Total hip arthroplasty improves pain and function but not physical activity

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Abstract

Background:

People with hip osteoarthritis are likely to limited physical activity (PA) engagement due to pain and lack of function. Total hip arthroplasty (THA) reduces pain and improves function, potentially allowing increased PA. PA of THA patients was quantified to 12m post-operation. The hypothesis was that post-operatively levels of PA would increase.

Methods:

PA of 30 THA patients (67±7 years) was objectively measured pre-operatively and three and 12 months post-operation. Harris Hip Score (HHS), Oxford Hip Score (OHS) and six minute walk test (6MWT) were recorded. Mixed linear modelling was used to examine relationships of outcomes with time, BMI, age, gender and baseline HHS.

Results:

Time was not a significant factor in predicting sit-to-stand transitions, upright time, steps, cadence of walking bouts >60s, or longest upright bouts. However, HHS, OHS and 6MWT all improved with time. Notably BMI was a significant predictor of upright time, steps, largest number of steps in an upright bout, HHS and 6MWT. Baseline HHS helped predict longest upright bout, cadence of walking bouts >60s and OHS. The significant effect of participant as a random intercept in the model for PA outcomes suggested habituation from pre- to post-surgery.

Conclusions:

PA did not change from pre- to 12m post-surgery despite improvement in HHS, OHS and 6MWT. Baseline BMI was a more important predictor of upright activity and stepping than time. Pre- and post-operative PA promotion could be used to modify apparently habitual low levels of PA to enable full health benefits of THA to be gained.

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Keywords

Physical activity, Total Hip Arthroplasty

List of Abbreviations

THA Total hip arthroplasty

PA Physical activity

HHS Harris Hip Score

OHS Oxford Hip Score

6MWT Six minute walk test

BMI Body mass index

Introduction

Total hip arthroplasty (THA) leads to reduction in pain[1–3] and improvement in functional capacity[4–6] and quality of life[7,8]. Additionally THA is associated with enhanced walking endurance (longer distances covered in the 6 minute walk test[9,10]) and improved balance (faster performance of the timed-up-and-go-test[10,11]). However, there is emerging evidence that there are only small changes in free-living physical activity (PA) following surgery[12–15]. With reduction in pain, enhancement of endurance and speed of walking following THA, it might be expected that individuals would be able to participant in health enhancing PA. However, it is possible that pre-operative habitual patterns of PA are not altered. If pre-operative patterns of PA are ingrained (at low levels), then pre-operative measurements could be extremely useful in targeting person-centred interventions to disrupt these patterns, potentially enhancing long-term health prospects. While PA may have become habituated, it is possible that changes following surgery may be dependent on a range of factors. A person's gender may have an impact on surgical outcomes, as might their weight and age at the point of surgery. Also their pre-operative clinical condition may be important in determining outcomes.

The aim of this study was to enhance understanding of PA following THA by using objective measurement to characterise PA from pre-operation through recovery to twelve months post-operation. The relationship between PA change with time following surgery and gender, age, BMI and baseline clinical score (Harris Hip Score) was investigated. Primary physical activity outcomes included the number of sit-to-stand transitions per day, the time upright per day and the number of steps per day. Also secondary outcomes were quantified to further characterise PA (characteristics of the longest bouts of activity), walking endurance (six minute walk test) and clinical outcomes (Harris Hip Score, Oxford Hip Score). The hypothesis was that all outcomes would improve following THA.

Patients and Methods

This was an observational cohort study. Ethical approval was obtained from the West of Scotland Research Ethics Committee 1 (12/WS/0098). The study population was all patients being seen for a primary total hip arthroplasty operation at an NHS elective arthroplasty centre. To ensure the external validity of the study results the inclusion / exclusion criteria were kept as wide as possible. Inclusion criteria for the study were patients who were able to give informed consent, were between 50-85 years old and could return for follow-up. Patients were excluded if they were undergoing a revision hip arthroplasty, had had a total hip or knee arthroplasty in the last 12 months, had extreme locomotor limitations due to cardio-pulmonary, central or peripheral nervous system deficits or spinal conditions or were diagnosed with a terminal disease (malignancy). From July to August 2012 and January to May 2013 (break in recruitment due to illness of lead investigator) all THA patients under the care of one consultant orthopaedic surgeon (n=64) were reviewed for eligibility for the study. All eligible patients (n=57) were approached for inclusion in the study. Published data to carry out an appropriate a-priori power calculation were not available. Therefore a target sample of 30 participants was set to provide a power of 0.8 to detect a difference of 1SD in outcomes with a significant level of 0.05. All the study participants gave informed consent and the complete assessment was carried out by the lead author, a registered Physiotherapist.

Participants were operated on by a single consultant surgeon (DA) or a trainee surgeon under his direct supervision. Using a posterior approach, all participants received either a Contemporary® cemented cup or Trident® uncemented cup with an X3 polyethylene liner and an Exeter® femoral component (Stryker Orthopaedics, Michigan, USA). The peri-operative care for all participants (from pre-assessment through to discharge) followed the institution's enhanced recovery programme[16]. The aim of this programme was to accelerate patients' rehabilitation and reduce in- hospital length of stay (to 3-4 days) by implementing a multimodal anaesthetic regime combined with pre-operative education and early mobilisation.

Data were collected at three time points: Pre-operatively within the two weeks before operation; three months after operation; twelve months after operation.

PA data were collected objectively for up to seven days using the activPAL3™ monitor (50x35x7mm, 30g) (PAL Technologies Ltd. Glasgow, UK; software version 7.1.18)[17,18]. Data from this instrument classified activities into sedentary (sitting/lying), standing and stride events. Thus a record of posture (upright or not) and stepping activity was generated. The monitor was attached to the anterior aspect of the thigh of the non-operated leg (24 hour/day wear) using a waterproof surgical dressing (Duoderm extra thin hydrocolloid dressing (Convatec) or Opsite flexifix (Smith & Nephew)). When compared to video based observation the activPAL3™ has only a 0.27% difference in upright time detection and -3.34% difference for step count in adults [19] during standardised activities. Whilst the upright time detection remains good in activities of daily living (-0.19% agreement) there is considerable undercounting of small stepping activity within these activities (-86%). This undercounting of small/slow steps associated with some ADLs is emphasised by the monitor’s progressively poorer performance below 0.5m/s [20]. The monitor therefore records purposeful stepping activity, but is poor at recording small/slow incidental stepping.

Compliance with monitor wear was assessed by self-report and post-hoc data examination by the research team. Only self-reported full 24 hours periods of wear were considered for inclusion. These records were manually inspected for apparent abnormalities. Any days with apparent abnormalities were excluded.

Primary outcome measures:

The primary outcome for the study was PA. To quantify the level of PA the following three outcome measures were averaged over all 24 hour periods recorded: Sit-to-stand transitions/day; time spent upright/day (hours/day); steps/day.

Secondary outcome measures:

The following characteristics of the longer bouts of activity for each recording period were calculated: Duration of longest continuous upright bout over the recording period; largest number of steps in an upright bout across the recording period (not necessarily the same bout as the longest continuous upright bout); mean cadence (steps/min) of all walking bouts of longer than 60s.

Participants were also assessed at all time points using the Harris Hip Score[21] (completed by the lead author by measurement and interview), the Oxford Hip Score[22,23] (self-completion) and a six minute walk test [24]. The six minute walk test was conducted in a 30m long corridor, which had regular rest stations at 10m intervals. The participants were advised to walk up and down the corridor at a self-selected speed to achieve the maximum distance within 6 minutes. The participants were informed that they could take a break when and for how long needed at any point during the 6 minutes.

The age, gender, height, weight, BMI and comorbidities (from medical notes) of participants were recorded. Major complications (Death, Pulmonary Embolism/Deep vein Thrombosis, dislocation, infection, and revision) were noted.

Data analysis and statistics

Outcomes were characterised as mean (SD). To examine the change pre- to post-operation mixed linear models were used to model the relationship between each PA or clinical outcome parameter and time. As three time points were recorded time could only be modelled as quadratic. Models were adjusted for gender, baseline BMI, age and baseline Harris Hip Score (apart from Harris Hip Score). The shape of each outcome curve over time was modelled with each outcome measurement at Level 1 and each patient at Level 2. Fixed and random effects were included at the patient level (Level 2) and measurement level (Level 1). The fixed part of each model describes the average growth curve for the sample; the random part splits variation between subjects at the higher level and variation between time in the study of the same person at the lower level. The models allowed a unique growth curve to be generated for each subject based on his or her deviation from the average curve. An unstructured covariance structure was used.

Models were created adding covariates sequentially and comparing models using the -2*logLikelihood (-2LnL). Covariates were only retained if there was a significant improvement in -2LnL (reduction of 3.84). The maximum likelihood method was used to estimate the coefficients so that unbiased estimates of -2LnL were calculated. Once the model had been selected the restricted maximum likelihood method was used to give unbiased estimates of the coefficients. From this model predictions were made. Residuals for both level 2 and level 1 were estimated and investigated, as was the variance of the model over time. Model parameters and 95%CI are presented along with predictions.

All statistical analysis was conducted in SPSS 23 (SPSS Inc, Chicago, IL) with the level of statistical significance taken to be $p<0.05$.

Results

Thirty participants (21F/9M) were recruited to the study. The STROBE flow diagram giving recruitment pathway and reasons for non-participation is given in Figure 1. All surgeries were successfully carried out. For the duration of the study (one year follow-up) there were no major complications. Of the 30 participants, 3 did not have 12 month data (Figure 1). All 30 participants' data were included in the mixed linear modelling. For the participants mean age was 67 years (range 50-82y), height 165cm (range 150-182cm), weight 82.9kg (range 57.8-132.6kg), BMI 31 kg/m^2 (range 19-43kg/m^2) and pre-operative Harris Hip Score 50 (range 27-66) and Oxford Hip Score 15 (range 4-30). Indication for surgery in all the participants was osteoarthritis. Along with this diagnosis 13 participants had hypertension, 7 had cardiac abnormalities, 4 had Diabetes Mellitus, 7 had asthma/COPD and 2 participants had previous THA on the contralateral side. A median of six days of PA data were recorded at each time point. Mean and standard deviation of outcomes are presented (Table 1) with significant predictors within the mixed linear models (Table 2) and graphical evidence of trends with these significant predictors (Figure 2).

When examined using mixed linear models gender was not a significant predictor of any outcomes. Age was only a significant predictor of HHS (b=0.38, p=0.047) with a higher age being associated with a higher HHS (Figure 2g).

Time was not a significant predictor of the number of sit-to-stand transitions per day, upright time per day, steps per day, longest upright bout, the largest number of steps in an upright bout or cadence based on the outcomes of the mixed modelling (Table 1 mean data, Table 2 model outcomes). However, BMI was a significant predictor of upright time per day (b=-0.153, p=-0.003) (Figure 2a), steps per day (b=-263, p=0.001) (Figure 2b) and largest number of steps in an upright bout (b=-144, p=0.001) (Figure 2d). In each of these cases higher BMI predicted a lower level of PA. Additionally Baseline HHS predicted variation in the longest upright bout (b=0.0325, p=0.053) (Figure 2c) and the cadence of walking in bouts longer than 60s (b=0.696, p=0.004) (Figure 2e). For all PA outcomes except the longest upright bout random intercepts explained a significant proportion of the outcome, indicating that participants tended to maintain the same level of PA in relation to the other participants across the study period.

Time and Time^2 were significant factors in the model for HHS, OHS and 6MWT outcomes (all p<0.001). Also BMI helped to predict outcomes for HHS (b=-0.41, p=0.070) (Figure 2f) and 6MWT (b=-6.09, p=0.03) (Figure 2i) with higher BMI indicating lower scores. HHS baseline value helped to describe OHS (b=0.19, p=0.053) (Figure 2h) change over the study period. There was significant variation across the study period between participants in HHS, OHS and 6MWT as indicated by significant (-2LnL) contributions to the model of random intercepts.

Discussion

This study demonstrated that at one year post-operation primary THA patients had made little change to their free-living PA from pre-operation levels, with time not being a predictor in the mixed linear model. However, BMI was a significant predictor in the model for upright time and stepping activity. The significance of the random parameter of participant within the model coupled with the lack of a significant effect of time, suggested that participants were tending to maintain the same relative volumes of PA across the study period. This appears to indicate that pre-operative PA may have become habitual (possibly related to BMI) and despite improvements in function of the joint, as seen in the improvement of clinical outcome measures, PA levels did not significantly increase post-operation.

There were a number of limitations to this study. The small size of the study and the participants being under the care of one consultant within one hospital could limit the generalisability of the results. In terms of study power, based on the standard deviation of the difference in steps per day from pre- to 12 months post-operation recorded in this study (2492), the sample used (27 full records) would have been sufficient to detect a difference of 1350 steps/day with a power of 0.8 and a confidence of 0.05. In support of the generalizability of the results, the participants' age was similar to that reported in arthroplasty registers [25,26] and similarly osteoarthritis was the main reason for operation. However, BMI (mean 31kg/m^2) was higher than reported elsewhere[25,27]. It is widely accepted that by 12 months post-operatively patients have gained the maximum benefit from their THA. However, it is possible that increased function is obtained at longer follow-up or that function at one year had already begun to deteriorate due to other co-morbidities. The original activPAL™ monitor has proven validity in adults [18] and older adults[17,28]. However, the step counting facility of the activPAL3™ has limitations at slow stepping speeds as it under-counts slow, short step-length steps [20,29]. Therefore, the monitor may not have reliably detected stepping which was not 'purposeful'. A further issue is that this was an observational study of a surgical intervention. Theoretically, it would have been possible to perform an RCT with a no surgery arm to examine natural progression within this population. A more subtle limitation is that this study did not measure the desire of participants to increase their level of PA post-surgery. Therefore, even with improved function participants may not have increased PA as they lacked motivation.

The results of this study confirm the previous reports of only small changes in PA following THA '[14,15,30,31]. However, there were differences in outcomes, e.g. the current study (Table 1) found lower sit-to-stand transitions per day both pre-operatively and at 3 months post-operatively and whilst the upright time/day was similar pre-operatively, there were varying levels of agreement post-operatively compared to other studies. There were differences in participant demographics, with the current study population being older and more overweight than those of previous reports, which might explain these differences.

The mixed model outcomes indicated that gender did not significantly predict results for any outcome parameters within this cohort and that age was only significant within the prediction model for HHS. These results are perhaps surprising in that age might have been considered important in predicting PA as the study participants covered 50-82 years of age. However, BMI or Baseline HHS appeared to be more important. BMI was a predictor of both PA and clinical score outcomes, highlighting the importance of pre-operative BMI in predicting outcomes following surgery.

The inclusion of the Time^2 term within the mixed model improved predictions of several outcomes (Harris Hip Score, Oxford Hip Score and six minute walk test), suggesting that there was a non-linear relationship with time. This is highlighted in mean scores for these outcomes where large improvements occurred to the 3 month post-operative time point, but only small changes from 3 to 12 months post-operative (Figures 2f-i).

In the current study additional PA measures were added to those previously reported. The longest upright bout and largest number of steps in an upright bout provide quantification of the longest times participants performed 'functional' tasks requiring the upright posture. Time was not a significant factor in predicting these outcomes (Table 2), indicating that participants were not extending their loaded use of their new hip joints. Similarly cadence of stepping for bouts longer than 60s gives an insight into the intensity of stepping over extended periods. Whilst cadence increased across the study period (Table 1), this was not significantly predicted by time (Table 2) and still remained below that of age matched peers (93 (±12) against 107 steps/min) [32–34]. The longest upright bout model did not have a significant random effect of participant suggesting that there was not a consistent ranking of participants with time (Table 2). It is possible that this outcome is highly influenced by particular social events or functional activities, pointing to a need to gather contextual information to gain a full understanding of the reasons for these patterns. However, the largest number of steps in an upright bout did have significant random effects of participant, suggesting similar volumes of stepping within one bout across the study period by participants.

The lack of time as a significant predictor within the model coupled with the significant random effect of participant suggests that pre-operative PA (except longest upright bout) may be habituated. Therefore, if pre-operative PA was measured, interventions could be used to target those likely to have low PA post-operatively to attempt to modify long-term behaviour. Enhancing PA has demonstrated secondary benefits of improving health (e.g. lower risk of cancer, ischemic events, diabetes [35] and enhanced quality of life[36,37]). A behaviour change intervention delivered through educational material, therapy sessions etc., could be used to attempt to maximise the potential gains from THA in terms of overall health improvement. The significance of BMI within several PA outcome models reinforces the need to consider this as an important factor in health promotion alongside PA promotion.

As expected [9,30], both Harris Hip Score and Oxford Hip Score highlighted improvement from pre- to post-operation, as did 6MWT (values similar to previous studies [12,31]). However, there was not an accompanying increase in PA levels, indicating that these measures cannot be used as surrogates for PA, i.e. that it is necessary to measure free-living PA directly to gain insight into any changes following surgery.

Conclusions

In this study primary total hip arthroplasty patients did not make significant changes in the volume of PA performed at one year post-operation and it appeared that participants tended to maintain the same relative level of PA in relation to their peers. However, standard clinical outcome measures improved, showing an increase in function. This may indicate that habitual free-living PA patterns are established pre-operatively, perhaps related to BMI, and these are not altered by the better function and pain reduction given by a THA. These results may indicate that intervention to modify habitual low levels of PA, associated with declining long term health, could be necessary in a proportion of primary THA patients to allow them to fully exploit the additional function that their new joint gives them.

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Suppliers

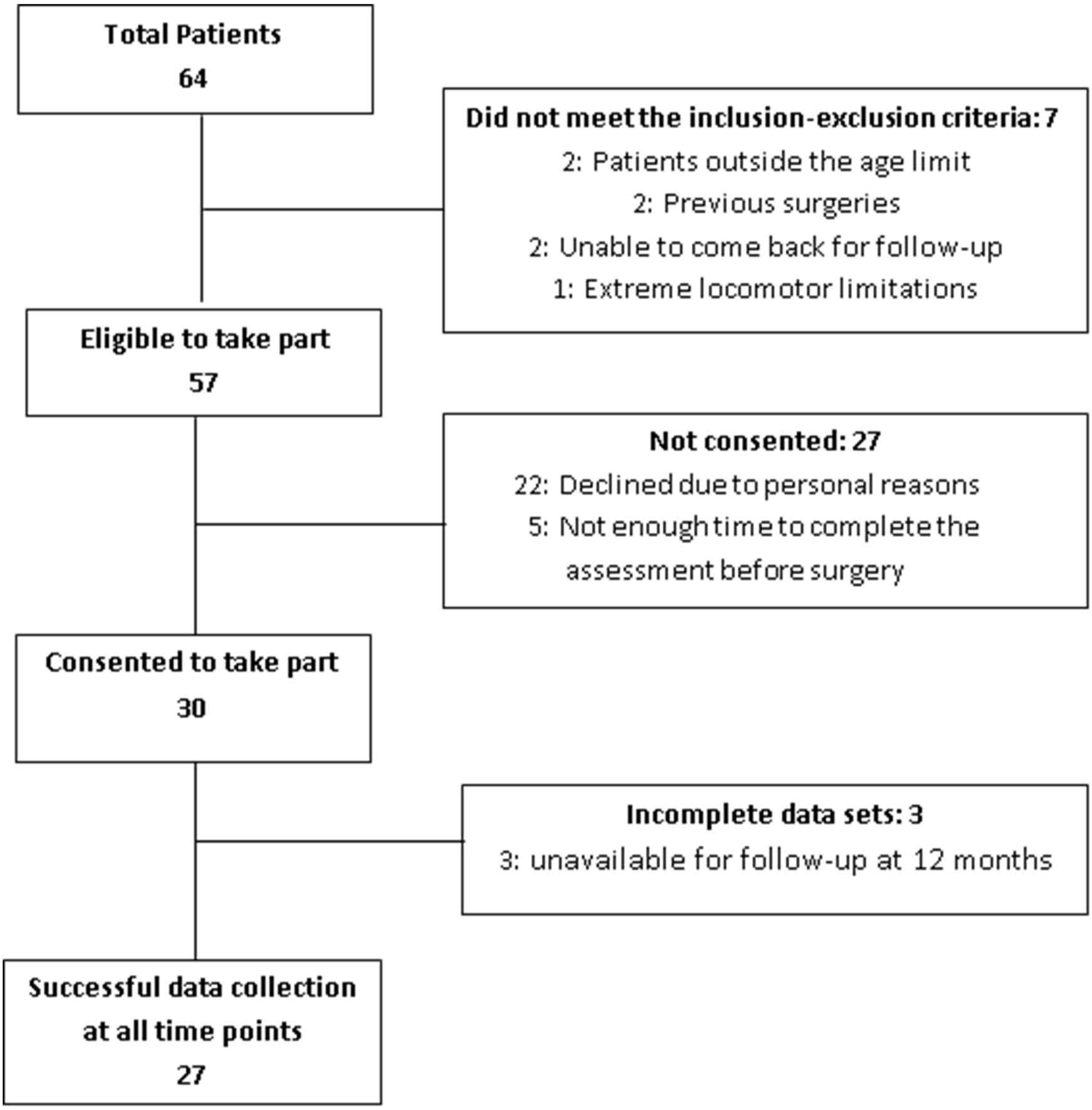
[a] **Stryker Orthopaedics**, Michigan, USA: Exeter® femoral component, Contemporary® cemented cup, Trident® uncemented cup, X3 polyethylene liner.

[b] **PAL Technologies Ltd**. Glasgow, UK: activPAL3™

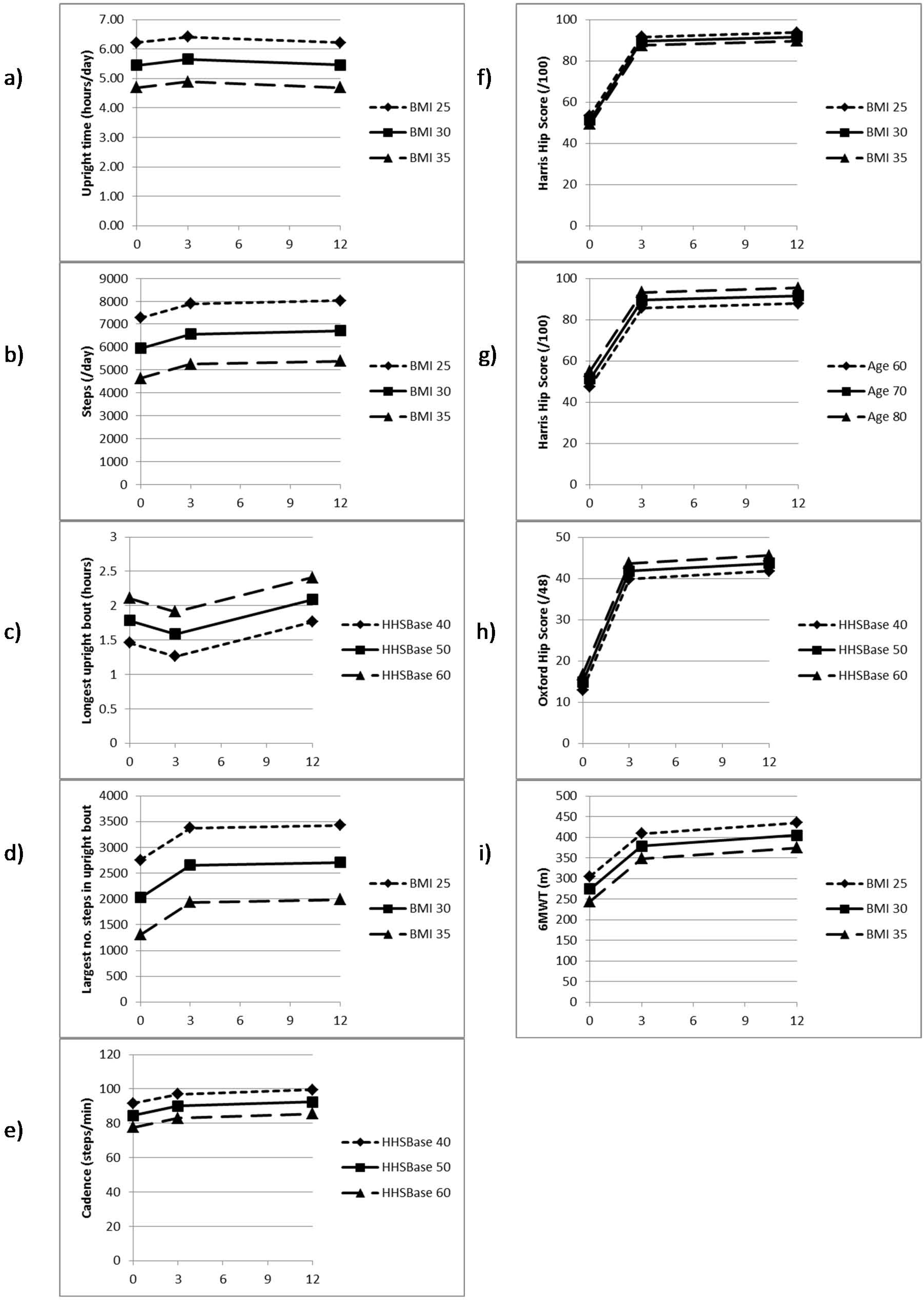
List of Figures

Figure 1 Strobe flow chart of participant recruitment.

Figure 2 Model outcomes for significant relationships by months-post operative. Note in figures a) to e) for illustrative purposes time and $time^2$ have been left in the models even though they were not significant (see Table 2 for significant model parameters). a) Upright time by BMI; b) Steps by BMI; c) Longest upright bout by Harris Hip Score baseline; d) Largest number of steps in an upright bout by BMI; e) Cadence of stepping bouts >60s by HHS baseline; f) Harris Hip Score by BMI; g) Harris Hip Score by age; h) Oxford Hip Score by Harris Hip Score baseline; i) Six minute walk test by BMI.



Total Patients
64
Did not meet the inclusion-exclusion criteria: 7
2: Patients outside the age limit
2: Previous surgeries
2: Unable to come back for follow-up
1: Extreme locomotor limitations
Eligible to take part
57
Not consented: 27
22: Declined due to personal reasons
5: Not enough time to complete the assessment before surgery
Consented to take part
30
Incomplete data sets: 3
3: unavailable for follow-up at 12 months
Successful data collection at all time points
27



a)
Upright time (hours/day)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
3
6
9
12
BMI 25
BMI 30
BMI 35
b)
Steps (/day)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
BMI 25
BMI 30
BMI 35
c)
Longest upright bout (hours)
3
2.5
2
1.5
1
0.5
0
HHSBase 40
HHSBase 50
HHSBase 60
d)
Largest no. steps in upright bout
4000
3500
3000
2500
2000
1500
1000
500
0
BMI 25
BMI 30
BMI 35
e)
Cadence (steps/min)
120
100
80
60
40
20
0
HHSBase 40
HHSBase 50
HHSBase 60
f)
Harris Hip Score (/100)
100
80
60
40
20
0
BMI 25
BMI 30
BMI 35
g)
Harris Hip Score (/100)
Age 60
Age 70
Age 80
h)
Oxford Hip Score (/48)
50
40
30
20
10
0
HHSBase 40
HHSBase 50
HHSBase 60
i)
6MWT (m)
500
450
400
350
300
250
200
150
100
50
0
BMI 25
BMI 30
BMI 35

Table 1 Outcomes at each time point.

Outcome	Pre-operative (Mean SD)	3m Post-operative (Mean SD)	12m Post-operative (Mean SD)
Primary outcomes			
Sit-to-stand transitions (/day)	46 (11)	44 (11)	44 (11)
Upright time (hours/day)	5.35 (2.07)	5.55 (1.74)	5.42 (1.61)
Steps (/day)	5320 (3015)	5943 (2675)	6155 (2631)
Secondary outcomes			
Longest upright bout (hours)	1.78 (1.48)	1.58 (0.82)	2.09 (1.96)
Largest number of steps in an upright bout	1934 (1480)	2559 (1841)	2671 (1705)
Cadence of bouts >60s (steps/min)	85 (16)	91 (13)	93 (12)
Harris Hip Score (/100)	50 (10)	88 (10)	91 (11)
Oxford Hip Score (/48)	15 (6)	42 (7)	44 (6)
Six minute walk test (m)	270 (93)	374 (87)	399 (104)

Table 2 Mixed linear model results, both fixed and random parameters for all outcomes. Those elements of the model that are included produced an improvement in 2LnL of a minimum of 3.84. Variables were centred as: BMI 30 kg/m^2, Age 70 years, HHS Baseline 50. Beta = change in outcome per unit of model element: Time (months), BMI (kg/m^2), Age (years), HHS (Harris Hip Score) Baseline (score/100). 95% confidence intervals are given.

Outcome	Fixed parameters												Random parameter	
	Intercept		Time		Time^2		BMI		Age		HHS Baseline		Intercept	
	Beta	P value	Beta	P value	Beta	P value	Beta	P value	Beta	P value	Beta	P value	Covariance	P value
Primary outcomes														
Sit-to-stand transitions (/day)	44.4 (40.8,47.9)	<0.001											75.7 (40.2,142.5)	0.002
Upright time (hours/day)	5.52 (4.99,6.05)	<0.001					-0.153 (-0.248,-0.057)	0.003					1.630 (0.862,3.087)	0.002
Steps (/day)	5950 (5184,6715)	<0.001					-263 (-401,-126)	0.001					3270000 (1680000,6365000)	0.003
Secondary outcomes														
Longest upright bout (hours)	1.81 (1.50,2.12)	<0.001									0.0325 (-0.0004,0.0655)	0.053		
Largest number of steps in an upright bout	2453 (2023,2883)	<0.001					-144 (-221,-67)	0.001					783500 (315500,1945300)	0.031
Cadence of bouts >60s (steps/min)	89.1 (84.9,93.2)	<0.001									0.696 (0.240,1.151)	0.004	75.3 (32.8,172.4)	0.018
Harris Hip Score (/100)	51.3 (47.7,54.9)	<0.001	15.84 (13.96,17.72)	<0.001	-1.04 (-1.18,-0.89)	<0.001	-0.41 (-0.85,0.04)	0.070	0.38 (0.01,0.76)	0.047			15.47 (3.53,67.70)	0.184
Oxford Hip Score (/48)	14.9 (12.5,17.2)	<0.001	11.16 (9.99,12.33)	<0.001	-0.73 (-0.82,-0.64)	<0.001					0.19 (-0.003,0.383)	0.053	14.33 (5.85,35.11)	0.029
Six minute walk test (m)	274 (241,307)	<0.001	42.62 (30.54,54.69)	<0.001	-2.646 (-3.582,-1.709)	<0.001	-6.09 (-11.36,-0.83)	0.03					5016 (2671,9419)	0.002

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