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Accelerometry as a measure of modifiable physical activity in high risk elderly preoperative patients, a prospective observational pilot study.

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Manuscripts

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5 **Accelerometry as a measure of modifiable physical activity in high risk elderly preoperative**
6 **patients, a prospective observational pilot study.**
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ABSTRACT

Objectives: To use wrist worn accelerometers[1] to establish normative physical activity (PA) and acceptability data for the high-risk elderly preoperative population to facilitate power calculations for future intervention studies, to assess whether PA could be modified by a prehabilitation intervention as part of routine care, to assess any correlation between accelerometer-measured PA and self-reported PA, to assess the acceptability of wearing wrist-worn accelerometers in this population.

Study Design: Prospective, observational, pilot study

Setting: Single NHS Hospital

Participants: Frail patients ≥ 65 years awaiting major surgery referred to a multidisciplinary preoperative clinic at which they received a routine intervention aimed at improving their PA. 35 patients were recruited. Average age 79.9 years (SD=5.6).

Primary outcomes: Normative PA data measured as a mean daily Euclidean norm minus one (ENMO) in milli-gravitational units(mg).

Secondary outcomes: Measure PA levels (mg) following a routine preoperative intervention. Determine correlation between patient reported PA (measured using the Physical Activity Scale for the Elderly[2]) and accelerometer-measured PA (mg). Assess acceptability of wearing a wrist-worn accelerometer measured using visual analogue scale questionnaire and device wear-time (hours).

Results: Median baseline daily PA was 14.3mg (IQR 9.75-22.04) with an improvement in PA detected following the intervention [median ENMO post-intervention 20.91mg (IQR 14.83-27.53), $p=0.022$]. There was no significant correlation between accelerometer-measured and self-reported PA [Baseline $\rho=0.162$ ($p=0.4$), Post intervention $\rho=-0.144$ ($p=0.5$)]. We found high acceptability ratings (Median score of 10/10 on VAS, IQR 8-10) and wear-time compliance [163.2 hours (IQR 150-167.5) pre-intervention and 166.1 hours (IQR 162.5-167) post-intervention].

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3 **Conclusions:** Accelerometry is acceptable to this population and increases in PA levels measured
4 following an unoptimized routine clinical intervention indicates that health behaviour change
5 interventions may be successful during the preoperative period. Accelerometers may therefore be a
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10 useful tool to design and validate interventions for improving PA in this setting.

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13 **Trial registration:** ClinicalTrials.gov (NCT03737903)

14 15 16 **ARTICLE SUMMARY**

17 18 19 **Strengths and limitations of this study**

- 20
21 • This is the first study to look at the use of wearable accelerometers to measure and
22 characterise physical activity in high risk elderly patients in the preoperative period
- 23
24 • We present a robust and objective method of measuring physical activity levels and compared
25 this to self-reporting methods of measuring physical activity.
- 26
27 • We were able to assess the impact of an existing unoptimized preoperative intervention using
28 accelerometry
- 29
30 • Limitations of this study include small sample size although this is justified by the fact that it
31 was an initial pilot study to establish normative physical activity and acceptability data to
32 facilitate power calculations for further studies.
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45 46 47 **INTRODUCTION**

48 The “high risk” surgical population is characterised by advanced age, frailty and multiple comorbidities
49 particularly when undergoing major surgery. This population accounts for just 12.5% of surgical
50 procedures, but over 80% of perioperative deaths in the UK[3]. With an aging population, increasing
51 numbers of high-risk patients require surgery. It is therefore important to improve understanding of
52 risk factors for perioperative complications in order to facilitate shared decision making and
53 appropriate planning of perioperative care.
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3 Frail patients are less able to recover from the physiological stress encountered during the
4 perioperative period and frailty status is an independent predictor of postoperative morbidity and
5 mortality[4,5]. Physical inactivity is a defining feature of frailty. Older adults spend a significant part
6 of their day being sedentary[6] and do not meet current PA recommendations[7,8]. Increased PA can
7 delay the onset of frailty and slow the progression from a non-frail to a frail state[9] and exercise
8 interventions can reverse the functional decline associated with acute hospitalisation of elderly
9 patients[10]. There is also growing evidence for the association between PA and perioperative
10 outcomes[11]. Prehabilitation programmes typically incorporate optimisation of PA alongside
11 medical, nutritional and psychological status. Prescribed exercise training programmes have specific
12 goals of muscle strengthening and increased physical fitness but are labour intensive and most have
13 suboptimal participant adherence rates[12]. The optimum frequency, intensity, timing and type of
14 exercise-prehabilitation intervention is uncertain, nor is it clear that prehabilitation reduces
15 postoperative morbidity and mortality[13]. Furthermore, prehabilitation-potential may vary
16 depending upon the surgical population of interest, and knowledge of this is important for targeting
17 of specific interventions.

18
19 Sustained changes in habitual, environmentally-cued health behaviours are notoriously difficult to
20 achieve[14], but it is plausible that the preoperative period, due to the well-defined target end-point
21 (surgery), may represent a unique teachable moment during which motivation to convert intention
22 into action may be elevated, and a sustained change in behaviour may be more achievable than other
23 settings. Thus, it may be possible to influence patient behaviours in order to reduce perioperative risk
24 and improve outcomes.

25
26 In order to develop and evaluate pre-operative interventions to promote PA it is critical to first have
27 a robust, precise method of measuring PA, and normative physical activity data for the population of
28 interest. Traditionally, in the perioperative setting, patients' PA levels have been evaluated using brief
29 self-report questionnaires, however these are prone to error and recall bias[15], particularly for low-

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3 intensity PA typically seen in an elderly cohort. The gold standard method of direct observation is
4 labour-intensive and time-consuming, and therefore not feasible for widespread use[16].
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6 Accelerometers could offer a potential solution; Tri-axial accelerometers detect magnitude and
7
8 direction of acceleration and have been used in large-scale epidemiological studies to provide a valid
9
10 estimate of overall PA[17]. They are unobtrusive and non-invasive and can be worn on locations such
11
12 as around the wrist or clipped onto a hip belt to measure PA in free-living environments.
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14 Accelerometers may offer a means to assess the efficacy and therefore optimise interventions to
15
16 improve PA. However, this first requires the specific population of interest to be characterised. To our
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18 knowledge wearable accelerometers have not previously been used to characterise PA in a high-risk
19
20 elderly population in the pre-operative period. Wrist-worn accelerometers have been shown to be
21
22 acceptable and valid measures of PA in volunteers in the 65-79yrs age group[17], but this population
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24 had already been recruited into a large-scale observational study involving intense phenotyping, and
25
26 it is likely that the high-risk preoperative elderly group is distinct in its activity behaviour due to
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28 comorbidities and underlying diagnoses. Furthermore, the acceptability of PA measurement has not
29
30 been established in these patients and they are likely to be distinct from non-surgical controls. In order
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32 to design and optimise future interventions it is first vital to understand baseline PA in this group.
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35 Through this pilot study we aimed to characterise PA levels across a variety of surgical specialties in
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37 order to obtain normative data to establish power calculations for future intervention studies. We
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39 also sought to assess whether there was a change in PA following current preoperative interventions
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41 (which form part of usual care in our centre) and quantify the variability of that change. We set out to
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43 quantify the correlation between objectively measured and self-reported PA in this patient group.
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45 Finally, as accelerometers have not previously been used in this setting we aimed to assess how
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47 acceptable it is to use wrist-worn accelerometers to measure PA in high risk elderly patients in the
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49 preoperative period prior to rolling them out into a larger scale programme of research.
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METHODS

Study approvals and population

This study was conducted at Cambridge University Hospitals NHS Foundation Trust and approval by a Research Ethics Committee was obtained prior to participant recruitment (Research ethics number: 18/SC/0287). Written informed consent was obtained from all participants. Inclusion criteria were patients referred to the Perioperative Review Informing Management of Elderly patients (PRIME) clinic (a multidisciplinary clinic specifically designed to optimise frail elderly patients pre-operatively), participants must have had capacity to consent and complete activity questionnaires and be willing and able to wear the accelerometer around their wrist. PRIME referral criteria were patients listed for major or complex surgery who were aged ≥ 65 years and either had a Rockwood Clinical Frailty Scale[18] score (CFS) of ≥ 4 or had a clinical picture that gave the pre-assessment nurse enough concern to refer for a multidisciplinary preoperative assessment. Referral to, and attendance at the PRIME clinic formed part of usual preoperative care at our institution. Participants were excluded from the study if they did not meet the inclusion criteria, they refused to participate or their PRIME clinic appointment was scheduled <72 hours after referral for recruitment, as previous research has shown a minimum period of 72 hours of continuous accelerometer wear-time is required to produce valid data[17]. Recruitment took place between July and December 2018.

Patient and Public involvement

Patient and public involvement (PPI) was sought during the study design process with the aim of ensuring that the research question was agreed to be important, the methods and running of the study were likely to be acceptable to patients and the documents were written appropriately for the target study population. Study documents including patient information leaflets, consent forms and information posters were circulated to Cambridge University Hospital PPI panel for review. Feedback from the PPI panel allowed us to construct more lay-friendly documents. The PPI panel considered the

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3 burden of intervention and time required to participate in research. We will consider further PPI
4 involvement in order to disseminate the study results to those participants who requested to be
5 informed.
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10 11 12 **Accelerometer and data collection** 13

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15 Participants wore a waterproof triaxial accelerometer (Axivity AX3, Newcastle, UK[1]) around their
16 wrist for 24 hours per day, for seven days prior to their PRIME clinic visit, and seven days immediately
17 after their PRIME clinic visit. Participants wore the device around their preferred wrist for convenience
18 and to maximise compliance. Participants were instructed by the research team how to re-fit the
19 accelerometer should they remove it for any reason. Accelerometer devices were programmed to
20 commence data collection on the same day that the device was fitted and to record for seven days.
21 The accelerometer measures acceleration in three axes sampled at 100Hz with a dynamic range of +/-
22 8g.
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36 The PRIME clinic visit involves a preoperative review by an anaesthetist, geriatrician, physiotherapist
37 and occupational therapist. During this clinic visit, patients were provided with a behaviour change
38 intervention as part of usual perioperative care at our institution (see behaviour change intervention
39 below). At the PRIME clinic visit, a member of the research team retrieved the accelerometer worn by
40 participants for the initial seven-day period and provided the participant with a new device for the
41 second seven-day period. Participants completed two questionnaires at the PRIME clinic visit: a
42 validated self-reported activity questionnaire; Physical Activity Scale for the Elderly (PASE)[2], and a
43 locally designed acceptability questionnaire (see assessment of acceptability below). Participants
44 were asked to repeat the PASE questionnaire at the end of the second seven-day wear period and
45 return the accelerometer and completed PASE questionnaire back to the study centre in a prepaid
46 envelope.
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Assessment of acceptability

Overall acceptability was assessed using a participant completed questionnaire utilising a visual analogue scale (VAS) from 0-10, 0 being “very unacceptable” and 10 being “very acceptable”. We also measured the length of time that the devices were worn in hours (wear time compliance).

Behaviour change intervention (PRIME clinic visit)

The behaviour change intervention (given as part of usual care) consisted of PA and exercise advice described as follows according to the TIDieR checklist[19]. The goals of the intervention were to improve PA levels on a day to day basis through activities of daily living (ADLs) or leisure activities, to improve specific aspects of fitness, perioperative respiratory function and promote independence with personal and domestic ADLs and leisure activities. Verbal and written advice was provided as follows: two generic exercise leaflets (general exercises for the whole body, and walking exercises), bespoke exercise programmes (generated using online Physiotoools[20] software) and local hospital-specific respiratory exercise information leaflets were provided along with advice and information about appropriate community services. The intervention was administered by an NHS Band seven Physiotherapist with a background in Surgery and Elderly rehabilitation and an NHS Band seven Occupational therapist with a background in Surgery, Orthopaedics and Elderly rehabilitation via one face-to-face session (PRIME clinic visit) lasting 40 minutes. The information described above was given to participants in the PRIME clinic room with the expectation that they would undertake the activities in their own homes. The intervention was tailored to each participant, depending upon presentation and planned surgical procedure. Personalised exercise programmes were designed by the Physiotherapist during the clinic visit and taught to participants during this session, with a written information leaflet given to the participant to take home. If participants required adaptive equipment,

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3 the Occupational therapist arranged for this to be delivered to the participant's home. Adherence to
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5 this intervention was not otherwise assessed.
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10 **Data processing and statistical analysis**

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13 Raw accelerometry data were downloaded and visually inspected in order to detect any
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15 accelerometer technical issues, to ensure that the accelerometer was worn and recorded for the
16
17 correct duration and had recorded the signals as expected. Data analyses were performed in R-
18
19 package GGIR, the details of which have been previously described[21].
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23 PA related acceleration was calculated using auto-calibrated Euclidian norm minus one (ENMO)[22].
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25 The values presented are the average ENMO for all of the available data normalised per 24-hour cycle
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27 (diurnally balanced), with invalid data imputed using the average at similar time points on different
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29 days of the week. We chose to use ENMO as our measure of PA since previously published cut-offs for
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31 mild/moderate/vigorous intensity PA may not apply to this patient population.
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35 We generated descriptive statistics for the number of participants, wear time in hours, and average
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37 daily ENMO milli-gravitational units (mg). We analysed the difference in ENMO before and after the
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39 existing intervention using the Wilcoxon signed rank test. We also analysed ENMO stratified into
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41 orthopaedic and non-orthopaedic surgical populations.
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45 Correlation between PA measured objectively using accelerometry, and subjectively using a self-
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47 reported PA questionnaire (PASE) was assessed using Pearson's product moment coefficient, and
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49 Wilcoxon signed rank or rank sum tests were used for comparisons.
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52 Statistical analysis was conducted using the R statistical language[23]. Mixed effects models were
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54 constructed using the lme4 package[24], significance testing was done using analysis of deviance. A
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56 statistical significance level of 5% was assumed throughout and no correction for multiple
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58 comparisons were made.
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RESULTS

36 patients were invited to take part in the study, of which 35 participants were recruited, 19 (54%) were female. 20 participants (57%) were listed for orthopaedic surgery, 7 (20%) gastrointestinal surgery, 5 (14%) urological surgery, and 1 each for vascular, gynaecology and breast surgery. The mean age was 79.9 years (SD = 5.6 years). Characteristics of the study population are given in Table 1. Median nurse-assessed Rockwood Clinical Frailty Score (CFS) was 5 (IQR 4-5).

Table 1. Characteristics of the study population, Values are mean (SD), number (proportion).

Characteristics of study sample, (n=35)	Value
Age; years	79.9 (5.6)
Sex,	
Female	19 (54%)
Male	16 (46%)
Rockwood Clinical Frailty Score,	
3	1 (2.9%)
4	12 (34.3%)
5	17 (48.6%)
6	5 (14.3%)
Surgical specialty,	
Orthopaedic	20 (57%)
Gastrointestinal	7 (20%)
Urology	5 (14%)

Gynaecology	1 (3%)
Vascular	1 (3%)
Breast	1 (3%)
ASA score*	
2	8 (23%)
3	27 (77%)

*ASA; American Society of Anaesthesiologists physical status classification system score

Accelerometry data were available for analysis for 34 participants before the intervention and 30 participants after the intervention. Data from one pre-intervention participant were unavailable due to an accelerometer programming error, three participants were withdrawn from the post-intervention part of the study because their surgical procedure was scheduled to be <72hrs after the PRIME clinic visit thus participants would not have been able to wear the device for the minimum required time of 72 hours. One participant was withdrawn from the post-intervention part of the study due to skin irritation around the wrist strap (notably similar irritation was also caused by their own wrist watch), and one participant was withdrawn due to an area of bruising around the wrist strap. This participant was taking oral anticoagulants.

Preoperative baseline PA levels were obtained in 34 participants. The median baseline daily PA level was 14.3mg (IQR 9.75-22.04). There was no significant difference in baseline median PA between males [12.6mg (IQR 9.5-15.7)], and females [16.9mg (IQR 12.5-23.9)], $p=0.18$). Median baseline daily PA in orthopaedic patients was 15.3mg (IQR 10.1-23.5), compared to a median of 12.7mg (IQR 9.2-

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3 16.6) in non-orthopaedic patients ($p=0.271$) as shown in Figure 1. Baseline PA was higher in females
4 than males in this orthopaedic sub-group (22.84mg vs 10.17mg, $p=0.046$).
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8 There was a significant increase in overall daily ENMO after the standard clinical intervention [median
9 baseline ENMO 14.3mg (IQR 9.75-22.04), median ENMO post-intervention 20.91mg (IQR 14.83-
10 27.53), $p=0.022$] as shown in Figure 1. There was no significant difference in ENMO before and after
11 the intervention in patients awaiting orthopaedic surgery [median baseline ENMO 15.29mg (IQR
12 10.07-23.5), median ENMO post-intervention 20.05mg (IQR 14.83-27.61), $p=0.304$]. However, in
13 those participants listed for non-orthopaedic surgery there was a significant increase in mean PA
14 following the intervention [median baseline ENMO 12.71mg (IQR 9.20-16.61), median ENMO post-
15 intervention 21.49mg (IQR 18.04-25.82), $p=0.019$] Figure 1.
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33 The distribution of PA over time for all patients is shown in Figure 2 for both pre- and post-
34 intervention. There was evidence for a linear increase (mixed effects model) in PA over time in the
35 pre-intervention group +0.28 mg/day, (95%CI: 0.011-0.53, $p=0.04$) with a similar finding in the post
36 intervention group +0.15 mg/day (95% CI: -0.19-+0.50, $p=0.37$), albeit not achieving statistical
37 significance. There was no evidence for a significant effect of whether the day was a weekend or not,
38 nor was there evidence for a non-linear time dependency.
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47 There was no significant difference in self-reported PASE scores before and after the PRIME clinic
48 intervention [median PASE pre-intervention was 67 (IQR 31-89.75), median PASE post-intervention
49 was 65 (IQR 45.5-101) $p=0.247$]. Furthermore, no significant correlation was found between the
50 accelerometer-measured PA and the self-reported PA measured using the PASE questionnaire, either
51 before or after the intervention [Baseline $\rho=0.162$ ($p=0.4$), Post intervention $\rho= -0.144$ ($p=0.5$)].
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3 The median wear time of the wrist-worn accelerometer was 163.2 hours (IQR 150-167.5) pre-
4 intervention and 166.1 hours (IQR 162.5-167) post-intervention. On average participants wore the
5 accelerometers for 98% of the measurement period indicating excellent wear-time compliance, with
6 values comparable to those achieved in other studies[17]. 33 participants completed the acceptability
7 questionnaire, and the median overall acceptability score obtained was 10 (IQR 8-10). The high wear-
8 time compliance, low voluntary withdrawal rate and high acceptability scores indicate overall
9 acceptability and feasibility of measuring PA in high risk elderly patients in the preoperative period
10 using these accelerometers.
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24 **DISCUSSION**

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27 These data demonstrate that wrist worn accelerometers can successfully be used to measure PA in
28 high-risk elderly patients in the preoperative period, and that this process was acceptable to
29 participants. The fact that there was no correlation between participant-reported PASE and
30 accelerometer-measured PA highlights the need for more objective measures of PA[25] and suggests
31 a role for such devices in perioperative research and perhaps clinical care. We demonstrated a
32 substantial variability in baseline PA in the frail elderly preoperative population. Our study also gives
33 an estimate of the typical mean daily PA levels in this specific group of patients which has not
34 previously been described. Such data should inform the planning of potential studies involving PA
35 measurements in this setting. We found low PA levels in this population: By way of comparison, the
36 UK Biobank study reported mean daily ENMO values in over three thousand 75-79 year olds (the most
37 comparable group to ours) women of 23.9mg (SD=6.5) and in men this was 22.9mg (SD=6.8)[17]. Our
38 study population had lower baseline mean daily ENMO of 18.9mg (SD=10.5) in women, and 13.71mg
39 (SD=6.1) in men, which may reflect their underlying medical conditions, frailty and increased age
40 (mean age of our study population was 79.9 years SD 5.6). Further work is be needed to develop
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3 metabolically meaningful PA intensity cut-points in this patient group but we suggest from our work
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5 that ENMO summary data is a useful surrogate even without this.
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10 In the non-orthopaedic subgroup we found a significant increase in PA following the PRIME clinic
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12 intervention, even though this was not optimised. Mixed effects modelling did not show any decrease
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14 in PA over time in either the pre- or post-intervention group suggesting that PA levels were sustained
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16 at least for the duration of the measurement period. Because we had no control on which day of the
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18 week participants would be recruited from clinic, we also looked at whether activity might be different
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20 on weekend days, but this did not seem to be the case in this population. The PA levels in some
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22 patients post-intervention resembled more closely the baseline levels reported in the Biobank study.
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24 The fact that the unoptimised intervention was successful is a remarkable and somewhat unexpected
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26 finding as health behaviour change is notoriously difficult to achieve[14]. Our findings provide some
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28 evidence to suggest that the preoperative setting may indeed represent a unique period during which
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30 behavioural interventions are more likely to be successful, perhaps due to the well defined end-point
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32 (surgical procedure) and the motivation that physical activity may impact perioperative outcome. It
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34 seems reasonable to suggest that a well-designed complex intervention could result in greater
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36 changes in PA.
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44 The lack of significant improvement in PA in those participants awaiting orthopaedic surgery may
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46 indicate a restriction of PA in this population, in which mobility is likely to be limited due to underlying
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48 orthopaedic problems (all orthopaedic participants were awaiting major lower limb joint
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50 replacements). The potential to increase preoperative PA in the orthopaedic population may be
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52 limited; waiting lists for joint replacement surgery in the UK are long, and such patients may have
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54 already been in the hospital system prior to the PRIME clinic visit (intervention). This potentially
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56 restricted PA, and prior engagement with hospital services may mean that these patients may have
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58 already received PA advice from their surgical and primary care teams prior to referral to the PRIME
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3 clinic and may have already reached their prehabilitation limit. Nevertheless, although PA in this
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5 subgroup group did not change following the existing unoptimized intervention, there is perhaps still
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7 scope for a better intervention, and wearable accelerometers may assist in determining what this may
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9 be. Our finding provides support for the idea that a complex intervention would need to be tailored
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11 to this population.
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16 We asked participants to wear the accelerometers around their wrist. Traditionally the hip has been
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18 the most widely used site for placement of the accelerometer as this was believed to best represent
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20 total body movement[26]. However, wear-time compliance has been a problem with hip-worn devices
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22 which limits the validity of the data analysis[27]. Cui et al[28] fixed an accelerometer to participants'
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24 chests using an adhesive plaster, however one quarter of participants did not wear the device for 72
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26 hours which may limit the validity of data. We opted for a wrist worn device to circumvent this issue,
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28 and asked participants to wear the device continuously (day and night) for a seven-day period to
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30 simplify proceedings. We also felt that this placement would capture PA associated with activities of
31
32 daily living, likely to form a significant proportion of PA amongst a high-risk elderly population. Whilst
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34 previous studies have utilised the non-dominant wrist[17], for this pilot study we allowed a pragmatic
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36 approach to allow participants to select their preferred wrist in order to maximise compliance and
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38 total wear time. Furthermore, previous work has shown no difference in PA measurements when
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40 measured simultaneously on the dominant and non-dominant wrist[29]. We accept that in a frail
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42 elderly population, many of whom use walking aids, a wrist-worn device must be used with caution
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44 and further work is warranted to evaluate the transferability of data from different sites.
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52 Limitations of this study include the small sample size. Within this small sample we were non-selective
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54 regarding recruitment of participants from various surgical specialties. As such, we were unable to
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56 further analyse data from subgroups other than orthopaedics versus non-orthopaedics. This is an area
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58 of potential future research incorporating larger patient numbers in various subspecialties. One
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3 further limitation was that we did not attempt to characterise the types of PA performed although
4 this would in principle be possible if 'signatures' of different activities were obtained.
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10 Whilst we have demonstrated that patients' behaviour can change in the preoperative period, we do
11 not know how this translates clinically, and indeed what degree (if any) of change in PA might lead to
12 a change in the outcomes that are important to patients. However, it is reasonable to propose that
13 such a relationship might exist, and further work is needed to investigate whether increasing PA levels
14 in the preoperative period has any impact on perioperative outcome, and if so, whether the response
15 is dose- or timing-dependent. Furthermore, if an association between preoperative PA and
16 perioperative outcome is discovered, it is important to determine the minimum duration of increased
17 PA levels required to influence patient outcome, and whether this would be feasible in the
18 preoperative period. If optimum PA level targets can be determined it would then be important to
19 find out whether it is actually possible to meet PA 'targets' in the high-risk elderly population by use
20 of preoperative interventions. Further research into the optimum prehabilitation programme for frail
21 elderly patients in various patient cohorts is also required. Whilst we have demonstrated that the
22 increase in PA after the intervention was sustained throughout the seven-day measurement period,
23 we do not know whether the increase in PA is sustained beyond this period. Further work is required
24 to elucidate this.
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45 **CONCLUSION**

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47 Using wrist-worn accelerometers to characterise daily typical activity levels and assess the impact of
48 an existing clinical intervention was feasible and acceptable in this patient population. An increase in
49 PA levels was measured following an unoptimized, and this increase in PA was sustained for at least a
50 week suggesting that the preoperative period may be a teachable moment in which health behaviour
51 change interventions may be successful. Patient reported PA did not correlate with our objective
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3 measurements. Accelerometers may therefore be a useful tool to design and validate interventions
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5 for improving PA in this setting.
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10 **ACKNOWLEDGEMENTS**

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29
30 This research received no specific grant from any funding agency in the public, commercial or non-for-
31
32 profit sectors. No competing interests declared.
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39 **DATA SHARING**

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41 The authors are happy to consider requests for sharing fully anonymised data for specific research
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43 proposals on a collaborative basis.
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50 **AUTHOR CONTRIBUTORS**

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52 LG, AE and SG contributed to the conception and design of the study, LG and AE wrote the protocol,
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54 LG and JO contributed to data collection. LG and AE were responsible for data analysis. LG and AE
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56 prepared the manuscript and all authors contributed to the review and revision of the manuscript and
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58 provided final approval of the version to be published.
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REFERENCES

- 1 Axivity. AX3_Data_Sheet (1). 2015. https://axivity.com/files/resources/AX3_Data_Sheet.pdf (accessed 12/06/2019)
- 2 Washburn R, Smith K. The physical activity scale for the elderly (PASE): development and evaluation. *J Clin Epidemiol* 1993;**46**:153–62. doi:10.1016/0895-4356(93)90053-4
- 3 Pearse RM, Harrison DA, James P, *et al*. Identification and characterisation of the high-risk surgical population in the United Kingdom. *Crit Care* 2006;**10**. doi:10.1186/cc4928
- 4 Makary MA, Segev DL, Pronovost PJ, *et al*. Frailty as a Predictor of Surgical Outcomes in Older Patients. *J Am Coll Surg* 2010;**210**:901–8. doi:10.1016/j.jamcollsurg.2010.01.028
- 5 Louwers L, Schnickel G, Rubinfeld I. Use of a simplified frailty index to predict Clavien 4 complications and mortality after hepatectomy: analysis of the National Surgical Quality Improvement Project database. *Am J Surg* 2016;**211**:1071–6. doi:10.1016/j.amjsurg.2015.09.015
- 6 Harvey JA, Chastin SFM, Skelton DA. Prevalence of sedentary behavior in older adults: A systematic review. *Int J Environ Res Public Health* 2013;**10**:6645–61. doi:10.3390/ijerph10126645
- 7 Taylor D. Physical activity is medicine for older adults. *Postgrad Med J*. 2014 Jan;**90**(1059)26-32. doi:10.1136/postgradmedj-2012-131366
- 8 British Heart Foundation. Physical inactivity across the Four Nations. *Phys Inact Sedentary Behav Rep 2017* 2017.
- 9 Rogers NT, Marshall A, Roberts CH, *et al*. Physical activity and trajectories of frailty among older adults: Evidence from the English Longitudinal Study of Ageing. *PLoS One*. 2017 Feb 2;**12**(2). doi:10.1371/journal.pone.0170878

- 1
2
3 10 Martínez-Velilla N, Casas-Herrero A, Zambom-Ferraresi F, *et al.* Effect of Exercise Intervention
4 on Functional Decline in Very Elderly Patients during Acute Hospitalization: A Randomized
5 Clinical Trial. *JAMA Intern Med* 2018;**179**:28–36. doi:10.1001/jamainternmed.2018.4869
6
7
8
9
10
11 11 Nilsson H, Angerås U, Bock D, *et al.* Is preoperative physical activity related to post-surgery
12 recovery? A cohort study of patients with breast cancer. *BMJ Open* 2016;**6**:e007997.
13 doi:10.1136/bmjopen-2015-007997
14
15
16
17
18 12 Picorelli AMA, Pereira LSM, Pereira DS, *et al.* Adherence to exercise programs for older
19 people is influenced by program characteristics and personal factors: a systematic review. *J*
20 *Physiother* 2014;**60**:151–6. doi:10.1016/J.JPHYS.2014.06.012
21
22
23
24
25 13 Milder DA, Pillinger NL, Kam PCA. The role of prehabilitation in frail surgical patients: A
26 systematic review. *Acta Anaesthesiol Scand* 2018;**62**:1356–66. doi:10.1111/aas.13239
27
28
29
30 14 Middleton KR, Anton SD, Perri MG. Long-Term Adherence to Health Behavior Change HHS
31 Public Access. *Am J Lifestyle Med* 2013;**7**:395–404. doi:10.1177/1559827613488867
32
33
34
35 15 Bond DS, Jakicic JM, Unick JL, *et al.* Pre- to postoperative physical activity changes in bariatric
36 surgery patients: self report vs. objective measures. *Obesity (Silver Spring)* 2010;**18**:2395–7.
37 doi:10.1038/oby.2010.88
38
39
40
41
42
43 16 Vanhees L, Lefevre J, Philippaerts R, *et al.* How to assess physical activity? How to assess
44 physical fitness? *Eur J Cardiovasc Prev Rehabil.* 2005 Apr;**12**(2):102-14.
45 doi:10.1097/01.hjr.0000161551.73095.9c
46
47
48
49
50 17 Doherty A, Jackson D, Hammerla N, *et al.* Large scale population assessment of physical
51 activity using wrist worn accelerometers: The UK biobank study. *PLoS One* 2017;**12**:1–14.
52 doi:10.1371/journal.pone.0169649
53
54
55
56
57 18 Rockwood K, Song X, MacKnight C, *et al.* A global clinical measure of fitness and frailty in
58 elderly people. *Can Med Assoc J* 2005;**173**:489–95. doi:10.1503/cmaj.050051
59
60

- 1
2
3 19 Hoffmann TC, Glasziou PP, Boutron I, *et al*. Better reporting of interventions: template for
4 intervention description and replication (TIDieR) checklist and guide. *BMJ* 2014;**348**:g1687.
5
6 doi:10.1136/bmj.g1687
7
8
9
10
11 20 PhysioTools Key Features | Physiotoools. [https://www.physiotools.com/physiotools-key-](https://www.physiotools.com/physiotools-key-features)
12 features (accessed 24 Feb 2019).
13
14
15 21 Van Hees VT, Fang Z, Zhao JH, *et al*. GGIR: Raw Accelerometer Data Analysis. *R Packag version*
16 *18-1* Published Online First: 2019. doi:10.5281/zenodo.1051064
17
18
19
20
21 22 van Hees VT, Fang Z, Langford J, *et al*. Autocalibration of accelerometer data for free-living
22 physical activity assessment using local gravity and temperature: an evaluation on four
23 continents. *J Appl Physiol* 2014;**117**:738–44. doi:10.1152/jappphysiol.00421.2014
24
25
26
27
28 23 Team RC. R: A language and environment for statistical computing. 2017. [https://www.R-](https://www.R-project.org/)
29 project.org/ (accessed 12/6/19)
30
31
32
33 24 Bates D, Mächler M, Bolker B, *et al*. Fitting Linear Mixed-Effects Models Using **lme4**. *J Stat*
34 *Softw* 2015;**67**:1–48. doi:10.18637/jss.v067.i01
35
36
37
38 25 Wareham NJ, Rennie KL. The assessment of physical activity in individuals and populations:
39 why try to be more precise about how physical activity is assessed? *Int J Obes Relat Metab*
40 *Disord* 1998;**22 Suppl 2**:S30-8.
41
42
43
44
45 26 Cleland I, Kikhia B, Nugent C, *et al*. Optimal placement of accelerometers for the detection of
46 everyday activities. *Sensors (Basel)* 2013;**13**:9183–200. doi:10.3390/s130709183
47
48
49
50
51 27 Troiano RP, McClain JJ, Brychta RJ, *et al*. Evolution of accelerometer methods for physical
52 activity research. *Br J Sports Med*. 2014 Jul;**48**(13):1019-23. doi:10.1136/bjsports-2014-
53 093546
54
55
56
57
58 28 Cui HW, Kirby GS, Surmacz K, *et al*. The association of pre-operative home accelerometry
59
60

with cardiopulmonary exercise variables. *Anaesthesia* Published Online First: 2017.

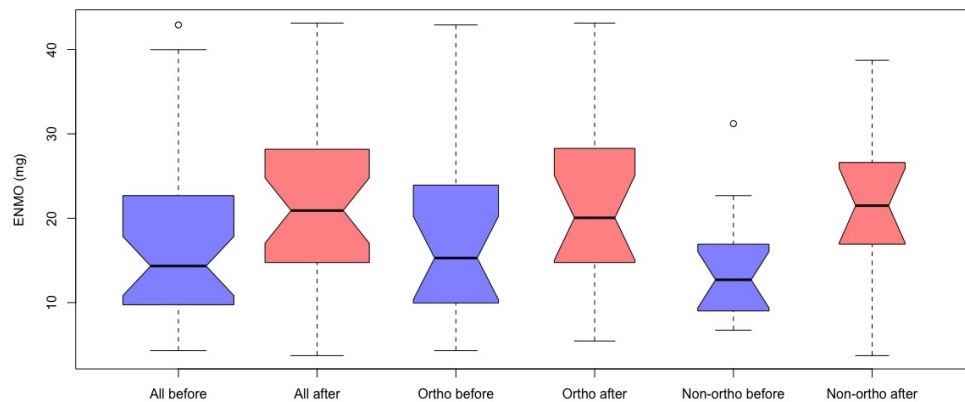
doi:10.1111/anae.14181

- 29 Dieu O, Mikulovic J, Fardy PS, *et al.* Physical activity using wrist-worn accelerometers: comparison of dominant and non-dominant wrist. *Clin Physiol Funct Imaging* 2017;**37**:525–9.
doi:10.1111/cpf.12337

LEGENDS

Figure 1. Notched Box Plots representing physical activity (ENMO, milli-gravitational units mg) before (□) and after (■) the PRIME clinic intervention in all participants (left), participants listed for orthopaedic surgery (middle) and non-orthopaedic surgery (right). Open circle (o) represents outliers. The notch represents the 95% confidence interval of the Median; 95% Confidence that the medians differ if two boxes' notches do not overlap.

Figure 2. Physical activity (ENMO) against time before (left panel) and after (right panel) the intervention for each patient. The dots / blue lines represent the mean across the patient group with +/- 1 s.d. shaded. Only complete (2-6) days included. Mean physical activity is increased after the intervention with no discernible decline in activity over time.



Notched Box Plots representing physical activity (ENMO, milli-gravitational units mg) before () and after () the PRIME clinic intervention in all participants (left), participants listed for orthopaedic surgery (middle) and non-orthopaedic surgery (right). Open circle (o) represents outliers. The notch represents the 95% confidence interval of the Median; 95% Confidence that the medians differ if two boxes' notches do not overlap.

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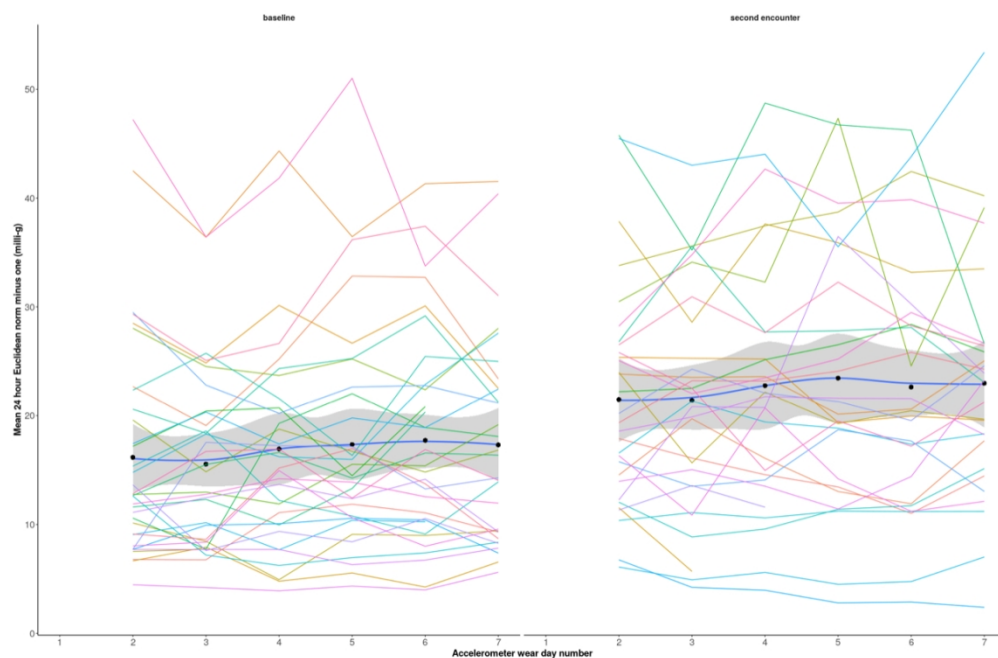


Figure 2. Physical activity (ENMO) against time before (left panel) and after (right panel) the intervention for each patient. The dots / blue lines represent the mean across the patient group with ± 1 s.d. shaded. Only complete (2-6) days included. Mean physical activity is increased after the intervention with no discernible decline in activity over time

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Accelerometry as a measure of modifiable physical activity in high risk elderly preoperative patients, a prospective observational pilot study.

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Primary Subject Heading:	Anaesthesia
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Keywords:	Adult anaesthesia < ANAESTHETICS, SURGERY, Elderly, Perioperative medicine, physical activity, wearable technology

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Manuscripts

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5 **Accelerometry as a measure of modifiable physical activity in high risk elderly preoperative**
6 **patients, a prospective observational pilot study.**
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ABSTRACT

Objectives: To use wrist-worn accelerometers (Axivity AX3) to establish normative physical activity (PA) and acceptability data for the high-risk elderly preoperative population, to assess whether PA could be modified by a prehabilitation intervention as part of routine care, to assess any correlation between accelerometer-measured PA and self-reported PA, to assess the acceptability of wearing wrist-worn accelerometers in this population.

Study Design: Prospective, observational, pilot study

Setting: Single National Health Service Hospital

Participants: Frail patients ≥ 65 years awaiting major surgery referred to a multidisciplinary preoperative clinic at which they received a routine intervention aimed at improving their PA. 35 patients were recruited. Average age 79.9 years (SD=5.6).

Primary outcomes: Normative PA data measured as a mean daily Euclidean norm minus one (ENMO) in milli-gravitational units(mg).

Secondary outcomes: Measure PA levels (mg) following a routine preoperative intervention. Determine correlation between patient reported PA (measured using the Physical Activity Scale for the Elderly) and accelerometer-measured PA (mg). Assess acceptability of wearing a wrist-worn accelerometer measured using visual analogue scale questionnaire and device wear-time (hours).

Results: Median baseline daily PA was 14.3mg (IQR 9.75-22.04) with an improvement in PA detected following the intervention [median ENMO post-intervention 20.91mg (IQR 14.83-27.53), $p=0.022$]. There was no significant correlation between accelerometer-measured and self-reported PA [Baseline $\rho=0.162$ ($p=0.4$), Post intervention $\rho=-0.144$ ($p=0.5$)]. We found high acceptability ratings (Median score of 10/10 on VAS, IQR 8-10) and wear-time compliance [163.2 hours (IQR 150-167.5) pre-intervention and 166.1 hours (IQR 162.5-167) post-intervention].

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3 **Conclusions:** Accelerometry is acceptable to this population and increases in PA levels measured
4 following an unoptimized routine clinical intervention indicates that health behaviour change
5 interventions may be successful during the preoperative period. Accelerometers may therefore be a
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10 useful tool to design and validate interventions for improving PA in this setting.

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13 **Trial registration:** ClinicalTrials.gov (NCT03737903)
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15 **ARTICLE SUMMARY**

16 **Strengths and limitations of this study**

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19 • This is the first study to look at the use of wearable accelerometers to measure and
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- We present a robust and objective method of measuring physical activity levels and compared this to self-reporting methods of measuring physical activity.
- We were able to assess the impact of an existing unoptimized preoperative intervention using accelerometry
- Limitations of this study include small sample size although this is justified by the fact that it was an initial pilot study to establish normative physical activity and acceptability data to facilitate power calculations for further studies.

45 **INTRODUCTION**

46
47
48 The “high risk” surgical population is characterised by advanced age, frailty and multiple comorbidities
49 particularly when undergoing major surgery. This population accounts for just 12.5% of surgical
50 procedures, but over 80% of perioperative deaths in the UK[1]. With an aging population, increasing
51 numbers of high-risk patients require surgery. It is therefore important to improve understanding of
52 risk factors for perioperative complications in order to facilitate shared decision making and
53 appropriate planning of perioperative care.
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3 Frailty status is an independent predictor of postoperative morbidity and mortality[2,3] and physical
4 inactivity is a defining feature of frailty. Older adults spend a significant part of their day being
5 sedentary[4] and do not meet current physical activity (PA) recommendations[5,6]. Increased PA can
6 slow progression to a frail state[7] and there is growing evidence for the positive association between
7 preoperative PA and perioperative outcomes[8]. Prehabilitation programmes incorporate
8 optimisation of medical, nutritional and psychological status alongside prescribed exercise training
9 programmes with specific goals of muscle strengthening and increased physical fitness, but are labour
10 intensive and most have suboptimal participant adherence rates[9]. PA may also be an attractive
11 prehabilitation target although it is currently not known whether improving PA is feasible or leads to
12 improvements in outcome.
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26 Sustained changes in habitual, environmentally-cued health behaviours are notoriously difficult to
27 achieve[10], but it is plausible that the preoperative period, due to the well-defined target end-point
28 (surgery), may represent a unique teachable moment during which motivation to convert intention
29 into action may be elevated, and a sustained change in behaviour may be more achievable than other
30 settings. Thus, it may be possible to influence patient behaviours in order to reduce perioperative risk
31 and improve outcomes.
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40 Since the high-risk surgical group is likely to differ from the general population, normative PA data
41 and patient acceptability data is lacking and this needs to be established before targeted intervention
42 studies can be designed. To this end, it is critical to first have a robust, precise method of measuring
43 PA and to understand PA related to daily routine in order to establish a baseline against which the
44 impact of future interventions could be measured. Traditionally, in the perioperative setting, patients'
45 PA levels have been evaluated using brief self-report questionnaires, however these are prone to error
46 and recall bias[11]. The gold standard method of direct observation is labour-intensive and time-
47 consuming, and therefore not feasible for widespread use[12]. Accelerometers could offer a potential
48 solution; Tri-axial accelerometers detect magnitude and direction of acceleration and have been used
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3 in large-scale epidemiological studies to provide a valid estimate of overall PA[13]. They are
4 unobtrusive and non-invasive and can measure PA in free-living environments and may offer a means
5 to assess the efficacy and therefore optimise interventions to improve PA. However, this first requires
6 the specific population of interest to be characterised. Although wrist-worn accelerometry has been
7 validated to measure PA in older patients[13], to our knowledge wearable accelerometers have not
8 previously been used to characterise PA in a high-risk elderly population in the pre-operative period.
9 Furthermore, the acceptability of PA measurement has not been established in these patients.

10 Through this pilot study we aimed to characterise PA levels in relation to daily routine across a variety
11 of surgical specialties in order to obtain normative data to inform sample size calculations for future
12 intervention studies. We also sought to assess whether there was a change in PA following current
13 preoperative interventions (which form part of usual care in our centre) and quantify the variability of
14 that change. We set out to quantify the correlation between objectively measured and self-reported
15 PA in this patient group. Finally, as accelerometers have not previously been used in this setting, we
16 aimed to assess how acceptable it is to use wrist-worn accelerometers to measure PA in high risk
17 elderly patients in the preoperative period prior to rolling them out into a larger scale programme of
18 research.

19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 **METHODS**

43 44 45 **Study approvals and population**

46 This study was conducted at Cambridge University Hospitals National Health Service (NHS) Foundation
47 Trust and approval by a Research Ethics Committee was obtained prior to participant recruitment
48 (Research ethics number: 18/SC/0287). Written informed consent was obtained from all participants.
49 All patients awaiting high-risk surgery are seen in a nurse-led preoperative assessment clinic
50 (outpatient setting) as part of routine care, at which point they undergo frailty screening and may be
51 referred to the 'Perioperative Review Informing Management of Elderly patients' (PRIME) clinic (a
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3 multidisciplinary clinic specifically designed to optimise frail elderly patients preoperatively). Inclusion
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5 criteria for this study were patients referred to the PRIME clinic, participants must have had capacity
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7 to consent and complete activity questionnaires and be willing and able to wear the accelerometer
8
9 around their wrist. PRIME clinic referral criteria were patients listed for major or complex surgery who
10
11 were aged ≥ 65 years and either had a Rockwood Clinical Frailty Scale[14] score (CFS) of ≥ 4 or had a
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13 clinical picture that gave the pre-assessment nurse enough concern to refer for a multidisciplinary
14
15 preoperative assessment. Referral to, and attendance at the PRIME clinic formed part of usual
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17 preoperative care at our institution. Participants were excluded from the study if they did not meet
18
19 the inclusion criteria, they refused to participate or their PRIME clinic appointment was scheduled
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21 < 72 hours after referral for recruitment, as previous research has shown a minimum period of 72 hours
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23 of continuous accelerometer wear-time is required to produce valid data[13]. Recruitment took place
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25 between July and December 2018.
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33 **Patient and Public involvement**

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35 Patient and public involvement (PPI) was sought during the study design process with the aim of
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37 ensuring that the research question was agreed to be important, the methods and running of the
38
39 study were likely to be acceptable to patients and the documents were written appropriately for the
40
41 target study population. Study documents including patient information leaflets, consent forms and
42
43 information posters were circulated to Cambridge University Hospital PPI panel for review. Feedback
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45 from the PPI panel allowed us to construct more lay-friendly documents. The PPI panel considered the
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47 burden of intervention and time required to participate in research. We will consider further PPI
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49 involvement in order to disseminate the study results to those participants who requested to be
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51 informed.
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58 **Accelerometer and data collection**

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3 Participants wore a waterproof triaxial accelerometer (Axivity AX3, Newcastle, UK[15]) which has been
4 used in other studies of functionally impaired people[16]. The device was worn around the wrist for
5 24 hours per day, for seven days prior to their PRIME clinic visit, and seven days immediately after
6 their PRIME clinic visit. Participants wore the device around their preferred wrist for convenience and
7 to maximise compliance. Participants were instructed by the research team how to re-fit the
8 accelerometer should they remove it for any reason. Accelerometer devices were programmed to
9 commence data collection on the same day that the device was fitted and to record for seven days.
10 The accelerometer measures acceleration in three axes sampled at 100Hz with a dynamic range of +/-
11 8g.
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14 Raw accelerometry data were downloaded and visually inspected in order to detect any
15 accelerometer technical issues, to ensure that the accelerometer was worn and recorded for the
16 correct duration and had recorded the signals as expected. Data analyses were performed in R-
17 package GGIR, the details of which have been previously described[17].
18

19 PA related acceleration was calculated using auto-calibrated Euclidian norm minus one (ENMO)[18].
20 The values presented are the average ENMO for all of the available data normalised per 24-hour cycle
21 (diurnally balanced), with invalid data imputed using the average at similar time points on different
22 days of the week. We chose to use ENMO as our measure of PA since previously published cut-offs for
23 mild/moderate/vigorous intensity PA may not apply to this patient population.
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26 The PRIME clinic visit involves a preoperative review by an anaesthetist, geriatrician, physiotherapist
27 and occupational therapist. During this clinic visit, patients were provided with a behaviour change
28 intervention as part of usual perioperative care at our institution (see behaviour change intervention
29 below). At the PRIME clinic visit, a member of the research team retrieved the accelerometer worn by
30 participants for the initial seven-day period and provided the participant with a new device for the
31 second seven-day period. Participants completed two questionnaires at the PRIME clinic visit: a
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3 validated self-reported activity questionnaire; Physical Activity Scale for the Elderly (PASE)[19], and a
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5 locally designed acceptability questionnaire (see assessment of acceptability below). Participants
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7 were asked to repeat the PASE questionnaire at the end of the second seven-day wear period and
8
9 return the accelerometer and completed PASE questionnaire back to the study centre in a prepaid
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11 envelope.
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14 15 16 17 18 **Assessment of acceptability**

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20 Overall acceptability was assessed using a participant completed questionnaire utilising a visual
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22 analogue scale (VAS) from 0-10, 0 being “very unacceptable” and 10 being “very acceptable”. We also
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24 measured the length of time that the devices were worn in hours (wear time compliance).
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30 31 **Behaviour change intervention (PRIME clinic visit)**

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33 The behaviour change intervention (given as part of usual care) consisted of PA and exercise advice
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35 described as follows according to the TiDieR checklist[20]. The goals of the intervention were to
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37 improve PA levels on a day to day basis through activities of daily living (ADLs) or leisure activities, to
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39 improve specific aspects of fitness, perioperative respiratory function and promote independence
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41 with personal and domestic ADLs and leisure activities. Verbal and written advice was provided as
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43 follows: two generic exercise leaflets (general exercises for the whole body, and walking exercises),
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45 bespoke exercise programmes (generated using online Physiotoools[21] software) and local hospital-
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47 specific respiratory exercise information leaflets were provided along with advice and information
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49 about appropriate community services. The intervention was administered by an NHS Band seven
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51 Physiotherapist with a background in Surgery and Elderly rehabilitation and an NHS Band seven
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53 Occupational therapist with a background in Surgery, Orthopaedics and Elderly rehabilitation via one
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55 face-to-face session (PRIME clinic visit) lasting 40 minutes. The information described above was given
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57 to participants in the PRIME clinic room with the expectation that they would undertake the activities
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3 in their own homes. The intervention was tailored to each participant, depending upon presentation
4 and planned surgical procedure. Advice given to participants was decided by experienced clinicians in
5 the PRIME clinic and was based upon their clinical judgement following a comprehensive assessment.
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7 Personalised exercise programmes were designed by the Physiotherapist during the clinic visit and
8 taught to participants during this session, with a written information leaflet given to the participant
9 to take home. Adherence to this intervention was not otherwise assessed.
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20 **Statistical analysis**

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22 We generated descriptive statistics for the number of participants, wear time in hours, and average
23 daily ENMO milli-gravitational units (mg). We analysed the difference in ENMO before and after the
24 existing intervention using the Wilcoxon signed rank test. We also analysed ENMO stratified into
25 orthopaedic and non-orthopaedic surgical populations.
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31 Since accelerometry and self-reported PA (measured using PASE) are continuous variable, we
32 analysed correlation using the Pearson correlation coefficient.
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37 Statistical analysis was conducted using the R statistical language[22]. Mixed effects models were
38 constructed using the lme4 package[23], significance testing was done using analysis of deviance. A
39 statistical significance level of 5% was assumed throughout and no correction for multiple
40 comparisons were made.
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49 **RESULTS**

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52 36 patients were invited to take part in the study, of which 35 participants were recruited, 19 (54%)
53 were female. 20 participants (57%) were listed for orthopaedic surgery, 7 (20%) gastrointestinal
54 surgery, 5 (14%) urological surgery, and 1 each for vascular, gynaecology and breast surgery. The
55 mean age was 79.9 years (SD = 5.6 years). Characteristics of the study population are given in Table 1.
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Our study was not powered to fully define the spectrum of comorbidities in this group. Instead, we summarised physical status in terms of the American Society of Anaesthesiologists physical status classification score (ASA score) which is widely used for perioperative risk assessment. Median nurse-assessed Rockwood Clinical Frailty Score (CFS) was 5 (IQR 4-5).

Table 1. Characteristics of the study population, Values are mean (SD), number (proportion).

Characteristics of study sample, (n=35)	Value
Age; years	79.9 (5.6)
Sex,	
Female	19 (54%)
Male	16 (46%)
Rockwood Clinical Frailty Score,	
3	1 (2.9%)
4	12 (34.3%)
5	17 (48.6%)
6	5 (14.3%)
Surgical specialty,	
Orthopaedic	20 (57%)
Gastrointestinal	7 (20%)
Urology	5 (14%)
Gynaecology	1 (3%)
Vascular	1 (3%)
Breast	1 (3%)

ASA score*	
2	8 (23%)
3	27 (77%)

*ASA; American Society of Anaesthesiologists physical status classification system score

Accelerometry data were available for analysis for 34 participants before the intervention and 30 participants after the intervention. Data from one pre-intervention participant were unavailable due to an accelerometer programming error, three participants were withdrawn from the post-intervention part of the study because their surgical procedure was scheduled to be <72hrs after the PRIME clinic visit thus participants would not have been able to wear the device for the minimum required time of 72 hours. One participant was withdrawn from the post-intervention part of the study due to skin irritation around the wrist strap (notably similar irritation was also caused by their own wristwatch), and one participant was withdrawn due to an area of bruising around the wrist strap. This participant was taking oral anticoagulants.

Preoperative baseline PA levels were obtained in 34 participants. The median baseline daily PA level was 14.3mg (IQR 9.75-22.04). There was no significant difference in baseline median PA between males [12.6mg (IQR 9.5-15.7)], and females [16.9mg (IQR 12.5-23.9)], $p=0.18$). Median baseline daily PA in orthopaedic patients was 15.3mg (IQR 10.1-23.5), compared to a median of 12.7mg (IQR 9.2-16.6) in non-orthopaedic patients ($p=0.271$) as shown in Figure 1. Baseline PA was higher in females than males in this orthopaedic sub-group (22.84mg vs 10.17mg, $p=0.046$).

There was a significant increase in overall daily ENMO after the standard clinical intervention [median baseline ENMO 14.3mg (IQR 9.75-22.04), median ENMO post-intervention 20.91mg (IQR 14.83-

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3 27.53), $p=0.022$] as shown in Figure 1. There was no significant difference in ENMO before and after
4 the intervention in patients awaiting orthopaedic surgery [median baseline ENMO 15.29mg (IQR
5 10.07-23.5), median ENMO post-intervention 20.05mg (IQR 14.83-27.61), $p=0.304$]. However, in
6 those participants listed for non-orthopaedic surgery there was a significant increase in mean PA
7 following the intervention [median baseline ENMO 12.71mg (IQR 9.20-16.61), median ENMO post-
8 intervention 21.49mg (IQR 18.04-25.82), $p=0.019$] Figure 1.
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20 The distribution of PA over time for all patients is shown in Figure 2 for both pre- and post-
21 intervention. There was evidence for a linear increase (mixed effects model) in PA over time in the
22 pre-intervention group $+0.28$ mg/day, (95%CI: 0.011-0.53, $p=0.04$) with a similar finding in the post
23 intervention group $+0.15$ mg/day (95% CI: -0.19-+0.50, $p=0.37$), albeit not achieving statistical
24 significance. There was no evidence for a significant effect of whether the day was a weekend or not,
25 nor was there evidence for a non-linear time dependency.
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34 There was no significant difference in self-reported PASE scores before and after the PRIME clinic
35 intervention [median PASE pre-intervention was 67 (IQR 31-89.75), median PASE post-intervention
36 was 65 (IQR 45.5-101) $p=0.247$]. Furthermore, no significant statistical correlation was found between
37 the accelerometer-measured PA and the self-reported PA measured using the PASE questionnaire,
38 either before or after the intervention [Baseline $\rho=0.162$ ($p=0.4$), Post intervention $\rho=-0.144$ ($p=0.5$)].
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49 The median wear time of the wrist-worn accelerometer was 163.2 hours (IQR 150-167.5) pre-
50 intervention and 166.1 hours (IQR 162.5-167) post-intervention. On average participants wore the
51 accelerometers for 98% of the measurement period indicating excellent wear-time compliance, with
52 values comparable to those achieved in other studies[13]. 33 participants completed the acceptability
53 questionnaire, and the median overall acceptability score obtained was 10 (IQR 8-10). The high wear-
54 time compliance, low voluntary withdrawal rate and high acceptability scores indicate overall
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3 acceptability and feasibility of measuring PA in high risk elderly patients in the preoperative period
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5 using these accelerometers.
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10 **DISCUSSION**

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13 These data demonstrate that wrist worn accelerometers can successfully be used to measure PA in
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15 high-risk elderly patients in the preoperative period, and that this process was acceptable to
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17 participants. The fact that there was no statistical correlation between participant-reported PASE and
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19 accelerometer-measured PA highlights the need for more objective measures of PA[24] and suggests
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21 a role for such devices in perioperative research and perhaps clinical care.
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27 We demonstrated a substantial variability in baseline PA in the frail elderly preoperative
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29 population. Our study also gives an estimate of the typical mean daily PA levels in this specific group
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31 of patients which has not previously been described. Such data should inform the planning of potential
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33 studies involving PA measurements in this setting. We found low PA levels in this population: We do
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35 not have access to a 'control' group as such a group would be difficult to define. However, by way of
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37 comparison, the UK Biobank study reported mean daily ENMO values in over three thousand 75-79
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39 year olds (the most comparable group to ours) women of 23.9mg (SD=6.5) and in men this was 22.9mg
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41 (SD=6.8)[13]. Our study population had lower baseline mean daily ENMO of 18.9mg (SD=10.5) in
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43 women, and 13.71mg (SD=6.1) in men, which may reflect their underlying medical conditions, frailty
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45 and increased age (mean age of our study population was 79.9 years SD 5.6).
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51 ENMO may not be as intuitive as post-processed PA intensity metrics such as step count or time spent
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53 in various intensities of PA. However, such metrics may not generalise outside the population in which
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55 they were developed[25]. Furthermore, we wanted to avoid using any potentially proprietary
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57 algorithms. Using unprocessed ENMO avoids both of these problems as it is the fundamental physical
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3 quantity measured by all accelerometers and should therefore be agnostic to patient-group. Further
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5 work is be needed to develop metabolically meaningful PA intensity cut points in this patient group,
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7 but we suggest from our work that ENMO summary data is a useful surrogate even without this.
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12 In the non-orthopaedic subgroup, we found a significant increase in PA following the PRIME clinic
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14 intervention, even though this was not optimised. Mixed effects modelling did not show any decrease
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16 in PA over time in either the pre- or post-intervention group suggesting that PA levels were sustained
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18 at least for the duration of the measurement period. Because we had no control on which day of the
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20 week participants would be recruited from clinic, we also looked at whether activity might be different
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22 on weekend days, but this did not seem to be the case in this population. The PA levels in some
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24 patients post-intervention resembled more closely the baseline levels reported in the Biobank study.
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26 The fact that physical activity levels increased to this extent following the unoptimised intervention is
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28 a remarkable and somewhat unexpected finding as health behaviour change is notoriously difficult to
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30 achieve[10]. Our findings provide some evidence to suggest that the preoperative setting may indeed
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32 represent a unique period during which behavioural interventions are more likely to result in
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34 improvements in PA, perhaps due to the well-defined endpoint (surgical procedure) and the
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36 motivation that physical activity may impact perioperative outcome. It seems reasonable to suggest
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38 that a well-designed complex intervention could result in greater changes in PA.
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46 The lack of significant improvement in PA in those participants awaiting orthopaedic surgery may
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48 indicate a restriction of PA in this population, in which mobility is likely to be limited due to underlying
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50 orthopaedic problems (all orthopaedic participants were awaiting major lower limb joint
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52 replacements). The potential to increase preoperative PA in the orthopaedic population may be
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54 limited; waiting lists for joint replacement surgery in the UK are long, and such patients may have
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56 already been in the hospital system prior to the PRIME clinic visit (intervention). This potentially
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58 restricted PA, and prior engagement with hospital services may mean that these patients may have
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3 already received PA advice from their surgical and primary care teams prior to referral to the PRIME
4 clinic and may have already reached their prehabilitation limit. Nevertheless, although PA in this
5 subgroup group did not change following the existing unoptimized intervention, there is perhaps still
6 scope for a better intervention, and wearable accelerometers may assist in determining what this may
7 be. Our finding provides support for the idea that a complex intervention would need to be tailored
8 to this population.
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19 We asked participants to wear the accelerometers around their wrist. Traditionally the hip has been
20 the most widely used site for placement of the accelerometer as this was believed to best represent
21 total body movement[26]. However, wear-time compliance has been a problem with hip-worn devices
22 which limits the validity of the data analysis[27]. Cui et al[28] fixed an accelerometer to participants'
23 chests using an adhesive plaster, however one quarter of participants did not wear the device for 72
24 hours which may limit the validity of data. We opted for a wrist worn device to circumvent this issue,
25 and asked participants to wear the device continuously (day and night) for a seven-day period to
26 simplify proceedings. We also felt that this placement would capture PA associated with activities of
27 daily living, likely to form a significant proportion of PA amongst a high-risk elderly population. Whilst
28 previous studies have utilised the non-dominant wrist[13], for this pilot study we allowed a pragmatic
29 approach to allow participants to select their preferred wrist in order to maximise compliance and
30 total wear time. Furthermore, previous work has shown no difference in PA measurements when
31 measured simultaneously on the dominant and non-dominant wrist[29]. We accept that in a frail
32 elderly population, many of whom use walking aids, a wrist-worn device must be used with caution
33 and further work is warranted to evaluate the transferability of data from different sites.
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54 Limitations of this study include the small sample size. Within this small sample we were non-selective
55 regarding recruitment of participants from various surgical specialties. As such, we were unable to
56 further analyse data from subgroups other than orthopaedics versus non-orthopaedics. This is an area
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3 of potential future research incorporating larger patient numbers in various subspecialties. One
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5 further limitation was that we did not attempt to relate ENMO measurements to specific activities of
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7 daily living. This will be an important subsequent study but was outside the scope of this work as it
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9 might have reduced tolerability.
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14 Whilst we have demonstrated that patients' behaviour can change in the preoperative period, we do
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16 not know how this translates clinically, and indeed what degree (if any) of change in PA might lead to
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18 a change in the outcomes that are important to patients. However, it is reasonable to propose that
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20 such a relationship might exist, and further work is needed to investigate whether increasing PA levels
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22 in the preoperative period has any impact on perioperative outcome, and if so, whether the response
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24 is dose- or timing-dependent. Furthermore, if an association between preoperative PA and
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26 perioperative outcome is discovered, it is important to determine the minimum duration of increased
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28 PA levels required to influence patient outcome, and whether this would be feasible in the
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30 preoperative period. If optimum PA level targets can be determined it would then be important to
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32 find out whether it is actually possible to meet PA 'targets' in the high-risk elderly population by use
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34 of preoperative interventions. Further research into the optimum prehabilitation programme for frail
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36 elderly patients in various patient cohorts is also required. Whilst we have demonstrated that the
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38 increase in PA after the intervention was sustained throughout the seven-day measurement period,
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40 we do not know whether the increase in PA is sustained beyond this period. Further work is required
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42 to elucidate this.
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50 **CONCLUSION**

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52 Using wrist-worn accelerometers to characterise daily typical activity levels and assess the impact of
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54 an existing clinical intervention was feasible and acceptable in this patient population. An increase in
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56 PA levels was measured following an unoptimized, and this increase in PA was sustained for at least a
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58 week suggesting that the preoperative period may be a teachable moment in which health behaviour
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3 change interventions may be successful. Patient reported PA did not correlate with our objective
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5 measurements. Accelerometers may therefore be a useful tool to design and validate interventions
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7 for improving PA in this setting.
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10 11 12 **ACKNOWLEDGEMENTS**

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14
15 This study was registered with ClinicalTrials.gov (NCT03737903) on 01/07/18. The authors would like
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18
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20
21 with participant recruitment, and Ms Amanda Saunders and Ms Sarah Lester for assistance with
22
23 retrieval and distribution of accelerometers in the PRIME clinic visit.
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30 31 32 **COMPETING INTERESTS AND FUNDING**

33 This research received no specific grant from any funding agency in the public, commercial or non-for-
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35 profit sectors. No competing interests declared.
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40 41 42 **DATA SHARING**

43 The authors are happy to consider requests for sharing fully anonymised data for specific research
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45 proposals on a collaborative basis.
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51 52 53 **AUTHOR CONTRIBUTORS**

54 LG, AE and SG contributed to the conception and design of the study, LG and AE wrote the protocol,
55
56 LG and JO contributed to data collection. LG and AE were responsible for data analysis. LG and AE
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3 prepared the manuscript and all authors contributed to the review and revision of the manuscript and
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5 provided final approval of the version to be published.
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For peer review only

REFERENCES

- 1 Pearse RM, Harrison DA, James P, *et al.* Identification and characterisation of the high-risk surgical population in the United Kingdom. *Crit Care* 2006;10 doi:10.1186/cc4928
- 2 Makary MA, Segev DL, Pronovost PJ, *et al.* Frailty as a Predictor of Surgical Outcomes in Older Patients. *J Am Coll Surg* 2010;210:901–8.doi:10.1016/j.jamcollsurg.2010.01.028
- 3 Louwers L, Schnickel G, Rubinfeld I. Use of a simplified frailty index to predict Clavien 4 complications and mortality after hepatectomy: analysis of the National Surgical Quality Improvement Project database. *Am J Surg* 2016;211:1071–6.doi:10.1016/j.amjsurg.2015.09.015
- 4 Harvey JA, Chastin SFM, Skelton DA. Prevalence of sedentary behavior in older adults: A systematic review. *Int J Environ Res Public Health* 2013;10:6645–61.doi:10.3390/ijerph10126645
- 5 Taylor D. Physical activity is medicine for older adults. *Postgrad Med J.* 2014Jan;90(1059)26–32.doi:10.1136/postgradmedj-2012-131366
- 6 British Heart Foundation. Physical inactivity across the Four Nations. *Phys Inact Sedentary Behav Rep 2017* 2017.
- 7 Rogers NT, Marshall A, Roberts CH, *et al.* Physical activity and trajectories of frailty among older adults: Evidence from the English Longitudinal Study of Ageing. *PLoS One.* 2017Feb2;12(2). doi:10.1371/journal.pone.0170878
- 8 Nilsson H, Angerås U, Bock D, *et al.* Is preoperative physical activity related to post-surgery recovery? A cohort study of patients with breast cancer. *BMJ Open* 2016;6:e007997. doi:10.1136/bmjopen-2015-007997
- 9 Picorelli AMA, Pereira LSM, Pereira DS, *et al.* Adherence to exercise programs for older

- 1
2
3 people is influenced by program characteristics and personal factors: a systematic review. *J*
4
5 *Physiother* 2014;60:151–6. doi:10.1016/J.JPHYS.2014.06.012
6
7
8
9 10 Middleton KR, Anton SD, Perri MG. Long-Term Adherence to Health Behavior Change HHS
10 Public Access. *Am J Lifestyle Med* 2013;7:395–404. doi:10.1177/1559827613488867
11
12
13 11 Bond DS, Jakicic JM, Unick JL, *et al.* Pre- to postoperative physical activity changes in bariatric
14 surgery patients: self report vs. objective measures. *Obesity (Silver Spring)* 2010;18:2395–7.
15
16 doi:10.1038/oby.2010.88
17
18
19
20 12 Vanhees L, Lefevre J, Philippaerts R, *et al.* How to assess physical activity? How to assess
21 physical fitness? *Eur J Cardiovasc Prev Rehabil.* 2005Apr;12(2):102-
22
23 14.doi:10.1097/01.hjr.0000161551.73095.9c
24
25
26
27
28 13 Doherty A, Jackson D, Hammerla N, *et al.* Large scale population assessment of physical
29 activity using wrist worn accelerometers: The UK biobank study. *PLoS One* 2017;12:1–14.
30
31 doi:10.1371/journal.pone.0169649
32
33
34
35 14 Rockwood K, Song X, MacKnight C, *et al.* A global clinical measure of fitness and frailty in
36 elderly people. *Can Med Assoc J* 2005;173:489–95. doi:10.1503/cmaj.050051
37
38
39
40 15 Axivity. AX3_Data_Sheet (1).
41
42 2015.https://axivity.com/files/resources/AX3_Data_Sheet.pdf(accessed 12/06/2019)
43
44
45
46 16 Clarke CL, Taylor J, Crighton LJ, *et al.* Validation of the AX3 triaxial accelerometer in older
47 functionally impaired people. *Aging Clin Exp Res*;29. doi:10.1007/s40520-016-0604-8
48
49
50
51 17 Van Hees VT, Fang Z, Zhao JH, *et al.* GGIR: Raw Accelerometer Data Analysis. *R Packag version*
52
53 18-1 Published Online First: 2019. doi:10.5281/zenodo.1051064
54
55
56 18 Van Hees VT, Fang Z, Langford J, *et al.* Autocalibration of accelerometer data for free-living
57 physical activity assessment using local gravity and temperature: an evaluation on four
58
59
60

- 1
2
3 continents. *J Appl Physiol* 2014;117:738–44. doi:10.1152/jappphysiol.00421.2014
4
5
6 19 Washburn R, Smith K. The physical activity scale for the elderly (PASE): development and
7
8 evaluation. *J Clin Epidemiol* 1993;46:153–62. doi:10.1016/0895-4356(93)90053-4
9
10
11 20 Hoffmann TC, Glasziou PP, Boutron I, *et al*. Better reporting of interventions: template for
12
13 intervention description and replication (TIDieR) checklist and guide. *BMJ* 2014;348:g1687.
14
15 doi:10.1136/bmj.g1687
16
17
18 21 PhysioTools Key Features | Physiotoools. [https://www.physiotools.com/physiotools-key-](https://www.physiotools.com/physiotools-key-features)
19
20 features (accessed 24 Feb 2019).
21
22
23 22 Team RC. R: A language and environment for statistical computing. 2017. [https://www.R-](https://www.R-project.org/)
24
25 project.org/ (accessed 12/06/19)
26
27
28 23 Bates D, Mächler M, Bolker B, *et al*. Fitting Linear Mixed-Effects Models Using lme4. *J Stat*
29
30 *Softw* 2015;67:1–48. doi:10.18637/jss.v067.i01
31
32
33 24 Wareham NJ, Rennie KL. The assessment of physical activity in individuals and populations:
34
35 why try to be more precise about how physical activity is assessed? *Int J Obes Relat Metab*
36
37 *Disord* 1998;22 Suppl 2:S30-8.
38
39
40
41 25 Schrack JA, Cooper R, Koster A, *et al*. Assessing Daily Physical Activity in Older Adults:
42
43 Unraveling the Complexity of Monitors, Measures, and Methods. *J Gerontol A Biol Sci Med Sci*
44
45 2016;71:1039–48. doi:10.1093/gerona/glw026
46
47
48 26 Cleland I, Kikhia B, Nugent C, *et al*. Optimal placement of accelerometers for the detection of
49
50 everyday activities. *Sensors (Basel)* 2013;13:9183–200. doi:10.3390/s130709183
51
52
53 27 Troiano RP, McClain JJ, Brychta RJ, *et al*. Evolution of accelerometer methods for physical
54
55 activity research. *Br J Sports Med*. 2014Jul;48(13):1019-23. doi:10.1136/bjsports-2014-
56
57 093546
58
59
60

- 1
2
3 28 Cui HW, Kirby GS, Surmacz K, *et al.* The association of pre-operative home accelerometry
4 with cardiopulmonary exercise variables. *Anaesthesia* Published Online First: 2017.
5
6
7 doi:10.1111/anae.14181
8
9
10 29 Dieu O, Mikulovic J, Fardy PS, *et al.* Physical activity using wrist-worn accelerometers:
11 comparison of dominant and non-dominant wrist. *Clin Physiol Funct Imaging* 2017;37:525–9.
12
13
14
15 doi:10.1111/cpf.12337
16
17
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27 **Figure 1.** Notched Box Plots representing physical activity (ENMO, milli-gravitational units mg) before
28 (blue) and after (red) the PRIME clinic intervention in all participants (left), participants listed for
29 orthopaedic surgery (middle) and non-orthopaedic surgery (right). Open circle (o) represents outliers.
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The notch represents the 95% confidence interval of the Median; 95% Confidence that the medians differ if two boxes' notches do not overlap. Significant differences between 'before-', and 'after-' intervention groups are indicated with an asterisk (*)

Figure 2. Physical activity (ENMO) against time before (left panel) and after (right panel) the intervention for each patient. The dots / blue lines represent the mean across the patient group with +/- 1 s.d. shaded. Only complete (2-6) days included. Mean physical activity is increased after the intervention with no discernible decline in activity over time.

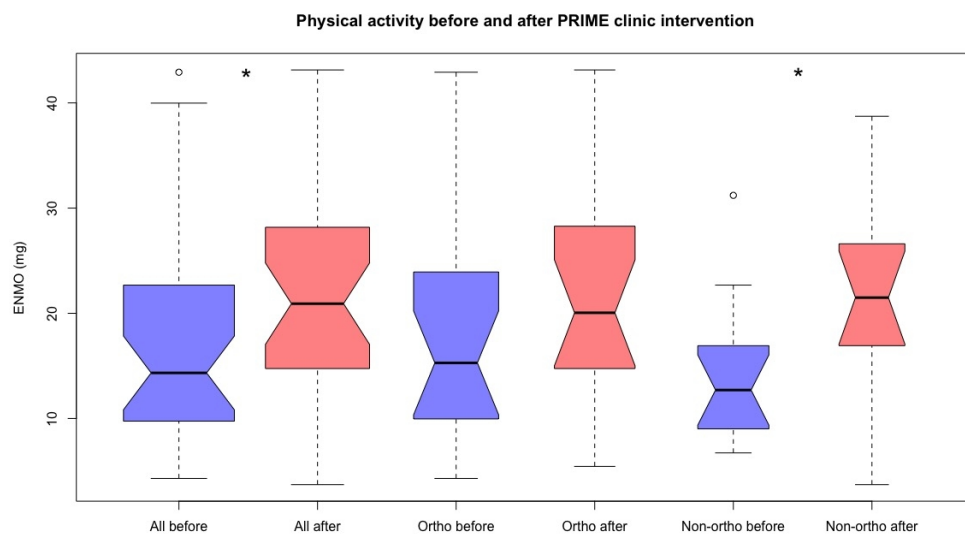


Figure 1. Notched Box Plots representing physical activity (ENMO, milli-gravitational units mg) before (blue) and after (red) the PRIME clinic intervention in all participants (left), participants listed for orthopaedic surgery (middle) and non-orthopaedic surgery (right). Open circle (o) represents outliers. The notch represents the 95% confidence interval of the Median; 95% Confidence that the medians differ if two boxes' notches do not overlap. Significant differences between 'before-', and 'after-' intervention groups are indicated with an asterisk (*)

412x246mm (72 x 72 DPI)

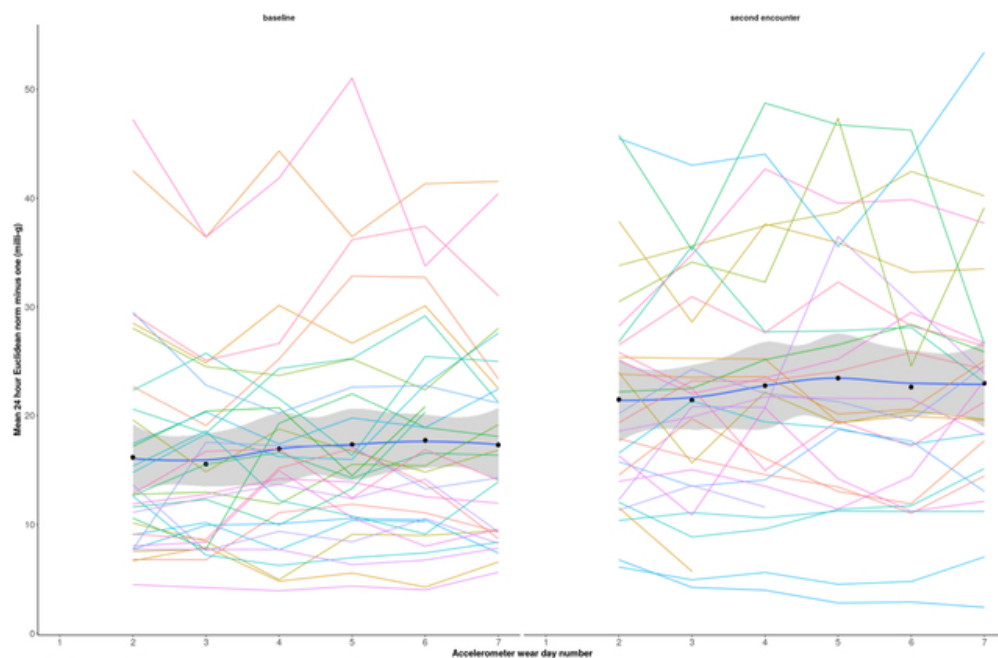


Figure 2. Physical activity (ENMO) against time before (left panel) and after (right panel) the intervention for each patient. The dots / blue lines represent the mean across the patient group with ± 1 s.d. shaded. Only complete (2-6) days included. Mean physical activity is increased after the intervention with no discernible decline in activity over time

54x35mm (300 x 300 DPI)