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**Title:**

# Minimal important difference of quadriceps maximal voluntary contraction (QMVC) in COPD: a prospective cohort study

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**Abstract**

**Background**

Quadriceps maximal voluntary contraction (QMVC) reliably measures quadriceps muscle force and predicts mortality in COPD. However, the minimal important difference (MID) of QMVC is not well-established.

**Aim**

To estimate the MID of QMVC parameters in people with COPD following pulmonary rehabilitation (PR).

**Methods**

QMVC was measured before and after eight-weeks of outpatient PR in people with COPD. Absolute and %change in QMVC, and change in normalised QMVC were calculated using paired t-tests. Anchor and distribution-based methods (0.5xSD change, Standard Error of Measurement (SEM), minimal detectable change at 95% confidence, effect size and 1.96SEM) were used to estimate the MID.

**Results**

Of 903 participants, 383 were excluded due to PR non-completion or missing QMVC data with 520 included in the analysis (37% female; mean(SD) age 70.2(8.4) years; $FEV_1$ 51.4(21.4)% predicted). QMVC parameters increased with PR; mean(95%CI) or mean (SD) change: QMVC 2.0kg (1.5kg to 2.5kg), 10.6% (27.7%) and normalised QMVC 5.0% predicted (3.9% to 6.2%). Anchor-based MID estimates were precluded due to weak/no correlation with external anchors. Using distribution-based methods, the MID for QMVC change, QMVC %change and normalised QMVC change were estimated as mean (range) 3.55kg (1.84kg to 5.11kg), 18.34%

(9.60% to 26.60%) and 7.78% (3.78% to 12.48%) for all participants. However, MID estimates for absolute and %change in QMVC differed markedly between men and women. Normalised QMVC estimates demonstrated smaller sex-based discrepancies.

**Conclusion**

We provide MID estimates for QMVC parameters. Sex-specific or normalised MID estimates for QMVC should be used to facilitate the interpretation of change.

**Key messages**

**What is already known on this topic:** Quadriceps maximal voluntary contraction (QMVC) reliably measures quadriceps muscle force, however, the minimal important difference (MID) of QMVC is not well-established.

**What this study adds:** We provide MID estimates for absolute and %change in QMVC and normalised QMVC change in a large cohort of patients undergoing pulmonary rehabilitation.

**How this study might affect research, practice or policy:** Our sex-specific or normalised MID estimates for QMVC MID should be used to facilitate the interpretation of change in clinical settings, and to support future research evaluating interventions using QMVC as an outcome measure.

## MAIN MANUSCRIPT

### Background

Quadriceps muscle weakness is common in chronic obstructive pulmonary disease (COPD) [1] and is associated with reduced exercise tolerance [2], functional performance [3], quality of life[4], physical activity [5], and increased mortality and healthcare utilisation [6,7]. It represents an important extrapulmonary manifestation of COPD that is potentially remedial with non-pharmacological or pharmacological interventions [8,9].

Several techniques to assess quadriceps muscle strength have been previously described [10]. Of these, isometric quadriceps maximal voluntary contraction (QMVC)[11] is most implementable into routine practice as it provides a reliable and reproducible measurement of quadriceps muscle force [12]. There are established reference values [1] and the measurement avoids the requirement for specialist and technically challenging nonvolitional techniques such as electrical/magnetic stimulation that can be uncomfortable for patients [13].

Although QMVC has been widely used to quantify lower limb muscle weakness in research, it is not widely used in clinical practice. For example, even though lower limb muscle strength is considered a key outcome measure in pulmonary rehabilitation [14], only 18.4% of clinical services in the national UK PR audit reported the routine measurement of lower limb muscle strength [15].

Limited data exist for the minimum important difference (the smallest change or difference that patients or clinicians perceive) of QMVC. Previous studies included small sample sizes [16], or predominantly men [17]. The latter is of relevance as there is a difference in

physiological adaptations to exercise interventions according to sex [8]. A potential barrier to clinical uptake includes difficulty with interpreting the clinical significance of change values.

The aims of the current study were to describe the response of different QMVC parameters to pulmonary rehabilitation, and to estimate the MID for these parameters using pulmonary rehabilitation as the therapeutic intervention [1,18].

## Materials and methods

### Ethical approval

This study was a planned secondary analysis of two prospective cohort studies: one examining sarcopenia and frailty in chronic respiratory disease, and the other estimating the minimum important difference of lower limb performance measures [19–21]. These were approved by the London – Central Research Ethics Committee (13/LO/1161) and the London – Camberwell St Giles National Research Ethics Service committee (11/LO/1780) respectively. All participants provided informed written consent. The study was conducted according to the Declaration of Helsinki and Good Clinical Practice standards.

### Participants

Inclusion criteria were stable COPD, diagnosed according to the Global initiative for chronic Obstructive Lung Disease (GOLD) guidelines [22], the ability to provide written informed consent, referred for and accepted for the Harefield Hospital pulmonary rehabilitation (PR) programme, and agreement to attend research visits outside of their PR assessments. Exclusion criteria were significant co-morbidities that would limit walking ability or

measurement of QMVC (e.g. unstable ischaemic heart disease, neuromuscular disease, severe hip/lower limb joint pain, lower limb amputation). People who did not complete PR (attended less than half of the prescribed sessions) or did not perform QMVC at both research visits, were excluded from analysis as the aim was to assess the responsiveness and estimate the MID of QMVC following PR. Figure 1 summarises the participant flow.

**Intervention**

All participants were offered a centre-based outpatient PR programme comprising two supervised exercise and education sessions per week for eight weeks (total 16 supervised sessions). The programme included individualised aerobic and resistance training; a detailed overview of the exercise modalities, prescription and progression are provided in supplementary table 1 and has been previously described[23]

## Study procedures

Participants underwent assessments before and after the PR programme. The following procedures were performed:

### *Quadriceps maximum voluntary contraction (QMVC)*

Participants were seated in a specially adapted chair with an inextensible strap placed around the ankle of the dominant leg (figure 2). The strap was connected to a strain gauge. QMVC was measured with hips and knees at 90° flexion. Participants were encouraged to maintain a maximal contraction for three seconds, with the maximal force sustained over the course of one second recorded. The best of three reproducible manoeuvres was reported [24]. Data

were recorded and analysed using LabChart 7 (ADInstruments, Oxford, UK). Normalised QMVC was calculated as %predicted of reference values as previously described by Seymour, Spruit *et al*: (56.2 - (0.306 x age in yrs) + (0.686 x Fat Free Mass in kg) - (0.156 x height in cm) - (3.42 if female)) [1]. Fat free mass (FFM) was estimated using bioelectrical impedance analysis as previously described. [25]

***External anchors***

We conducted the following measures as they are known to be responsive to PR, have established minimum important differences and have been previously shown to correlate with QMVC: Incremental shuttle walk (ISW) [26] and five repetition sit to stand (5STS) [19]. The MID for these outcomes measures are 35.0 to 36.1 m [27] and 1.7 seconds [19] respectively. The ISW was performed over a flat 10-metre course according to international technical standards [26]; a practice walk test was performed for all participants. Participants were seated on a straight-backed armless chair at a height of 48cm for the 5STS and instructed to stand up fully and sit down as fast as possible, five times without using their arms on the chair, as previously described[19].

To measure patient self-reported symptom improvement with PR, participants completed the self-reported Chronic Respiratory Questionnaire (CRQ), [28] which is responsive to PR with an established MID of 0.5 per domain[29]. The Global Rating of Change Questionnaire (GRCQ) was measured at the post-PR assessment only. Participants were asked to rate their own health status after pulmonary rehabilitation according to five responses: “1: much better”;

"2: a little better"; "3: no change"; "4: a little worse" and "5: much worse". Participants completed the GRCQ before the ISW, 5STS and CRQ were performed so they were blinded to the results of the validated outcome measures.

## Statistical analysis

Data were inspected for normality using histograms and Shapiro Wilk tests. Baseline characteristics were reported using descriptive statistics and presented as mean (SD) or median (IQR). Responses to PR (pre- to post-PR) were normally distributed, and therefore analysed using a paired t-test. Responsiveness of QMVC and other outcome measures was assessed using the standardised response mean (Δmean/ΔSD), and were interpreted as: 0.2 (small), 0.5 (medium), and 0.8 (large)[30]. Relationships between absolute and % change in QMVC and change in normalised QMVC with change in other outcome measures were calculated using Pearson's product-moment correlation. Change in QMVC parameters within the GRCQ groups was tested for normality using histograms, and variance between the four GRCQ groups was tested using Levene's test. The difference in change in QMVC parameters between GRCQ groups were then analysed using a one-way ANOVA with Hochberg's GT2 test for multiple *post hoc* comparisons.

## Sample size

As a secondary analysis, the study population was a convenience sample, and the sample size was not formally determined.

**Estimating the MID**

To estimate the MID, we planned to use anchor-based and distribution-based methods [31]. The *a priori* criteria for establishing the validity of an external anchor were: 1) a statistically significant correlation between change in QMVC parameter and change in proposed anchor at the 5% level; 2) a correlation coefficient of at least 0.3 [19,31]. Planned anchor-based methods included linear regression and receiver operating characteristic (ROC) curves.

Distribution-based approaches included 0.5 SD change, Standard Error of Measurement (SEM) (SDΔ*√(1-ICC)), minimal detectable change at 95% confidence (1.96*√2*SEM), Cohen's D effect size (0.2*SD(pooled)) and 1.96*SEM [32,33]. The Intraclass correlation (ICC) used for calculation of SEM was based on test-retest reliability of QMVC derived from a previous study in patients with COPD (ICC=0.88)[34]. Effect size and 0.5SD were not calculated for %change in QMVC since they require the use of moment values (i.e baseline and post intervention values, not available as a percentage).

A two-tailed level of $p<0.05$ was considered statistically significant. Data analyses were performed by SPSS Version 29.0.1.0 for Windows (IBM, Inc., Chicago, IL) and GraphPad Prism 9 (GraphPad Software, USA).

## Results

In a convenience sample of 903 patients with COPD, 251 did not complete PR and 132 had missing QMVC data; 520 (319 men and 201 women) were included in the analysis (figure 1). Baseline characteristics are detailed in Table 1, and, sex specific characteristics in supplementary tables 2-3.

The standardised response mean for QMVC parameters ranged from 0.38 to 0.39, lower than for other functional (5STS, ISW) and health status measures (CRQ) measured before and after PR (Table 1).

**Table 1 – Baseline characteristics and response to pulmonary rehabilitation (whole cohort)**

| Variable | Baseline | Post-PR | Change | Effect size (Standardised Response Mean) |
|---|---|---|---|---|
| Age (years) | 70.2 (8.4) | - | - | - |
| Sex (Male: n (%)) | 319 (61.3) | - | - | - |
| $FEV_1$ (% predicted) | 51.4 (21.4) | - | - | - |
| $FEV_1$/FVC ratio | 0.50 (0.16) | - | - | - |
| BMI ($kg/m^2$) | 27.6 (5.9) | - | - | - |
| FFM (kg) | 47.9 (9.9) | - | - | - |
| MRC dyspnoea scale | 3 (2, 4) | - | - | - |
| QMVC (kg) | 27.0 (10.2) | 29.0 (10.7) | 2.0 (1.5 to 2.5) | 0.38 |

| | | | | |
|---|---|---|---|---|
| QMVC %predicted | 65.7 (18.6) | 70.8 (19.2) | 5.0 (3.9 to 6.2) | 0.39 |
| %change in QMVC | - | - | 10.6 (27.7) | 0.38 |
| 5STS (sec) | 11.8 (9.6, 14.9) | 10.0 (8.2, 11.9) | -2.3 (-2.9 to -1.7) | 0.47 |
| ISW (m) | 250 (140, 360) | 320 (200, 445) | 62.4 (55.8 to 69.0) | 0.88 |
| CRQ-Dyspnoea | 14.2 (5.7) | 19.2 (6.6) | 5.0 (4.4 to 5.5) | 0.80 |
| CRQ-Fatigue | 14.0 (5.3) | 17.1 (5.1) | 3.1 (2.7 to 4.4) | 0.69 |
| CRQ-Emotion | 31.4 (9.1) | 35.5 (8.6) | 4.1 (3.5 to 4.7) | 0.57 |
| CRQ-Mastery | 18.2 (5.5) | 21.0 (5.0) | 2.8 (2.4 to 3.2) | 0.58 |
| CRQ-Total | 77.8 (21.2) | 92.8 (21.1) | 15.0 (13.4 to 16.6) | 0.83 |

Data presented as mean (standard deviation), median (25th, 75th centile) or mean (95% confidence interval) unless shown otherwise. $FEV_1$: Forced Expiratory Volume in one second; FVC: Forced Vital Capacity BMI: Body Mass Index; FFM: Fat Free Mass; MRC: Medical Research Council; QMVC: Quadriceps Maximal Voluntary Contraction; 5STS: Five repetition sit to stand; ISW: Incremental Shuttle Walk test; CRQ: Chronic Respiratory Questionnaire.

## Estimation of MID- anchor-based approaches

### *5STS, ISW, CRQ-total and CRQ (all domains)*

The relationship with change in external anchors did not reach the pre-defined level of association ($r \geq 0.3$) or significance ($p<0.05$) with change in QMVC parameters (supplementary tables 4-6). Anchor-based estimates of the MID were therefore not calculated[32].

***Global Rating of Change questionnaire (GRCQ)***

Overall, 52.1% (n=269) of participants felt much better, 40.1% (n=207) felt a little better, 6.6% (n=34) reported no change and 1.2% (n=6) reported they were a little worse after PR; no participants stated they were much worse after PR. Normality of the data were confirmed with histograms, and Levene's test was non-significant, therefore a one-way ANOVA with Hochberg's GT2 test for multiple *post hoc* comparisons was applied. There were no significant differences in QMVC parameters across GRCQ responses, precluding an anchor-based MID estimate with GRCQ (supplementary table 7).

**Estimation of MID: Distribution-based approaches**

Table 2 summarises the distribution-based estimates of the MID for QMVC, QMVC %predicted and %change in QMVC.

For the whole cohort, the mean (range) MID estimates for absolute and %change in QMVC, and change in normalised QMVC were 3.55kg (1.84kg – 5.11kg), 18.34% (9.60% – 26.60%) and 7.78% (3.78% – 12.48%) respectively. In our cohort, 184 patients (35%) improved by the MID of absolute QMVC change, 146 (28%) by the MID of %change in QMVC, and 204 (39%) patients by the MID of normalised QMVC change.

The MID estimates for absolute and %change in QMVC differed considerably between men and women; MID estimate for absolute QMVC in women was mean (range) 2.81kg (1.39kg – 4.48kg), lower than the MID estimate for men (3.63kg (1.97kg – 5.47kg)). Using these sex-specific estimates, a similar proportion of women (40%) and men (37%) improved by the MID.

The MID estimate for %change in QMVC for women was mean (range) 22.97% (12.02% – 33.32%), and 14.63% (7.66% – 21.22%) for men. 26% of women and 33% of men improved by the sex-specific %change in QMVC MID. The difference in MID estimates for QMVC normalised to reference values was minimal: mean (range) 7.46% (3.41% - 12.39%) in women; 7.97% (3.97% – 12.58% in men. 37% of women and 39% of men improved by the MID of QMVC normalised to reference values.

**Table 2 – Distribution based MID estimates**

| QMVC parameter | Population | Distribution based method | | | | | Mean (range) |
|---|---|---|---|---|---|---|---|
| | | 0.5xSD | SEM | MDC 95% | Effect size | 1.96SEM | |
| Absolute change QMVC (kg) | Whole cohort | 5.10 | 1.84 | 5.11 | 2.09 | 3.61 | 3.55 (1.84 -5.11) |
| | Male | 4.84 | 1.97 | 5.47 | 2.00 | 3.86 | 3.63 (1.97 – 5.47) |
| | Female | 3.41 | 1.62 | 4.48 | 1.39 | 3.17 | 2.81 (1.39 – 4.48) |
| %change QMVC (%) | Whole cohort | - | 9.60 | 26.60 | - | 18.81 | 18.34 (9.60 – 26.60) |
| | Male | - | 7.66 | 21.22 | - | 15.01 | 14.63 (7.66 – 21.22) |
| | Female | - | 12.02 | 33.32 | - | 23.56 | 22.97 (12.02 – 33.32) |
| Change normalised QMVC (%) | Whole cohort | 9.30 | 4.50 | 12.48 | 3.78 | 8.83 | 7.78 (3.78 – 12.48) |
| | Male | 9.85 | 4.54 | 12.58 | 3.97 | 8.89 | 7.79 (3.97 – 12.58) |
| | Female | 8.25 | 4.47 | 12.39 | 3.41 | 8.76 | 7.46 (3.41 – 12.39) |

QMVC: Quadriceps Maximal Voluntary Contraction; SEM: Standard Error of Measurement; MDC: Minimal Detectable Change

## Discussion

This is the largest study to date to describe the response of QMVC to pulmonary rehabilitation. Using this dataset of 520 participants with COPD, we were able to provide estimates for the MID of different QMVC parameters, including sex-specific estimates, using distribution-based methods. We were unable to calculate anchor-based estimates due to weak or non-significant correlations with external anchors.

### *Previous studies*

Previous studies have used QMVC as an outcome measure following resistance training or quadriceps electrical stimulation [35,36]. A Cochrane review summarised improvements in quadriceps strength measured using fixed or handheld dynamometry following neuromuscular electrical stimulation in 933 participants with COPD or other chronic diseases (12 studies), finding a difference of approximately 1.1kg compared to the control [36]. This is lower than the observed change in our cohort, probably because neuromuscular stimulation is a passive treatment, with a much lower intensity than resistance-training prescribed during PR[36] [37]. In people with COPD, O'Shea et al. report a mean (range) improvement in knee extensor strength measured by QMVC or isokinetic techniques of 25% (11.8% to 52.5%) following resistance training (10 studies, n=138), a higher increase than in our cohort [35]. This is likely to be due to the focused resistance training employed in their study compared with the mixed aerobic and resistance training employed during PR.

Despite the use of QMVC as an outcome measure in studies investigating the effects of lower limb strengthening, there are limitations to existing data estimating the MID of QMVC following PR in patients with COPD. Using a heavily weighted cohort of male participants (94% men), and relatively small sample size (n=69 versus n=520 in our study), Iwakura et al. were able to anchor the QMVC against a clinical measure (the 6MWT) unlike in our dataset. Their anchor-based MID estimate of 3.3kg was similar to our distribution-based estimate[17]. Santin et al. estimated the MID of QMVC following a 12-week high intensity exercise program; this included cycle ergometry at up to 100% maximum workload, walking at up to 110% of baseline 6MWT speed and quadriceps resistance training at up to 110% of baseline one repetition max [16]. In this small cohort of 21 people with COPD, their proposed MID was between 9.4 to 16 Nm or 7.4% to 12% change, using distribution-based methods. Vaidya et al. estimated the MID of QMVC as 7.5Nm following pulmonary rehabilitation in 157 people with COPD using distribution-based methods [38]. Nm and Kg are not directly comparable, therefore it is difficult to draw comparisons with our data. The %change QMVC estimate in our study is higher than Santin et al., perhaps because we used a wider range of distribution-based estimates [33,39].

Oliveira et al. measured QMVC in 70 participants before and after a 12-week community-based PR programme [40]. The proposed MID was 5.2 kg for QMVC, larger than our estimate, but with estimates ranging widely from 0.2 to 8.1 kg. Like the Iwakura study, their study cohort was predominantly male (84%), with a higher baseline QMVC, which may have influenced absolute MID estimates. Furthermore, this study used hand dynamometry to measure QMVC, unlike the fixed strain gauge approach adopted in our study. The hand dynamometry method is arguably more dependent on the technique and strength of the

assessor. Previous studies have shown that there are wide limits of agreement for hand dynamometry even in frail older adults [41].

*Clinical implications*

Measurement of muscle strength is a core outcome for pulmonary rehabilitation[15], but previous national audit data from the UK identified that only a minority of clinical PR services routinely measure this. There may be several reasons for this including non-familiarity with measurement techniques, clinical space, or difficulties interpreting change data. Furthermore, because several techniques to measure lower limb muscle strength have been described, there does not seem to be consensus on which technique to use in clinical practice. Advantages of QMVC include: a high test-retest reliability, (ICC=0.88)[34], established reference values [1], non-reliance on assessor strength [41], and the relatively cheap cost of a strain gauge, compared to, for example resistance gymnasium equipment required to measure one repetition maximum.

Our study provides further information to support clinicians and trialists wishing to use QMVC as an outcome measure, especially in the PR setting. We demonstrate the responsiveness of QMVC to an outpatient PR programme, and provide MID estimates for different QMVC parameters for both males and females. This may help evaluate intervention effectiveness, allowing benchmarking between different services and settings. Furthermore, determination of the QMVC MID may support researchers evaluate interventions with QMVC as an outcome (for example, in estimating a sample size).

Our data suggest that there were notable differences in the MID estimates for QMVC parameters between women and men. However, there was only a small difference in our estimates of the MID for change in normalised QMVC between men and women. This is unsurprising given that normalised QMVC takes into account sex. Therefore, we recommend clinicians either using sex-specific MID estimates when interpreting QMVC change, or use change in normalised QMVC[1] if a single MID estimate is preferred.

***Strengths and limitations***

Acknowledging that there are differences in physiological adaptations to exercise interventions according to sex [8], and a documented need for sex-specific reporting in research[42], the size of our study population allowed us to provide sex-specific MID estimates. In addition, we calculated the MID of other QMVC parameters including %change in QMVC which accounts for baseline QMVC, and change in normalised QMVC, which accounts for age, FFM, height, and sex, enabling researchers and clinicians to calculate a more individualised MID [1].

However, this was a single centre study, and our findings may not be generalisable to other populations, settings or treatments. It was not possible to use anchor-based methods to determine the MID as the *a priori* criteria for determining the validity of external anchors (statistically significant correlation at 5% and a correlation coefficient >0.3) were not met. The lack of correlation between QMVC and external anchors suggests that that change in functional or health-related quality of life measures are not good surrogates of muscle

strength, further supporting the need for specific muscle strength measurements. Our findings are corroborated by studies of anabolic agents. Two trials in recent years have attempted to build locomotor muscle strength using activin IIb receptor blockade [43] or selective androgen receptor modulation. [44] In the first the active group increased thigh muscle volume and had numerical but not statistically significant increases in one repetition maximum (1-RM) (perhaps a reflection on the 1-RM technique) [43]. In the second, selective androgen receptor modulation increased 1-RM in men and (although without statistical significance) in women, and lean body mass in both [44]. However, in neither study was there an improvement in function using the 6-minute walk test, Timed Up and Go test, hand grip strength, 4 metre gait speed or Endurance Shuttle Walk Test, or in self-reported symptoms using the St. George's Respiratory Questionnaire or COPD Assessment Test.

Our estimates of the MID are therefore reliant on distribution-based approaches which are statistically based, similar to other previous studies estimating the MID for QMVC [16,38,40]. Although there is no consensus on the optimal method to determine the MID, anchor-based approaches are preferred as they account for the patient perception of improvement [31,33]. However, we did use several well-established distribution-based approaches and were transparent about the range of estimates. Nevertheless, our data needs to be corroborated in future studies. In particular, relating improvement in QMVC to better prognosis (such as improved survival, reduced hospitalisation or significant falls) would further support the wider use of QMVC.

Another limitation is that the mean QMVC change following PR was modest, although statistically significant. For QMVC parameters, the standardised response means ranged from

0.38 to 0.39 (small to medium effect size) and lower than the other clinical outcome parameters measured before and after PR. It is not clear whether this is related to the responsiveness of the measure itself, or whether the intervention in this study was more focused on aerobic training and aerobic outcome measures [15]. The mean QMVC change in our study was smaller than observed with specific lower limb resistance training [35], but larger than seen with neuromuscular electrical stimulation [36], or the longitudinal decline over one year in people with COPD [45]. We did not measure the long-term effect of PR on QMVC nor the longitudinal decline of QMVC following PR, both of which should be evaluated in future research.

## Conclusions

In summary, we propose that the MID of absolute and %change in QMVC, and change in normalised QMVC are mean (range) 3.55kg (1.84kg – 5.11kg), 18.34% (9.60% – 26.60%) and 7.78% (3.78% – 12.48%). However, there are differences in the MID estimates for absolute and %change in QMVC between men and women. Therefore sex-specific or normalised QMVC parameters should be used to facilitate the interpretation of change with interventions.

## Statements

### Author contributions

Concept and design of study: All authors; Data collection: SP, JC, SK, REB, SJ, JAW, KI, CMN; Analysis of data: TOJ, GDE, CMN; Writing initial draft manuscript: TOJ, WD-CM; Revision and approval of final manuscript: All authors; Guarantor: WD-CM.


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**Ethics approval**

Approved by the London – Central Research Ethics Committee (13/LO/1161) and the London – Camberwell St Giles National Research Ethics Service committee (11/LO/1780).

**Data sharing**

Data are available upon reasonable request from the corresponding author.

**Clinical trial registration**

This study was not a clinical trial as defined by the ICMJE.

**AI use statement**

AI was not used in the creation of this manuscript.

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## FIGURE LEGENDS

**Figure 1 legend:** Participant flow diagram

**Figure 2 legend:** QMVC measurement chair