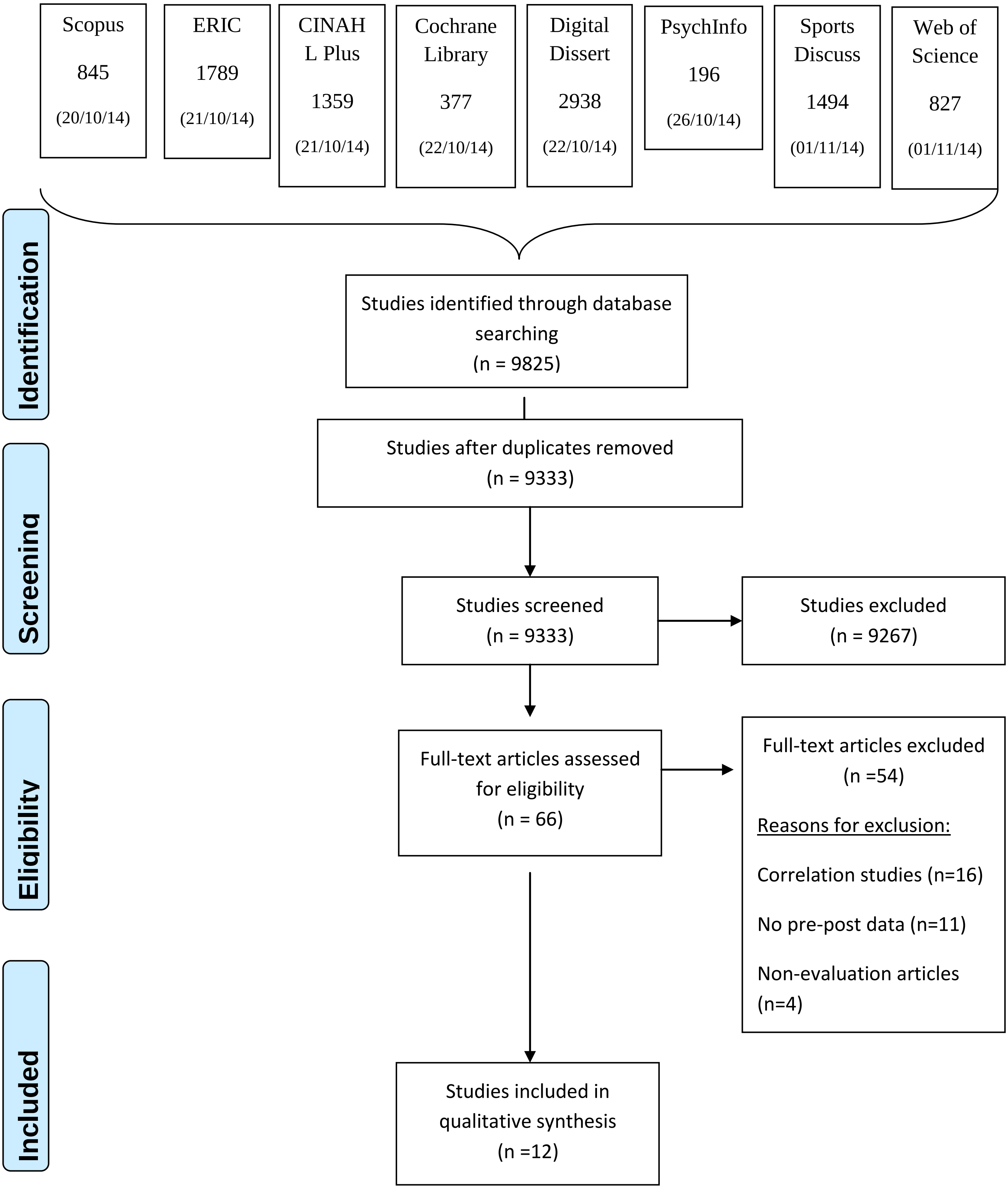
Inclusion criteria	Exclusion criteria
• **Evaluation studies with comparison groups and/or preintervention and postintervention data** • **Adults rather than schoolchildren** • **Data relating to commuting to work** • **Written in English**	• Correlation studies (identifying determinants of commuter cycling) • No comparison groups or pre–post data available • Indiscriminate data (e.g. only aggregated data of walking and cycling) • Irrelevant data (has data only on other forms of commuting, e.g. walking only or cycling for recreation) • Non-evaluation (editorials, commentaries, opinion pieces) • Others including:

	– Temporal/trend analysis of cycling behaviour – Reviews of correlation studies – School children – Written in a language other than English

The titles, abstracts and key words of 9,333 papers were screened according to the criteria set out in table 2. 9,267 titles were excluded leaving 66 studies to be retrieved for full-text screening. At level 2 screening all full texts were screened independently by myself and a senior research fellow through the application of the eligibility criteria using a data extraction table adapted from NICE (National Institute for Health and Clinical Excellence (NICE) 2014) and the Centre for Research and Dissemination (Centre for Research and Dissemination January 2009) (appendix 5). Where consensus could not be reached (2/66 texts) disagreement was resolved by asking the opinion of a senior lecturer. 54 studies were considered not eligible and therefore excluded from the review. The aim of this chapter was to establish what interventions might increase commuter cycling. 16 correlation or modelling studies were therefore excluded as whereas they may potentially indicate areas for future research and / or independent variables that might be usefully investigated in order to increase commuter cycling they do not include an interventions. 11 studies were excluded as data was only given for walking and cycling together, for variables other than commuter cycling such as walking or perceptions, 14 as they were not evaluation studies and 9 for other reasons such as non-English or abstract only in English, the population was not adults, or the full-text was not available. Appendix 6 contains a list of the rejected papers together with the reasons for exclusion.

12 studies were therefore identified as eligible for full review. A PRISMA diagram of the study identification and inclusion process is included in Fig 1:

Fig 1: PRISMA flow diagram*



*informed by Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS

Data analysis

Data was analysed qualitatively taking into account four key attributes pertaining to the robustness and generalisability of the evidence and included; the population size in which the reported effect was observed, the size of the effect observed, the robustness of the comparator and robustness of study design. Interventions were a mixture of individual and environmental interventions assessed through a mixture of methodological designs. Due to the heterogeneity of both as well as outcomes measured it was decided that a meta-analysis would be both inappropriate and impractical.

Results

Study characteristics

Six of the included studies were from the UK, two from Australia and one each from Sweden, Ireland, New Zealand and the USA. Two studies were RCTs, all the others were pre-intervention / post-intervention studies. Six of the included studies were of individual or group-based interventions and six were of environmental change. Table 3 provides an overview of included studies and the effects of interventions.

Table 3: Characteristics of, and results from, included studies

Study	Country / setting	Intervention	Study design	Time period	Sample size	Effect
Brockman and Fox (2011)	England (University of Bristol)	Workplace travel plan(s)	Repeated cross sectional travel surveys	Surveys from 1998 to 2007	1950 to 2829	Non statistically significant increase in cycling to work from 7 to 12%.
Hemming-sson et.al (2009)	Sweden / communit y	Moderate intensity PA support programme including provision of	RCT	18 months	120	Proportion of participants cycling > 2 km / day was 38.7%

		cycles				(OR 7.8)
Mutrie et.al (2002)	Scotland / Hospital Trust, Health Board and University	Self-help travel pack including maps, activity diary, safety accessories	RCT	6 months	295 people identified as thinking about active commuti ng	No effect found
Telfer et.al (2006)	Australia (Sydney)	Cycle proficiency training	Before and after study	2 months	113	No difference in mean frequency or duration of cycle trips
O'Fallon (2010)	New Zealand / number of workplace s	Number of workplace interventions	Before and after study	12 months	3825	675 respondent s to cycle question – 112 cycled less (16.6%), 347 (51.4%) about the same, 216 (32.0%)mor e
Johnson and Margolis (2013)	London / communit y setting	Cycle training	Before and after study	12 months	130	No of days cycled to work in last week increased from 0.66 to 1.33

						(P=0.002)
Caufield (2013)	Ireland / Dublin	Whole city approach	Before and after study	5 years	Dublin population 1.2 million	Percentage of cyclists increased from 4 to 5% (20,588 to 26,670)
Rose et.al (2007)	Australia (Victoria)	Ride to work day	Before and after study	5 months	5577	27% of first time riders still cycling to work after 5 months
McCartney et.al (2012)	Scotland (Glasgow)	Building a bridge	Before and after study	2007 to 2010	216, 897 people living south of city centre	47.5% increase in the number of cyclists (n= approx. 400)
Goodman et.al (2013)	England – Cycling Cities and Towns initiative (12 locations)	Whole city approaches	Difference in differences study	2008 to 2012	1,266,337	Difference of differences increased compared to matched towns of 0.69 (95% CI 0.60 to 0.77)
Krizek et.al (2009)	US – Minneapolis / Minnesota	Changes in cycle infrastructure	Before and after study	1990 to 2000	4855	0.493 percentage increase

Control variables

As noted above commuter cycling is subject to multiple influences (Heinen, Van Bee et al. 2010). The following therefore lists each study, controls used and how they were specified (if provided). RCT methodology precludes the need for controls and therefore these studies are not listed (table 4):

Table 4: Studies included, covariates cited and how specified:

Study	Covariates cited	How specified
Individual level interventions		
Brockman, Fox (2011)	Gender Age Salary	Male / female In years In sterling (£)
Telfer, Rissel et al. (2006)	None	N/a
Rose, Marfurt (2007)	Gender Age Length of journey If first-time participant for Bike to Work (BTW) day	Male / female Specified in years By bicycle in minutes Prior participation or not
O'Fallon (2009)	None	N/a
Johnson, Margolis (2013)	None	N/a
Environmental interventions		

Caulfield (2014)	Gender Age Car-ownership Commuter journey start time Travel time Socio-economic group	Male / female In years Number of cars Time of departure ……………………… In minutes Occupation
Goodman, Sahlqvist et al. (2013)	Gender Age Ethnicity Any child aged under 16 Education ertrdtrertrtertwer Annual household income Employment status Any car in household Any adult cycle in household Weight status General health Long-term illness that limits daily activities Time walking / cycling in	Male / female In years White, non-white Yes / no d gsfse dfsdfs sfsfse sdfef fw Tertiary or equivalent, secondary school, None or other In sterling (£) sdfssdfsdfsdfgdrgdrgfdrfgsdfw Working, student, retired, other Yes / no Yes / no ssdfsdfsdfgdrgdrgfdrfgsdfw eswe sdfssdfsdfsdfgdrgdrgfdrfgsdfw Normal/underweight, overweight, obese Excellent/good, fair/poor Yes / no sdffdsfdfsfsdfsdfsdfsdfss dfsdfsdfgdrgdrgfdrfgsdfw None, 1-149, 150-29, 300-449, 450+

	past week	
Krizek, Barnes et al. (2009)	Gender Age Income	Male / female Only 18 – 44 cited Only <$15,000 or >$50,000 cited
(McCartney, Whyte et al. 2012)	Gender Age Deprivation	Male / female In years Most deprived quintile, least deprived quintile
Goodman, Panter et al. (2013)	None	N/a

Individual or group interventions

Randomised control trials

Two of the included studies were RCTs. The first was situated in Glasgow, Scotland which had the aim of determining whether interactive self-help materials based on the transtheoretical model of change could increase active commuting behaviour (walking and cycling). Self-help materials were randomly assigned to 295 employees already assessed to be either thinking about active commuting (contemplators) or already irregular active commuters (preparers) in three workplaces; an acute hospital trust, a university and a health board (Mutrie, Carney et al. 2002). At 6 months 49% (n = 50) of the intervention group had moved to a higher stage of active commuting behaviour compared to 31% (n = 29) of the control group. However, any change was accounted for by change in walking behaviour as at six months there was no difference in the average weekly minutes cycling between the intervention (n = 9) and control groups (n = 9). Unfortunately, it is not indicated in which month the intervention took place so any seasonal effect (which may be substantial in Scotland) cannot be assessed.

The second RCT was also underpinned by the transtheoretical model of change and similarly aimed to increase PA through active commuting (Hemmingsson, Ekelund et al. 2011). 120 abdominally obese women with a waist circumference of ≥ 88cm in Stockholm, Sweden were recruited through an advertisement in a free newspaper. Randomisation was stratified by age and waist circumference. Standard care delivered to all trial participants was a pedometer-driven walking intervention with two 2-hour counselling sessions at baseline and at six months. Participants were encouraged to gradually increase their step-count to 5000 steps a day above baseline. The importance of building routines for integrating PA into everyday life, primarily by changing the mode of travel to work was emphasised. The intervention group received standard care plus individual 30 min sessions with a physician experienced in behaviour change at baseline, six and 12 months including PA prescriptions as well as two additional 2-hour group counselling sessions and a free new cycle (value approx. £600) with a free bicycle service. Cycling treatment success was defined as cycling ≥2 km/day. This was achieved in 38.7% of the intervention group and 8.9% of the control group (OR = 7.8, 95% CI 4.0 to 15.0, $p<0.001$). Similarly, using a cut-off of 4km / day this was seen in 24.8% of the intervention group and 4.6% of the control group ($p<0.001$) whilst the mean proportion of participants using a cycle at least once a week during months 2 – 18 was 29.4% in the intervention group compared to 8.0% in the control group ($p<0.001$). 29.4% of the intervention group used their bicycle once a week between months 2 – 18 for commuting compared to 8.0% in the control group ($p<0.001$).

Pre-post intervention studies

Two pre-post studies sought to understand the effect of 'bike to work' (BTW) travel initiatives either through a one day event or a sustained programme. In Melbourne, Australia the effects of a Ride to Work day (RTWD) event were evaluated (Rose, Marfurt 2007). The RTWD is an annual mass participation event promoted through radio, television and print media and attracts over 2,500 participants each October when the weather begins to become warmest. The highlight is a free breakfast for all participants. From an initial recruitment of 5577 registrants baseline data was received from 1952 people of whom 17% had not cycled to work before. At 5 months, 27% of first-timers were still cycling to work at least once a week e.g. an increase in commuter cyclists of approximately 90. In New Zealand 40 organisations were recruited to the ‘Bike Now’ programme which included bike mentoring / buddying, establishing ‘bike-buses’, cycle-skills training, secure cycle parking and providing ‘cycle fleets’ at workplaces (O'Fallon 2009). Baseline data was received from 3825 respondents. At 18 months follow-up data was available from 675 participants of whom 32.0% (216) indicated that they were cycling more at one year, 51.4% (347) ‘about the same’ and 16.6% (112) less.

Two studies examined the effect of cycle training on cycling to work behaviour. In Sydney no difference was found in either duration or frequency of cycling at two months following a cycle proficiency programme (n = 110) though statistically significant increases were found in those who did not cycle before the course (Telfer, Rissel et al. 2006). In London the mean number of days cycled to work in the past week increased from 0.66 to 1.33 follow-up at 3 months (n = 140) (Johnson, Margolis 2013).

None of these studies included a control group making robust conclusions difficult. For example the effect of a bike to work event held in spring is difficult to distinguish from the effect of the season itself when people may be more willing to cycle to work. Similarly, without a control group it is difficult to account for such as weather, national trends, the effect of sporting events such as the Tour de France, the 2012 Olympics, changes pertaining to other modes of transport that might make cycling more or less attractive or other unidentified phenomena.

Environmental interventions

Environmental interventions were all pre-post studies of which two included control groups. Their ‘span’ ranged from the construction of a single bridge (McCartney, Whyte et al. 2012) or infrastructure (Goodman, Sahlqvist et al. 2013), the evaluation of several policies taken together in a university (Brockman, Fox 2011) or a city (Krizek, Barnes et al. 2009) to the evaluation of a programme targeted at 12 cities and towns with some 2.7 million residents over 3 years (Goodman, Panter et al. 2013). All studies were from countries with a low cycling modal share and the majority used census data for either direct measurement of commuter cycling or for comparative purposes posing difficulties in detecting real effects in relatively small samples of persons measured at a population level.

In Glasgow the opening of the Tradeston bridge for pedestrians and cyclists only across the river Clyde was associated with a 47.5% increase in the number of cyclists entering the city centre from the South with almost no change in the number of cyclists crossing other bridges (McCartney, Whyte et al. 2012). At the same time whilst the bridge carried some 4,500 pedestrians per day it was associated with a fall of some 2,200 pedesrians per day on the nearest bridge. There is a problem of measurement in this study; potentially impressive actual numbers can only be ‘guesstimated’ from graphs provided and seem to imply an increase of perhaps 200 from a population in south Glasgow of 217,000. The authors also speculate that some change may have resulted from roadworks to the nearby M74.

In the UK the Connect2 study used panel data to isolate the effect of traffic-free infrastructure projects (a main project plus feeder routes) in Cardiff, Kenilworth and Southampton on residents living within 5 km of the respective projects at one and two year follow-up (Goodman, Sahlqvist et al. 2013). 22,500 survey packs were distributed to which 3516 (15.6%) people provided baseline data and 53% and 43% of these provided data at 1 and 2 year follow-up. Proximity to Connect2 was associated with both increased distance and kilometres cycled for transport within an increased percentage of the population cycling to work; 5% of the infrastructure project users reported using cycling to work at both 1 and 2 year follow up compared to 1% and 2% of people not using the infrastructure. Whilst there is a potential in this study that the low response rates indicate selection bias participants were generally older than the general population but otherwise similar in their demographic, socio-economic and travel characteristics. It is further noted that the outcome measures of use of infrastructure do not include frequency of use making it difficult to extrapolate the effect of the intervention to impact on levels of physical activity.

The effect of a university travel plan on staff travel behaviour cycling was assessed in Bristol (Brockman, Fox 2011). The plan included both ‘carrot and stick’ measures such as limiting car-parking, increasing car-parking charges, improved changing facilities, cycle storage, a subsidised cycle purchase scheme and further measures to encourage walking. Cycle commuting modal share rose from 7% in 1998 to 11.8% in 2007 but was not found to be statistically significant. Again, without a control it is difficult to assess the effect of these measures, even taken as a whole.

Hence, Bristol was a CCT and indeed was named as England's first cycling city in 2008 with the ambition of doubling its cycling share over the next three years[15]. Separating the effect of interventions across Bristol in general and the university in particular would require more research.

In Ireland, the Department of Transport set a target of increasing cycling as a mode share from 2% of journeys in 2009 to 10% by 2020. Changes were hypothesised to result from a mixture of financial incentives, infrastructure change, promotional events such as Bike week (family rides, removing traffic from streets and promotional talks), a shared bike scheme and the publication of the first design standards for cycling in Ireland (Caulfield, Brick et al. 2012). At a city level census data (every 5 years in Ireland) was slightly positive; in Dublin cycle mode rose from 4% in 2006 to 5% in 2011 whereas in Cork and Galway (the second and third largest cities) modal share was 1% and 2% respectively in both censuses. However, cordon count data indicated increases in cyclists of up to 10% in the city centre compared to the suburbs where mode share remained static or may even fallen. As initiatives were concentrated in the centre this city-wide 1% increase is therefore taken as evidence of effect although it is not indicated whether this effect was statistically significant. Whilst welcomed it is unclear how adequate the controls used in this study were - Dublin is some 9 – 10x larger than either Cork or Galway.

Census Transportation Planning Package data showed slight positive effect in the Minneapolis and St. Paul metropolitan area in Minnesota (USA), known as the 'twin cities'. Improved and increased cycling facilities / infrastructure in the centre of urban districts was associated with increased cycle commuting whilst modal share remained static or fell in the suburbs (Krizek, Barnes et al. 2009). However, whilst increases could be measured in numbers of standard deviations (z-scores) in absolute terms changes were similar to those observed in the CCTs and Dublin e.g. less than 1% increase. The authors are also very aware of the 'seemingly countless array of factors' that might influence cycling prevalence highlighting once again the need for controls.

The English Cycling Cities and Towns (CCT) programme was a £43m programme (plus local matched funding) in 12 cities and towns in England with the intention 'to

[15] http://news.bbc.co.uk/1/hi/england/bristol/7462791.stm Site accessed 18th September 2016

explore whether and how increased investment in cycling as part of a whole-town strategy could lead to a significant and sustained increase in the number of cyclists and frequency of cycling' (Redfern, Tarry et al. January 2011). This was evaluated through a 'difference-in-difference' (DID) analysis comparing cycle commuting as measured through the 2001 and 2011 censuses in which respondents are asked 'How do you usually travel to work?' with 11 options including 'bicycle'. A priori controls were local authorities measured as 'most similar' by National Statistics 2001 Area Classification for Local Authorities (Goodman, Sahlqvist et al. 2013). It is noted that often the greatest public health gains will be made by creating at least small changes but across large populations (Biddle, Batterham 2015) so the overall positive effect of 0.69% is welcomed and, if real, over such a population, would have important public health implications. However, the use of 2001 census data as a baseline for an intervention that was not funded until 2008 is problematic. Neither is it inconceivable that further effects of an intervention for which funding ceased in 2011 would be apparent beyond that time period.

Discussion

Commuter cycling is of interest to public health as it is an activity that is likely to integrate PA into everyday life. This is evident even from affluent countries with high levels of car ownership such as the Netherlands, Germany and Denmark where up to 30% of journeys are by bicycle (Pucher, J. and Buehler, R. 2008). It does not seem to be unrelated that the population attributable fraction (PAF) of physical inactivity for all-cause mortality in each country compared to the UK is 29%, 44% and 56% respectively (Lee, Shiroma et al. 2012). Further research is required to establish whether this relationship between reduced PAFs and higher prevalences of commuter cycling is likely to be correlational or causal.

Whilst large segments of the population do not meet PA recommendations the potential for commuter cycling to meet at least some of this need is large; most car journeys are under 5 km, most people can cycle and even if there is an initial financial outlay this would soon be balanced and outweighed by savings from avoided motor or public transport costs. The perception that levels of cycling have always been higher on the Continent than in the UK is also quite false; in fact the opposite is true; in the 1950s cycling levels were higher in the UK than in Germany

(Pucher, J. and Buehler, R. 2008). City-level data indicates that cycle mode share has waxed and waned in both UK and European cites (Ministerie van Verkeer en Waterstaat (Transport, Public Works and Water Management) 2009).

It is therefore of concern that there is such a sparsity of robust research evidence of what may increase commuter cycling both nationally and internationally. This finding is apparent even without specifying 'strict' inclusion criteria. For an issue that has profound implications for individual and population health, financial resilience, healthcare systems and climate change there is remarkably little evidence of what is effective. This may be due to the methodological difficulties of robustly controlling for an effect in a variable that may be affected by so many influences (Heinen, Van Bee et al. 2010). However, perhaps the most startling finding from this review is just how well the inverse evidence law (Ogilvie, Egan et al. 2005) seems to operate in relation to commuter cycling. It is further noted that this literature review did not find evidence that interventions to increase commuter cycling were associated with increased PA. The differences in PAF between the UK and high prevalence cycling countries for physical inactivity may be indicative but no studies were found that explored whether interventions that were successful in increasing cycling also reduced PA in other life domains. From the perspective of public health this is a fundamental point.

Evidence from this review is that projects / interventions aimed at individuals do not seem to have been effective except where there has been substantial input into the intervention group and in a particular population that may be particularly motivated thereby raising doubts about both the scalability of the intervention and its external validity. Whatever the methodological design however interventions that need to recruit subjects will always be subject to selection bias in that it will be those who are most willing who give consent. Equally, these may not be those who are in most need of the intervention. Environmental interventions are plagued with difficulties in measurement but seem to have small but generally significant effects. If real, small effects at a population level can be important from a public health perspective; the increase of 0.69% across the populations of the CCTs would represent an increase of some 18,600 commuter cyclists. Yet it is the ascertainment of the validity of the question 'if real' that is difficult to assess. It is of concern therefore that in April 2013 the DfT felt compelled to withdraw all the evaluation documents relating to this programme[16].

The multitude of potential influences upon cycling is outlined above meaning that robust measurement is difficult without timely accurate and reliable tools to measure such change. Though obviously useful census data, particularly in the UK where it is collected every 10 years is not ideal for measuring the effect of an intervention that began 7 years after baseline data was collected. Measurement on a specific day may also be subject to factors pertaining to the day / week of measurement and influences which may be time-limited such as the Olympics or 'the Lance Armstrong effect' in the US (Krizek, Barnes et al. 2009) (before the drugs revelations). A large number of outcome measures was noted within this search; cycling to work or not, frequency of cycling to work, percentage of population cycling to work, use of transport infrastructure, frequency or duration of journeys as well as evaluation periods (2 months to 10 years). A meta-analysis of the effect of interventions to increase commuter cycling was therefore considered impractical. Equally difficult for comparative purposes was the range of targeted populations which included unspecified working populations, people working in health and education settings, abdominally obese women, people recruited without specification through open advertising to whole populations. Even at a very general level therefore making an assessment of which intervention is most cost-effective or even effective is tremendously difficult.

There are two points on interest related to the above. Firstly, using less vigorous inclusion / exclusion criteria Pucher (Pucher, Dill et al. 2010) has documented policies and interventions in some 20 cities across the globe on cycling prevalence including and up to of 36%. This may indicate that practical evidence is accumulating more quickly than it is being documented in the academic literature. Scopus analytics indicates that the number of documents containing 'cycling' in their title has increased from 456 in the year 2000 to 1,446 in 2015[17] but this does not

[16] https://www.gov.uk/government/publications/evaluation-of-the-cycling-city-and-towns-programme Site accessed 1st March 2016.
[17] https://www-scopus-com.ezproxy.brunel.ac.uk/term/analyzer.uri?sid=F3BB7E710FFD0180C675BCE8F902C28D.aqHV0EoE4xlIF3hgVWgA%3a10&origin=resultslist&src=s&s=TITLE%28cycling%29&sort=plf-

indicate the quality of the study or indeed if the document related to cycling for transport purposes. Equally, and more cynically, it may reflect that some cities are becoming more focused on publicising what may or may not be effective cycling interventions. Secondly, the work of Pucher et al. may indicate the time and effort required to achieve cycling prevalence of towards 30%. Cycling levels in the UK and Holland were not dissimilar in the 1950's (Ministerie van Verkeer en Waterstaat (Transport, Public Works and Water Management) 2009) and seem to have diverged most markedly in the 1970s. A number of complimentary influences may has impacted upon this divergence; in the Netherlands a confluence between child mortality from road traffic injuries led to mass protests ('Stop de kindermoord' (Stop the child murder) whereas the oil crisis of the early 1970's made motoring more expensive (Bicycle Dutch 2011). In the UK policy towards increasing both motoring and motoring infrastructure was already set in the 1960's and the discovery of North Sea oil protected against the oil crisis (Gunn 2013). Analysis of this divergence is beyond the scope of this thesis but it is apparent that from the 1960's onwards the two countries have pursued different policies towards cycling. Allied to this is that it may be that a cycle network is only as strong as its weakest link and that achieving population change will require a 'comprehensive network or routes' (National Institute for Health and Clinical Excellence (NICE) 2008) before cycle infrastructure projects are primarily used for recreation.

There are a number of limitations to this literature search not least of which is the limitation due to a lack of resources to English language articles. Notably, if highest prevalences of commuter cycling are found in non-English language countries evidence of best practice may also be found in non-English language journals. This may be a major limitation. Other limitations will relate the numbers of 'hits' and the subsequent need to use filters in some databases which may have excluded relevant studies. Equally, it is evident that the use of different inclusion / exclusion can yield very different results.

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f&sdt=b&sot=b&sl=14&count=21468&analyzeResults=Analyze+results&txGid=0 site accessed 18th September 2016

Conclusion

Despite the profound impacts that commuter cycling might have upon health there is little evidence of what might realise this effect. Within this evidence there appears to be less evidence as to what might be the effect increasing cycling in one domain (cycling) on other domains. This is of particular importance if the public health gains of increased PA are to be realised. Reasons for a lack of evidence potentially include the difficulty of achieving behaviour change at a population level and / or evidencing this change, the potential number of variables that need to be controlled for and possibly the difficult of applying clinical frameworks of evidence to population level interventions. However, the potential of commuter cycling to improve both individual and population health indicates that work is necessary to fill these gaps. In the UK the CCTs were a large-scale intervention with potentially profound influences for both individual and societal health across a number of health conditions including mental health and wellbeing. Chapter four will therefore outline how the CCT programme is to be evaluated in this thesis and how the data for this evaluation was identified.

Recommendations

- If the individual and societal health benefits of utility cycling are to be realised more research is needed into what interventions might increase this behaviour;
- Given the ubiquity of terms such as ‘cycle’, ‘transport’, ‘active’ and ‘travel’ a consensus on a term to indicate cycling for transport should be developed. ‘Utility cycling’ may be useful;
- Consistency of understanding of terms such as ‘cycle to work’ would allow for more interventions to be meaningfully compared e.g. cycling to work or not, the percentage of population cycling to work. This should include some indication of frequency e.g. number of days a week / month and length of journey;
- To understand the effect of the intervention rather than ‘what would have happened anyway’ research to determine the effectiveness of interventions to increase ‘utilitarian cycling’ should wherever possible include controls to

account for a) selection bias and b) a counterfactual of what may have happened without the intervention;

- There is a need for evidence that indicates whether increased cycling for transport purposes displaces physical activity in other life domains or leads to an overall increase in physical activity.

Chapter 4: Evaluation of Public Health interventions: a conceptual mapping

Chapter three highlighted that there is little evidence of what interventions may be successful in achieving a ‘modal shift’ towards commuter cycling i.e. a change in the mode of transport of transport used either in those who do not do any utility cycling or those who do some commuter cycle journeys. It further highlighted that even where evidence does suggest that utility cycling has increased there is a lack of evidence of whether that increase was accompanied by any changes in prevalence of PA in other life domains. From a public health perspective of increasing prevalence of PA this is of fundamental importance.

From a methodological perspective CCTs (AECOM 2011) may be regarded as a large public health intervention over three years of non-randomised free-living individuals in dispersed geographies of which no data has been purposively and prospectively collected. They therefore represent an evaluative challenge not amenable to more traditional research designs such as the ‘gold standard’ RCT. This chapter seeks to outline what the Cycling Cities and Towns programme was, how it might be evaluated including for its effect on PA in other life domains apart from utility cycling and what data sources might be useful in this purpose.

This chapter is in two sections. The first includes an introductory paragraph describing the CCTs which is followed by an outline of the ‘hierarchy of evidence’ and why this hierarchy is inappropriate for the evaluation of interventions such as the CCTs. An alternative hierarchy as proposed by the Cabinet Office is illustrated. The strengths and weaknesses of ‘natural experiments’ are then outlined. It is shown that natural experiment evaluation methodology is widespread in science, has been used widely in public health and that the Medical Research Council (MRC) has issued guidance for the evaluation of natural experiments. It is then shown that the CCT programme can be regarded as a natural experiment and that it meets the criteria outlined by the MRC for being evaluated as such a phenomenon.

Section two describes the search strategy to find datasets through which the CCTs could be evaluated, the search terms and selection criteria used, datasets found and reasons for inclusion or exclusion in the evaluation of the CCT programme. The implications of this for analysis are then discussed followed by the chapter's conclusion and recommendations.

Section 1

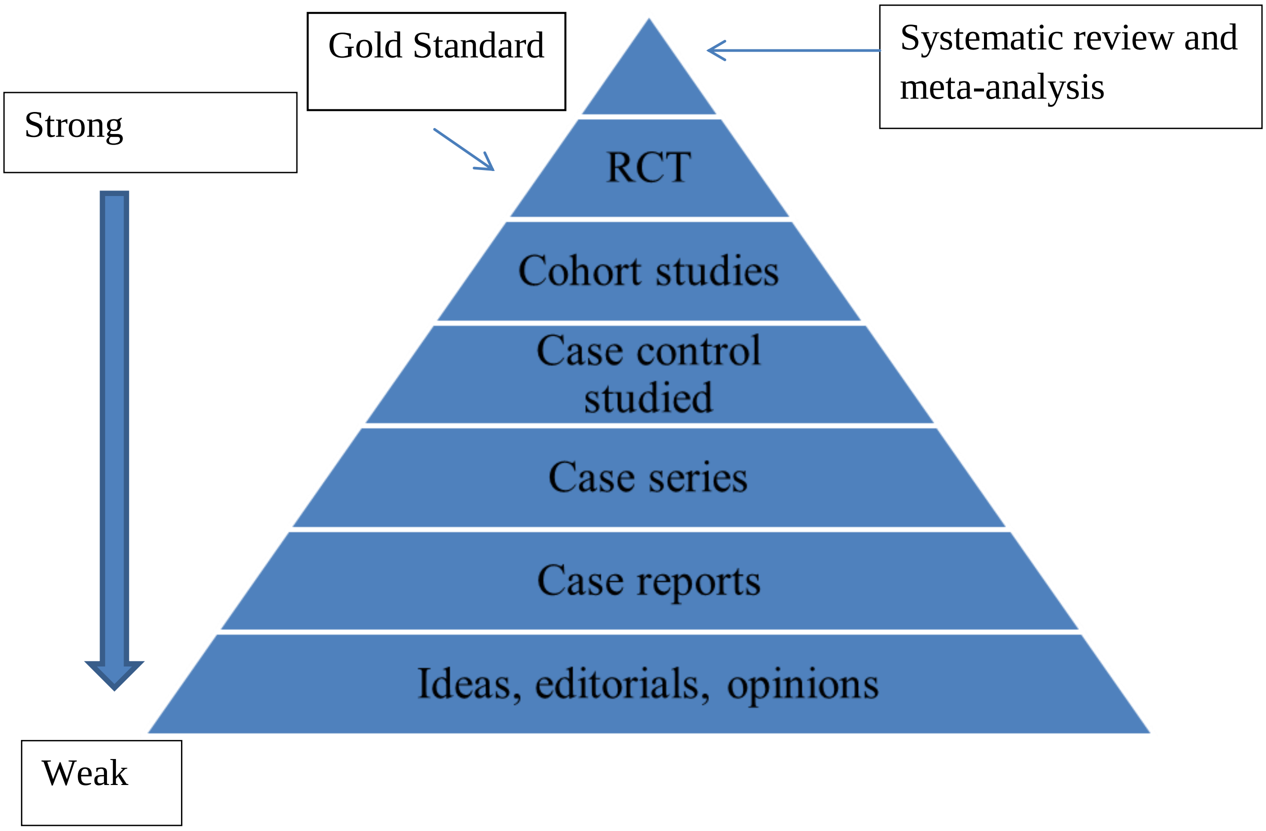
Description of the Cycling Cities and Towns

In 2005 Cycling England and the Department for Transport (DfT) jointly funded six Cycling Demonstration Towns (CDTs) – Aylesbury, Brighton & Hove, Darlington, Derby, Exeter and Lancaster with Morecombe to 'stimulate increased levels of cycling' (Cope, Muller et al. 2009). Following successful evaluation of the CDTs it was agreed that a second phase of the programme; Cycling Cities and Towns (CCTs) would be funded (Sloman, Cavill et al. 2009). Following a competitive tendering process 12 cities and towns; Blackpool, Cambridge, Colchester, Chester, Greater Bristol, Leighton Linslade, Shrewsbury, Southend, Southport, Stoke, Woking and York were selected to develop programmes to ensure 'more people cycling, more safely, more often'. Individual CCTs had very different baseline prevalences of cycling which were reflected in respective investment strategies (AECOM January 2011).

Hierarchy of evidence

Evidence-based medicine (EBM) indicates that there is a clear hierarchy of evidence. The National Institute of health and Care Excellence (NICE) guidance states that within primary studies Randomised Control Trials (RCTs) have the highest level of internal validity and, where feasible, should be the research design of choice when evaluating effectiveness of interventions (Weightman, Ellis et al. 2005). Whereas other methodologies will always have the implication of a systematic difference between intervention and control groups affecting the outcome variable (blinded) RCTs both randomise this allocation and blind both participants and investigators to this status so providing the clearest evidence of a causal association between intervention and outcome (Sibbald 1998). The RCT is therefore the 'gold standard' (Bonnell, Hargreaves et al. 2010) of investigation, Fig 2:

Fig 2: Hierarchy of evidence (Bondemark, Ruf 2015)



Using the RCT methodology to evaluate the effectiveness of population level environmental interventions such as CCTs is, however, rarely possible due to a number of methodological barriers. In the absence of a concurrent evaluation the most obvious is that RCTs employ a prospective methodology whilst the CCT programme ended in 2011. Other reasons include both randomisation and blinding; planned environmental interventions are rarely random and indeed CCT funding needed to be actively competed for. Equally, blinding would have been impossible in that people in intervention areas were likely to have been aware of CCT interventions, this would have been hoped for and expected by respective local governments and indeed residents would not be able to use or react to new facilities, policies, programmes or campaigns without awareness of them. Further, there is an obvious impracticality of allocating placebos at an environmental level; there is no placebo for a cycle lane.

The lack of applicability of an RCT methodology is not entirely confined to environmental or wider interventions; an RCT investigation into the causality of smoking upon lung cancer is 'possible to conceive but impossible to conduct'

(Ellenberg, p.355) for both ethical reasons of causing harm and practical reasons of needing to isolate a study sample for a number of years. Equally, its strength, that it can measure the effect of an intervention in an ideal setting may also be seen as its weakness e.g. that the translation from the ideal to the 'real' world may mean that the intervention may not be as effective as expected or hoped for (Victoria, Habict et al. 2004).

These methodological difficulties and the pre-eminence given to the hierarchy of evidence have been parodied (Smith, Pell 2003) but also noted as diverting attention away from complex policy interventions and / or broader structural issues to focus on either disease treatment or single element interventions (Abeysinghe, Parkhurst 2013). The subsequent lack of evidence for broader public health interventions has been regretted by policy makers (Petticrew, Cummins et al. 2005) including the House of Commons Select Committee on Health Inequalities (House of Commons Health Committee 2009) and the authors of the Foresight report (Goodwin, Cummins et al. 2012). The final Wanless report regretted the limited evidence base for public health interventions but suggested that some gaps might be filled by the use of 'natural experiments' (Petticrew, Cummins et al. 2005). Subsequently, the Cabinet Office has proposed an alternative hierarchy of evidence more useful to the evaluation of social interventions (fig 3).

Fig 3: Hierarchy of evidence proposed by the Cabinet Office (Cabinet Office Social Exclusion Task Force 2008)

Systematic review	→	Synthesis from several studies
↑		
Randomised controlled trial	→	Population allocated randomly to groups
↑		
Quasi – experimental study	→	Similar populations compared
↑		
Pre – post study	→	Results compared before and after intervention

Evaluation of natural experiments

Others have argued that there are many areas of science in which manipulative controlled experiments are impossible (Diamond, Robinson 2010). Astronomy, evolutionary biology, palaeontology and historical geology all use natural experiments as phenomena such as planets, dinosaurs, volcanoes, heatwaves etc cannot be controlled. Rather than dismiss or ignore circumstance therefore consideration is given to where 'interventions' have occurred or been implemented in a number of areas and to evaluate differences in outcomes. It is acknowledged that such experiments are 'blunt' in that outcome variables may be influenced by a multitude of vectors but continues that natural experiments have become familiar methodology in anthropology, archaeology, economic history, economics, political science and sociology (Diamond, Robinson 2010).

Whilst there are varying definitions of natural experiments (also known as quasi-experimental studies) in the literature (Craig, Cooper et al. 2012) key features may be considered to be that the intervention was not undertaken for the purpose of research and that variation in exposure and outcomes are analysed in an attempt to make causal inferences (Craig, Cooper et al. 2011). Some examples of such 'natural experiments ' have been documented, most notably in the prevention of suicide (Gunnell, Fernando et al. 2007), passive smoking (Kreitman 1976) and weight loss and regain in Cuba (Franco, Bilal et al. 2013).

Gerring (2011) therefore argues for a ‘good enough’ best possible evaluation that judges overall methodology in light of other possible research designs that could be applied to a research question. In this sense quasi-experimental designs may be especially useful ‘where interventions are aimed at whole populations or large regions where the allocation of individuals to intervention and non-intervention groups is impossible’ (Bauman, Nutbeam 2014). The challenge within this methodology will be to distinguish between what is causal and what is correlational e.g. between a relationship in which one effect (the dependent variable) is the outcome of another (the independent variable) and a relationship in which both variable change simultaneously.

The Use of Natural Experiments in Public Health

There is a long-tradition of the evaluation of natural experiments in epidemiology and public health; John Snow and the evaluation of the cholera outbreak, the effects of famine, clean air legislation and smoking legislation are all examples in which an RCT evaluation has never taken place and would be considered unethical and / or impractical. This is not to suggest that natural experiments are not without many sources of potential bias (Petticrew, Cummins et al. 2005). What is difficult is ‘navigating between the Scylla of unrealistic methodologic expectations and the Charybdis of such poor quality that it is unhelpful’ (Ogilvie, Mitchell et al. 2006), the balance between the extremes of inert scepticism and naïve credulity (Campbell 1988). Recognising this dichotomy the Medical Research Council (MRC) has produced guidance ‘to help producers, users, funders and publishers of evidence understand how and when ‘natural experiments’ can be used to good effect’ (Craig, Cooper et al. 2012).

The use of natural experiment methodology to evaluate the CCTs

Evaluations of city-wide programmes appear to have promising but possibly equivocal positive results on commuting cycling. Thus effects of city-wide developments were equivocal in Dublin across a population of 1.2 million (Caulfield 2014), possibly resultant from other external factors in south Glasgow (216,000)

(McCartney, Whyte et al. 2012) and Minnesota (213,000) (Krizek, Barnes et al. 2009) but more promising in the iConnect study (22,500) where knowledge of infrastructure change seems to have been predictive of transport cycling (Goodman, Sahlqvist et al. 2013). The only evaluation found of the CCTs used a natural experiment methodology to show a small but positive effect over a large population (1.8 million) but from a baseline taken seven years before the programme initiation (Goodman, Panter et al. 2013). It is noted that none of the above studies accounted for the effect of interventions on overall physical activity e.g. did any increase in physical activity achieved through commuter cycling result in a change in physical activity in other life-domains?

An assessment of CCTs against MRC guidance for the use of natural experiments is provided below (table 5) (Craig, Cooper et al. 2012). The challenge for current research is to validate both the direction and size of effect found in previous work in utility cycling and to assess whether this effect was associated with any change in physical activity in other life domains.

Table 5: MRC guidance on natural experiments and evaluation of CCTs against criteria

MRC guidance	CCT 'fit' with guidance
There is a reasonable expectation that the intervention will have a significant health impact, but scientific uncertainty about the size or nature of the effects	PA has been described as a 'public health best buy' (Morris 1994) and cycling as an everyday activity that can be incorporated into everyday life (Department of Health 2011). There is little evidence of the effect of CCTs on cycling prevalence and none found on their impact on PA.
A natural experimental study is the most appropriate method for studying a given type of intervention	The CCT programme was an environmental intervention that was both unique in time and place and aimed at free-living populations for whom both blinding and randomisation were impossible. However, controls can be selected as those

	classified by the Office for National Statistics as the closest corresponding local authority to the respective CCTs.
It is possible to obtain the relevant data from an appropriate study population, comprising groups with different levels of exposure to the intervention	The UK has a number of national surveys which may be useful in determining the effectiveness of the CCTs as a means of increasing physical activity. A search can be made of the UK dataservice. The CCTs were implemented in 12 geographies indicating that comparisons might be made to non-intervention areas.
The intervention or the principles behind it have the potential for replication, scalability or generalisability.	CCTs were implemented to evaluate the effect of increasing cycling funding in English towns and cities to North European levels where cycling prevalence is up to 10x higher (Pucher, J. and Buehler, R. 2008). The principle underlying CCTs, that a 'whole town approach' to increasing cycling' if shown to be effective, could be replicated in any urban setting.

As indicated above this methodology should indicate if cycling for utilitarian purposes increased in the CCTs and what the subsequent effect on PA might have been. Using natural experiments to assess the effectiveness or not of CCTs has three main strengths:

- The use of a control group (e.g. non-intervention areas) will allow comparisons with similar groups to indicate if a change in cycling rates would have taken place without the intervention.
- The use of trend data from before and after the intervention will give an indication if cycling prevalence changed across both the intervention and control groups pre and post the intervention;

- It will give an indication of the actual effect of an intervention delivered in a 'real-life' situation rather than an ideal setting.

MRC guidance is that intervention and control groups should be as similar as possible at baseline and that if there are substantial differences between groups then complete control for confounding will be difficult (Craig, Cooper et al. 2012). Matching at a town level will not be perfect but ONS bases its classification of local authorities on an initial analysis of 167 variables that cover the main domains of the census grouped into five categories of variables; demographic structure, household composition, housing, socio-economic character and employment (Office for National Statistics (ONS) 2015). Authorities are then categorised as 'extremely similar' to 'less similar' depending on whether their Squared Euclidean Distance (SED) is 1.63 or lower to 16.33 or greater. SED is a measure of dissimilarity where the distance between two local authorities is determined by values in census data (Office for National Statistics 2015).

As well as the potential limitation of suitable controls there are two further issues apparent in the evaluation of the CCTs as a natural experiment. Firstly, a methodological difficulty in assessing the effect of urban form on walking and cycling in that if an area is perceived as 'friendly' towards walking and / or cycling they may move to that area for those reasons making differentiation of cause and effect difficult (Krizek, Barnes et al. 2009). Here it is thought unlikely that persons will move to the CCTs to take advantage of the intervention. Secondly however, it remains that CCT funding was not assigned randomly but rather allocated as the result of competitive tendering based on leadership, strategy and matched funding (Goodman, Panter et al. 2013). By virtue of being a control and therefore, by definition either not bidding for or winning funding, controls were dissimilar to the CCTs.

Section 2: Data

To evaluate any effect of the CCTs a data-set was required that would allow the comparison of the prevalence of utility cycling and PA in the CCTs and their controls over the time period of the programme i.e. 2008-2011. Although the UK has a number of previous and current large-scale national surveys it was no certain which, if any, survey would meet these criteria. A search of the UK data service was therefore undertaken.

Search Strategy

The search for datasets that contained data on utility cycling and PA that would be suitable for the evaluation of the CCTs was undertaken between January and March 2014 using two strategies:

- Examination of any data identified in the literature review in chapter three
- A search of the UK data service. The UK data service is the curator of the largest collection of digital data in the social sciences and humanities in the United Kingdom. It is funded by the Economic and Social Research Council (ESRC) and the Joint Information Systems Committee (JISC) - the UK higher, further education and skills sectors' not-for-profit organisation for digital services and solutions. It is managed by the University of Essex[18]. It has been designated a 'Place of Deposit' by the National Archives and recognises that data that 'has been collected for one study can be analysed again for an entirely different piece of research'.

Search terms (applicable to search of the UK data service)

As questions on commuter cycling may be termed differently depending on the nature of the survey two searches were undertaken; the first sought surveys that had included the terms 'cycl*' OR bike, the second "travel to work". Both searches were undertaken between January and March 2014. Any dataset for which utility cycling could be derived needed to include data from which PA could also be derived.

Selection criteria

Datasets were reviewed using the following criteria:

- Relating to the English adult population (aged 16+);
- Recording of commuter cycling or variable from which non-sporting cycling could be derived;
- Recording of PA or variable from which PA could be derived;
- Included data that was able to provide baseline and follow-up data;

[18] http://www.data-archive.ac.uk/about/archive site accessed 22nd June March 2016.

- Ability to analyse data at the same geographic level as the CCTs e.g. Local Authority level or smaller;
- Be able to provide a control to the CCTs e.g. what may have happened in the absence of the CCT funding;
- Be able to demonstrate any difference over the time-period of the CCTs e.g. 2008 to 2011.

Results

Searches of the UK data archive can produce multiple results from the same survey series. For example the term cycl* returns 1053 'hits' of which the first three were the OPCS Omnibus July 1995, August 1995 and September 1995.

The search term 'cycl* OR bike' produced 431 results from 13 datasets (including two which had been re-named). The second term; "travel to work" produced 44 results from two datasets which had already been included in the first search (the Labour Force Survey (LFS)) and the ONS Omnibus Survey). Three surveys had been restructured or merged into the Integrated Household Survey to leave 10 potential databases for analysis.

Each dataset included in the results was then examined against the above criteria for its suitability for analysis of the effects of the CCT programme. Special licenses were obtained from the UK dataservice where required to download data / questionnaires to understand the questions in surveys. Following examination, all but one survey was excluded as they focused on young people aged under 16 (two datasets), their sample size was insufficient to allow analysis at the spatial level of the CCTs (two datasets), did not measure / record commuter cycling (three datasets), excluded cycling for other than health or recreational purposes (one dataset) or closed before the end of the CCT programme (three datasets) (Table 6 below):

Table 6: Datasets found through UK Data-archive, inclusion or exclusion and reasoning

Dataset	Description	Suitable for analysis of commuter cycling in CCTs? / reasoning	Suitable for analysis of PA from commuter cycling / reasoning	Inclusion (Yes or No)
Annual Population Survey	Combined survey in Great Britain of approximately 360,000 people.	No – travel to work question was not included until 2009, after the CCTs had started.	No	No
Integrated Household Survey (HIS)	Combined survey made up of Annual Population Survey (above) and Living Cost and Food Survey (below)	As above	No	No
Health Survey for England (HSE)	Series of annual surveys carried out since 1991 with a number of core questions and particular topic focus.	No – does not include CCT indicator variable	No – does not include commuter cycling	No
Millennium Cohort Study	Longitudinal study aiming to chart the	No – does not include adults aged 16+	N /a	No

	conditions of social, economic and health advantages and disadvantages facing children born at the start of the 21st century.			
National Travel Survey (NTS)	Series of household surveys to study personal travel behaviour from 1972 onwards.	No – NTS local level cycling statistics are derived from the Active People Survey*	No – NTS local level cycling statistics are derived from the Active People Survey*	No
ONS Opinions Survey, from 2008 the Opinions (Omnibus) survey and part of the Integrated Household Survey	Regular multi-purpose survey covering core demographic information with non-core questions that vary from month to month.	No – does not ask about commuter cycling	No – commuter question unsuitable	No
British Social Attitudes Survey	Tracks people's changing social, political and moral attitudes.	No – does not ask about commuter cycling	No – commuter question unsuitable	No
ONS Omnibus Survey (see	See above			

above - formerly Opinions Survey)				
Active People Survey	Continuous survey of participation in sport and active recreation (since 2005/6).	Yes, able to derive cycling not for the purposes of health, recreation, training or competition	Yes – through derivation of variable.	Yes
Labour Force Survey (LFS)	Survey of the employment circumstances of the UK population.	Yes – includes 'usual means of travel to work'	No – first collection of travel to work data was in 2009, after CCTs had begun	
General Household Survey	Continuous annual national survey of people living in private households, conducted by the Office for National Statistics (ONS).	No – does not ask about commuter cycling	No – commuter question unsuitable	No
Expenditure and Food Survey	Now known as the Living Costs and Food Survey (LCF) module of the	No – does not ask about commuter cycling	No – commuter question unsuitable	No

	Integrated Household Survey (HIS) this survey collects information on spending patterns and the cost of living.			
Longitudinal Survey of Young People in England	Also known as Next Steps this is a survey of people aged 13 and 14 in 2004.	No – does not include adults	No – does not include adults	No
Living Costs and Food Survey (see above – Expenditure and Food Survey)	See above – Expenditure and Food Survey			
National Child Development Survey	Longitudinal study started in 1958 aiming to understand the factors affecting human development over the whole lifespan.	No – does not include adults	No – does not include adults	No

*Local Area Walking and Cycling Statistics. Department for Transport (undated).

Implications for empirical analysis

Following the above search for data the Active People Survey (APS) was selected as the most appropriate dataset for the analysis of the CCT programme. The APS allows for the derivation of variables to indicate both non-sporting cycling as well as other forms of PA. It further allows for measurement of physical activity. As it is a survey of local authorities it allows for both isolating those areas that were exposed to the CCT programme and those which were not so allowing for the counter-factual of what may have happened in the absence of the CCT programme. This in itself will allow a 'difference in differences' (DID) analysis of repeated cross-sectional data to show any difference in utilitarian cycling that occurred in the CCTs that may be attributed to CCTs themselves rather than 'what would have happened in the absence of the intervention' (Craig, Cooper et al. 2012).

The above may also indicate some of the sociological and pragmatic issues of why there is a lack of evidence for the effectiveness of interventions to increase commuter cycling as shown in chapter 2, the literature review. Where data were found on 'cycling to work' at a granularity sufficient to understand behaviour change at a local authority level data was only recorded every 10 years. Where data was recorded annually this was only at regional basis. The APS itself has only been running since 2005 whereas the decline in cycling prevalence began in the 1950s. Even here utility cycling can only be derived through the exclusion of cycling for the purposes of health, training, competition or recreation. Without data for analysis therefore it is perhaps unsurprising that there is a lack of empirical evidence of what interventions might affect prevalence of commuter cycling. It is unknown if there is a similar lack of data in other countries.

By the mid 1960's the future of transport was considered to be the 'freedom of the motor-car' supported by a system of motor-ways across the country. Whilst Prime Minister Thatcher may or may not have stated that a man still catching the bus to work at 26 was a failure[19] the statement is apocryphal and begs the question of the person on a cycle. Cycling therefore has fallen outside of Government policy to the private sphere of either leisure or a child's plaything outside of the purview of the

[19] The Wheels on the bus. The Economist. Sept 28th 2006. http://www.economist.com/node/7970987. Site accessed 19th September 2016.

state (Aldred 2012). Whilst this may offer an explanation of why there are few data on non-sporting cycling it does not support the collection of data for the support of public health. Certainly, there would seem to be a juxtaposition between the ready availability of data on healthcare conditions or leisure cycling and the paucity of data on a health behaviour that the CMO argues may be most easily integrated into everyday life (Department of Health 2011). As implied by the name of its commissioning body (Sport England) the APS is primarily intended to measure sport and active recreation, not utilitarian cycling. This is not to argue that this is an uncontested policy area, the Cameron Government rose to power proclaiming 'vote blue, go green' (Carter 2009). However, for a variety of reasons it would seem that the collection of data on healthcare far outweighs that of health behaviour.

Conclusion

CCTs were established to 'explore whether and how increased investment in cycling as part of a whole-town strategy could lead to a significant and sustained increase in the number of cyclists and frequency of cycling' (AECOM January 2011). Though a substantial intervention (£43m plus match funding) there are a number of reasons why CCTs cannot be evaluated through the gold standard of an RCT. The most obvious is time in that the programme is now ended but others include that (a) funding was not randomly allocated but rather needed to be competed for; (b) at least some Local Authority officers and residents would have been aware of CCT status c) at least some intended recipients of interventions residents would have been aware of changes in the environment / cycling initiatives even if they were not aware of CCT status and d) the impracticality of a placebo.

CCTs therefore represent a public health intervention which does not fit easily into the traditional hierarchy of evidence but which itself has been criticised. 'Natural experiments' or 'quasi-experimental' methodology are an example of an alternative methodology which will allow an evaluation of the CCTs to show if they had any effect whilst controlling for what might have happened in their absence; the counter-factual (Craig, Cooper et al. 2012). One dataset, the APS, was found which would allow this evaluation for both utility cycling and PA.

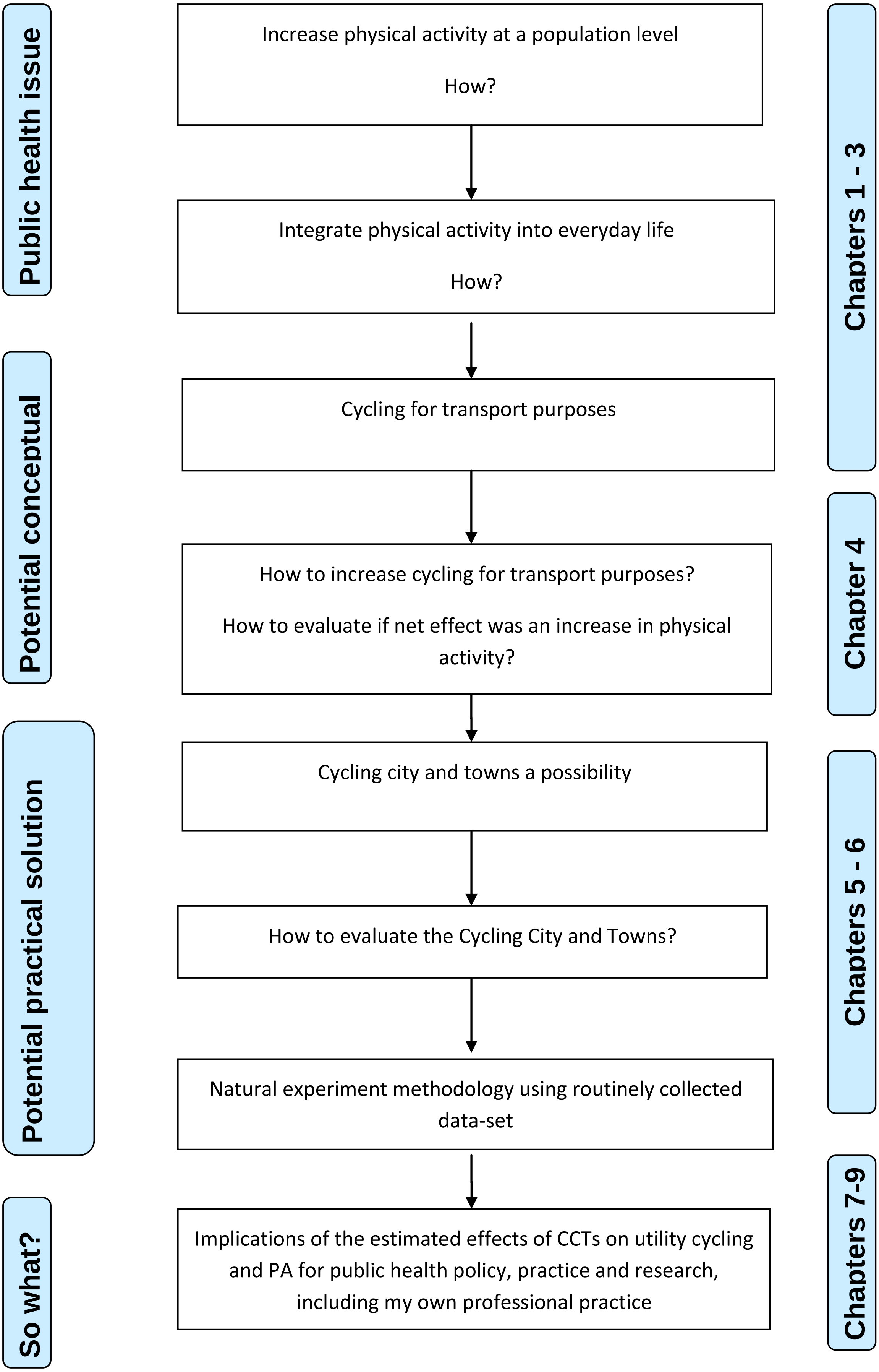
Recommendations

- The hierarchy of evidence may not always be appropriate or useful for evaluating large-scale public health interventions, an alternative or supplementary hierarchy of evidence, more applicable to public health should be developed;
- Following MRC guidance, more use should be made of natural experiments to evaluate population level interventions. MRC guidance on natural experiments should be followed;
- It is perhaps surprising that there is so little data on an activity that would intuitively potentially have a significant impact upon the health of the population. Consideration should be given to including data on mode of travel in more surveys, particularly national surveys.

Conceptual mapping of this thesis

A concept map of this thesis is provided in fig 4. The first part is the public health issue that this thesis seeks to address e.g. a lack of physical activity in the population. The second highlights a conceptual solution to this problem and the third how this conceptual solution may be applied practically. The third part is the evaluation framework to understand if this hypothesised solution has had an effect when implemented and the fourth relates back to the original public health issue (fig 4):

Fig 4: Conceptual map of thesis



CHAPTER 5: Effect of CCTs on utility cycling and physical activity[20]

Introduction

Chapter three showed that there is a lack of evidence for what interventions increase commuter cycling and that although CCTs were found to have a small positive effect across a large population data issues indicate that this is not certain. It has also been noted that the main public health benefit of increased physical activity through utility cycling will only be realised if there is no equivalent decrease in physical activity in other life-domains. Chapter four illustrated the use of natural experiment methodology in science in general and public health in particular and that the APS is a suitable dataset through which CCTs could be evaluated as a natural experiment. This chapter therefore seeks to address limitations in the literature by evaluating CCTs for their effect on a) utility cycling and b) physical activity.

Methods

It was found in chapter four that the APS was the most appropriate source of data through which the CCT programme could be evaluated. As the APS is an annual cross-sectional survey this analysis is therefore a 'difference in differences' (DID) analysis using data collected between October to October from 2005 to 2012 (excluding 2006 when no survey was undertaken).

Data

Data was obtained from the UK Dataservice. The APS is an annual cross sectional survey on sport and active recreation in England conducted for Sport England, a non-departmental public body sponsored by the Department for Culture, Media and Sport (DCMS). It is a random digit dialling (RDD) survey weighted to be representative of each reporting geographical area (Local Authority, County Council, London Borough, Government region). Within each geographical area, the survey was weighted by age, gender, ethnicity, socio-economic classification, household size and working status. Whilst originally the survey was of people aged 16 and over

[20] An abstract of this paper has been accepted by The Lancet; Stewart, G., Anokye,, N.K. and Pokhrel, S. (2016). Improving population levels of physical activity through integration into everyday life: a pre-post analysis of the Cycling Cities and Towns (CCTs) programme (abstract, The Lancet, in press)

in APS 6 (2011 to 2012) this was extended to include those aged 14 and over. Interviews are distributed evenly over each 12-month period with the survey designed to achieve a minimum of 500 interviews in all Local Authorities apart from the City of London and the Isles of Scilly with a target of 100 and 150 interviews respectively. The person in the household interviewed was selected through Computer Aided Telephone Interviewing (CATI) software which randomly selects either the telephone responder or any other adult in the household for the survey. Response rates to the survey have consistently been approximately 27%. For practical purposes residents in institutions (armed forces barracks, student halls of residence, hospitals, care homes, etc.) are excluded and it is recognised that mobile-only households (approximately 15% in 2011) are also excluded (Stewart, Anokye et al. 2015a).

From October 2012 to October 2013 approximately 1,000 interviews were undertaken using a Random Digit Dialling (RDD) mobile phone survey and a shortened version of the APS questionnaire. Compared to landline respondents mobile phone respondents were more likely to be male, younger and from non-white ethnic groups than landline responders. No systematic difference was found between landline and combined landline–mobile results for once a week or once a month participation for the ten largest sports nor once a week or three times a week participation for all sports (Stewart, Anokye et al. 2015a).

Production of dataset

Variables from each year's APS survey were combined to produce a final dataset of 7 years data (APS 1 – 7) and 1,432,766 respondents. Each APS includes approximately 165,000 individuals (though APS 1 included 364,724) and approximately 1500 bits of information on each individual. Seven years of data therefore contains approximately 15 billion separate pieces of information[21]. As this was beyond the computer power available and because much of this data was extraneous to the aims of this thesis a database was therefore created for the purposes of analysis. Production of this dataset involved a number of steps within each survey (APS1 – 7):

[21] 1,432766*1500*7

1. Identification of variables pertinent to analysis; a) utility cycling, b) physical activity and c) control city / towns and d) covariates.

   The APS was originally intended to measure participation in sport and / or active recreation indicating that the actual dataset needed to be inspected to identify variables. The APS evolved over time and contained between some 1466 (in APS1) to 6822 (APS7) potential variables for each individual. However, Stata has a filter function which was used to isolate variables. The dataset is downloaded from the UK dataservice as a zip file which contains the actual questionnaire for each survey so allowing a thorough understanding of the dataset.

2. Merging of the CCTs as an independent variable and their respective 'closest corresponding city and towns as a matched control.

   In the APS each local authority is numbered. A binary variable was created where 1 = the CCT matched authorities (the control) and 2 = the CCTs.

3. Derivation of the variable 'utility cycling' from questions of cycling for any purpose and cycling for the purposes of health, recreation, training or competition;

   Derivation of these variables is outlined in more detail under 'outcome variables' below.

4. Check that variables actually included data

   In APS7 data on variables for income and car ownership were not included despite being in the file deposited with the UK dataservice. Similarly, whereas the APS7 questionnaire includes questions on height and weight these were not included in the APS dataset as the question was commissioned by Public Health England who subsequently owned the information indicating that it was not available for the APS (personal communication – appendix 7).

5. Examination of all included variables to ensure that they were identically labelled throughout APS1 to 7;

With the evolution of APS variables were coded differently in separate years. For example, all Local Authorities were labelled differently in 2008 from 2005 – 2007. Each included variable therefore needed to be checked in each APS and recoded if necessary.

6. Re-formulating of any variables that were not identically specified throughout all surveys:

   The variable ‘ethnicity’ in APS1 was originally divided into 453 categories which were subsequently collapsed into six categories following the breakdown of ethnicity in studies from the literature review. A similar process was undertaken for socio-economic status.

7. Check that variables were consistently coded throughout all the APS surveys used.

   Coding for Local Authorities changed in 2008 from 2005 to 2007. They were recoded back to their original coding in 2009. Each variable included therefore needed to be checked for coding and recoded if necessary.

8. Finally, when all relevant variables in each APS survey had been cleaned they were merged into a separate database using the keep command in Stata.

Outcome variables

In order to understand the effect of CCTs on cycling as well as the possibility of a substitution effect, or not, outcome variables were defined to include alternative specifications of physical activity; a) utility cycling and b) sport or active recreation.

The main dependent variable was participants recorded as doing or not doing any utility cycling in the past four weeks. A secondary outcome was participants recording as having done any physical activity in the past four weeks defined as having undertaken any recreational walking, cycling, sport or other active recreation for at least 30 minutes at moderate intensity in the past 28 days. A list of sports included in the APS is in appendix 8.

a) utility cycling

Utility cycling was specified as the probability of undertaking utility cycling in the past 28 days. The APS survey question is framed as 'I would now like you to think about any cycling you may have done. Please include any casual cycling in your local area, any cycling in the countryside or on cycling routes, cycling to or from work or any competitive cycling. In the last four weeks, that is since [^INSERT DATE^] have you done at least one continuous cycle ride lasting at least 30 minutes?' The response categories were 1 (Yes), 2 (No) and 3 (Don't know). Respondents were then asked on how many days they had cycled for at least 30 minutes and subsequently 'how many of those days were you cycling for the purpose of health, recreation, training or competition not to get from place to place?

The main outcome variable was utility cycling defined as whether utility cycling had taken place in the past 28 days e.g. cycling that was **not** for the purpose of health, recreation, training or competition in the past four weeks.

b) Sport or active recreation

The outcome variable was the probability of undertaking sport and recreational physical activity in the past 28 days. The APS survey question is framed as 'Thinking about the [ACTIVITIES ROUTED FROM Q10 LIST22] [and] [RECREATIONAL WALKING] [and] [RECREATIONAL CYCLING] you have done in the last four weeks. Can I ask on how many days in the last four weeks, in total, did you do at least one of these activities [this activity] for at least 30 minutes? The response categories were the number of days, 1 – 28, don't know.

The main outcome variable was defined as whether any activity defined as recreational walking, recreational cycling or sport or active recreation had taken place in the past four weeks.

Cycling City or Towns

CCTs were specified as all areas that had the CCT intervention. Of the 12 original CCTs Leighton-Linslade, Shrewsbury and Southport and Ainsdale have never been included as separate geographies in the APS. Chester became part of Cheshire

[22] Sports and active recreation

West and Chester on April 1st 2009 as part of the structural changes to local government meaning that analysis was restricted to the remaining eight CCTs of Bristol, Blackpool, Cambridge, Colchester, Stoke, Southend, Woking and York. A table of CCTs and their first to fifth closest corresponding local authorities is included in appendix 9.

Non intervention areas

Non-CCT towns were taken from the ONS 2011 Area Classification for Local Authorities which updates the 2001 classifications of the same name. Locations are matched on 167 variables that are grouped into five categories; demographic structure, household composition, housing, socio-economic character and employment (Office for National Statistics (ONS) 2015). 'Most similar' local authorities which were used as controls except for Bristol where Leeds, the second most similar authority was used as the most similar authority, Cardiff, is in Wales and therefore not part of the Sport England APS. Table 7 shows each included CCT and their most similar local authority:

Table 7: Included CCTs and their most similar corresponding local authorities

Cycling City or Town	Most similar local authority
Blackpool	Hastings
Cambridge	Oxford
Colchester	Worcester
Bristol	Cardiff (Leeds)
Southend	Ipswich
Stoke	Rochdale
Woking	Elmbridge
York	Bath and North East Somerset

Control variables

Inclusion of control variables was informed by variables cited by studies identified in the literature search in chapter three but reliant upon what data was available throughout APS 1 – 7 (see p.48). Explanatory variables included in this analysis were; age (16–34, 35–54, 55+), gender (male/female), ethnicity (White, Asian, Black, Chinese, Mixed, Other), National Statistics Socio-Economic Classification (NS-SEC) grades (1–4, 5–8, 9) and number of children in the household (0, ≥1).

Appendix 10 includes the APS survey questions used as either variables or to derive variables used in this analysis.

Effect of CCT programme and time

Funding for the CCT programme was announced in 2008. Although funding was announced this does not necessarily indicate when the effects of this funding would become apparent. Three different comparison periods were therefore applied; 2005 - 8 v 2009 - 12, 2005 - 7 v 2008 – 12 and 2005 – 7 v 2009 – 12. 2008 was also plotted separately. To account for any national trends the effect of year was plotted for the same periods as was a further graph showing the interaction effect of CCT and year.

Statistical analysis

Descriptive statistics of for the CCTs and their most similar local authorities were calculated for gender, age, socio-economic status, ethnicity and presence of a child in the household.

One of the aims of the CCTs was for more people cycling (AECOM 2011). As the outcome is binary (e.g. utility cycling or not) logistic regression is used to predict this outcome when based on a number of explanatory variables (Petrie, Sabin 2000). Here the aim was to determine the odds of cycling in the CCTs in relation to their matched controls before the intervention and compare these to the odds of cycling in the CCTs in relation to their matched controls after the intervention. The outcome of interest was the odds of cycling for transport purposes in the CCTs post-2008 period. Both CCTs and their matched controls may have been subject to national temporal trends in utility cycling between 2005 and 2012, which if not taken into account in the analysis, could have overestimated the true effect of the CCTs. Therefore, the logistic model specified was based on the interaction between the geographic area and the period. The model specified as a probability model for the likelihood of cycling for transport purposes was:

Utility cycling = β_0 + β_1 (CCT) + β_2 (time) + β_3 (CCT*period) +β_k (age, gender, NS-SEC, child in household, ethnicity) + *e*

Where β_0 is the model intercept, β_1 is the coefficient for CCTs, β_2 the coefficient for the period (pre- or post-2008), β_3 the coefficient for the interaction between the indicator variables for CCTs and the yearly time trend and βk denotes other control variables (age, gender, National Statistics Socio-economic status (NS-SEC), having a child in the household and ethnicity) and e is the model error term.

For the purpose of this thesis, the coefficient of interest was (β_1 + β_3) - and not (β_1) or (β_3) on their own - as this combined measure (β_1 + β_3) was the effect of the CCTs compared to their matched control in the post-2008 period (period = 1). This measure (β_1 + β_3) therefore demonstrated the difference in utility cycling prevalence between the CCTs and their matched controls, taking into account the potential existence of national trends in utility cycling between 2005 and 2012. Thus, it is important to note - in the context of national decline generally in cycling prevalence over time – that one would expect the effect size shown by the combined measure (β_1 + β_3) to be lower than that shown by the coefficient of CCTs alone (β_1).

For more intuitive interpretation, the coefficients were converted into the odds ratios (ORs) by applying exponentiation (Petrie, Sabin 2000) . ORs are interpreted as the ratio of the odds of utility cycling in the CCTs compared to that in the matched control, whilst adjusting for other variables. In the above equation, exp (β_1) measured the odds of utility cycling in CCTs compared to their matched controls for the whole sample. The interaction effect was measured by exp (β_3) which is the ratio of the OR (CCT) and OR (Period) respectively. Therefore, the combined effect = exp (β_1)*exp (β_3) and was expressed as an odds ratio.

For all scenarios, two logistic regression models were used; an unadjusted model allowed bivariate analysis examining the relationship between undertaking utility cycling and each of the control variables separately. Secondly, an adjusted analysis allowed a multivariate analysis in which all explanatory variables were included in the same model.

Missing data may be problematic in a study as it can lead to a loss in statistical power and / or as it may introduce bias into analysis. Statistical power is lost as the sample size is smaller. Bias is introduced when data is 'not missing at random' but is rather related to the data itself (Higgins, Green 2011). In this study this would mean that the fact of missing responses to having undertaken utility cycling or not was related to an independent variable. Chi-squared tests were therefore undertaken to determine whether missing data occurred at random. Where data was not missing at random within a variable it was included as a category within that variable for regression purposes. No missing data was found for the variables gender, or age but was apparent for ethnicity, socio-economic status, child in household. Table 8 shows the numbers and percentages of people who had undertaken utility cycling in the past 28 days and whether this was significant.

Table 8: Numbers and percentages of people undertaking utility cycling:

Covariates	No (%)YES utility cycling	No (%) NOT utility cycling	P-value	No (%) of missing variables
Gender				
Male	564,114 (3.66)	21,416 (96.34)	N/a	None
Female	834,391 (98.48)	12,845 (1.52)		
Age				
16 – 34	12,479 (4.36)	273,738 (95.64)	N/a	None
35 – 54	14,720 (2.89)	495,080 (97.11)		
55+	7,062 (1.11)	629,687 (98.89)		
Child in house				
Yes	12,087 (3.21)	363,897 (96.79)		489 (1.1)
No	21,685 (2.10)	1,009,515 (97.90)		
Missing	489 (1.91)	25,093 (98.09)	0.000	
SES status				
NS SEC 1 – 4	18,199 (2.18)	818,135 (97.82)		90 (4.30)
NS SEC 5 – 8	11,016 (2.38)	452,034 (97.62)		
NS SEC 9	4,956 (3.77)	126,334 (96.23)	0.000	
Missing	90 (4.30)	2002 (95.70)		

Ethnicity				
White	31,342 (2.39)	1,279,030 (97.61)	0.000	642 (2.47)
Mixed	532 (3.95)	12,949 (96.05)		
Asian	621 (1.5)	40,827 (98.50)		
Black	695 (2.44)	27,745 (97.56)		
Other	255 (3.13)	7,896 (96.87)		
Chinese	172 (3.53)	4,760 (96.47)		
Missing	642 (2.47)	25,298 (97.53)		

Goodness of fit was evaluated through the Hosmer-Lemeshow test but using quintiles rather than deciles as it is less likely to over or under-predict observations in large datasets with a smaller number of quantiles. Specification errors were tested using the linktest. Unadjusted and adjusted odds rations (AORs) were calculated for each independent variable.

The threshold for statistical significance was set at ≤5% in all analyses. Analyses were undertaken using Stata SE 12.1.

Results

APS surveys 1 – 7 (2005 to 2012) contained 1,432,766 respondents. Of these 34,362 lived in CCTs and 32,975 in their most similar matched authorities. CCTs and the matched controls were similar across all covariates; 41% of respondents were male, 22% aged 16-34, 36% aged 35-54, 94% white, 59% in NS SEC cateogories 1-4, 31% in NS SEC categories 5-8 and 73% without a child present in the household.

Table 9 summarises the characteristics of the sample.

Table 9: Characteristics of CCTs and the most similar local authorities

	Gender		Age			Socio-economic status		
	Male	**Female**	**16-34**	**35-54**	**55+**	**NS-SEC 1 - 4**	**NS-SEC 5 - 8**	**NS-SEC 9**
Cycling City and Towns Number (%)	14,154 (41.19)	20,208 (58.81)	7,466 (21.73)	12,230 (35.59)	14,666 (42.68)	20,046 (58.41)	10,961 (31.94)	3,315 (9.66)
Closest Local Authority Number (%)	13,510 (40.97)	19,456 (59.03)	7,138 (21.65)	11,904 (36.10)	13,933 (42.25)	19,653 (59.70)	10,125 (30.76)	3,139 (9.54)
	Ethnicity						Children in Household	
	White	Mixed	Asian	Black	Other	Chinese	Yes	No
Cycling City and Towns Number (%)	31,923 (94.65)	312 (0.93)	769 (2.28)	378 (1.12)	187 (0.55)	157 (0.47)	8,747 (25.92)	24,998 (74.08)
Closest local authority Number (%)	30,163 (93.23)	401 (1.24)	987 (3.05)	491 (1.52)	187 (0.58)	126 (0.39)	8,781 (27.18)	23,526 (72.82)

In 2005, 6.30% of residents in CCTs indicated that they had undertaken at least one day of utility cycling for 30 minutes in the past four weeks compared to 3.96% of residents of their closest matched authorities (p=0.000). By 2011 this difference had become non-significant and remained non-significant in 2012 (Table 10).

Table 10: Percentage of residents reporting one day of utility cycling in past four weeks, 2005 to 2012 in CCTs and their closest matched authority

	2005	2007	2008	2009	2010	2011	2012
% reporting utility cycling in CCTs	6.30	6.07	5.42	3.76	4.05	1.92	1.97
% reporting utility cycling in matched Local Authorities	3.96	3.77	3.89	5.85	2.91	1.57	1.55
$\chi 2$ (1)	46.34	24.64	11.53	20.20	8.11	1.48	2.05
P-value	0.000	0.000	0.001	0.000	0.004	0.223	0.152

Each year approximately 50% of residents in both the CCTs and their nearest matched authorities reporting undertaking physical activity in the past four weeks. No significant difference was found except in the years 2009-10 and 2010-11 when more people reported physical activity in the CCTs than in their nearest matched authorities (table 11).

Table 11: Percentage of people reporting 30 minutes physical activity on at least one day in the past 28 days in CCTs and their closest matched authority

	2005-6	2007-8	2008-9	2009-10	2010-11	2011-12	2012-13
% recreational walking, cycling or sport in CCTs	49.03	46.83	55.09	51.74	51.59	50.16	49.39
% reporting walking, cycling or sport in matched Local Authorities	50.97	53.17	44.91	48.26	48.41	49.84	50.61
$\chi 2$ (1)	2.96	0.20	0.77	6.08	5.54	0.13	1.06
P-value	0.09	0.66	0.38	0.01	0.02	0.72	0.30

Regression model

Table 12 shows the adjusted and unadjusted odds ratios of utility cycling in the CCTs post intervention 2005-8 compared to 2009-12. Overall, CCTs were associated with higher odds of utility cycling (OR= 1.59). However, although the interaction effect between geographical area and temporal trend in cycling prevalence was insignificant, it caused a reduction in the above observed effect of CCTs (interaction OR =0.93). Being in a CCT was therefore associated with higher odds of having cycled (AOR=1.59*0.93= 1.48), after taking into account the interaction effect. The odds of females, those with children in the household, those in socio-economic categories NS_SEC 5 – 8, people aged 35+ and those of Asian ethnicity was significantly less than that of males, those in socio-economic categories NS-SEC 1-4, those with no children and those of an Asian ethnicity. Those in NS-SEC 9 had higher odds of undertaking utility cycling as were those for whom ethnicity and socio-economic status was unknown.

Table 12: Unadjusted and adjusted odds ratios for the effect of CCTs on utility cycling, 2005 -2008 compared to 2009 – 2012

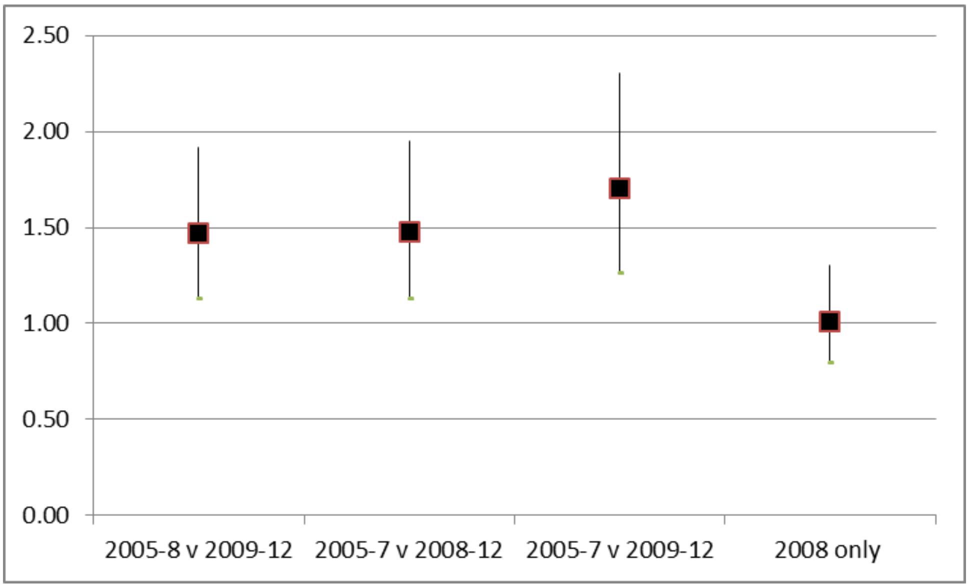
Independent variables	**Unadjusted odds ratio (95% confidence interval)**	**Adjusted odds ratio (95% confidence interval)**
CCTs	1.57 (1.42 – 1.74)***	1.59 (1.43 – 1.75)***
Year	0.62 (0.55 – 0.70)***	0.66 (0.58 – 0.76)***
CCTs x Year 2005-8 v 2009-12	0.93 (0.79 – 1.09)[a]	0.93 (0.79 – 1.10)[a]
Gender		
Male	1.00	1.00
Female	0.54 (0.50 – 0.58)***	0.55 (0.51 – 0.60)***
NS-SEC		
NS SEC 1 – 4	1.00	1.00
NS SEC 5 – 8	0.77 (0.70 – 0.84)***	0.78 (0.71 – 0.86)***
NS SEC 9	1.71 (1.53 – 1.92)	1.56 (1.38 – 1.77)***
Missing	2.22 (0.97 – 5.08)	4.59 (1.84 – 11.45)***
Child in household?		
No children	1.00	1.00
Having children	0.70 (0.64 – 0.76)***	0.97 (0.88 - 1.06)
Missing	0.73 (0.53 – 1.00)	0.32 (0.22 – 0.46)***
Age		
16 – 34	1.00	1.00
35 – 54	0.69 (0.63 – 0.75)***	0.75 (0.68 – 0.82)***

55+	0.28 (0.25 – 0.31)***	0.31 (0.27 – 0.34)***
Ethnicity		
White	1.00	1.00
Mixed	1.63 (1.19 – 2.22)***	1.17 (0.84 – 1.61)
Asian	0.72 (0.54 – 0.97)**	0.48 (0.36 – 0.65)***
Black	1.12 (0.80 – 1.57)	0.81 (0.58 – 1.13)
Other	1.82 (1.21 – 2.72)***	1.27 (0.80 – 2.02)
Chinese	2.11 (1.38 – 3.21)***	1.26 (0.81 – 1.97)
Missing	1.30 (1.00 – 1.69)**	1.22 (0.92 – 1.62)

** p ≤0.05, *** p ≤0.01, [a]Interaction effect of geographical area and temporal trends on prevalence. This figure was used to adjust the OR of CCTs.

CCT funding became available in 2008 indicating that it is not certain when interventions began. To take this uncertainty in to account, sensitivity analyses were conducted for different scenarios: 2005-2008 compared to 2009-2012, 2005-2007 compared to 2008-12 and 2005-2007 compared to 2009-2012. Very similar results were found when comparing each scenario (appendices 9 – 10). The AOR in the CCTs on utility cycling was 1.47 (95% CI 1.13 to 1.92) comparing 2005-8 to 2009-12, 1.48 (1.12 – 1.95) comparing 2005-7 to 2008 – 12 and 1.70 (1.26 – 2.30) comparing 2005-7 to 2009-12, obtained as above by multiplying the interaction effect by the ORs for the CCTs (Graph 1).

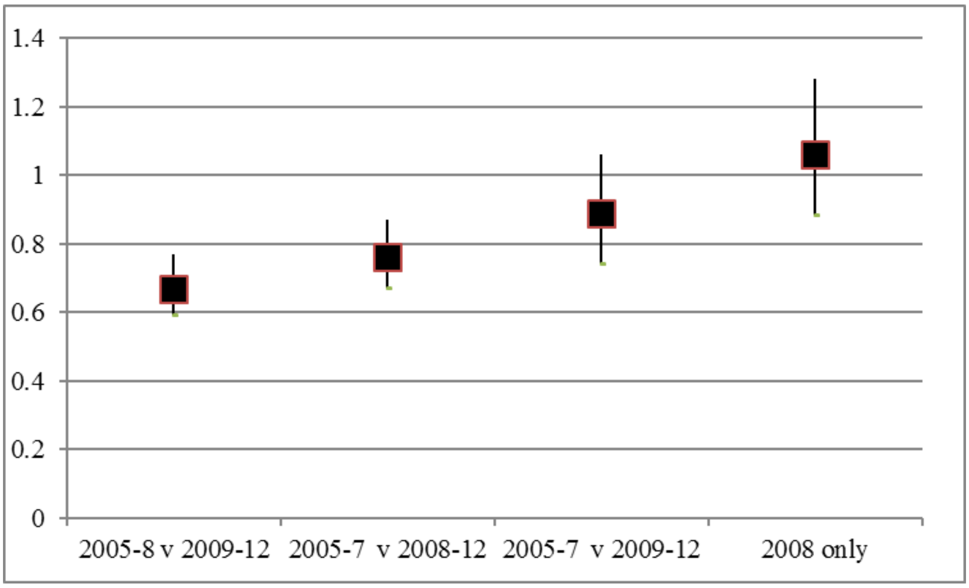
Graph 1: Odds ratios of effect of CCTs on probability of utility cycling, (95% confidence intervals)



The adjusted and unadjusted ORs for all variables for comparison periods 2005-7 compared to 2008-12 and 2005-7 to 2009-12 are shown in appendix 11.

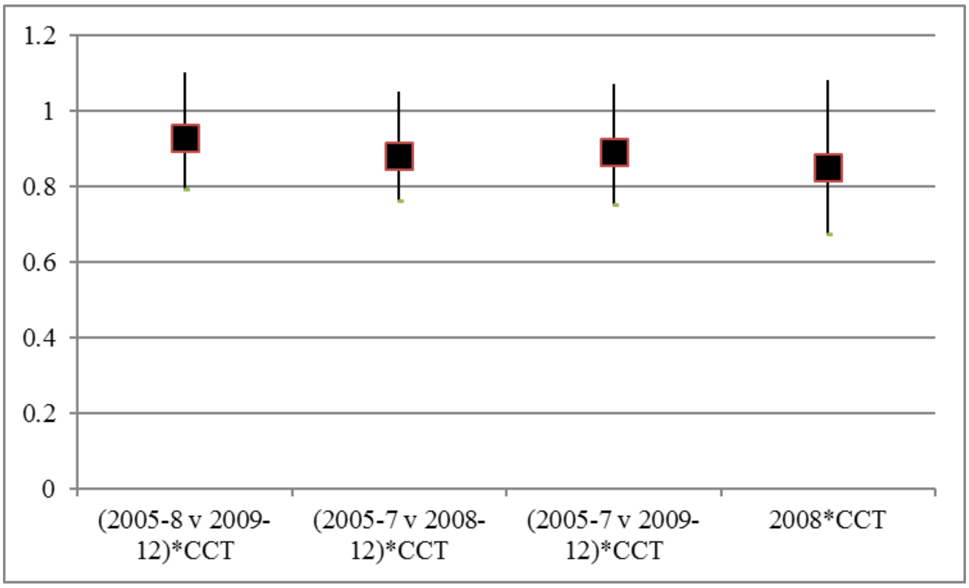
The effect of year on utility cycling was negative or non-significant apart from the single year 2008 that had a slight and non-significant positive effect (graph 2):

Graph 2: Odds ratios of effect of time periods on probability of utility cycling, (95% confidence intervals)



All interaction effects between the CCTs and year were non-significant (graph 3):

Graph 3: Odds ratios of effect of interaction between CCTs and Year (95% Confidence intervals):



Physical activity

Table 13 shows the adjusted and unadjusted odds ratios for having undertaken physical activity in the CCTs post intervention 2005-8 compared to 2009-12. Both before and after adjustment the odds ratio for having undertaken physical activity in a CCT was non-significant; unadjusted OR 0.98 (0.94 – 1.03), [AOR 0.99 (95% CI 0.94 – 1.03)]. The effect of year was positive, AOR 1.11 (1.06 – 1.16) whilst the interaction between CCT and year was non-significant; AOR 0.96 (0.91 – 1.03) Having adjusted for the interaction effects, the odds ratio for CCTs was 0.95 (=0.99*0.96).

Greater PA was associated with being male, aged 16 – 34, for whom socioeconomic status was not known, being without children in the household and of white ethnicity. Females, those in NS-SEC 5-9, with children in the household, aged 35+ or of an Asian, Black, other or Chinese ethnicity were significantly less likely to have undertaken physical activity than their corresponding reference category (Table 13):

Table 13: Effect of CCTs on sport or active recreation (including recreational walking and cycling), 2005 -2008 compared to 2009 – 2012

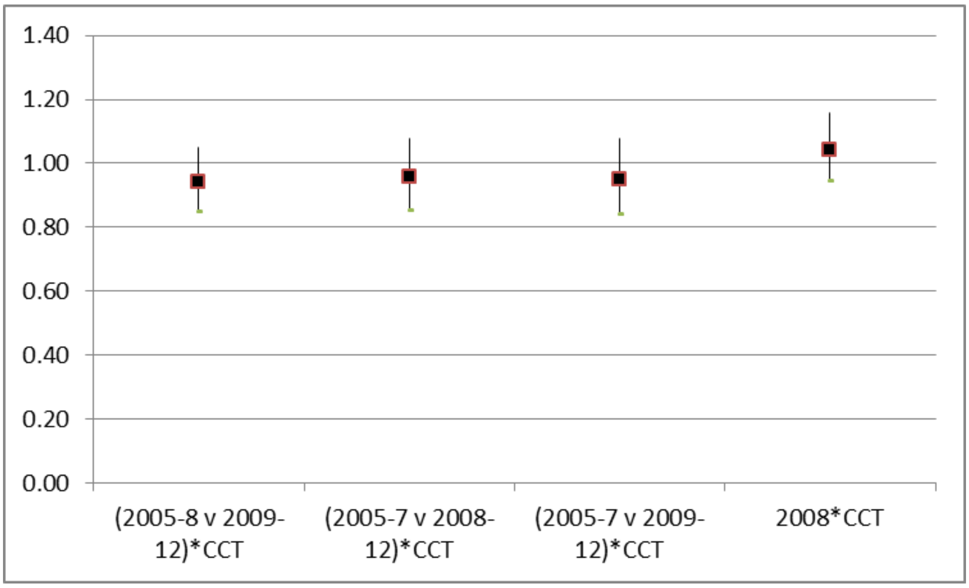
Independent variables	Unadjusted odds ratio (95% confidence interval)	Adjusted odds ratio (95% confidence interval)
CCTs	0.98 (0.94 – 1.03)	0.99 (0.94 – 1.03)
Year	1.01 (0.97 – 1.06)	1.11 (1.06 – 1.16)***
CCTs x Year 2005-8 v 2009-12	0.96[a] (0.92 – 1.04)	0.96[a] (0.91 – 1.03)
Gender		
Male	1.00	1.00
Female	0.72 (0.70 – 0.74)***	0.69 (0.74)***
NS-SEC		

NS SEC 1 – 4	1.00	1.00
NS SEC 5 – 8	0.49 (0.47 – 0.50)***	0.47 (0.45 – 0.49)***
NS SEC 9	0.98 (0.93 – 1.04)	0.86 (0.80 – 0.91)***
Missing	10.11 (5.09 – 20.08)***	16.63 (8.25 – 33.50)***
Child in household		
No children	1.00	1.00
Having children	0.53 (0.51 – 0.55)***	0.88 (0.85 – 0.92)***
Missing	0.65 (0.58 – 0.73)	0.38 (0.33 – 0.44)***
Age		
16 – 34	1.00	1.00
35 – 54	0.66 (0.63 – 0.69)***	0.61 (0.59 – 0.64)***
55+	0.23 (0.22 – 0.24)***	0.22 (0.21 – 0.23)***
Ethnicity		
White	1.00	1.00
Mixed	1.49 (1.28 – 1.73)***	1.00 (0.85 – 1.17)
Asian	0.91 (0.82 – 1.00)**	0.51 (0.46 – 0.56)***
Black	0.84 (0.73 – 0.96)**	0.58 (0.50 – 0.67)***
Other	0.99 (0.81 – 1.22)	0.73 (0.58 – 0.93)**
Chinese	1.26 (0.99 – 1.60)	0.74 (0.58 – 0.95)**
Missing	0.93 (0.83 – 1.04)	0.90 (0.80 – 1.03)

** p ≤0.05, *** p ≤0.01 [a]Interaction effect of geographical area and temporal trends on prevalence. This figure was used to adjust the OR of CCTs.

The OR for the effect of the CCTs on physical activity undertaken through sport and / active recreation was also calculated for the comparison periods 2005-7 compared to 2008-12 and 2005-7 compared to 2009-12 where the AOR was equal for both 0.98 (95% CI 0.92 – 1.01). As above the actual AORs for all time periods was calculated for each comparator period by multiplying the interaction effect by the ORs (Graph 4):

Graph 4: Odds ratios of effect of time periods on probability of having undertaken physical activity, (95% confidence intervals)



Discussion

Compared to their matched corresponding local authorities there was an approximately 50% greater probability of cycling in the CCTs compared to their matched controls. No significant difference in prevalence of PA between the CCTs and their controls was found indicating that increased PA through utility cycling in the CCTs was not associated with less PA in other life domains. This may indicate that the CCTs were successful in raising levels of PA in their respective populations. Others have similarly found that an increase in utility cycling is not associated with a reduction in other forms of physical activity (Foley, Panter et al. 2015, Panter, Heinen et al. 2016). CCTs may therefore have increased physical activity and potentially had a positive impact upon health; cycling is associated with a 28% reduction in all-cause mortality (Andersen, Schnohr et al. 2000). However, further research is needed to understand what effect this increase in the probability of utility cycling may have had on meeting recommended levels of PA.

Those more likely to have undertaken utility cycling were male, aged 16 – 34 and without classification of socio-economic status. No difference in utility cycling was found for either having a child in the household or for ethnicity. Those least likely to have undertaken utility cycling were female, in NS-SEC categories 5 – 9, aged 35+

and of Asian ethnicity. Those more likely to have undertaken PA through sport or active recreation were male, of unknown socio-economic status and aged 16 – 34. Those least likely to have undertaken sport or active recreation were female, in socio-economic categorisations 5 – 9, aged 35+ and be of Asian, Black, Chinese or 'other' ethnicity. The probabilities of both utility cycling and PA were exceptionally high for those for whom no socio-economic status is recorded. Reasons for this are unclear.

These findings are similar to those of others who have contrasted the demographic profiles of utility cycling in countries with a 'mature' cycling economies (Harms, Bertolini et al. 2015) where females make more cycling trips than males (Heinen, van Wee et al. 2010) and where as many as 24% of journeys by people aged 85+ may be by bicycle (Pucher, J. and Buehler, R. 2008). It is also within the context of an overall trend of a fall in utility cycling in both CCTs and their matched authorities as indicated by the negative interaction term. This is incongruent with National Travel Survey (NTS) data where the recorded number of trips (one-way journey) from 2015 – 2012 by bicycle only varied between 15 and 17 per person per year (Department for Transport 2015). Reasons for this are unclear but may be related to different measurements and definitions in the two surveys. Equally, there were a number of factors that that may or may not be supposed to have had an effect on both utility and / or sporting purposes during the time CCTs were funded; the RAC calculates that between 1998 and 2008 the real price of motoring fell by 18% (House of Commons Transport Committee 2009) and from 2008 Britain had sporting success in both the Beijing Olympics and the Tour de France. However, assessing the cause(s) of this trend is beyond the scope of this dissertation.

Those who undertook utility cycling were also of a similar demographic profile to those who undertook sport or active recreation. It is already noted as of concern that females, older people and those 'from lower socio-economic groups' are less likely to be physically active than others (HM Government 2015) with others seeking to design interventions to meet the needs of diverse groups (Mansfield, Anokye et al. 2015). In this sense the CCTs may have increased inequalities in relation to PA. Alternatively it may be that a cycling infrastructure / network needs to be developed before non-traditional groups start to cycle for transport purposes (Krizek, Forsyth et al. 2009). If so then CCTs may be the start of such an infrastructure. Whether further increases in utility cycling in England would lead to a more equitable demographic distribution of cycling is unclear. Whilst Transport for London (TfL) estimates that 55% of potential cyclists to be female, 60% aged 35 and over and 38% from Black or minority ethnicities (Transport for London 2010) the perception that ‘cycling’ is undertaken by ‘middle-aged men in lycra’ (MAMILs) (Aldred, Jungnickel 2014) will stifle this growth. Indeed, in some Asian populations the suggestion of utility cycling is ‘laughable’ (Steinbach, Green et al. 2011).

There are a number of limitations to this analysis. It would have been useful to estimate any modal shift from motorised transport as a result of the CCTs but unfortunately the variable ‘car-ownership has not been consistently included in the APS. There are some difficulties with the APS that may relate to that it was designed to measure participation in sport and active recreation so that utility cycling is derived from what it is not; cycling for ‘health, recreation, training or competition and not to get from place to place’. It is unclear, for example, how ‘cycling to work’ for health purposes would be categorised. Equally, the survey is only of households with landlines and excludes people in institutions. Whilst some directions of bias may be surmised the overall direction may be subject to speculation. ‘Institutions’ for example includes both residential homes for the elderly and army barracks. It is also possible that any increase in PA through utility cycling was compensated for by a decrease in PA through the workplace. However, this is thought unlikely given the increased automation of everyday tasks, evidence from the Health Survey for England (Craig, Mindell 2014) and current prevalence of obesity (Public Health England 2013). Further, for reasons outlined in chapter four this is not an RCT and there may be systematic differences between the CCTs and the controls used. Although those chosen were measured by the ONS to be the CCT’s ‘closest matched local authorities’ and differences in covariates were controlled for this cannot account for a) that the CCTs were by virtue of winning funding different from their controls and b) any unmeasured differences between CCTs and their controls.

Conclusion

CCTs were associated with an increased probability of utility cycling compared to their closest matched corresponding authorities. No corresponding decrease in PA through other life domains was found. The CCT programme may therefore have had a positive effect upon PA and therefore health. Integrating PA into everyday life may therefore be a means of increasing population levels of PA and physically active transport may be one means of achieving this. Those demographic groups who had greater probability of undertaking utility cycling were similar to those who also undertook PA through sport and / or active recreation. The CCTs may therefore have increased inequalities in PA. Whether they also represent a 'first step' towards increasing utility cycling more widely across the population will require further research.

Recommendations

- Further research is needed to understand what the effect of utility cycling may be on increasing PA in relation to UK Government guidance;
- Further research is needed to understand if expansion of programmes such as the CCTs can increase PA in other demographic groups;
- Survey instruments designed with utility cycling as a focus would be useful. This should include the consistent inclusion of variables likely to impact upon cycling behaviour;
- Future telephone surveys should not only include 'mobile' only households, particularly as these are likely to become more common and
- It may be useful to develop instruments that capture the PA of people in institutions. As these are often the most vulnerable in society this may be a health equity issue.

CHAPTER 6: Quantifying the contribution of utility cycling to population levels of physical activity[23]

The previous chapter showed that the CCT programme had a positive effect on utility cycling which did not displace physical activity undertaken in other life domains indicating an overall positive effect on PA. However, if policy makers are to make fully informed decisions they will need to know what size of effect interventions may have. This chapter therefore analyses the APS to quantify the contribution of utility cycling to meeting the recommended 150 minutes of PA per week.

Prevalence of cycling in England for transport purposes is far lower than in parts of Northern Europe where up to 37% of journeys between 2.5 and 5 km may be by bicycle (Pucher, J. and Buehler, R. 2008). Achieving a transport modal shift towards active transport may have public health benefits through such as improved air quality as motorised transport is a major source of pollutants such as $PM_{2.5}$ and Nitrogen dioxide (NO_2) (Walton, Dajnak et al. 2015). However, it is likely that the greatest public health benefits from such a modal shift are likely to come from increased physical activity. Using the current PA recommendations of 150 minutes a week it is estimated that physical inactivity in the UK is responsible for 10.5% of the incidence of CHD, 18.7% of colon cancer, 17.9% of breast cancer, 13.0% of type 2 diabetes and 16.9% of premature all-cause mortality (Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. 2012). This does not account for any potential effect on other long-term conditions such as musculo-skeletal conditions and dementia (Department of Health 2011).

Methods

This was an analysis of a cross-sectional survey (the APS) to determine whether there were significant differences in meeting the recommended levels of PA between those who undertook utility cycling and those who did not. In the APS participants were recorded as doing or not doing utility cycling in the past four weeks. This was

[23] A summarised version of this chapter has been published as a journal paper Stewart, G., Anokye, N.K. and Pokhrel, S. (2015). Quantifying the contribution of utility cycling to population levels of physical activity: An analysis of the Active People Survey. Journal of Public Health (Oxford, England), doi:10.1093/pubmed/fdv182.

then mapped to levels of PA that participants reported for the same period. Confounding variables were accounted for to quantify the net contribution of utility cycling to the probability of meeting the recommended levels of PA of 150 minutes a week.

Data

Data was sourced from APS 7 (October 2012 to October 2013). A full description of the APS is given in chapter five, p.90. In summary the APS is a random digit dialling (RDD) annual cross sectional survey weighted to be representative of each reporting geographical area (Local Authority, County Council, London Borough, Government region) by age, gender, ethnicity, socio-economic classification, household size and working status.

In this analysis APS 7 data was used with a final sample size of 165,191 of which 66,962 (40.5%) were male and 98,229 female (59.5%).

Outcome variable

Meeting recommended levels of PA was the outcome variable. Two alternative specifications of this variable was used- (a) meeting Chief Medical Officer (CMO) guidelines of 600 minutes moderate to vigorous PA in the past month either through any number of activities and (b) through one activity only (i.e. sport or utility cycling or utility walking).

Explanatory variables

The main explanatory variable was 'utility cycling'. It was measured as a binary variable that took a value of 1 if the respondent had undertaken utility cycling (either solely or in addition to other activities) and 0, no utility cycling had been undertaken. Utility cycling was defined as cycling for purposes other than for the purposes of health, recreation, training or competition. In APS7 three questions were required to derive this variable:

- The initial survey question is framed as: "I would now like you to think about any cycling you may have done. Please include any casual cycling in your local area, any cycling in the countryside or on cycling routes, cycling to or from work or any competitive cycling. In the last four weeks, that is since

[^INSERT DATE^] have you done any cycling?" The response categories were: 1 (Yes), 2 (No) and 3 (Don't know).

- If respondents answer 'yes' to the above they are subsequently asked: "In the last four weeks, that is since [^INSERT DATE^] have you done at least one continuous cycle ride lasting at least 30 minutes?" Response categories were: (1) Yes, (2) No, (3) Don't know
- If respondents answer 'yes' to the above a subsequent question is framed as "You said that you had cycled for 30 minutes on [^INSERT FROM Q7^ IF Q7 = Don't know INSERT 'at least one'] day(s) in the last four weeks. Can I ask, on how many of those days were you cycling for the purpose of health, recreation, training or competition not to get from place to place?

People who reported general cycling but reported zero days of cycling for the purposes of health, recreation, training or competition were considered as doing 'utility cycling'.

In addition to walking and cycling, APS participants were asked about all activities they had done in the last four weeks whether for competition, training, receiving tuition, socially, casually or for health and fitness. A list of the some 200 included sports / activities is listed in appendix 8. The following questions were used to derive the variable of having met physical activity guidelines (or not):

- "I have already asked you about walking and cycling. I would now like to ask you about other types of sport and recreational PA you may have done. Please think about all the activities you did, in the last four weeks, whether for competition, training or receiving tuition, socially, casually or for health and fitness, but do not include any teaching, coaching or refereeing you may have done. So thinking about the last four weeks, that is since [^INSERT DATE^], did you do any sporting or recreational PA?" Response categories were: (1) Yes, (2) No, (3) Interviewers do not read out. Code if respondent has stated they are severely disabled and do no activity. Code only as a last resort if respondent is frustrated or unhappy with activity, and (4) Don't know.
- "On how many days in the last four week have you done [^INSERT ACTIVITY^]. There are 28 days in the last four weeks". Response categories were number of days – Number range 0 to 28.

- "And how long do you USUALLY do [^INSERT ACTIVITY^] for?" Response categories hours and / or minutes.

Control variables

Control variables were selected based on the literature review in chapter three (see p.55) together with 'region' to discern if any effect was evident following cycling infrastructure investment in London. Other included explanatory variables therefore were: age (16-34, 35-54, 55+), gender (male/female), ethnicity (White, Mixed, Asian, Black, Chinese, Other), National Statistics Socio-Economic Classification (NS-SEC) grades (1 -4, 5-8, 9) , number of children in the household (0, ≥1) and region (North East, North West, Yorkshire and the Humber, West Midlands, East Midlands, East of England, South West, South East and London).

Statistical Analysis

Means (standard deviation —SD) and proportions were calculated for continuous data and categorical data as appropriate. Chi-square and Fischer's exact tests were used to examine whether missing data occurred completely at random. All variables were categorical and the indicator method was used to adjust for missing data (i.e. item non-response was included in the omitted category) (Petrou, Kupek 2008).

A logistic regression model was used to estimate the likelihood of meeting the recommended level of PA for participants who undertook utility cycling compared to no utility cycling whilst adjusting for other covariates. Two sets of logistic regression models for each specification of the outcome variable were fitted. First an unadjusted model allowed bivariate analysis examining the relationship between meeting the recommended level and each of the individual explanatory variables separately. Second, an adjusted analysis allowed a multivariate analysis in which all explanatory variables were included into the same model. The analysis was repeated for the sample of inner and outer London residents separately to see whether the likelihood of meeting the recommended levels of PA might differ and for the ten areas in England recording the highest levels of 'cycling to work'.

Goodness of fit was evaluated using quintiles rather than the usual deciles as the Hosmer-Lemeshow test is less likely to over- or under-predict observations in large data-sets with a smaller number of quantiles (Prabasaj, Pennellb et al. 2013).

Specification errors were tested in all models using the linktest. Both unadjusted and adjusted odds ratios (AORs) were computed for each independent variable. The threshold for statistical significance was set at ≤5% in all analyses. Analyses were undertaken using Stata SE 12 (StataCorp 2011).

Results

Sample characteristics

Table 14 summarises the characteristics of the sample. Of the 165,191 people who took part in APS7, 66, 962 (40.5%) were males. The majority of respondents were aged 55+ (51%), white (91%), of NS-SEC categories 1 – 4 (56%) and without children in the household (72%). Just over 20% participants in the sample were from South East of England whereas 4% came from the North East.

Table 14: Sample characteristics of APS 7

Characteristics	Number (%)	Met physical activity recommendations (%)
GENDER		
Male	66,962 (40.54)	41.87
Female	98,229 (59.46)	30.27
Age		
16 – 34	25,693 (15.55)	55.21
35 – 54	53,784 (32.56)	40.22
55+	83,622 (50.62)	25.54
Missing	2,092 (1.27)	
ETHNICITY		
White	149,998 (90.80)	34.79
Mixed	1609 (0.97)	47.67
Asian	4733 (2.87)	35.73
Black	3439 (2.08)	37.22
Other	748 (0.45)	38.77
Chinese	198 (0.12)	40.91
Missing	4,466 (2.70)	
SOCIO-ECONOMIC STATUS		
NS SEC 1 – 4	92,921 (56.25)	35.40
NS SEC 5 – 8	52,023 (31.49)	31.90
NS SEC 9	18,155 (10.99)	37.92
Missing	2,092 (1.27)	
IF CHILDREN PRESENT IN HOUSEHOLD?		
None	119,178 (72.15)	32.09
One or more	38,570 (23.35)	42.87
Don’t know / missing / refusal	7,443 (4.51)	
REGION		
North East	6,084 (3.68)	34.07
North West	20,286 (12.28)	33.84

Yorkshire	10,684 (6.47)	34.93
West Midlands	15,219 (9.21)	32.45
East Midlands	20,343 (12.31)	33.55
East	23,893 (14.46)	34.68
South West	18,893 (11.10)	33.90
South East	33,998 (20.58)	35.87
London	16,355 (9.90)	44.92

Compared to the national average London respondents were younger, more ethnically diverse and slightly more likely to have children (Table 15).

Table 15: London, inner-London and outer-London sample characteristics

	London		***Inner London***		***Outer London***	
Characteristics	***No (%)***	***Met PA guidelines***	***No (%)***	***Met PA guidelines (%)***	***No (%)***	***Met PA guidelines (%)***
Gender						
Male	6,394 (39.1)	3,200 (50.1)	2,345 (38.4)	1,236 (52.7)	4,028 (39.6)	1,954 (48.5)
Female	9,961 (60.9)	4,416 (41.6)	3,757 (61.6)	1,751 (46.6)	6,151 (60.4)	2,382 (38.7)
Age						
16 – 34	3,809 (23.29)	2,221 (58.3)	1,537 (25.2)	956 (62.2)	2,240 (22.0)	1,254 56.0)
35 – 54	5,974 (36.5)	3,017 (50.5)	2,285 (37.5)	1,257 (55.0)	3.670 (36.1)	1,766 (48.1)
55+	6,353 (38.8)	1,961 (30.9)	2,218 (36.4)	740 (33.4)	4,116 (40.4)	1,208 (29.6)
Missing	219 (1.3)		62 (1.0)		153 (1.5)	
Ethnicity						
White	10,999 (67.2)	5,044 (45.9)	4,037 (66.2)	2,047 (51.4)	6,861 (67.4)	2,938 (42.8)
Mixed	521 (3.2)	238 (54.3)	237 (3.9)	125 (52.7)	287 (2.8)	158 (55.1)
Asian	1,694 (10.4)	711 (41.9)	411 (6.7)	194 (47.2)	1,250 (12.3)	506 (40.5)
Black	1,929 (11.8)	781 (40.5)	879 (14.4)	347 (39.5)	1,069 (10.5)	445 (41.6)
Other	319 (2.0)	140 (43.9)	151 (2.5)	73 (48.3)	183 (1.8)	74 (40.4)
Chinese	69 (0.4)	37 (53.6)	30 (0.5)	17 (56.7)	37 (0.4)	18 (48.7)
Missing	824 (5.0)					
Socio-economic status						
NS SEC 1 – 4	9,518 (58.20)	4,502 (47.3)	3,601 (59.0)	1,889 (52.5)	5,825 (57.2)	2,574 (44.2)
NS SEC 5 – 8	4,099 (25.06)	1,523 (37.2)	1,440 (23.6)	556 (38.6)	2,647 (26.0)	967 (36.5)
NS SEC 9	2,519 (15.40)	1,174 (46.6)	999 (16.4)	508 (50.9)	1,554 (15.3)	687 (44.2)
Missing	219 (1.34)	147 (67.1)	62 (1.0)			

				34 (54.9)	153 (1.5)	108 (70.6)
No of children in house						
None	10,928 (66.8)	4,645 (42.5)	4,254 (69.7)	2,011 (47.3)	6,638 (65.2)	2,635 (39.7)
One or more	4,554 (27.8)	2,300 (50.5)	1,511 (24.8)	824 (54.5)	2,938 (29.4)	1,454 (48.7)
Don't know / missing / refusal	873 (5.3)	401 (45.9)	337 (5.5)	152 (45.1)	552 (5.4)	247 (44.6)

A total of 112, 816 (68.29%) participants reported undertaking at least 1 minute of PA in the past four weeks. In London 12,625 (77.19%) reported the same. Approximately a quarter of respondents reported at least one minute of utility walking and no other activity, less than 1% utility cycling and no other activity and just less than 20% one minute sport with no other activity (table 16).

Table 16: Participants reporting at least one minute PA – England and London

	England Number (%)	London Number (%)	Inner London Number (%)	Outer London Number (%)
At least 1 min utility walking (no sport, no utility cycling)	38,783 (23.48)	4672 (28.57)	1755 (28.76)	2893 (28.42)
At least 1 min utility cycling (no utility walking, no sport)	1130 (0.68)	77 (0.47%)	38 (0.62)	39 (0.38)
At least 1 min sport (no utility walking, no utility cycling)	31,325 (18.96)	2264 (13.84)	777 (12.73)	1481 (14.55)
At least 1 min utility walking or Utility cycling or sport	112,816 (68.29)	12,625 (77.19)	4,808 (78.79)	7,619 (74.85)

Contribution of utility cycling to meeting the recommended level of physical activity

Table 17 shows the unadjusted and adjusted odds of meeting the recommended level of participation through any number of activities (Model 1) and through one activity only (Model 2) for the explanatory variables. Individuals who undertook utility cycling had higher odds of meeting the recommended levels of PA compared with those who did not undertake utility cycling (AOR=4.08, p<0.001 in Model 1 and AOR=2.73, p<0.001 in Model 2). Utility cyclists were therefore approximately about 3-4 times as likely to meet recommended levels of PA as those who were not, after allowing for other correlates.

Meeting guidelines was associated with being younger, male, of higher socio-economic position, having children, being from London and being of mixed ethnicity though all other ethnicities were less likely than those of white ethnicity to meet guidelines.

Table 17: Unadjusted and adjusted odds of meeting physical activity guidelines

	Model 1 (meeting guidelines regardless of any number of activities)		**Model 2 (meeting guidelines through one activity only)**	
Independent variables	*Unadjusted Odds ratio (95% Confidence Interval)*	*adjusted Odds ratio (95% Confidence Interval)*	*Unadjusted Odds ratio (95% Confidence Interval)*	*adjusted Odds ratio (95% Confidence Interval)*
UTILITY CYCLING				
No utility cycling	1.00	1.00	1.00	1.00
Utility Cycling	5.21 (4.96-5.47)***	4.08 (3.88-4.29)***	3.56 (3.40-3.72)**	2.73 (2.61-2.86)***
AGE				
16 - 34	1.00	1.00	1.00	1.00
35 - 54	0.59 (0.58-0.61)	0.59 (0.57-0.61)***	0.62 (0.60-0.64)***	0.62 (0.60-0.64)***
55+	0.29 (0.28-	0.30 (0.29-	0.32 (0.31-0.32)***	0.33 (0.32-0.34)***

	0.30)	0.31)***		
GENDER				
Male	1.00	1.00	1.00	1.00
Female	0.61 (0.60-0.63)	0.65 (0.64-0.66)***	0.60 (0.59-0.62) ***	0.63 (0.62-0.65)***
ETHNICITY				
White	1.00	1.00	1.00	1.00
Mixed ethnicity	1.78 (1.62-1.97)***	1.11 (1.01-1.24)**	1.71 (1.55-1.88)**	1.12 (1.01-1.24)**
Asian	1.08 (1.02-1.14)**	0.67 (0.62-0.71)***	1.04 (0.98-1.11)	0.67 (0.63-0.72) ***
Black	1.10 (1.03-1.18)**	0.71 (0.66-0.77)***	1.11 (1.04-1.19)**	0.75 (0.70-0.81) ***
Other	1.20 (1.04-1.39)**	0.76 (0.66-0.89)***	1.19 (1.02-1.38) **	0.79 (0.68-0.93) ***
Chinese	1.35 (1.01-1.78)**	0.82 (0.61-1.10)	1.30(0.98-1.72)	0.83 (0.62-1.11)
SOCIO-ECONOMIC STATUS				
NS-SEC 1 - 4	1.00	1.00	1.00	1.00
NS-SEC 5 – 8	0.81 (0.80-0.83)***	0.82 (0.80-0.83)***	0.85(0.84-0.87)***	0.86 (0.84-0.88) ***
NS-SEC 9	1.09 (1.06-1.13)***	0.97 (0.93 – 1.01)	1.11 (1.08-1.15)***	0.99 (0.95-1.03)
CHILDREN PRESENT IN HOUSEHOLD				
No children	1.00	1.00	1.00	1.00
Having children	1.69 (1.65-1.73)***	1.06 (1.04-1.10)***	1.59 (1.55-1.63)***	1.04 (1.01-1.07)**
REGION				
North East	1.00	1.00	1.00	1.00
North West	0.99 (0.93-1.05)	0.98 (0.92-1.04)	0.99 (0.93-1.05)	0.97 (0.92-1.04)
Yorkshire	1.03 (0.97-1.10)	1.00 (0.94-1.08)	1.04 (0.97-1.11)	1.02 (0.95-1.09)
West Midlands	0.94 (0.89-1.00)	0.93 (0.87-0.99)**	0.93 (0.87-0.99)**	0.92 (0.85-0.98)**

East Midlands	0.98 (0.93-1.04)	0.95 (0.90 -1.02)	0.98(0.92-1.04)	0.95 (0.90-1.02)
East	1.04 (0.99-1.11)	0.97 (0.90 – 1.03)	1.03(0.97-1.09)	0.97 (0.91-1.03)
South West	1.01 (0.95 - 1.07)	0.98 (0.92 -1.05)	0.99 (0.93-1.05)	0.98 (0.92-1.04)
South East	1.10 (1.04-1.17)**	1.04 (0.98-1.10)	1.08 (1.02-1.15)	1.03 (0.97-1.09)
London	1.41 (1.33-1.50)***	1.28 (1.20-1.36)***	1.32 (1.24-1.41)***	1.21 (1.13-1.29) ***

**p ≤0.05 ***p≤0.001

In inner and outer London, utility cycling was associated with respectively six and five times greater odds of meeting PA guidelines compared to no utility cycling. Other variables in outer London had the same effect as nationally in predicting the likelihood of meeting recommended guidelines. In inner-London, however, the difference between genders in predicting likelihood of meeting recommended levels disappeared (table 18).

Table 18: Unadjusted and adjusted odds ratios for meeting physical activity guidelines regardless of any number of activities in inner and outer London

	Inner London		**Outer London**	
Independent variables	*Unadjusted Odds ratio (95% Confidence Interval)*	*adjusted Odds ratio (95% Confidence Interval)*	*Unadjusted Odds ratio (95% Confidence Interval)*	*adjusted Odds ratio (95% Confidence Interval)*
UTILITY CYCLING				
No utility cycling	1.00	1.00	1.00	1.00
Utility Cycling	7.93 (6.17-10.18)***	6.08 (4.07-7.86)***	6.62 (5.30-8.27)***	5.26 (4.19-6.61)***
AGE				

16 - 34	1.00	1.00	1.00	1.00
35 - 54	0.74 (0.65-0.85)***	0.69 (0.60-0.80)***	0.73 (0.66-0.81)***	0.66 (0.59-0.74)***
55+	0.30 (0.26-0.35)***	0.28 (0.24-0.33)***	0.33 (0.29-0.36)***	0.30 (0.26-0.34)***
GENDER				
Male	1.00	1.00	1.00	1.00
Female	0.78 (0.71-0.87)***	0.91 (0.81-1.01)	0.67 (0.62-0.73)***	0.73 (0.67 - 0.79)***
ETHNICITY				
White	1.00	1.00	1.00	1.00
Mixed ethnicity	1.05 (0.81-1.37)	0.82 (0.62-1.08)	1.64 (1.29-2.07)***	1.20 (0.94-1.54)
Asian	0.85 (0.69-1.03)	0.63(0.51-0.79)***	0.91 (0.80-1.03)	0.65 (0.58-0.75)***
Black	0.62 (0.53-0.71)***	0.54 (0.46-0.64)***	0.95 (0.84-1.08)	0.73 (0.63-0.84)***
Other	0.89 (0.64-1.23)	0.67 (0.47-0.95)**	0.91 (0.67-1.22)	0.68 (0.49-0.93)**
Chinese	1.24 (0.60-2.55)	0.86 (0.40-1.82)	1.26 (0.66-2.41)	0.84 (0.43-1.64)
SOCIO-ECONOMIC STATUS				
NS-SEC 1 - 4	1.00	1.00	1.00	1.00
NS-SEC 5 – 8	0.57 (0.50-0.65)***	0.70 (0.61-0.80)***	0.73 (0.66-0.80)***	0.73 (0.66-0.81)***
NS-SEC 9	0.94 (0.81-1.08)	0.93 (0.79-1.12)	1.00 (0.89-1.12)	0.89 (0.78-1.02)
CHILDREN PRESENT IN HOUSEHOLD				
No children	1.00	1.00	1.00	1.00
Having children	1.34 (1.19-1.51)***	0.99 (0.86-1.13)	1.43 (1.31-1.57)***	1.00 (0.90-1.11)

**p ≤0.05 ***p≤0.001

2011 census data indicates that the ten local authorities with the highest rates of commuter cycling are Cambridge, Oxford, the Isles of Scilly, Hackney, York, Gosport, Islington, Norwich, Kingston upon Hull and Lambeth respectively (Office for National Statistics (ONS) 2014). Individually the odds ratio in favour of utility cycling in meeting PA guidelines ranged from 3.19 (95% CI 1.52 to 6.73) in Islington to 10.31 (95% CI 3.05 to 34.82) in Lambeth (Table 17) whilst collectively the odds ratio in favour of utility cycling for meeting PA guidelines was 4.90 (95% CI 4.03 to 5.96) (table 19).

Table 19: Odds ratios in favour of utility cycling for meeting physical activity guidelines in areas recording highest levels of cycling in 2011 census

Area	OR (95% Confidence interval)
Cambridge	6.32 (4.04 to 9.88)
Oxford	7.09 (4.10 to 12.27)
Isles of Scilly	3.66 (1.04 to 12.86)
Hackney	7.21 (3.51 to 14.78)
York	6.08 (3.53 to 10.47)
Gosport	4.74 (2.50 to 9.02)
Islington	3.20 (1.52 to 6.73)
Norwich	5.79 (2.94 to11.38)
Kingston upon Hull	3.31 (1.75 to 6.25)
Lambeth	10.31 (3.05 to 34.82)
Overall	4.90 (4.03 to 5.96)

Collectively the odds ratio in favour of meeting PA guidelines in the towns reporting highest levels of commuter cycling were 1.65 (95% CI 1.60 to 1.70) before adjustment to 4.90 (95% CI 4.03 to 5.96) in model 1 and 1.27 (95% CI 1.22 to 1.31) before adjustment to 2.71 (95% CI 2.28 to 3.22) after adjustment (Table 20):

Table 20: Unadjusted and adjusted odds of meeting physical activity guidelines in 'top 10' cycling towns in England and Wales (Model 1 and Model 2)

	Model 1 (meeting guidelines regardless of any number of activities)		**Model 2 (meeting guidelines through one activity only)**	
Independent variables	*Unadjusted Odds ratio (95% Confidence Interval)*	*adjusted Odds ratio (95% Confidence Interval)*	*Unadjusted Odds ratio (95% Confidence Interval)*	*adjusted Odds ratio (95% Confidence Interval)*
UTILITY CYCLING				
No utility cycling	1.00	1.00	1.00	1.00
Utility Cycling	1.65 (1.60 to 1.70)***	4.90 (4.03 to 5.96)***	1.27 (1.22 to 1.31)***	2.71 (2.28 to 3.22)***
AGE				
16 - 34	1.00	1.00	1.00	1.00
35 - 54	0.60 (0.50 to 0.72)***	0.62 (0.50 to 0.71)***	0.65 (0.55 to 0.77)***	0.64 (0.54 to 0.76)***
55+	0.28 (0.23 to 0.33)***	0.27 (0.22 to 0.36)***	0.32 (0.27 to 0.38)***	1.40 (0.66 to 2.95)
GENDER				
Male	1.00	1.00	1.00	1.00
Female	0.71 (0.63 to 0.81)***	0.75 (0.64 to 0.82)***	0.71 (0.63 to 0.81)***	0.73 (0.64 to 0.82)***
ETHNICITY				
White	1.00	1.00	1.00	1.00
Mixed ethnicity	1.13 (0.75 to 1.70)	0.82 (0.53 to 1.25)	1.05 (0.70 to 1.58)	0.78 (0.52 to 1.19)
Asian	1.24 (0.87 to	0.81 (0.55 to	1.13 (0.80 to	0.76 (0.54 to

	1.76)	1.17)	1.61)	1.12)
Black	0.87 (0.66 to 1.14)	0.69 (0.59 to 0.91)**	0.90 (0.69 to 1.19)	0.74 (0.56 to 0.98)**
Other	0.49 (0.25 to 0.96)	0.40 (0.20 to 0.79)**	0.63 (0.33 to 1.20)	0.54 (0.28 to 1.04)
Chinese	0.66 (0.13 to 3.35)	0.34 (0.69 to 1.69)	0.44 (0.08 to 2.43)	0.26 (0.05 to 1.97)
SOCIOECONOMIC STATUS				
NS-SEC 1 - 4	1.00	1.00	1.00	1.00
NS-SEC 5 – 8	0.66 (0.58 to 0.76)***	0.70 (0.61 to 0.80)***	0.72 (0.63 to 0.83)***	0.76 (0.66 to 0.87)***
NS-SEC 9	0.93 (0.77 to 1.13)	0.92 (0.73 to 1.17)	0.94 (0.78 to 1.13)	0.90 (0.72 to 1.13)
CHILDREN PRESENT IN HOUSEHOLD				
No children	1.00	1.00	1.00	1.00
Having children	1.45 (1.26 to 1.68)***	0.98 (0.85 to 1.15)	1.40 (1.22 to 1.61)***	0.98 (0.84 to 1.15)

**p ≤0.05 ***p≤0.001

Discussion

Following chapter five that showed that utility cycling had a net positive effect on prevalence of PA this chapter sought to understand the difference that utility cycling might make to meeting recommended guidance for PA. This is in the context of marked differences in the use of cycling as a means of transport even in developed countries and where levels of car-ownership are similar to the UK such as the Netherlands, Denmark and Germany (Pucher, J. and Buehler, R. 2008). There is also a marked difference in cycling to work in English towns (Office for National Statistics (ONS) 2014). Variation in prevalence can imply potential for change.

The APS is the largest survey of sport and active recreation undertaken in Europe (Sport England undated). Analysis of this survey indicates that the probability of those who undertake utility cycling meeting PA guidelines is considerably higher in those who undertake utility cycling than those who do not. Nationwide those undertaking utility cycling were four times more likely to meet PA guidelines, in Oxford seven times and in Cambridge and inner-London six times. In the 'top 10 cycling towns' it was five times. In a sample of 500 in a Local Authority the numbers of people reporting utility cycling can be small. However, it is noted that in Lambeth those who undertook utility cycling were 10 times more likely to meet PA guidelines than those who did not (48 people reporting utility cycling). In those who undertake utility cycling it is a significant factor in helping to meet PA guidelines.

In England, it is perhaps unsurprising that those with the highest odds of meeting guidelines through utility cycling were young and male. England is a not a cycle-friendly country and cycling is associated with those who are more risk-tolerant and sportier (Aldred, Woodcock et al. 2015). It is therefore possible that these findings reflect that those demographics which are already active are also those that are more likely to undertake utility cycling. In this sense utility cycling may be reinforcing inequalities in PA. However, what may be of more interest is that the traditional disparity between males and females disappeared in inner-London where considerable effort has been made to improve the cycling infrastructure. Women are often considered an 'indicator species' for cycle-friendly infrastructure, partly because a number of disciplines have found women to be more risk-averse and partly because their journeys tend to be more practical and task-orientated (Baker 2009). This finding therefore may indicate that the developments in inner-London are having a positive effect not only on physical activity but on gender inequalities in PA. It does however stand in contrast to the findings of Aldred et.al who found almost no difference between the 2001 and 2011 censuses data in the proportion of males and females cycling to work including in inner-London (Aldred, Woodcock et al. 2015). This may reflect different outcome variables; meeting PA guidelines compared to 'cycling to work' or it may reflect different measurement tools; the APS and census data. Although encouraging therefore further investigation of this is warranted. However, it is also noted that in the Netherlands, Germany and Denmark women cycle almost as much as men and rates only decline slightly with age (Pucher, J. and Buehler, R. 2008). Equally, it is of note is that the only region in which the odds ratio of meeting guidelines was statistically significant was London.

Utility cycling was more common in NS-SEC 1–4 than NS-SEC 5–8 but with no significant difference in those in NS-SEC 9. The unadjusted odds ratio indicated significantly more utilitarian cycling in NS-SEC 9 but this disappeared after adjusting for confounding factors. Given the potential for cost-saving it is perhaps counter-intuitive that utility cycling was also associated with more affluent socio-economic categories. Contrary to the above discussion it is evident that in England even utilitarian cycling is associated with 'middle-aged men in lycra' (mamils) for whom the cycle and its associated paraphernalia are not only a means of transport but may also represent conspicuous consumption (Steinbach, Green et al. 2011). The current predominance of cycling as male, white and affluent signifies that its potential to reduce inequalities is not being realised, in itself part of the mission statement for Public Health England (Public Health England 2015) and statutory guidance to for all Local Authorities and Clinical Commissioning Groups through their Health and Wellbeing Strategies (Department of Health 2013). Again, despite some promising findings it is evident that England has a long way to go if it is to become a cycling country for all.

It is estimated that long-term conditions account for some 70% of the NHS budget (National Health Service (NHS) 2014), that 20 – 40% of these conditions could be avoided by meeting PA guidelines (Department of Health 2011) and that 42.9% of the working population of 26.5 million has a commuting journey of under 5km (Office for National Statistics (ONS) 2014). This is considerably less than the 8 km cited by the BMA that a 'person can easily cover' (British Medical Association 2010). The Department for Transport has reported that schemes that encourage walking and cycling have a cost benefit ratio of 5.62:1, far above the threshold considered to be of 'high value' of 4:1 by the DfT (Department for Transport November 2014). It has been further estimated that a doubling of the distance walked and an eight-fold increase in that cycled would save the NHS £17 billion within 20 years (Jarrett, Woodcock et al. 2012). The policy implications of these findings are therefore profound for health, healthcare, local Government and transport sectors.

This study has a few noteworthy limitations. Data is cross-sectional and therefore any finding here cannot be taken as causal. This study cannot determine whether people who were inclined to undertake more PA were also those who were inclined to cycle more. Indeed, this is a very plausible possibility. Equally, there may be a third variable leading to both PA and utility cycling. The APS was not designed to measure cycling for non-sporting or non-health purposes and consequently the variable of utility cycling is not entirely satisfactory; it is not clear how those who stated that they cycled to work for health purposes would have been categorised in the APS survey. This is regrettable as it precludes measurement of a healthy behaviour integrated into everyday life. Two further limitations arise from the APS; firstly there is not recording in the survey of how 'vigorous' cycling was. Actual PA guidance is for 150 minutes moderate activity or 75 minutes vigorous activity or a combination of the two. CMO guidance is that cycling at 10 – 12 mph is likely to contribute to moderate activity whilst 12 – 14 mph vigorous (Department of Health 2011). As all cycling in this study was effectively counted as 'moderate' activity this analysis may therefore have considerably underestimated the actual contribution of utility cycling to meeting PA guidelines. This may be a significant effect as Transport for London (TfL) estimates that some 27% of the commuting population meet PA recommendations through active travel alone (including walking to and from transport hubs such as bus-stops and underground stations) (Transport for London 2014) and 58% of Londoners have been found to undertake some form of active travel on any given day (Fairnie, Wilby et al. 2016). Equally in The Netherlands 38% of adults (aged 18 or over) have been found to meet or exceed 10 MET-hours per week through active travel (walking and cycling) alone (Fishman, Bocker et al. 2015). Secondly, an important confounder for cycling, car-ownership, was not included in this survey (though it is included in earlier APS surveys).

Conclusion

These results suggest that in those who undertake utility cycling it has a considerable impact on their probability of meeting PA guidelines. More sensitive instruments than the APS able to differentiate between moderate and vigorous cycling activity may indicate that this effect is much stronger than implied by the headline figures here. This analysis was a cross-sectional study and causality cannot be assumed but if verified these findings imply that utility cycling has the potential to have a significant impact on health, healthcare and the NHS budget. That the traditional gap in PA between the genders disappeared is an encouraging initial finding which warrants further research and may indicate the success of cycle infrastructure developments in inner-London. Despite this it remains that nationally cycling remains male, white and affluent indicating that much more work is needed before England becomes a high-prevalence cycling country.

Recommendations

- These findings are significant and should be disseminated to the public health community in particular and policy makers in general;
- Future research into the effect of utility cycling on PA should differentiate between moderate and vigorous intensity cycling;
- Any future survey should constantly include other variables that might impact upon prevalence of utility cycling. This should include 'car ownership';
- The results of this study need to be confirmed through further studies that note the limitations of this work. In particularly prospective, rather than cross-sectional studies would be useful to inform the public health evidence base
- Further studies are needed to indicate if the disappearance of a difference between the genders in cycling in inner-London is a statistical anomaly, the result of changes in infrastructure or due to other factors.

CHAPTER 7: Discussion

In this chapter I will discuss a number of conclusions provided in earlier chapters as whole. Specifically, I will outline the contribution of this thesis to the existing knowledge base, its limitations and implications, its potential importance to public health policy and practice and implications from this thesis for future research.

Contributions of this thesis

This thesis contributed to the literature through its consideration of how PA might be integrated into everyday life. Raising levels of PA is of concern both nationally (Sport England 2016) and internationally (World Health Organisation 2016). It is difficult to discern time-trends of PA but it is apparent that current levels in England are insufficient for maximal health. The CMO has stated that ‘the easiest and most acceptable forms of physical activity are those that can be incorporated into everyday life. Examples include walking and cycling instead of travelling by car (Department of Health 2011). This thesis therefore explored evidence of such an integration of PA into everyday life and what might its effects be both at a population level and for meeting recommendations for PA.

Chapter 3 is a systematic literature review that has been published as a separate paper (Stewart, Anokye et al. 2015b). It highlighted that there is a lack of evidence as to what interventions might increase commuter cycling and that where evidence was found it was frequently problematic in that studies frequently did not include a control group thereby making consideration of the counter-factual difficult, pertained to specific populations, included baselines that preceded interventions or had high loss to follow-up indicating potential selection bias. Second, and more problematically from a public health perspective it found that there are numerous influences that a) might affect the uptake of commuter cycling and b) make it very difficult to isolate the effect of an intervention on utility cycling. This itself may be contributing to the ‘inverse evidence law’ whereby those interventions that may be most likely to affect population health are precisely those for which there is least evidence. Thirdly, chapter three highlighted the practical difficulties of a systematic review of ‘cycling’ due to the ubiquity of this term in the academic literature. Fourthly, related to this, this chapter found that less robust search inclusion terms would be likely to result in markedly different conclusions from those found in this chapter. Fifthly, it was noted that where studies have sought to assess impact of interventions on utility cycling no study in this literature review also sought to assess the impact of any change in utility cycling on overall prevalence of PA. Finally, one of the questions posed by this review; what is it that will raise population levels of cycling sufficiently to achieve health gain has already been noted in the academic literature (Panter, Ogilvie 2016).

Chapter 4 contributed to the literature by providing a conceptual framework for a systematic enquiry into how the effect of CCTs on both utility cycling and PA could be analysed. This is a framework that may be used for similar questions and / or in other areas. The methodological and practical difficulties of applying traditional clinical evaluative methodologies to interventions aimed at populations rather than individuals were illustrated and an alternative hierarchy of evidence more suitable to population level interventions illustrated. It was shown both that the CCT programme can be regarded as a ‘natural experiment’ and that it meets MRC criteria for the evaluation of such an intervention. Fourthly this chapter searched the UK dataservice to establish what data-sources might be appropriate for the evaluation of the effect of CCTs on both utility cycling and PA. The lack of appropriate data-sets for the analysis of commuter cycling was noted.

An abstract of Chapter 5 has been accepted by the Lancet (Stewart, Anokye et al. In press). This chapter contributes to increased knowledge by firstly showing how a routinely collected dataset can be used to evaluate the effect of a large-scale intervention on both utility cycling and PA in other life-domains. This includes the production of a data-set through which such an evaluation can be undertaken. It is shown that the framework used allows for some control for variables that might affect prevalence of each (though unobserved differences between the CCTs and their matched controls could not be accounted for). Assessing the effect of the intervention on both utility cycling and PA in other life-domains is of critical importance if the benefits of increased PA are to be realised. Thus this thesis contributed to the literature by establishing that whilst CCTs may have had a positive effect on utility cycling no significant effect was found on prevalence of PA in other life-domains. In this sense therefore the CCTs might be regarded as a successful public health intervention. Those most likely to have cycled for utility purposes were male, aged 16 - 34 year olds, and those in the ONS socio-economic category NS SEC 9. Those least likely were those in NS SEC 5 - 8 and of Asian ethnicity.

Chapter 6 has been published as a separate chapter (Stewart, Anokye et al. 2015a). The aim of this chapter was to determine that if CCTs contributed to increasing PA what might be the effect of utility cycling in meeting PA recommendations. It was shown that those who cycled for utility purposes were four times more likely to meet PA recommendations than those who did not undertake utility cycling. In inner-London this increased to six times and in the towns with highest utility cycling prevalence as measured by cycling to work five times. In inner-London, where there has been substantial investment in the cycling infrastructure the traditional disparity in which males are often observed to be more physically active than females disappeared. This is a potentially important finding as a higher prevalence of female cyclists is frequently regarded as a marker of better cycling infrastructure. Those who were more likely to meet PA guidelines were male, younger (aged 16 – 34), white, in NS SEC 1 – 4, living in London and to be without children in the household. Those least likely were female, aged 55+, of Asian ethnicity, in NS SEC 5 – 8, be without children in the household and be living in the West Midlands.

In exploring how PA might be increased through integration into everyday life via utility cycling this thesis has made a number of contributions to the literature and knowledge. This has included increasing the understanding of the evidence base for interventions that might increase utility cycling, establishing a framework through which this and similar research questions might be addressed, identifying a database for this analysis, analysing the effect of the CCTs on utility cycling and if it had any concomitant effect on PA and a further analysis of the potential contribution of utility cycling to meeting PA guidance. The overall contribution therefore is to establish that utility cycling could be an intervention worthy of consideration for the promotion of PA at a population level.

Limitations

No research is without its limitations and this thesis is no exception. These should be noted for they provide a context within which the implications of this work should be considered.

Much of this work is based on the APS commissioned by Sport England. Although a random digit dialling survey weighted to be representative of each reporting geographical area this survey may not be truly representative of the English population; not only are people in institutions excluded but the response rate of approximately 27% indicates a potential selection bias for which the direction cannot be ascertained. For example it may be that people in some institutions are more likely to undertake utility cycling; young males in the armed forces, or less likely; those who are incarcerated or residential homes. Equally, people who participate in sport may be simply less likely to be available to answer the phone. Perhaps of increasing importance since the survey began in 2005 mobile telephone only households (that do not have landline telephones) are also excluded. Again, the direction of this bias is difficult to ascertain though it may be surmised that this is more likely to affect young people. However, in the sense that this is a retrospective study and the APS was found to be the only dataset appropriate for evaluation purposes it is difficult to see how these limitations could have been avoided.

A second obvious limitation is that as observed in the Health Survey for England (HSE) 2008 there can be wide disparities between self-report and objective measurements of physical activity. HSE 2008 found that whilst 39% of males and 27% of females reported meeting the (then) recommended guidelines of five sessions of PA per week of 30 minutes duration PA as measured through the use of accelerometers in a self-selected sub-sample wearing the devices for 10 hours a day for seven days recorded only 6% of males and 4% of females actually meeting guidelines (Craig, Mindell et al. 2009). Accelerometers are not themselves the ‘gold standard’ for measurement of PA and are therefore not themselves without limitations; the gold standard is doubly labelled water and accelerometers have been found to be inaccurate accurate when measuring such as slower running, static exercise and may not be suitable for either contact or water-based sports (Hills, Mokhtar et al. 2014). However, again it is hard to see how this limitation could have been avoided for an intervention that has already happened.

A more serious limitation evident from the systematic review is that following the 'Copenhagenize' top cycling cities in the world rankings only three cities in the top 20 are in countries with a first language of English and none in the top 10[24]. The obvious implication of this is that if good practice exists a review that only included English language publications may easily exclude examples of good practice that have been published in other languages. Unfortunately a lack of resources for translation made this inevitable. As alluded to above a further issue was that very quickly it became apparent that any search of the evidence base including the term 'cycle' quickly becomes cumbersome. The initial database search returned over 2 million 'hits'. It is unclear how this might have been avoided; every database search apart from Scopus returned over 10,000 hits and two over a million each. Reducing the number of search terms inevitably risks bias as did the necessary use of filters. A step forward may be from copying the Dutch language where 'fiets' refers to what in English would be termed a 'sit-up' or 'utility cycle' whereas 'wielrenfiets' refers to race or sporting cycling[25]. An English equivalent of 'fiets' could be adopted. The term 'utility cycling' may be a prospective candidate going forward. As a balance between a lack of evidence found by studies using robust inclusion criteria (Ogilvie, Egan et al. 2004, Yang, Sahlqvist et al. 2010) and the recognition that population level interventons may be excluded by this approach a more pragmatic approach advocated by Pucher (Pucher, Dill et al. 2010) was employed. Undoubtedly the systematic review did not include all studies. It is noted for example that such as the evaluation of 'Odense – Danmarks Nationale Cykelby' (Odense – Denmarks National Cycle City) was excluded from this review as a) it did not include pre / post

[24] Ranking of 150 cities based on 13 criteria of advocacy, bicycle culture, bicycle facilities, bicycle infrastructure, bike share programme, gender split, modal share, modal share increase since 2006, perception of safety, political climate regarding urban cycling, social acceptance of cyclists by drivers and the community at large, urban planning and traffic calming. http://copenhagenize.eu/index/index.html site accessed 5th September 2016.

[25] Lycra in the streets of the Netherlands. https://bicycledutch.wordpress.com/2012/05/28/lycra-on-the-streets-of-the-netherlands/ Site accessed 12th March 2016.

evaluation data and b) whilst the summary was written in English the main text was in Danish.

Whilst it is unclear what bias might be present in this thesis from limitations of the systematic review other limitations of the APS may have led to an under-estimation of the effects of the CCT programme. This survey was originally designed ‘to record levels of participation in sport and active recreation’ (Ipsos MORI 2007) in bouts of 30 minutes or more as per recommended levels of PA before 2011. Consequently the only journeys included were those of 30 minutes or more. This may have led to a serious under-estimation of utility cycling; 42.9% of commuting journeys that are under 5 km (Office for National Statistics 26th March 2014), a distance that many people would easily cycle in much less than 30 minutes. Here it should be noted that a person commuting by cycle 5 days a week would only need to cycle 15 minutes each way to meet PA recommendations and that even if recommendations were not met the greatest gains from PA accrue to those who move from ‘no’ to ‘some’ PA (Department of Health 2011).

A second limitation of deriving utility cycling from the APS is that it also fails to account for vigorousness of activity. Recommended CMO guidelines are actually to achieve 150 minutes of moderate PA a week or 75 minutes vigorous activity or a combination of the two. The CMO report cites cycling at 10 – 12 mph as ‘moderate’ activity and at 12 – 14 mph at vigorous activity (Department of Health 2011). Whilst again it is difficult to see how the limitations of the APS could be avoided the net result might be surmised to be that is that the analysis of the CCTs on utility cycling does not capture its full effect. Equally, this indicates that the use of the measure of 150 minutes a week may have under-estimated the true contribution of utility cycling to meeting guidelines. However, it was felt that a conservative estimation of effect would be more useful for policy makers than what may be unrealistically raising expectations.

The APS has two final limitations for which it is difficult to circumvent. Firstly, until 2012 the APS sought to identify and record cycling for non-utility purposes. The survey therefore asks the respondent if they have done any cycling including casual cycling, in the countryside, on cycle routes, to and from work and any competitive cycling in the past 28 days. It then continues ‘how many of those days were you cycling for the purpose of health, recreation, training or competition not to get from place to place?’. The first of these questions is a binary yes / no whereas the second includes the number of days cycled for the purposes stated. However, neither this, nor the supporting technical documentation makes clear how a respondent might be recorded if, for example, they have decided to cycle to work for health purposes. Secondly, whilst the number of covariates that might affect utility cycling is possibly greater than that which might be pragmatically collected (Heinen, Van Bee et al. 2010) there are at least two potential covariates; car or bicycle ownership (Fairnie, Wilby et al. 2016) and Body Mass Index (BMI) (Tully, Panter et al. 2014) that were either not collected or not collected each year making their analysis over the time-period of the CCTs impossible.

Chapter four highlighted that large scale interventions are not easily evaluated by more traditional means of producing evidence in health(care). The methodology employed for the analysis of the CCTs is obviously not that of an RCT, a limitation that is likely to be encountered by many large-scale interventions and particularly those targeted at geographical areas. Reasons for this will include difficulties of randomisation, allocation and blinding. RCTs are regarded as the ‘gold-standard’ of evaluation and any non-randomised study will be subject to potential bias even if only from unobserved biases between interventions and controls. As noted, the quantity of potential covariates may make this particularly true of utility cycling. There is also one bias that cannot be accounted for; by definition CCTs were different from their matched controls in that they were successful in bidding for, and obtaining, funding for the CCT programme whereas their controls were not. The direction of bias from this is probably towards exaggerating the effect of the CCTs as it is likely that local government employees in the CCTs were more motivated / effective in advocating for increased cycling and / or their respective populations were more sympathetic towards cycling. It is noted for example that Bristol has a long history of promoting cycling, was the city in which the Charity ‘Sustrans’ (sustainable transport) was founded and of which the current mayor was a founder member (Bristol City Council 2015). Equally, Cambridge is frequently cited as the city in England with the highest cycling to work modal share in the country but which bans students (approximately 1/5 of the population) from having motor vehicles within 10 miles of the city centre[26]). However, the size of this effect is unknown and possibly unquantifiable given the historic nature of the data available.

This analysis of the CCTs showed that being resident in a CCT town was associated with a greater likelihood of having undertaken utility cycling than being resident in non-CCT towns whilst prevalence of physical activity achieved through sport or active recreation remained constant. This may be the most important public health finding of this thesis. However, one further limitation of the APS should also be acknowledged. The APS surveys do not include any measurement of PA undertaken in the work environment. It is not unfeasible that increases in PA achieved through utility cycling were compensated for by a reduction in PA in the workplace. However, this cannot be calculated and intuitively it might be surmised that the increasing use of electronic communication and labour-saving devices would have meant a decrease rather than an increase in this domain.

The empirical analysis of the contribution of utility cycling to meeting PA guidelines was similarly not without limitations. The analysis was cross-sectional and therefore unable to attribute causality as it may be that those who undertook sport were also those that undertook utility cycling. Indeed it may be that cycling was only used as a means of transport to sports or leisure services. If so, this would lessen the public health benefits of utility cycling as the marginal benefits of PA decrease with increased duration per week (Department of Health 2011). Chapters five and six indicate that there may be at least some veracity to this; sporting participation is traditionally undertaken by those who are young and male who were also those most likely to undertake utility cycling and achieve PA guidelines. This may indicate that England is not a 'mature' cycling economy where females undertake more cycling journeys than males even if the distances are smaller (Heinen, Van Bee et al. 2010).

A further limitation of this thesis is that although the 'external costs of motorised transport' have been alluded to a number of times no attempt has been made to

[26] http://www.cambridge-news.co.uk/Meet-Cambridge-University-Motor-Proctor-Tony/story-27941521-detail/story.html Site accessed 14th June 2016.

explore or quantify these. The public health benefits of utility cycling are primarily through PA; over 30,000 deaths a year are ascribed to physical activity through CHD alone (NOO). Equally, it is estimated that in 2010 air pollution, for which the main constituents are particulates relating to transport was responsible for 140,743 life-years lost in London alone (Walton, Dajnak et al. 2015). Nonetheless, estimating these costs is beyond the scope of this thesis.

As with all research therefore this thesis is not without its limitations. Here they relate to the balance between sensitivity and specificity of the search of the evidence base, a lack of resources for translation, the use of a dataset intended for other purposes, self-report data, the lack of an experimental methodology and derivation of the dependent variables. However, many of the assumptions implicit to this research were conservative so that whilst it is recognised that there is much in this thesis that requires confirmation by other studies, data-sets and research methodologies it is asserted that this thesis shows that programmes such as the CCT programme may be useful in the consideration of interventions that may increase population levels of PA.

Implications

There is strong evidence that PA is essential for maximal health (Department of Health 2011) as well as that the English population does not meet current PA guidelines (Scholes, Mindell 2013). Within public health it is insufficient to understand that there is an issue and what that issue is. Rather there is a need to seek to resolve the issue (Wanless 2004), (Ogilvie, Egan et al. 2004), (Fraser, Lock 2011), (Yang, Sahlqvist et al. 2010). The most important implication of this thesis therefore is that population levels of physical activity might be increased by the adoption of programmes similar to that of the CCTs. Such an assertion can also be supported by reference to the literature on behaviour change which itself may be useful for policy makers.

Actual behaviour can be a result of conscious reflection of what is desirable and intended to achieve a specific result or it may be automatic, formed from emotional responses, physiological states and habit. Any behaviour takes place within the context of an external environment which is never neutral; any environment will either encourage or hinder any particular behaviour (Halpern 2015). Thus the 'Behaviour Change Wheel' (BCW) outlines a 'behaviour system' with three essential conditions for behaviour change: capability, opportunity and motivation (the COM-B system) where capability is defined as psychological and physical capacity to engage in the desired behaviour, motivation as the brain processes that energize and direct behaviour and opportunity as all factors outside the individual that make the behaviour possible (Michie, Van Stralen et al. 2011). The CCTs cannot be defined as one intervention, indeed given the variety in initial cycling prevalence local authorities were given discretion to allocate funding according to their specific circumstances. Further research would therefore be helpful in determining what interventions were most effective in what populations at what time, at least in relation to utility cycling.

As outlined above there are many limitations to this thesis. Given the potential health benefits it would be prudent that the first implication is that the findings here are verified with other methodologies, datasets, populations and settings. However, as indicated by the literature review and others this research does not exist in a vacuum and there is increasing evidence that environmental interventions can and do increase levels of PA (Mytton, Panter et al. 2016, Panter, Ogilvie 2016, Goodman, Sahlqvist et al. 2014). This research therefore adds to this body of evidence.

One of the questions posed at the beginning of this thesis was of how to increase population levels of PA. Implementing evidence based policies and programmes is obviously important both for the protection of health and for maximising the impact of resources. Previous criticisms made within health have been that authorities waited too long for definitive evidence before acting to control in areas such as tobacco and asbestos (Martuzzi, Tickner 2004). Although potentially salutary rather than dangerous the same point might be made in reference to utilitarian cycling. One of the arguments made within the 'Five Year Forward View' (FYFV) is that in 2002 we were warned that without preventative action multiple problems would present themselves to the NHS. FYFV states that these have now arrived (NHS 2014). Equally, climate change has been described as the greatest threat to global health in the 21st century (Costello 2009) with June 2016 being recorded as the 14th consecutive month of record-breaking temperatures[27]. Utility cycling may offer part of the solution to both these issues. Physical inactivity is estimated to be the fourth leading risk factor for global mortality (World Health Organisation 2010). For some policy makers the evidence of how to increase utility cycling from Northern European countries is already sufficient (All Party Parliamentary Cycling Group 2016). At a practical level therefore an implication of this thesis is that CCTs have shown that population levels of PA can be increased and practitioners now need to apply the learning. There are two points here; firstly CCTs may offer an exit from the vicious circle of no evidence to support the implementation of evidence-based interventions but without the intervention no evidence can be found. Secondly, if the potential health benefits of utility cycling are to be realised time is of the essence; it has been estimated that the time lag between health research and implementation is 17 years (Morris, Wooding et al. 2011). As The Netherlands began building in the mid 1970's we already have some 40 years of evidence.

England is a data-rich country; the public health outcomes framework (PHOF) that 'sets out a vision for public health, desired outcomes and the indicators that will help us understand how well public health is being improved and protected'[28] has some 162 key performance indicators yet can only draw data on PA from the APS. Given the public health implications of transport in general and cycling in particular there is a strong need for a 'fit for purpose' dataset through which utility cycling can be routinely and accurately measured and analysed. NICE guidance is that 'all relevant sectors contribute resources and funding to encourage and support people to walk and cycle' (NICE 2012) and that local transport authorities, transport planners and local authorities should reallocate space to support physically active modes of transport which could include cycle lanes, restricting motor vehicle access and traffic calming measures (NICE January 2008). The British Medical Association (BMA) has called for an increase in cycling (British Medical Association 2010) and the Royal College of Physicians has stated that cycling should be promoted by doctors (Royal

[27] Hottest ever June marks 14th month of record-breaking temperatures. https://www.theguardian.com/environment/2016/jul/20/june-2016-14th-consecutive-month-of-record-breaking-heat-says-us-agencies Site accessed 6th September 2016.
[28] http://www.phoutcomes.info/public-health-outcomes-framework#gid/1000049 site accessed 18th June 2016.

College of Physicians 2010). Without adequate data collection it is hard to foresee how it will be shown this guidance is having an effect. Indeed, without data it will be difficult to establish if these calls have had any effect and if further action is needed.

There is currently (August 2016) considerable interest in developing cycling infrastructure in the capital including the Greater London Assembly (GLA) funding of £100m to three outer-London boroughs aiming 'to transform local cycling facilities and encourage people to take to two wheels'[29]. This thesis provides some evidence that such funding may be effective in increasing PA. Further research is required to both substantiate the findings here and to indicate what the effect may be in a population of some 8.2 million (compared to the largest CCT with a population of 428,000) (2011 census).

In 2010 the UK government established the 'world's first government institution dedicated to the application of behavioural sciences[30]'. The first recommendation of the Behaviour Insights Team (BIT) (more commonly known as the 'nudge unit') is to make the behaviour sought 'easy' and less 'challenging or effortful' (Behavioural Insights Team undated). In Copenhagen when residents are asked why they cycle it is for reasons of convenience and speed[31]. At best there only seems to be chequered understanding of this at a Governmental level. Whilst the need for 'weaving incidental activity into our daily lives' has been recognised at a national level (Public Health England 2014) actual implementation has yet to happen; cycling comprises of but 2% of trips (Department for Transport 2015b) and census data is that only 2.8% of residents reported cycling to work in both the 2001 and 2011 censuses (Office for National Statistics (ONS) 2014).

Finally, it may be of use to outline an implication of this thesis for public health, the profession which defines itself as 'the science and art of promoting and protecting health and well-being, preventing ill-health and prolonging life through the organised efforts of society[32]. As the evidence base and therefore science of how utility cycling

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[29] https://tfl.gov.uk/travel-information/improvements-and-projects/cycle-mini-hollands Site accessed 7th August 2016.
[30] http://www.behaviouralinsights.co.uk/about-us/ Site accessed 14th June 2016.
[31] http://www.copenhagenize.com/2010/05/cycling-isnt-fun-its-transport.html site accessed 16th June 2016.
[32] http://www.fph.org.uk/what_is_public_health. Faculty of Public Health. Site accessed 8th August 2016.

might be promoted becomes clearer so the call to action becomes louder. With this it becomes more incumbent for public health professionals to work with national and local politicians, planning and transport departments, local communities and the NHS to disseminate and implement the evidence base of how additional utility cycling might increase population levels of PA.

Future research

The CCTs were established to get ‘more people cycling, more often, more safely’. In this, subject to limitations and future research, they seem to have been successful. As the CCTs were only funded at European levels for three years, further research would be needed to establish if further funding would continue to increase utility cycling and the prevalence of physical activity. It would not seem unreasonable to assume that further or even synergistic effects might be found; cycle-friendly policies seem to have been successful in Holland (Ministerie van Verkeer en Waterstaat (Transport, Public Works and Water Management) 2009) and others have noted that transport systems require developed networks rather than cycle paths or lanes (Krizek, Forsyth et al. 2009). Such a conclusion would also reflect emerging evidence from the Commuting and Health in Cambridge study that new infrastructure can encourage both walking and cycling (Panter, Heinen et al. 2016, Prins, Panter et al. 2016) and uncontrolled city-wide evidence that cycling prevalence is not immutable but subject to policy implementation (Pucher, Dill et al. 2010).

Even if the above hypothesis is accepted there are a number of research questions that might aid policy makers in the efficient use of resources. These include specifically what interventions might encourage which populations to adopt cycling for travel purposes, what interventions might produce synergistic effects, how utility cycling might reduce health inequalities and what interventions are most likely to appeal to each gender, different ethnicities and ages. The latter might be particularly useful given the potential health benefits of cycling for older ages (Woodcock, Tanio et al. 2014). Equally, England is not a ‘mature cycling country’ (Harms, Bertolini et al. 2014) and cycling in England is not merely ‘transport’ but rather has a ‘plurality of meanings’ (Steinbach, Green et al. 2011) that will resonate with individuals according to their own perceptions of cycling and self-perceptions of gender, ethnicity, age socio-economic status etc. The ‘act of cycling is a negotiation of identity through behaviour, clothing and modesty, personality traits and outward expressions of economic success. For some the adoption of cycling as a means of transport may have become ‘inherently inappropriate, laughably so’ (Steinbach, Green et al. 2011). Research into these identities and how they might be developed and negotiated might support efforts to support modal shifts, particularly as black and minority ethnicities constitute 35% of ‘potential cyclists’ in London (Transport for London 2010). It is therefore regrettable that analysis of the ‘bikeability’ cycle training scheme for primary schools shows that uptake has been lowest in non-white populations, particularly south Asians and amongst children with less wealthy parents (Goodman, Sluijs et al. 2015).

Other qualitative research might also be useful. Given the proliferation of potential health benefits it is perhaps unsurprising that there has been a myriad of strategies to increase cycling. The UK’s first National Cycling Strategy was launched aiming to ‘double the number of trips by cycle (on 1996 figures) by the end of 2002 and quadruple the number of trips by cycle (on 1996 figures) by the end of 2012’ (Golbuff, Aldred 2012). In 2014 the DfT published the ‘Cycling Delivery Plan’ stating that the Government’s vision was that ‘walking and cycling become the natural choices for shorter journeys - or as part of a longer journey- regardless of age, gender, fitness level or income’ (Department for Transport 2014), a vision reiterated in the subsequent cycling and walking investment strategy (Department for Transport 2015a). A target of 10% of all trips by 2025 is proposed (All Party Parliamentary Cycling Group 2016), a target more in line with cities and countries that have set ambitious cycling targets and trajectories (Pucher, Dill et al. 2010). Whilst CCTs and other infrastructure interventions may indicate how the above might be achieved what may also be of interest and relevance may be research with policy makers of why this has not happened and what more might be needed to support implementation.

Recommendations

- Further research should be undertaken to account for the limitations of this thesis and to verify its conclusions. These should include verification of the evidence base, the development and use of a data-set more appropriate for the measurement of utility cycling and the use of other study designs;
- Further research is needed to understand if the observed effect of meeting PA guidelines through utility cycling in females in inner-London is real and what specific interventions may have been causal, either singularly or as part of a network;
- Research is needed to understand what more may be needed to increase utility cycling in other population groups – principally older populations and non-white populations;
- Research into the ‘external costs of motorised transport’ would help inform the policy debate. External costs would include Road Traffic Injuries (RTI’s), air pollution, community segregation, noise, vibration, loss of land and planning blight and loss of freedom for young people;
- Acknowledging the limitations of this study the ‘public health community’, the NHS, transport and town planning agencies and Local Authorities need to be galvanised into action to increase utility cycling.

CHAPTER 8: Conclusion

Population levels of PA are below recommendations with severe implications for both health and healthcare systems. It is possible that this is at least partly due to the elimination of PA from life through the electrification and motorization of everyday tasks. One means of increasing prevalence of PA therefore may be through its integration into everyday life. One means of doing this may be through active transport of which cycling is that means most likely to be of sufficient vigorousness to become a 'health-enhancing physical activity'. A modal shift towards active transport is likely to have public health gains beyond those of PA.

There is little evidence of what interventions would increase population levels of commuter cycling. Reasons for this include the methodological and pragmatic difficulties of evaluating public health interventions in free-living individuals. Where such evidence does exist it suggests that population level interventions are more likely to be effective than those aimed at individuals. Equally, where such evidence does exist no evidence was found for the effect of any change in cycling on overall prevalence of PA.

'Natural experiment' methodology offers one means through which large-scale public health interventions may be evaluated. The APS is a dataset through which the CCT programme could be evaluated both for its effect on prevalence of utility cycling and for its effect on prevalence of PA in other life-domains. It was therefore concluded that the effect of CCTs on PA was likely to be positive. After adjustment for covariates those who undertook utility cycling were four-times more likely to meet PA guidelines than those who did not. Those who undertook utility cycling were of similar demographics to those who undertook sport or active recreation which may indicate both that CCTs increased inequalities in relation to PA and that they represent a 'first step' towards a potential means of increasing PA through its integration into everyday life.

CHAPTER 9: Reflection

The Doctorate in Public Health is not a standard PhD and includes the intention of:

- the development of advanced public health knowledge, expertise and skills within both professional practice and the broader discipline;
- the development and enhancement of leadership; and
- the integration of these within the dynamic nexus of public health research, policy development, and practice.

The following is my reflection of how my study relates to the above. It is an outline of lessons learnt from my time as a DrPH student.

Background

This thesis formally began in 2010. Informally it probably began some years before when I worked in a voluntary capacity as the chair of a cycling pressure group. At the same time I did an M.Sc. in Exercise and Health and was struck by how the course outlined the health benefits of 'exercise' but then focused on performance improvement in elite level athletes. On the back of this M.Sc. though I joined the NHS with a remit for health promotion in young people. It was here that I first met a Consultant in Public Health was struck by the disparity between the number of people we wanted to influence and the number we reached through interventions. I then did an M.Sc. in Public Health, became a Consultant in Public Health myself and became more interested in how to affect the behaviour of large numbers of people.

My first degree was in Sociology and I always thought that Marx understood the context of behaviour; 'men make their own history, but they do not make it as they please; they do not make it under self-selected circumstances, but under circumstances existing already, given and transmitted from the past' (Marx 1852). He also calls for action; philosophers have only interpreted the world, in various ways; the point is to change it' (Marx 1845). To some extent therefore this thesis has been a search for an answer of how to change behaviour at a population level.

The FPH states that reflection is ‘consciously thinking about and analysing what you are doing and what you have done; thinking about what and how you have learnt’ (Faculty of Public Health 2012). Peters provides a framework for this; describe, analyse, theorise, act (DATA) (Peters 1991).

Describe

The first year of this doctorate was a taught course. It was not dissimilar in format to studying a Masters degree. I remember a Professor saying but not particularly understanding that if a Masters student asks questions the PhD student needs to ‘questioning everything’. This has been a journey that has not come overnight. I have several memories of tutors pointing out assumptions and asking for evidence. Hopefully it is a sign of progress that I can now often anticipate and answer such a challenge before it arises.

A challenge and opportunity for this thesis is that I have studied for it part-time whilst working as an Assistant Director of Public Health full-time. The challenges have been as might be assumed; principally a lack of time and mental energy as well as not being able to participate in academic life including seminars and meeting other students nearly as much as I would have wished. A frustration has been that I have not been given support for this from work. The great opportunity though has been to apply the learning of this thesis to work where my borough was one of three London boroughs to receive £30 million from the Greater London Assembly (GLA) to improve and increase cycling prevalence. The work of this thesis therefore has been a useful and productive interplay of the academic and the practical. This includes from the initial bid for which I wrote the health implications as well as the supporting statements for commissioner and provider NHS organisations in my borough to working with and persuading both Local Authority officers and members of the public of the merits of the programme. This has not just been a battle of knowing facts and figures (though writing this has helped) but a struggle for hegemony of who is responsible for a vulnerable road users safety; is it the individuals who should therefore wear ever more protective and reflective clothing or is it society’s which creates conditions in which individuals are likely to be injured?

Analysis

This thesis then has been a challenge of time and energy and a mixture of the academic and pragmatic. The task was a little daunting; at the beginning of the course I knew that the majority of people who started doctorates do not finish and guessed that most candidates were likely to know this but considered that they would be the exception. Very few must start a course with the intention of not finishing. In terms of persistence having done the two M.Sc's helped; both had been part-time and for each I had thought of them as one month, one essay at a time; the strategy of how do you eat an elephant? – 'one bite at a time'. This obviously breaks the task down into manageable chunks but a learning point has been that for a longer-term piece of work the weakness of this approach is that the focus is on immediate or short-term time-scales. Whereas within a taught part-time M.Sc. it is possible to almost abdicate responsibility for the overall goal (take care of the essays and the course will take care of itself) this is less satisfactory for a doctorate.

Time is obviously a consideration of studying part-time and working full-time. An implied aspect to working full-time is that I do not live on campus. Time and distance therefore have meant that I have not been able to attend any number of seminars etc. or embed myself in academic life to anything like the extent I would have liked. Allied to this is the need to remain current within the field. Electronic databases and automatic searches have obviously helped but talking to established academics equally shows that the area of study has moved on from what it was when I did my M.Sc. in Exercise and Health. One academic told me that when he started he was a 'big fish in a small pond'. Rightfully, now there are a number of university transport departments with an increasing focus on active transport including Leeds, Bristol, University College London and the Centre for Diet and Activity Research (CEDAR) at Cambridge funded by the MRC. As another academic said to me; 'everything seems to be about cycling nowadays'. From a public health perspective this is only to the good, from a personal perspective it has been both helpful and intimidating. Helpful in the sense of learning, evidence and direction. Intimidating in terms of the sheer volume of work being undertaken.

Professionally this thesis has only been to the good. It has given me a more than sound understanding of the academic literature and a more thorough understanding of the evidence base for promoting physical activity and how that might be done. I believe that one of the reasons for why Enfield was able to secure the GLA funding was that from my academic work I was able to not only write a very credible section of why Enfield wanted to implement a mini-Holland programme but was also able to persuade NHS organisations in the borough to support the bid. As one Chief Executive said of their draft supporting statement I had written for them outlining the benefits of physical activity 'if this is true the [organisation] is of course happy to support the bid'.

This academic work has further supported my professional work with Local Authority officers, Councillors and members of the general public. As alluded to above a major part of the ethos of the mini-Holland programme is to challenge the current consensus that 'cycling is dangerous'. I have chaired a number of seminars with officers and particularly road safety officers to move to a more environmental and less victim-blaming approach within the Council. Hence when I first started in Enfield I attended a seminar in which older people were advised to carry white reflective plastic bags in dark winter evenings. Now (12th August 2016) the Enfield Road Safety facebook page is carrying posters created by schoolchildren advocating 20 mph and 'kill your speed'[33]. Councillors are the democratically elected representatives of the local populace; they set strategic direction (and budgets) for the Council. The DrPH has equally allowed me to gain and maintain support for the mini-Holland programme including over two elections and determined opposition from sections of the opposition party and general public. Equally, the DrPH has more than helped in working with the general public; feedback I have received from the Voluntary and Community sector is that opposition to Cycle Enfield does not want to engage with the public health arguments about cycling as they are 'bullet-proof'. Obviously this has led us to leading on the public health arguments but I feel it has encouraged all involved in the implementation that we are doing is 'the right thing'.

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33 https://www.facebook.com/roadsafetyenfield/photos/a.194757703953024.42741.194752247286903/1108176042611181/?type=1&theater site accessed 12th August 2016.

Theorise

Part of this DrPH was to understand its context, how it has impacted upon practice and what changes have resulted. The context has certainly changed; on 1st April 2013 public health funding and resources were moved from the NHS to Local Authorities, a move described by the Local Government Association as public health 'coming home' (Local Government Association 2014). Although both are large bureaucracies they are very different; Primary Care Trusts (PCTs), the predecessors of Clinical Commissioning Groups (CCGs) were very much directed by the DH, local authorities are very much led by Councillors who regard themselves as having a democratic mandate. Many NHS organisations have a historical deficit, Local Authorities are legally bound to balance their finance. Local Authorities work on electoral time-scales and are subject to 'purdah' in the weeks immediately preceding elections. This is not to say that the NHS is not subject to politics but my experience is that Local Authorities are much more 'political animals'.

The context then is critical; my work context has moved from a healthcare organisation to one with a duty 'to take such steps as they consider appropriate for improving the health of the people in their areas' (Heath 2014). In one sense this was welcomed; I have always thought that public health should address the 'wider determinants of health' and I was a little surprised that the Chief Executive referred to above did not know at least some of the benefits of physical activity. At the same time the lack of interest in lifestyles evident in the NHS has been decried for many years (Wanless 2004). More Chief executives have been hired and fired for finance rather than health reasons. On the other hand the politics of local authorities bring their own challenges. There are many more checks and balances in Local Authorities than NHS organisations meaning that creating and maintaining support for a programme can require much more time and energy, particularly one that threatens resident's car-parking.

An interesting aspect to the DrPH and the constant intellectual challenge has been to understand what 'evidence' means to whom, and when and in which contexts. Certainly the methodology chapter has helped in challenging misinterpretations of evidence; a lack of evidence is not evidence of lack. It has also made clear how difficult it can be to robustly evaluate initiatives in a local authority context and revealing in what might be taken as evidence of effectiveness in a local authority context and how different this can be from academic evidence. Marrying the two conceptions has been challenging. Increasingly it has shown that the 'right answer' and how it is presented depends on both context and audience as well as that for some the 'right' answer has little to do with evidence.

The outcome of this DrPH in a work context therefore is that I am considered an expert in physical activity and utility cycling, that I 'know more about it than anyone else in the borough' and that the public health arguments for cycling are considered 'bullet proof' and not grounds for challenge. More importantly applied learning from the DrPH has helped changed perceptions and therefore the practice of local authority officers whilst having the support of academic rigor has given impetus and galvanised efforts to implement the mini-Holland programme.

Act

The DrPH is a professional doctorate in public health. It is both academic and pragmatic. Ultimately it is intended to improve practice and (hopefully) the health of the public. Whilst I have had my own reasons for undertaking this doctorate it would be of little consequence to many others unless it informed and changed practice.

I believe that as outlined above this doctorate has already informed practice both in myself and others with whom I work. The context has changed and undoubtedly will continue to do so as public health becomes more embedded into the everyday fabric of local authorities. It has given me a more strategic focus; for example whilst originally based in Health, Housing and Adult Social Care I have successfully argued for my team to be transferred to the Regeneration Directorate within the Local Authority which has responsibility for urban planning. My paper on the contribution of utility cycling to PA has been included by Public Health England in a published briefing to Local Authorities for promoting active travel (Public Health England 2016). Hopefully, the impact at a local level has been more tangible.

A newly qualified PhD student once told me that faced with the same task again it would take them half as long. This is probably one of the points of a doctorate or indeed any course. A number of times I have heard the academic staff say that one of the great advantages of doing a doctorate is that 'making mistakes doesn't matter as long as you learn from them'. Hopefully I have taken this on board and future academic practice will be informed by learning from this DrPH. This will include systematic reviews, understanding the methodology of research, quantitative analysis and understanding the steps requisite before statistical programmes are run. More than that however I hope it has informed and influenced practice; this work has allowed me to work with colleagues both internal and external to the Local Authority with the confidence that I am cognisant of best practice and evidence and that what we are doing will have a significant effect upon health.

Results

Attributing cause and effect in a Local Authority is always difficult and frequently cannot claim academic vigour. Despite this, I believe that ultimately this thesis and the work contributing to it has been influential not only in winning £30 million to increase cycling in Enfield but also that it has helped public health have more influence on the 'wider determinants of health'. Throughout my work in Enfield I have emphasised that public health is not interested in cycling as an end in itself but rather cycling as a means of increasing physical activity e.g. integrating PA into everyday life. Subsequent to this work therefore we (my team) are also influential in urban planning, quieter neighbourhoods and housing. We are currently working to apply the principles pioneered by Jan Gehl that emphasise that a city that is good for cycling is good for people (Gehl 2010). Thus this DrPH is not an end in itself but part of a journey.

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Appendices

Appendix 1: Licenses obtained from the UK dataservice

Experian Postal Sector Data End User Licence Special Conditions

You (the End User) and the Data Team agree that in relation to the data collection set out below:

A the Data Team consists of:

1. Census Dissemination Unit, Mimas (University of Manchester), the data service provider;
2. Economic and Social Research Council (with the support of the Joint Information Systems Committee*), the service funder;
3. Experían Limited, the data collection funder;
4. Experían Limited, the original data creator;
5. Experían Limited, the data depositor;
6. The Census Registration Service (University of Essex), the registrar; and

B the following additional conditions of use apply:

1. The data collection will only be used for academic purposes, defined as academic teaching and/or research. In this context, academic research is defined as research, the cost of which is met wholly within the higher education sector in Great Britain or from the Department of Education Northern Ireland and the results of which may appear in academic publications or in other publications available to the public.
2. The End User will not pass on the data to any other individual or attempt to sell or re-license it in any way.

Capitalised terms not defined in these Special Conditions are defined in your End User Licence.

DATA COLLECTION

These Special Conditions are applicable to the following data products (together the ‘data collection’):

Experían Postal Sector Data.

* The JISC – Joint Information Systems Committee – is a joint committee of the UK further and higher education funding bodies, and is responsible for supporting the innovative use of information and communication technology (ICT) to support learning, teaching and research. It is best known for providing the JANET network, a range of support, content and advisory services, and a portfolio of high-quality resources. Information about the JISC, its services and programmes can be found at http://www.jisc.ac.uk.

OECD Special Conditions

As part of the UK Data Service* online registration process, you are required to accept the End User Licence conditions of use before accessing the data.

The following additional Special Conditions of use apply to the OECD databases (hereinafter called the *"Work"*) obtained through the UK Data Service:

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DATA COLLECTION

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- OECD Main Economic Indicators
- OECD International Development
- OECD International Direct Investment
- OECD International Migration Statistics
- OECD Main Science and Technology Indicators
- OECD Measuring Globalisation Statistics
- OECD Statistics in International Trade in Services, Value Added and Employment
- OECD Social and Welfare Statistics
- OECD International Trade by Commodities Statistics Database, rev 2, 1961.
- OECD Structural Analysis (STAN) Database
- OECD National Accounts databases
- OECD Agriculture Statistics
- OECD Banking Statistics (Bank Profitability)
- OECD Environment Statistics
- OECD Product Market Regulation Statistics
- OECD Economic Outlook
- OECD Employment and Labour Market Statistics (Annual and Quarterly Labour Force Statistics and Labour Markets Database).
- OECD Health Statistics
- OECD Structural and Demographic Business Statistics

- OECD Insurance Statistics
- OECD Monthly Statistics of International Trade
- OECD Tax Statistics (Revenue Statistics and Taxing Wages)
- OECD Telecommunications and Internet Statistics.
- OECD Patent Statistics
- OECD Pensions Statistics
- OECD Productivity Statistics
- OECD Regional Statistics
- OECD Institutional Investors Statistics

If you have any questions, please get in touch with the UK Data Service Helpdesk.

* Note: The UK Data Service incorporates the former Economic and Social Data Service (ESDS).

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DATA COLLECTION

These Special Conditions are applicable to the following data products (together known as the "*data collection*"):

- IEA World Energy Statistics and Balances
- IEA Oil Information
- IEA Natural Gas Information
- IEA Coal Information
- IEA Electricity information
- IEA CO2 Emissions from Fuel Combustion
- IEA Energy Prices and Taxes
- IEA Renewables Information
- IEA Energy Technology Research and Development
- -IEA Energy Projections for IEA Countries

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Summary of End User Licence

Seventeen points to help you understand the End User Licence (EUL). These pointers are for general guidance and you must read and understand the full EUL before agreeing to it. By accepting the EUL, you agree:

1. to use the data in accordance with the EUL and to notify the UK Data Service of any breach you are aware of
2. not to use the data for commercial purposes without obtaining permission and, where relevant, an appropriate licence if commercial use of the data is required
3. that the EUL does not transfer any interest in intellectual property to you
4. that the EUL and data collections are provided without warranty or liability of any kind
5. to abide by any further conditions notified to you
6. to give access to the data collections only to registered users (who have accepted the terms and conditions, including any relevant further conditions). There are some exceptions relating to teaching.
7. to ensure that the means of access to the data (such as passwords) are kept secure and not disclosed to anyone else
8. to preserve the confidentiality of, and not attempt to identify, individuals, households or organisations in the data
9. to use the correct methods of citation and acknowledgement in publications
10. to email the Help desk with the bibliographic details of any published work based on the data collections
11. that personal data about you may be held for validation and statistical purposes and to manage the service, and that these data may be passed on to other parties
12. to notify the Help desk of any errors discovered in the data collections
13. that personal data submitted by you are accurate to the best of your knowledge and kept up to date by you
14. to meet any charges that may apply
15. to offer for deposit any new data collections which have been derived from the materials supplied
16. that any breach of the EUL will lead to immediate termination of your access to the services and could result in legal action against you

Appendix 2: Effect of physical activity on various health outcomes

Source: Start Active, Stay Active'. A report on physical activity for health from the four home countries' Chief Medical Officers. Dept. of Health, 2011. Adapted from Department of Health and Human Services (2008) Physical Activity Guidelines Advisory Committee Report, Washington, DC: US

Health outcome	**Nature of association with physical activity**	**Effect size**	**Strength of evidence**
All-cause mortality	Clear inverse relationship between physical activity and all-cause mortality.	There is an approximately 30% risk reduction across all studies, when comparing the most active with the least active.	Strong
Cardiorespiratory health	Clear inverse relationship between physical activity and cardiorespiratory risk.	There is a 20% to 35% lower risk of cardiovascular disease, coronary heart disease and stroke.	Strong
Metabolic health	Clear inverse relationship between physical activity and risk of type 2 diabetes and metabolic	There is a 30% to 40% lower risk of metabolic syndrome and type 2 diabetes in at least moderately active people	Strong

	syndrome.	compared with those who are sedentary.	
Energy balance	There is a favourable and consistent effect of aerobic physical activity on achieving weight maintenance.	Aerobic physical activity has a consistent effect on achieving weight maintenance (less than 3%change in weight). Physical activity alone has no effect on achieving 5% weight loss, except for exceptionally large volumes of physical activity, or when an isocalorific diet is maintained throughout the physical activity intervention. Following weight loss, aerobic physical activity has a reasonably consistent effect	Strong Strong Moderate

		on weight maintenance.	
Musculoskeletal health	**Bone:** There is an inverse association of physical activity with relative risk of hip fracture and vertebral fracture. Increases in exercise and training can increase spine and hip bone marrow density (and can also minimise reduction in spine and hip bone density). **Joint:** In the absence of a major joint injury, there is no evidence that regular moderate physical activity	**Bone:** Risk reduction of hip fracture is 36% to 68% at the highest level of physical activity. The magnitude of the effect of physical activity on bone mineral density is 1% to 2%. **Joint:** Risk reduction of incident osteoarthritis for various measures of walking ranges from 22% to 83%.	Moderate (weak for vertebral fracture) Weak

	promotes the development of osteoarthritis. Participation in moderate intensity, low-impact physical activity has disease-specific benefits in terms of pain, function, quality of life and mental health for people with osteoarthritis, rheumatoid arthritis and fibromyalgia. **Muscular:** Increases in exercise training enhance skeletal muscle mass, strength, power and intrinsic neuromuscular activation.	Among adults with osteoarthritis, pooled effect sizes (ES) for pain relief are small to moderate, i.e. 0.25 to 0.52. Function and disability ES are small: function ES = 0.14 to 0.49 and disability ES = 0.32 to 0.46. **Muscular:** The effect of resistance types of physical activity on muscle mass and function is highly variable	Strong

		and dose-dependent.	Strong
Functional health	There is observational evidence that mid-life and older adults who participate in regular physical activity have reduced risk of moderate/severe functional limitations and role limitations. There is evidence that regular physical activity is safe and reduces the risk of falls.	There is an approximately 30% risk reduction in terms of the prevention or delay in function and/or role limitations with physical activity. Older adults who participate in regular physical activity have an approximately 30% lower risk of falls.	Moderate to strong Strong
Cancer	There is an inverse association between physical activity and risk of breast and colon cancer.	There is an approximately 30% lower risk of colon cancer and approximately 20% lower risk of breast cancer for adults participating in	Strong

		daily physical activity.	
Mental health	There is clear evidence that physical activity reduces the risk of depression and cognitive decline in adults and older adults. There is some evidence that physical activity improves sleep. There is limited evidence that physical activity reduces distress and anxiety.	There is an approximately 20% to 30% lower risk for depression and dementia, for adults participating in daily physical activity. There is an approximately 20% to 30% lower risk for distress for adults participating in daily physical activity.	Strong Moderate Limited

Appendix 3: Comparison of percentages of people reporting meeting physical activity recommendations 2008, 2008 reanalysed and 2012

	Recommended guidelines	**Age for guidelines**	**% of males meeting guidelines**	**% of females meeting guidelines**
2008	5 x 30 minutes per week for	16+	39	27
2008 (reanalysed)	150 minutes moderate / 75 minutes vigorous per week	18+	65	53
2012 (initial results)	150 minutes moderate / 75 minutes vigorous per week in bouts of 10 minutes or more	18+	66	56

Source: Health Survey for England (2012) Is the adult population in England active enough? Initial results.

Appendix 4: Four Home Country's physical activity guidelines for all ages

From: Start Active, Stay Active. A report on physical activity for health from the four home countries' Chief Medical Officers. Dept. of Health, 2011.

Guidelines for early years (Under 5's)

1. Physical activity should be encouraged from birth, particularly through floor-based play and water-based activities in safe environments.

2. Children of pre-school age* who are capable of walking unaided should be physically active daily for at least 180 minutes (3 hours), spread throughout the day.

3. All under 5s should minimise the amount of time spent being sedentary (being restrained or sitting) for extended periods (except time spent sleeping).

Guidelines for children and young people (5 – 18)

1. All children and young people should engage in moderate to vigorous intensity physical activity for at least 60 minutes and up to several hours every day.

2. Vigorous intensity activities, including those that strengthen muscle and bone, should be incorporated at least three days a week.

3. All children and young people should minimise the amount of time spent being sedentary (sitting) for extended periods.

Guidelines for adults (19 – 64)

1. Adults should aim to be active daily. Over a week, activity should add up to at least 150 minutes (2½ hours) of moderate intensity activity in bouts of 10 minutes or more – one way to approach this is to do 30 minutes on at least 5 days a week.

2. Alternatively, comparable benefits can be achieved through 75 minutes of vigorous intensity activity spread across the week or a combination of moderate and vigorous intensity activity.

3. Adults should also undertake physical activity to improve muscle strength on at least two days a week.

4. All adults should minimise the amount of time spent being sedentary (sitting) for extended periods.

Guidelines for older adults (65+)

1. Older adults who participate in any amount of physical activity gain some health benefits, including maintenance of good physical and cognitive function. Some physical activity is better than none, and more physical activity provides greater health benefits.

2. Older adults should aim to be active daily. Over a week, activity should add up to at least 150 minutes (2½ hours) of moderate intensity activity in bouts of 10 minutes or more – one way to approach this is to do 30 minutes on at least 5 days a week.

3. For those who are already regularly active at moderate intensity, comparable benefits can be achieved through 75 minutes of vigorous intensity activity spread across the week or a combination of moderate and vigorous activity.

4. Older adults should also undertake physical activity to improve muscle strength on at least two days a week.

5. Older adults at risk of falls should incorporate physical activity to improve balance and co-ordination on at least two days a week.

6. All older adults should minimise the amount of time spent being sedentary (sitting) for extended periods.

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Appendix 5 (web supplement): Data extraction table*

General information	
Title	
Reference	
Country of origin	
Aims and objectives - research questions - perspective - alternatives being considered	
Inclusion/exclusion criteria	
Population and/or sample size Is whole population covered? E.g. did it cover a distinct geographical area?	
Time period	
Comparators How were comparators	

compiled / described?	
Data and sources	
Exposure – How cycling measured?	
Statistical approach	
Evaluation e.g. how intervention evaluated	
Main findings	
Substantive results - change in commuter cycling? - Change in cycling?	
Limitations	
Authors' indication Implications for: generalisability of findings;	
Reviewer's assessment Conclusion based on findings? Robustness of methods and their implications for current UK study	
Notes (include any salient points)	

* Informed by NICE (Methods for the development of NICE public health guidance (third edition): Appendix F Quality Appraisal Checklist—quantitative intervention studies. 3rd edn.National Institute for Health and Care Excellence, 2012) and Centre for Review and Dissemination. Systematic Reviews: CRD's Guidance for Undertaking Reviews in Health care. 2009.

Appendix 6: Papers excluded from literature search

	Paper	Reason for exclusion
1	Patterns of neighborhood environment attributes related to physical activity across 11 countries: a latent class analysis. International Journal of Behavioral Nutrition and Physical Activity Volume 10, 14 March 2013, Article number 34	Cycling could not be distinguished from overall physical activity (no commuter cycling data)
2	The influence of individual perceptions and bicycle infrastructure on the decision to bike Transportation Research Record Issue 2140, 2009, Pages 165-172.	Analysis only of perceptions of what would influence modal choice (no intervention)
3	International perspectives on the physical inactivity crisis—Structural solutions over evidence generation? Preventive Medicine 49 (2009) 309–312	No intervention
4	Socioeconomic inequalities in occupational, leisure-time, and transport related physical activity among European adults:	Review of studies of physical activity rather than effects of an

	A systematic review. J.International Journal of Behavioral Nutrition & Physical Activity. 2012, Vol. 9 Issue 1, p116-138. 23p	intervention on levels of physical activity (no intervention).
5	Active Travel in Germany and the U.S. Contributions of Daily Walking and Cycling to Physical Activity Buehler,R.; Pucher,J. Am.J.Prev.Med., 2011, 41, 3, 241-250	Comparison of travel survey data rather than pre and post evaluation of an intervention (no intervention).
6	Cost-Effectiveness of Interventions to Promote Physical Activity: A Modelling Study PLoS Med., 2009, 6, 7	Modelling study rather than actual interventions (no intervention).
7	Perceptions of representatives of public, private, and community sector institutions of the barriers and enablers for physically active transport Transp.Policy, 2010, 17, 6, 496-504	Perceptions rather than interventions (no intervention)
8	Decarbonizing urban transport in European cities: four cases show possibly high co-benefits Environ. Res. Lett. 7 (2012) 044042 (9pp)	Modelling scenarios rather than actual intervention (no intervention)

9	Neighbourhood, Route and Workplace-Related Environmental Characteristics Predict Adults' Mode of Travel to Work Dalton AM, Jones AP, Panter JR, Ogilvie D (2013) PLoS ONE, 2013, 8, 6	Ecological study without any intervention or pre / post evaluation (no intervention).
10	The association of leisure-time physical activity and active commuting with measures of socioeconomic position in a multi-ethnic population living in the Netherlands: results from the cross-sectional SUNSET study BMC Public Health, 2012, 12, 1	Descriptive study without any intervention (no intervention)
11	Epidemiology of physical inactivity in Poland: Prevalence and determinants in a former communist country in socioeconomic transition Public Health, 2009, 123, 9, 592-597	Cross-sectional analysis with no intervention
12	Green commuter planning: A role for business . Business Strategy and the Environment 8, 82–87 (1999)	No intervention
13	Stepping towards causation: Do built environments or neighborhood and travel preferences explain physical	Study of walking and

	activity, driving, and obesity? Soc.Sci.Med., 2007, 65, 9, 1898-1914	not cycling
14	Walking and cycling to work despite reporting an unsupportive environment: insights from a mixed-method exploration of counterintuitive findings BMC Public Health 2013, 13:497	Qualitative study (no intervention)
15	Gender differences in recreational and transport cycling: a cross-sectional mixed-methods comparison of cycling patterns, motivators, and constraints International Journal of Behavioral Nutrition and Physical Activity 2012, 9:106	No intervention
16	Implementation of sustainable urban transport in Latin America Res.Transp.Econ., 2013, 40, 1, 66-77	No intervention
17	Socio-demographic and lifestyle correlates of commuting activity in Poland Prev.Med., 2010, 50, 5-6, 257-261	Cross-sectional study (No intervention)

18	Active commuting: its impact on physical activity and health, and its main determinants Sci.Sports, 2010, 25, 5, 227-237	Abstract only in English, article in French
19	How well do cognitive and environmental variables predict active commuting? Int.J.Behav.Nutr.Phys.Act., 2009, 6	No intervention
20	Public Health Perspectives on Household Travel Surveys: Active Travel Between 1997 and 2007 Am.J.Prev.Med., 2010, 39, 2, 113-121	No intervention
21	Environmental correlates of cycling: Evaluating urban form and location effects based on Danish micro-data Transp.Res.Part D Transp.Environ., 2013, 22, 4044	No intervention
22	Environmental and Psychological Correlates of Older Adult's Active Commuting Med.Sci.Sports Exerc., 2011, 43, 7, 1235-1243	No intervention
23	Effects of a non-motorized transport infrastructure development in the Bucharest metropolitan area WIT Trans.Ecol.Environ., 2006, 93, 589-597	No intervention

24	Walking and cycling in the United States, 2001-2009: Evidence from the National Household Travel Surveys Am.J.Public Health, 2011, 101, SUPPL. 1, S310-S317	No intervention
25	Factors associated with active commuting to work in employees of industries in Paraiba Rev.Educ.Fis., 2011, 22, 2, 265-272	In Spanish, not English
26	Neighborhood Design and Perceptions: Relationship with Active Commuting Medicine & Science in Sports & Exercise Issue: Volume 42(7), July 2010, pp 1253-1260	Analysis of walking to school in schoolgirls.
27	Motivators and deterrents of bicycling: Comparing influences on decisions to ride Transportation, 2011, 38, 1, 153-168	No intervention
28	Neighborhood built environment and transport and leisure physical activity: Findings using objective exposure and outcome measures in New Zealand Environ.Health Perspect., 2012, 120, 7, 971-977	No intervention
	Association of neighbourhood residence and	

29	preferences with the built environment, work-related travel behaviours, and health implications for employed adults: Findings from the URBAN study Soc.Sci.Med., 2012, 75, 8, 1469-1476	No intervention
30	Understanding the relationships between private automobile availability, overall physical activity, and travel behavior in adults Transportation, 2008, 35, 3, 363-374	No intervention
31	Campus Sustainability: Climate Change, Transport and Paper Reduction Atherton,Alison; Giurco,Damien International Journal of Sustainability in Higher Education, 2011, 12, 3, 269-279, International Journal of Sustainability in Higher Education	No intervention
32	Factors Associated with Active Commuting to Work Among Women Bopp,Melissa; Child,Stephanie; Campbell,Matthew Women Health, 2014, 54, 3, 212-231	No intervention
33	Walking, Bicycling, and Urban Landscapes: Evidence From the San Francisco Bay Area	No intervention

	Cervero,Robert; Duncan,Michael Am.J.Public Health, 2003, 93, 9, 1478-1483	
34	Objective Measures of the Environment and Physical Activity--Results of the Environment and Physical Activity Study in English Adults Foster,Charlie; Hillsdon,Melvyn; Jones,Andy; Grundy, Chris; Wilkinson,Paul; White,Martin; Sheehan,Bart;Wareham,Nick; Thorogood,Margaret Journal of Physical Activity & Health, 2009, 6, S70-S80	Only abstract available
35	Environment and active living: The roles of health risk and economic factors Lee,Chanam American Journal of Health Promotion, 2007, 21, 4, 293-304, American Journal of Health Promotion	No intervention
36	Patterns and predictors of changes in active commuting over 12 months Panter,Jenna; Griffin,Simon; Dalton,Alice, M.; Ogilvie,David Prev.Med., 2013, 57, 6, 776-784	No intervention
37	Promoting Safe Walking and Cycling to Improve Public Health: Lessons From The Netherlands and Germany Pucher,J.; Dijkstra,L.	No intervention

	Am.J.Public Health, 2003, 93, 9, 1509-1516	
38	Commuting and Health in Cambridge: a study of a ‘natural experiment’ in the provision of new transport infrastructure David Ogilvie, Simon Griffin, Andy Jones, Roger Mackett, Cornelia Guell, Jenna Panter, Natalia Jones, Simon Cohn, Lin Yang, Cheryl Chapman	No intervention
39	Active travel intervention and physical activity behaviour: An Evaluation Patricia Norwood, Barbara Eberth, Shelley Farrar, Jillian Anable, Anne Ludbrook Social Science & Medicine 113 (2014) 50-58	No commuter cycling data
40	Assessing the impact of road traffic on cycling for leisure and cycling to work Charlie E Foster, Jenna R Panter and Nicholas J Wareham International Journal of Behavioral Nutrition and Physical Activity 2011, 8:61	Correlation and no intervention.
41	Causality between the Built Environment and Travel Behavior:	No intervention

	A Structural Equations Model Applied to Southern California KeWang Submitted to the Transportation Research Board: 15thNov, 2012	
42	Commuter Mode Choice and Free Car Parking, Public Transportation Benefits, Showers/Lockers, and Bike Parking at Work: Evidence from the Washington, DC Region Andrea Hamre and Ralph Buehler Journal of Public Transportation, Vol. 17, No. 2, 2014	Modelling study (no intervention)
43	Cycling to work in 90 large American cities: new evidence on the role of bike paths and lanes Ralph Buehler • John Pucher Transportation (2012) 39:409–432	No intervention
44	Evaluation of an alternative transport initiative in Perth, Western Australia 2000-2004 McManus, Alexandra and Smith, Jennifer and McManus, Jennifer and MacDonald, Emma and	Cross sectional survey and no intervention

	Williams, Megan. Health Promotion Journal of Australia 16: 184-188 2005	
45	Five-year workplace wellness intervention in the NHS Holly Blake, Dingyuan, Mark E Batt Perspectives in Public Health 2013 133: 262	No before and after data
46	Use of a New Public Bicycle Share Program in Montreal Canada Fuller,Daniel; Gauvin,Lise; Kestens,Yan; Daniel,Mark; Fournier,Michel; Morency,Patrick; Drouin,Louis Am.J.Prev.Med., 2011, 41, 1, 80-83, Elsevier Science, Netherlands	No before and after data
47	Evaluation of the Cycle Challenge project: a case study of the Nottingham Cycle-Friendly Employers' project J. Cleary and H.McClintock Transport Policy 7 (2000) 117–125	No commuter cycling data

48	Urban Trails and Physical Activity A Natural Experiment Eugene C Fitzhugh, David R. Bassett, Mary F. Evans Am J Prev Med 2010;39(3):259 –262	No commuter cycling data
49	Transforming a Small Midwestern City for Physical Activity: From the Sidewalks Up Kristin Hendricks, Risa Wilkerson, Christine Vogt, and Scott TenBrink Journal of Physical Activity and Health, 2009, 6, 690-698	No commuter cycling data
50	Urban Containment Policies and Physical Activity. A Time-Series Analysis of Metropolitan Areas, 1990-2002 Aytur, S.A., Rodriguez, D.A.,Evenson, K.R., Catellier, D.J. American Journal of Preventive Medicine 34 (4) , pp. 320-332, 2008	No cycling data

51	Infrastructure, programs, and policies to increase bicycling: An international review Pucher,J.; Dill,J.; Handy,S. Prev.Med., 2010, 50, SUPPL., S106-S125	Walking and cycling treated as one variable.
52	Evaluation of a workplace intervention to promote commuter cycling: A RE-AIM analysis Veerle Dubuy, Katrien De Cocker, Ilse De Bourdeaudhuij, Lea Maes2, Jan Seghers, Johan Lefevre, Kristine De Martelaer and Greet Cardon BMC Public Health 2013, 13:587	No intervention
53	Promoting active transport in a workplace setting: evaluation of a pilot study in Australia Li Ming Wen, Neil Orr, Jeni Bindon and Chris Rissel Health Promotion International, Vol. 20 No. 2	Walking and cycling treated as one variable

54	Effect of Bike Lane Infrastructure Improvements on Ridership in One New Orleans Neighborhood Kathryn M. Parker, Janet Rice, Jeanette Gustat, Jennifer Ruley, Aubrey Spriggs, Carolyn Johnson Ann. behav. med. (2013) 45 (Suppl 1):S101– S107	No commuter cycling data

Appendix 7: Personal communication with UK dataservice re: missing variables APS survey (personal information excluded)

Dear Glenn,

Yes, the same is true of variables D12 and D13. The car ownership questions were not asked in APS7 as described in the APS7 questionnaire section of the Technical Report. See http://doc.ukdataservice.ac.uk/doc/7493/mrdoc/pdf/7493_aps_7_technical_report.pdf#page=265

Kind regards
XX

-----Original Message-----
From: Glenn Stewart [mailto:Glenn.Stewart@brunel.ac.uk]
Sent: 23 October 2014 13:06
To: UK Data Service Support Team
Subject: RE: (QTHELP-9550) Glenn Stewart; Income, height, weight variables in Active People Survey 7 (SN 7493)

thanks v much XX

Sorry, another question - is it the same for D12 and D13 (car / van in household, car / van available)?

Thanks again

Glenn

From: UK Data Service Support Team [support@ukdataservice.ac.uk]
Sent: 22 October 2014 12:37
To: Glenn Stewart
Subject: RE: (QTHELP-9550) Glenn Stewart; Income, height, weight variables in Active People Survey 7 (SN 7493)

Dear Glenn,

We have asked the depositors about this and they have responded to say that the income questions were not asked in this round. It is unfortunate, therefore, that the file deposited with us includes those variables. The BMI questions were asked on behalf of Public Health England and they, not Sport England, own that information. Again, therefore, that information is not available for APS 7.

We hope this clarifies matters.

Kind regards,
XX
-----Original Message-----
From: Glenn Stewart [mailto:Glenn.Stewart@brunel.ac.uk]
Sent: 21 October 2014 14:53
To: UK Data Service Support Team
Subject: RE: (QTHELP-9550) Glenn Stewart; Income, height, weight variables in Active People Survey 7 (SN 7493)

thanks XX, any help much appreciated

Glenn

From: UK Data Service Support Team [support@ukdataservice.ac.uk]
Sent: 21 October 2014 14:44
To: Glenn Stewart
Subject: RE: (QTHELP-9550) Glenn Stewart; Income, height, weight variables in Active People Survey 7 (SN 7493)

Dear Glenn,

Thank you for contacting the UK Data Service.

We have a had a look at the data and we agree that it strange that the depositors have not supplied the income information for the 2012/13 survey. There is no special licence equivalent so it is not a question of permission and those variables are fully coded in the 11/12 data so there may be a technical reason as to why they show up as -1 in each case for the more recent survey.
The BMI question seems to be more recent introduction to the survey so the absence of height/weight variables is something we can only speculate about at the moment. We are raising this with the our Data Curation Manager and we will be in touch when have more information.

Kind regards,
XX

UK Data Service Support Help Desk

W http://ukdataservice.ac.uk/help/get-in-touch.aspx

UK Data Service
UK Data Archive
University of Essex

Legal Disclaimer: Any views expressed by the sender of this message are not necessarily those of the UK Data Service or the UK Data Archive.

-----Original Message-----
Sent: 21 October 2014 14:36
To: UK Data Service Support Team
Subject: [JIRA] (QTHELP-9550) Glenn Stewart; Income, height, weight variables in Active People Survey 7 (SN 7493)

>
>   Key: QTHELP-9550
>
> Hi - have a couple of questions about APS 7 which I have downloaded:
> 1) I don't seem to be able to get into the income variables - d23new or D_23_Bands_6, all the answers appear to be -1. Is there a reason for this and do I need further permission?
> 2) the APS questionnaire includes height / weight which is published in the NOO site but doesn't seem to be in the APS 7 dataset. Again, is there a reason for this and do I need furhter permission?
> Thanks
> Glenn

Appendix 8: Active People Survey questions used for variables

Variable	Question(s)
Utility cycling	I would now like you to think about any cycling you may have done. Please include any casual cycling in your local area, any cycling in the countryside or on cycling routes, cycling to or from work or any competitive cycling. In the last four weeks, that is since [^INSERT^] have you done any cycling? 1. Yes 2. No 3. Don't know On the days that you cycled, what was the total length of time you USUALLY spent cycling during the course of the day? (Question updated in January 2012, previously based on cycling of 30 minutes duration). You said that you had cycled on [^INSERT FROM Q6b^ IF Q6b = DK INSERT 'at least one'] day(s) in the last four weeks. Can I ask, on how many of those days did you cycle for the purpose of health, recreation, training or competition not to get from place to place?
Sport and active recreation	I have already asked you about walking and cycling. I would now like to ask you about other types of sport and recreational physical activity

	you may have done. Please think about all the activities you did, in the last four weeks, whether for competition, training or receiving tuition, socially, casually or for health and fitness, but do not include any teaching, coaching or refereeing you may have done. So thinking about the last four weeks, that is since [^INSERT^], did you do any sporting or recreational physical activity?

Demographics	
Gender	I would like to finish the survey by asking you a few questions about you and your household. Please be assured that we are bound by the MRS code of conduct and all of your details are held in the strictest confidence. Gender
Age	How old are you? ASK IF REFUSED Then can you tell me, are you…. Age 25 or under Age 26 or over Refused ASK IF REFUSED And which age band do you fall into? READ OUT LIST. SINGLE CODE. 16 to 24 25 to 34 35 to 44

	45 to 54 55 to 64 65 to 74 75 to 84 85+
Ethnicity	What is your ethnic group? I will read out the options, choose one option that best describes your ethnic group or background. READ OUT. SINGLE CODE. 1. White, or 2. Mixed/ Multiple ethnic groups, or 3. Asian/ Asian British, or 4. Black/ African/ Caribbean/ Black British,or 5. Chinese, or 6. Arab, or 7. Other ethnic group IF 1 (WHITE) ASK. And which one of these best describes your ethnic group or background? IF RESPONDENT SAYS 'ENGLAND ENGLISH', 'SCOTLAND OR SCOTTISH' 'WALES OR WELSH' OR ANY PART THESE COUNTRIES E.G. CORNW BRISTOL ETC. CODE AS 'BRITISH'. 1. English / Welsh / Scottish / Northern Irish / British, or 2. Irish, or 3. Gypsy or Irish Traveller, or 4. Any other White background? – please specify

	IF 2 (MIXED) ASK. And which one of these best describes your ethnic group or background? 1. White and Black Caribbean, or 2. White and Black African, or 3. White and Asian, or 4. Any other mixed / multiple ethnic background? – please specify IF 4 (BLACK) ASK. And which one of these best describes your ethnic group or background? 1. African, or 2. Caribbean, or 3. Any other Black / African / Caribbean background? – please specify IF 7 (OTHER) ASK. Please can you describe your ethnic group or background?
Socio-economic status	SOC UNIT GROUP (A-C) AND EMPLOYMENT STATUS/SIZE OF ORGANISATION VARIABLE (D-H) USED TO DERIVE NS – SEC. NS-SEC CODED TO OPERATIONAL CATEGORIES THEN TO ANALYTIC CLASSES What does [did] the firm/organisation you work [worked] for mainly make or do at the place where you work [worked]? What was your main job in the week ending last Sunday [your last main job]? What do [did] you mainly do in your job? What qualifications are required for your job? Are (were) you working as an employee or are

	(were) you self-employed? In your job do (did) you have any formal responsibility for supervising the work of other employees? PLEASE DO NOT INCLUDE SUPERVISORS OF CHILDREN E.G. TEACHERS, NANNIES, CHILD MINDERS, SUPERVISORS OF ANIMALS, OR PEOPLE WHO SUPERVISE SECURITY OR BUILDINGS ONLY How many employees [are there / were there] at the place where you [work/ worked]? How many employees are [were] you responsible for? ASK IF SELF EMPLOYED [Are [were] you working on your own or do (did) you have employees? ASK IF HAVE EMPLOYEES How many people do (did) you employ at the place where you work [worked]? ALL EMPLOYMENT QUESTIONS ARE REPEATED FOR HOUSEHOLD REFERENCE PERSON WHERE THIS IS NOT THE RESPONDENT. This long series of questions are necessary to allow coding for the new NS-SEC classification (National Statistics Socio Economic Classification).
Address details	Can I take your full postcode? ADD IF NECESSARY: THE INFORMATION WILL BE USED TO SHAPE LOCAL SERVICES IN THE FUTURE SO WE NEED TO CONFIRM EXACTLY

	WHERE YOU LIVE. PLEASE BE REASSURED THAT THE ANSWERS YOU GIVE WILL BE ADDED TO THOSE FROM OTHER PEOPLE IN YOUR AREA FOR AN OVERALL PICTURE. This is (display address), Is this correct? Please can you give me your house name or number? Please can you tell me the name of your and town or village? Can you give me the first part of your postcode? Which of the following local authorities do you live in? (All respondents unable or unwilling to provide address details).
Children in household	Please tell me how many people aged 15 or under currently live in your household? 1 2 3 4 5 6 7 8 9 10 or ore Don’t know Refused

Appendix 9: Activities included in Active People Survey 7

Abseiling	Bocce	Boules	Climbing - rock	Diving - deep water / free	Football (outdoors) – small sided (e.g. 5-a-side)
Aerobics	Bmx	Bowls	Climbing - rope	Dodge ball	Frisby / Frisbee
Aikaido	Bobsleigh	Bowls - Crown green	Coasteering	Drag racing	Futsal
Air chair	Basketball – Outdoors	Bowls - Flat green indoor	Conditioning activities / circuit training	Dragon boat racing	Gaelic football
American football	Baton twirling	Bowls - Flat green outdoor	Cricket	Exercise bike / spinning class	Gaelic sports
Aquafit / aquacise / aqua aerobics	Biathlon	Bowls - Short mat	Cricket - other	Exercise machine /running machine / treadmill	Gliding
Archery	Bicycle polo	Boxercise	Cricket (Indoors)	Extreme adventure	Goalball
Arm wrestling	Boccia	Boxing	Cricket (Indoors) - nets /practice	Fencing	Go karting

Athletics - field	Body attack	Boxing	Cricket (Outdoor) - nets /practice	Fishing - Coarse	Golf - Driving Range
Athletics - track	Body balance	Bungee jumping / heli-bungee jumping / para bungee	Cricket (Outdoors) - match	Fishing - Game	Golf - full course
Australian rules football	Body boarding	Camogie	Cross training	Fishing - sea	Golf - Putting
Auto cross	Body building	Canoe polo	Curling	Fives - eton	Golf - Short course / Par 3 / Pitch and Putt
Autotest	Body combat / cardio kick	Canoeing	Cycling	Fives - rubgy	Gym
Backpacking	Body jam	Canyoning	Cycling - downhill riding / gravity riding	Floorball	Gymnastics
Badminton – Indoor	Body pump	Caving / pot holing	Cycling - stunt riding	Football (indoors)	Handball
Badminton – Outdoor	Body step	Cheerleading	Cyclo-cross	Football (Indoors) –	Hang-gliding

				small sided (e.g. 5-a-side)	
Baseball	Body vive	Climbing - ice	Dance exercise	Football (outdoors) – 11-aside	Harness racing
Basketball – Indoors	Bouldering	Climbing - indoor	Deck bowls	Football (outdoors) - Other	Health and fitness
High wire	Ju-jitsu	Mine exploration	Nordic (previously Telemark	Rambling	Sailing – Yacht Racing (inc.Multihull)
Highland games	Kabaddi	Modern pentathlon	Octopush	RAQUETBALL (American version NOT played on standard squash court)	Sandboarding / sand boarding
Hill climb	Karate	Motor racing	Orienteering	Road racing (motors)	Sea level traversing
Hill trekking	Karting	Motor sprints	Paintball	Roller blading / roller skating	Self defence
Hockey - Field - indoor	Kayaking	Motorcycling - drag/sprint	Parachuting	Rope coursing	Sepak takraw
Hockey - Field -	Kayaking - whitewater	Motorcycling - enduro	Paragliding	Rounders	Shinty

outdoor					
Hockey - roller	Keepfit / keep fit / sit ups	Motorcycling - motocross	Parakarting	Rowing - Outdoor / Water based	Shooting
Hockey - street	Kendo	Motorcycling - off road	Parascending	ROWING MACHINE / Indoor Rowing	Skateboarding
Hockey - underwater	Kho-kho	Motorcycling - rallying	Petanque	Rugby – other	Skating - in-line
Hockey - ice	Kick boxing / thai boxing	Motorcycling - sidecar racing	Pilates	Rugby Union	Ski flying
Horse riding	Kite surfing	Motorcycling - super	Polo	Running -	Skiing
Horse riding - three day eventing	Koozahngal	Motorcycling - track racing	Polocrosse	Running - fell	Ski-ing - barefoot snow
Hovering	Korfball	Motorcycling - trail riding	Power kiting	Running - road	Ski-ing - barefoot water
Hurling	Lacrosse	Motorcycling - trials riding	Powerboat racing	Running - track	Ski-ing - extreme
Ice skating	LEGS, BUMS and TUMS	Mountain biking	Powerlifting	Running - ultra marathon	Ski-ing - free
Irish handball	Life saving	Mountain boarding	Press ups	Sailing – Dinghy	Ski-ing - grass or dry

				Racing (inc. Multihull)	ski slope
Jam-alai	Luge	Mountain walking	Quoits	Sailing – Dinghy Cruising (inc.Multihull)	Ski-ing – mono
Jet ski-ing	Luge - street	Mountaineering	RACKETBALL (played on standard Squash Court)	Sailing - ice	Ski-ing - parachute
Jogging	Martial arts	Mountaineering - high altitude	Rafting	Sailing – keelboat cruising	Ski-ing - ribbing
Judo - Contact	Martial arts – Chinese	Netball - indoor	Rally cross	Sailing – keelboat racing	Ski-ing - speed
Judo - Non-contact	Medau	Netball - outdoor	Rallying	Sailing – Yacht Cruising(inc. Multihull)	Skipping

Skittles	Swimming - open water	Volleyball - outdoors	Wrestling - olympic freestyle		
Sky diving	Swimming / diving [indoors]	Wake boarding	Wrestling - olympic grecoroman		
Sky surfing	Swimming / diving [outdoors]	Walking	Wrestling - westmoreland		
Snomobile	Table tennis –	Walking -	Yachting - ice		

racing	indoor	cliff			
Snorkelling	Table tennis - outdoor	Walking - gorge	Yachting – land		
Snow mountain bike racing	Taekwando	Walking - hill walking	Yoga		
Snowboarding	Tai chi	Water polo	Zumba		
Snowsport	Tang soo do	Waterskiing			
Soaring	Tchoukball	Weightlifting			
Softball	Tennis - indoor	Wheelchair sports - archery			
Sombo	Tennis - outdoor	Wheelchair sports - basketball			
Speed biking	Tenpin bowling	Wheelchair sports - fishing			
Speedway	Tobogganing	Wheelchair sports - Rugby			
Sportsboats	Trampolining	Wheelchair sports – table tennis			
Squash	TRAMPOLINING - in garden	Wheelchair sports - Tennis - indoor			

Step machine	Trials racing	Wheelchair sports - Tennis - outdoor			
Stool ball	Triathlon	Windsurfing or boardsailing			
Sub aqua / scuba diving /scuba diving	Trifoiling	Wrestling - beach			
Super-modified shovel racing	Trotting	Wrestling - grappling			
Surf life saving	Tug of war	Wrestling - cornish			
Surfing	Ultimate frisbee	Wrestling – Cumberland			
Swimming - deep water	Volleyball - indoors	Wrestling - Lancashire or 'Catch as Catch Can'			

Appendix 10: CCTs and their most similar corresponding Local Authorities

Office for National Statistics (ONS) 2011 area classifications.

http://www.ons.gov.uk/ons/guide-method/geography/products/area-classifications/ns-area-classifications/ns-2011-area-classifications/about-the-area-classifications/index.html

CCT	Most similar LA	2nd most similar LA	3rd most similar LA	4th most similar LA	5th most similar LA
Blackpool	Hastings	Torbay	Weymouth & Portland	Darlington	Great Yarmouth
Cambridge	Oxford	Brighton and Hove	Kingson upon Thames	Bristol	Reading
Colchester	Worcester	Chelmsford	Leeds	York	Bath & NE Somerset
Bristol	Cardiff (Leeds)	Leeds	Southampton	Brighton & Hove	Reading
Southend	Ipswich	Bury	Worthing	Darlington	Gloucester
Stoke	Rochdale	Bolton	Tameside	Walsall	Wakefield
Woking	Elmbridge	Windsor & Maidenhead	Reigate & Bansted	Wycombe	St Albans
York	Bath and NE Somerset	Exeter	Canterbury	Colchester	Cheltenham

Appendix 11: Unadjusted and adjusted odds ratios for the effect of CCTs on utility cycling, 2005 -2007 compared to 2008 – 2012 and 2005 -2007 compared to 2009 – 2012 and 2008.

Table 21: Unadjusted and adjusted odds ratios for the effect of CCTs on utility cycling, 2005 -2007 compared to 2008 – 2012

Independent variables	***Unadjusted odds ratio (95% confidence interval)***	***Adjusted odds ratio (95% confidence interval)***
CCTs	1.64 (1.46 – 1.84)***	1.64 (1.46 – 1.84)***
Year	0.70 (0.61 – 0.79)***	0.75 (0.66 – 0.85)***
CCTs x Year 2005-7 v 2008-12	0.89 (0.76 – 1.05)	0.89 (0.76 – 1.05)
Gender		
Male	1.00	1.00
Female	0.54 (0.50 – 0.58)***	0.56 (0.51 – 0.60)***
NS-SEC		
NS SEC 1 – 4	1.00	1.00
NS SEC 5 – 8	0.76 (0.70 – 0.84)***	0.78 (0.71 – 0.85)***
NS SEC 9	0.66 (1.48 – 1.86)***	1.53)1.34 – 1.73)***
Missing	2.22 (0.97 – 5.08)	4.48 (1.80 – 11.16)**
Child in household		
No children	1.00	1.00
Having children	0.70 (0.64 – 0.76)***	0.98 (0.89 – 1.07)
Missing		0.29 (0.19 – 0.42)
Age		

16 – 34	1.00	1.00
35 – 54	0.69 (0.63 – 0.75)***	0.75 (0.68 – 0.82)***
55+	0.27 (0.25 – 0.31)***	0.30 (0.27 – 0.34)***
Ethnicity		
White	1.00	1.00
Mixed	1.63 (1.19 – 2.23)***	1.17 (0.85 – 1.61)
Asian	0.72 (0.54 – 0.96)**	0.48 (0.36 – 0.65)***
Black	1.12 (0.81 – 1.57)	0.81 (0.58 – 1.14)
Other	1.80 (1.20 – 2.69)***	1.26 (0.80 – 1.96)
Chinese	2.09 (1.37 – 3.19)***	1.26 (0.81 – 1.96
Missing	1.28 (0.99 – 1.67)	1.28 (0.96 – 1.70)***

** p ≤0.05, *** p ≤0.01

Table 22: Unadjusted and adjusted odds ratios for the effect of CCTs on utility cycling, 2005 -2007 compared to 2009 – 2012 and 2008.

Independent variables	*Unadjusted odds ratio (95% confidence interval)*	*Adjusted odds ratio (95% confidence interval)*
CCTs	1.64 (1.46 – 1.84)***	1.64 (1.46 – 1.84)***
Year (2005-7 v 2009-12)	0.89 (0.75 – 1.06)	0.90 (0.75 – 1.06)
Year (2008)	0.86 (0.68 – 1.09)	0.88 (0.70 – 1.11)
CCTs x Year 2005-7 v 2009-12	0.89 (0.75 – 1.06)	0.89 (0.75 – 1.07)
2008	0.86 (0.68 – 1.09)	0.85 (0.67 – 1.08)
Gender		
Male	1.00	1.00
Female	0.54 (0.50 – 0.58)***	0.57 (0.51 – 0.60)***
NS-SEC		
NS SEC 1 – 4	1.00	1.00
NS SEC 5 – 8	0.80 (0.70 – 0.84)	0.78 (0.71 – 0.86)***
NS SEC 9	1.71 (1.53 – 1.91)***	1.56 (1.37 – 1.76)***
Missing	2.21 (0.97 – 5.08)	4.63 (1.86 – 11.54)***

Child in household		
No children	1.00	1.00
Having children	0.70 (0.64 – 0.76)***	0.97 (0.89 – 1.06)
Missing	0.72 (0.52 – 1.00)**	0.31 (0.21- 0.46)***
Age		
16 – 34	1.00	1.00
35 – 54	0.69 (0.63 – 0.75)***	0.75 (0.68 – 0.83)***
55+	0.28 (0.25 – 0.31)***	0.31 (0.27 – 0.34)***
Ethnicity		
White	1.00	1.00
Mixed	1.63 (1.19 – 2.22)***	1.17 (0.85 – 1.61)
Asian	0.72 (0.54 – 0.97)**	0.49 (0.36 – 0.65)***
Black	1.12 (0.81 – 1.57)	0.81 (0.58 – 1.14)
Other	1.81 (2.21 – 2.71)***	1.27 (0.81 – 2.03)
Chinese	2.09 (1.38 – 3.20)***	1.26 (0.81 – 1.97)
Missing	1.31 (1.00 – 1.70)***	1.23 (0.93 – 1.63)

** $p \leq 0.05$,   *** $p \leq 0.01$

Appendix 12: Unadjusted and adjusted odds ratios for the effect of CCTs on physical activity as measured through sport and active recreation, 2005 -2007 compared to 2008 – 2012 and 2005 -2007 compared to 2009 – 2012 and 2008

Table 23: Unadjusted and adjusted odds ratios for the effect of CCTs on physical activity using years 2005-7 compared to 2008-12

Independent variables	***Unadjusted odds ratio (95% confidence interval)***	***Adjusted odds ratio (95% confidence interval)***
CCTs	0.98 (0.93 – 1.03)	0.98 (0.93 – 1.03)
Year	0.99 (0.95 – 1.03)	1.08 (1.03 – 1.13)***
CCTs x Year 2005-7 v 2008-12	0.97 (0.91- 1.03)	0.98 (0.92 – 1.05)
Gender		
Male	1.00	1.00
Female	0.72 (0.70 – 0.74)***	0.73 (0.70 – 0.75)***
NS-SEC		
NS SEC 1 – 4	1.00	1.00
NS SEC 5 – 8	0.49 (0.47 – 0.50)***	0.47 (0.45 – 0.49)***
NS SEC 9	0.98 (0.93 – 1.03)	0.84 (0.80 – 0.90)***
Missing	10.18 (5.12 – 20.21)***	16.74 (8.31 – 33.73)***
Child in household		
No children	1.00	1.00
Having children	0.53 (0.51 – 0.55)***	0.88 (0.85 – 0.92)***
Missing	0.65 (0.58 – 0.73)***	0.38 (0.33 – 0.44)
Age		

16 – 34	1.00	1.00
35 – 54	0.66 (0.63 – 0.69)***	0.62 (0.59 – 0.65)***
55+	0.23 (0.22 – 0.24)***	0.29 (0.22 – 0.24)***
Ethnicity		
White	1.00	1.00
Mixed	1.49 (1.30 – 1.73)***	0.99 (.084 – 1.16)
Asian	0.91 (0.82 – 1.00)**	0.52 (0.47 – 0.58)***
Black	0.84 (0.73 – 0.96)**	0.58 (0.51 – 0.67)***
Other	0.99 (0.81 – 1.22)	0.73 (0.57 – 0.92)***
Chinese	1.26 (0.99 – 1.59)	0.73 (0.57 – 0.94)**
Missing	0.93 (0.83 – 1.05)	0.90 (0.80 – 1.03)

** $p \leq 0.05$, *** $p \leq 0.01$

Table 24: Unadjusted and adjusted odds ratios for the effect of CCTs on physical activity using years 2005-7 compared to 2009-12.

Independent variables	*Unadjusted odds ratio (95% confidence interval)*	*Adjusted odds ratio (95% confidence interval)*
CCTs	0.98 (0.93 – 1.03)	0.98 (0.93 – 1.03)
Year (2005-7 v 2009-12)	0.94 (0.88 – 1.02)	0.97 (0.90 – 1.05)
Year (2008)	1.00 (0.95 – 1.05)**	1.04 (0.94 – 1.15)
CCTs x Year 2005-7 v 2009-12	1.01 (0.92 – 1.11)	1.04 (0.94 – 1.15)
Gender		
Male	1.00	1.00
Female	0.72 (0.70 – 0.74)***	0.71 (0.69 – 0.74)***
NS-SEC		
NS SEC 1 – 4	1.00	1.00
NS SEC 5 – 8	0.49 (0.47 – 0.50)***	0.47 (0.45 – 0.49)***
NS SEC 9	0.98 (0.93 – 1.04)	0.86 (0.80 – 0.92)***
Missing	10.11 (5.09 – 20.08)***	16.69 (8.28 – 33.62)***
Child in household		
No children	1.00	1.00
Having children	0.53 (0.51 – 0.55)***	0.88 (0.85 – 0.92)***
Missing	0.65 (0.57 – 0.73)***	0.38 (0.33 – 0.48)***
Age		
16 – 34	1.00	1.00
35 – 54	0.66 (0.63 – 0.69)***	0.61 (0.59 – 0.64)***
55+	0.23 (0.22 – 0.24)***	0.22 (0.21 – 0.23)***

Ethnicity		
White	1.00	1.00
Mixed	1.49 (1.28 – 1.73)***	1.00 (0.85 – 1.17)
Asian	0.91 (0.82 – 1.00)**	0.51 (0.46 – 0.56)***
Black	0.84 (0.73 – 0.96)**	0.58 (0.50 – 0.67)***
Other	0.99 (0.81 – 1.22)	0.74 (0.58 – 0.93)***
Chinese	1.26 (0.99 – 1.59)	0.74 (0.58 – 0.95)**
Missing	0.93 (0.83 – 1.04)	0.91 (0.80 – 1.03)

** $p \leq 0.05$, *** $p \leq 0.01$