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Cover Letter (Include IRB statement)

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The Editors,
Journal of Arthroplasty

6th January 2017

Dear Sir/Madam,

Re: JOA-D-15-001158 Reubmission of Manuscript to Journal of Arthroplasty

We have completed additional revision of this manuscript in line with the reviewers' comments. The current title of the manuscript is: **Total hip arthroplasty improves pain and function but not physical activity**

I trust that you find all necessary documentation complete with regards to the resubmission of the manuscript.

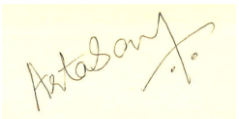
Each of the authors has read and concurred with the content of the manuscript .The material within has not been and will not be submitted for publication elsewhere except as an abstract.

All authors have made substantial contributions to all of the following: (1) The conception and design of the study (all authors), acquisition of data (AJ,BS, AD), or analysis and interpretation of data (All authors), (2) drafting the article (BS,AJ) or revising it critically for important intellectual content (All authors), (3) final approval of the version to be submitted (All authors).

We confirm that the work received Institutional Review Board approval before commencement.

Should you require any further information please do not hesitate to contact me at the above

Yours sincerely,



Artaban Johnson Jeldi

Golden Jubilee National Hospital and Glasgow Caledonian University

6th January 2017

JOA-D-15-001158

Total hip arthroplasty improves pain and function but not physical activity

We would like to thank the reviewers for their time in reviewing this manuscript and their comments. We have addressed each comment in turn as below.

Reviewer #2: Thank you for revising the analysis. The manuscript is improved. A few minor changes are required

Abstract
line 5- change 'limited' to "limit"

Line 16 -remove "However..time."

We have implemented these changes.

Discussion -
Just because PA is associated with BMI does not mean that is the cause of the habitual behaviour. If anything, you could argue habitual sedentary behaviour then influences BMI. I would change where you make this link in the Discussion and just go with BMI not time was a predictor of PA. Note - specify that it is BMI pre-op (unless you also got BMI across time).

We have examined the discussion to ensure we are not implying a causal link between PA and BMI in either direction. We have removed suggested links.
We have added additional text to ensure the reader understands we are using BMI baseline (pre-op) in our analysis.

Table 2 - is messy. better way to set out? Not sure if it was just how it printed out at my end.

We have attempted to improve the presentation of Table 2. This is difficult as we have included all model outcomes here, which requires numerous columns across all outcomes. We hope that the revision makes reading the table easier.

Reviewer #3: I agree with the authors use of mixed linear modelling for analysis to identify covariates. However, it would be useful to show p values in Table 1. Difference in PA and functional outcomes between pre- and post-3 months and post-12 months. As I suggested before, the authors could use paired t test to give these p values. I do not think it will change their conclusions, but I believe that it will add strength to the analysis.

We have added an assessment of differences between baseline and 3 and 12 month outcomes to Table 1. In examining the appropriate statistical tests to perform we found that most outcomes were normally distributed and the statistically significant differences were the same if parametric or non-parametric analysis was performed. Therefore, we have presented

unadjusted paired t test outcomes as requested by the reviewer. This highlights differences between time points for the largest number of steps in an upright bout (pre to 3 months post) and between baseline cadence and post-operative cadence at both time points. We have incorporated this into the results and discussion within the paper.

Line 189 and Table 2: Define "Time and Time2"

Here we have used Time in seconds as a predictor in the model. We have also used $Time^2$, i.e. (Time x Time) within the model. This allows for non-linear relationships with time. We have included an additional line in the methods section:

"(both Time and $Time^2$ terms were introduced in the model)."

Table 2 is confusing. I think this data could be presented better.

As per the response to Reviewer 2 we have attempted to improve the presentation of Table 2. This is difficult as we have included all model outcomes here, which requires numerous columns across all outcomes. We hope that the revision makes reading the table easier.

***Conflict of Interest Statement (Blinded - no signatures)**

BLINDED CONFLICT OF INTEREST STATEMENT

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One of the authors is a co-inventor of activPAL and a director of PAL technologies that manufactures the activPAL devices used in this study

5. Research support from a company or supplier as a Principal Investigator (The following conflicts were disclosed)
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Manuscript Title: **Pre-operative physical activity is habituated and little changed following total hip replacement**

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Mr Artaban Johnson Jeldi		7th October ,2015
Author Name (Print or Type)	Author Signature	Date

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Dr. Angela Deakin — Author Name (Print or Type)

Author Signature

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Dr. Ben Stansfield — 7th October 2015

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Professor Malcolm Granat		7th October ,2015
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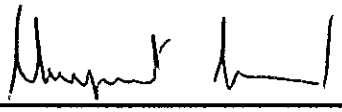
Dr. Margaret Grant		7th October ,2015
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Title: Total hip arthroplasty improves pain and function but not physical activity

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Abstract

Background:

People with hip osteoarthritis are likely to limit 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, baseline BMI, age, gender and baseline HHS.

Results:

Time was not a significant factor in predicting volume measures of PA, including sit-to-stand transitions, upright time and steps. Notably baseline 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:

Volume measures of 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.

Title: Total hip arthroplasty improves pain and function but not physical activity

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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.

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^{TM} 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^{TM} 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). Changes between baseline and 3 months and 12 months post-operation were assessed using paired T tests. Additionally, 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 (both Time and $Time^2$ terms were introduced in the model). 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. Pre-operatively 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 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).

There were no significant differences in the primary outcomes between baseline and 3 and 12 months post-operation (Table 1). However, for the secondary PA outcomes there were significant increases in the largest number of steps in an upright bout at 3 months ($p=0.024$) (but not 12) and in cadence at both 3 ($p=0.028$) and 12 months ($p=0.007$) post-operation. Harris Hip Score (HHS), Oxford Hip Score (OHS) and six minute walk test (6MWT) all demonstrated increases from baseline to 3 and 12 months post-operation (all $p<0.001$).

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, baseline 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 baseline 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 baseline 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 baseline 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. This was confirmed by a lack of significant difference in the primary PA outcomes and with time not being a predictor in the mixed linear model. However, secondary PA outcomes did change, suggesting underlying modification of walking performance. Baseline 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 and despite improvements in function of the joint, as seen in the improvement of clinical outcome measures, volumes of PA 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, baseline 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^{TM} monitor has proven validity in adults [18] and older adults[17,28]. However, the step counting facility of the activPAL3^{TM} 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.

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

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

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

258 In the current study additional PA measures were added to those previously reported. The
259 longest upright bout and largest number of steps in an upright bout provide quantification
260 of the longest times participants performed 'functional' tasks requiring the upright posture.
261 Also cadence of stepping for bouts longer than 60s gives an insight into the intensity of

stepping over extended periods. Paired T test outcomes indicated no significant difference in the primary outcomes between baseline and post-operation time points. However, there were differences in the secondary PA outcome measures of the largest number of steps in an upright bout and the cadence of longer stepping bouts (>60s). These changes suggest that characteristics of PA behaviour may be improving, such as the ability to routinely walk faster (confirmed by a correspondingly higher 6MWT outcome). However, these do not appear to necessarily translate into greater volumes of overall daily activity.

Within the model, Time was not a significant factor in predicting longest upright bout or largest number of steps in an upright bout (Table 2), indicating that participants were not extending their loaded use of their new hip joints. Whilst cadence increased across the study period (Table 1), this was not significantly predicted by time in the model (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 baseline 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 HHS and OHS 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 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

306 term health, could be necessary in a proportion of primary THA patients to allow them to
307 fully exploit the additional function that their new joint gives them.

308

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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™

Figure 1

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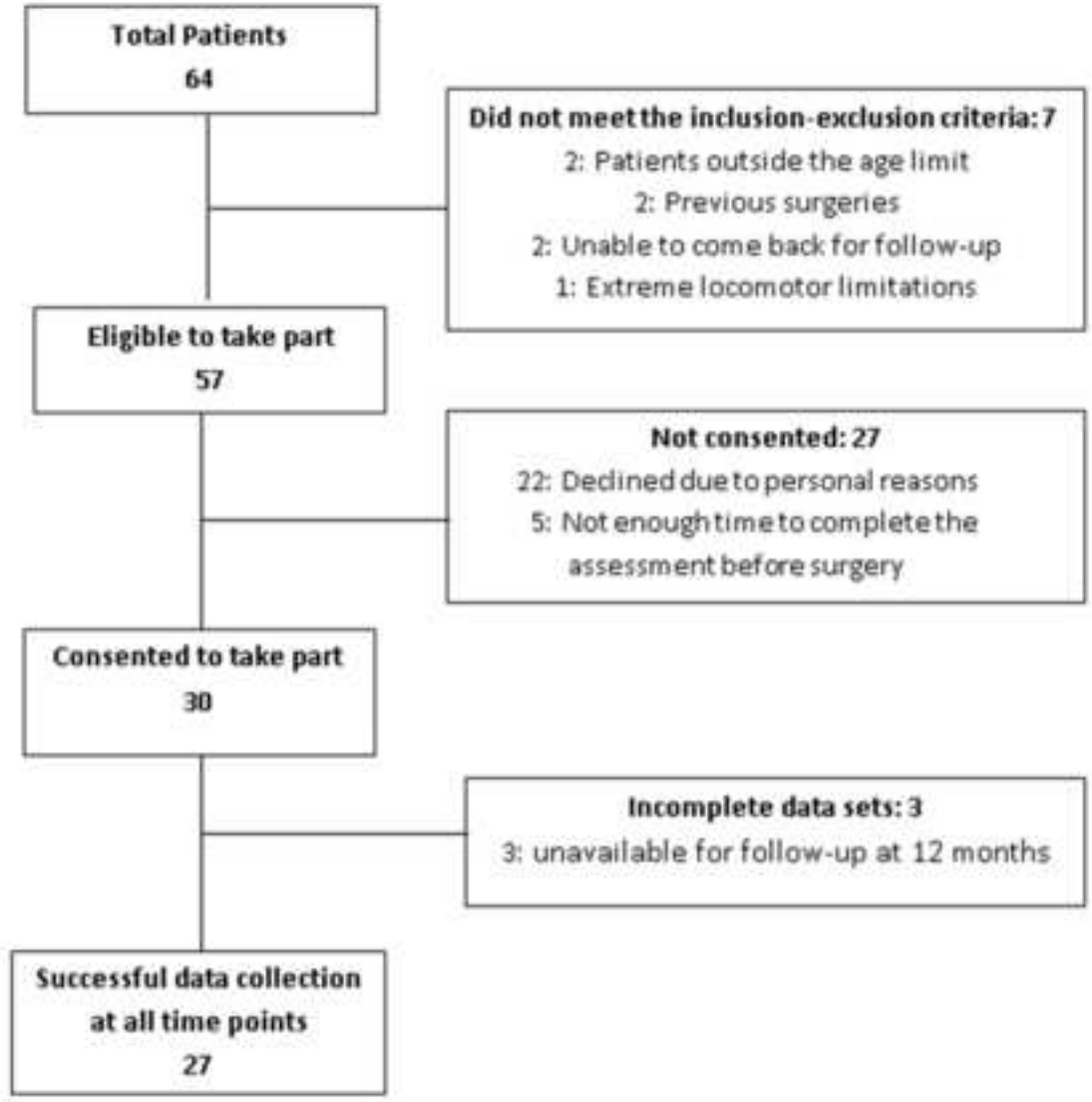

Figure 2

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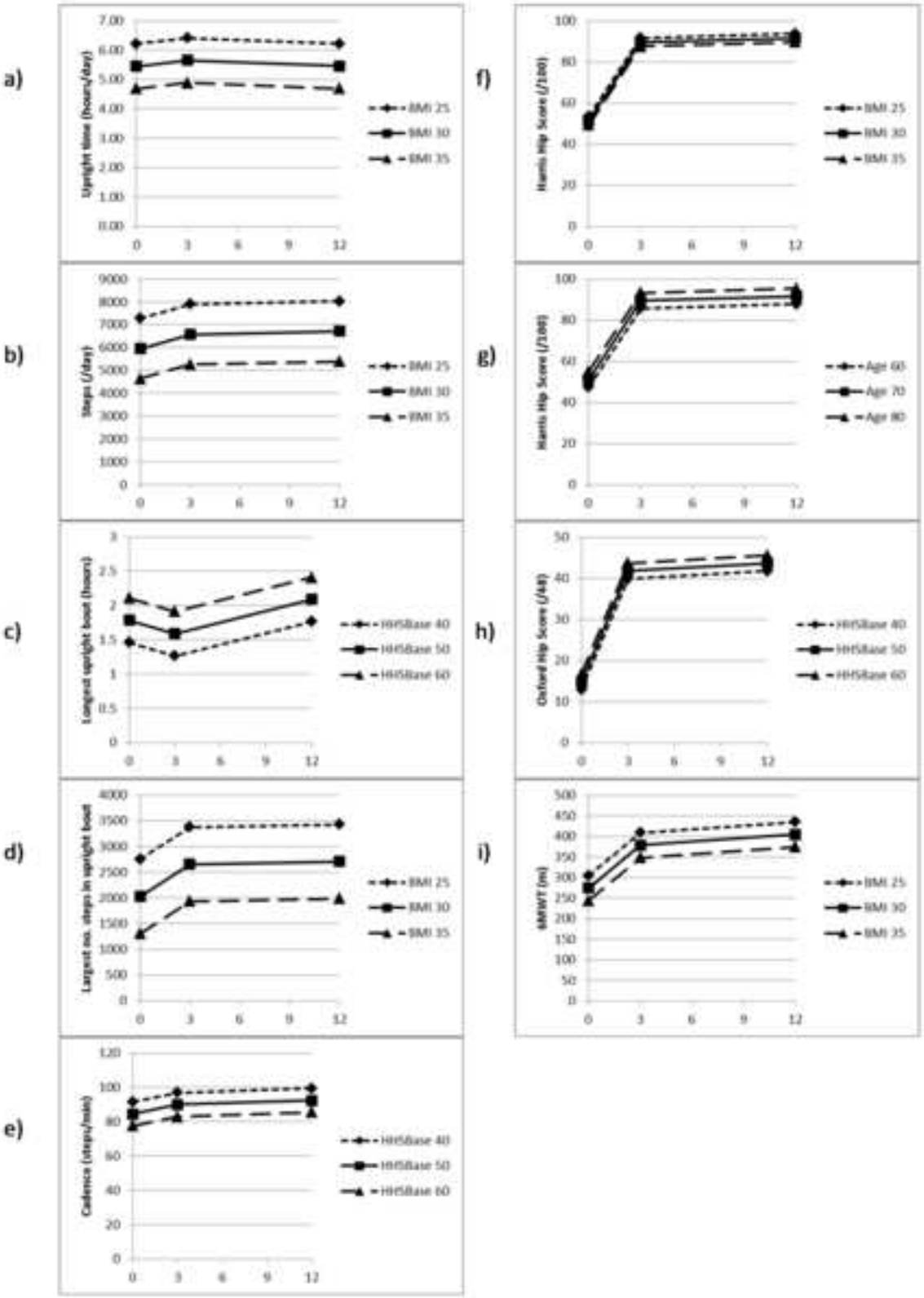

List of Figures

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.

Table 1

Table 1 Outcomes at each time point and unadjusted statistical differences between post- and pre-operative time points.

Outcome	Pre-operative (Mean SD)	3m Post-operative (Mean SD)	p-value	12m Post-operative (Mean SD)	p-value
Primary outcomes					
Sit-to-stand transitions (/day)	46 (11)	44 (11)	0.237	44 (11)	0.138
Upright time (hours/day)	5.35 (2.07)	5.55 (1.74)	0.406	5.42 (1.61)	0.979
Steps (/day)	5320 (3015)	5943 (2675)	0.071	6155 (2631)	0.152
Secondary outcomes					
Longest upright bout (hours)	1.78 (1.48)	1.58 (0.82)	0.462	2.09 (1.96)	0.356
Largest number of steps in an upright bout	1934 (1480)	2559 (1841)	**0.024***	2671 (1705)	0.129
Cadence of bouts >60s (steps/min)	85 (16)	91 (13)	**0.028***	93 (12)	**0.007***
Harris Hip Score (/100)	50 (10)	88 (10)	**<0.001****	91 (11)	**<0.001****
Oxford Hip Score (/48)	15 (6)	42 (7)	**<0.001****	44 (6)	**<0.001****
Six minute walk test (m)	270 (93)	374 (87)	**<0.001****	399 (104)	**<0.001****

Paired sample T-test *different from pre-operative at $p<0.05$, **different from pre-operative at $p<0.001$

Table 2

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 (Harris Hip Score) Baseline 50. Beta = change in outcome per unit of model element: Time (months), Time^2 (months^2), BMI Baseline (kg/m^2), Age (years), HHS Baseline (score/100). 95% confidence intervals of Beta are given.

	Fixed parameters												Random parameter	
	Intercept		Time		Time^2		BMI Baseline		Age		HHS Baseline		Intercept	
Outcome	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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