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Systematic review

Minimal change in physical activity after lower limb joint arthroplasty, but the outcome measure may be contributing to the problem: a systematic review and meta-analysis

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Abstract

Background The literature pertaining to changes in physical activity (PA) in people who have undergone lower limb arthroplasty is controversial, but it is unknown whether this is due to participant characteristics or how physical activity is measured.
Objectives To determine whether PA changes after total knee or hip arthroplasty and what explains contradictory results between different published studies.
Data sources Five online databases were searched for keywords and MeSH headings. Reference lists were also hand-searched.
Study selection Cohort studies and the control groups of clinical trials that examined PA levels prior to total arthroplasty as well as 6- and/or 12-month post-operative included. PA could be measured using accelerometery, pedometery or patient reported outcomes.
Data extraction PA outcomes were categorised into frequency, intensity, duration and type. Meta-analysis was performed when possible.
Results Eleven studies, examining 277 individuals with THA and 406 people with TKA were included. Studies differed in the outcome measure reported, device used and placement of accelerometers. When measured as steps per day, pooled data revealed a small increase in the frequency of PA at 12 months post-TKA (SMD 0.44 [0.2, 0.67] $I^2 = 0\%$) and moderate increase in individuals post-THA (SMD 0.65 [0.32, 0.97] $I^2 = 0\%$). Pooled evidence indicated no change in PA duration when measured as time spent active (SMD 0.05 [−0.42, 0.52] $I^2 = 46\%$) or proportion of time spent active (SMD 0.5 [−0.17, 1.16] $I^2 = 75\%$) 6-months post-TKA. Data examining PA duration, intensity and type at 12-months could not be pooled.
Conclusion The true nature of changes in PA post-surgery remains largely unclear. While frequency of PA may increase, the balance of evidence indicates that PA does not substantially increase post total joint arthroplasty. Improvements in the consistency of device type, placement and outcome measure would substantially assist in improving knowledge in this area.
Trial registration CRD42015029686.

Keywords: Replacement; Knee; Hip; Exercise; Accelerometry; Patient reported outcome measures

Introduction

For individuals undergoing total knee or hip arthroplasty (TKA, THA), improvements in joint pain, mobility and function are commonly expected outcomes from surgery [1–3]. The balance of evidence from current studies demonstrates that these surgeries do yield substantial improvements in these aforementioned health domains though not always to the level of aged-matched peers devoid of symptomatic arthritis [3–6]. For some individuals, resumption in or commencement of physical activity or exercise may also be

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expected following surgery [3,4]. Whether physical activity (PA) levels improve or not after TKA or THA is important to know. If activity levels increase, the health profile of those who undergo it may improve, at least in terms of the comorbidities that are amenable to exercise. Given high rates of obesity, diabetes, hyperlipidaemia, hypertension and heart disease are commonly observed amongst arthroplasty cohorts [7–10], and all of the aforementioned conditions are ameliorated by exercise [11,12], an increase in PA could be a highly beneficial outcome for many.

In recent years, systematic reviews have been conducted to investigate the question of whether or not PA increases following TKA or THA [13,14] and whether patients themselves are interested in returning to pre morbid levels of activity [15]. Two meta-analyses evaluating whether PA increases or not concluded that objectively measured PA does not increase markedly within the first year after surgery such that PA levels remain or are likely to remain lower than those of healthy aged-matched norms [13,14]. There are two primary limitations in these reviews. First, neither review acknowledges that PA is a complex set of behaviours that need to be comprehensively measured across multiple domains, typically frequency, duration, intensity and type [16]. Second, neither review systematically analysed patient-reported PA so it is unclear whether patients likewise report no substantial increase in activity or whether they perceive themselves to be more active. Interestingly, in a review capturing patient perceptions of PA after arthroplasty, whilst patients may desire to return to pre morbid PA levels, this often does not translate to a greater engagement in activity post surgery [15].

A further conclusion of prior reviews is that the individual studies varied in their findings. Differences in study design, including length of follow-up, population characteristics and tools used to measure PA, all likely contribute to inconsistent results. A synthesis of why results from different studies are contradictory is important for improving study design for future investigations in this area. An expert panel has recently proposed that a single metric be employed by cohort studies examining PA in people with OA in order to improve homogeneity and comparability [17]. What is not known is whether the heterogeneity in metrics also contributes to discord in results reported by studies of arthroplasty population and thus whether the recommendation of a single PA metric needs to extend to this population.

In light of the above, the aims of this systematic review were to determine if PA levels improve after TKA or THA, and whether outcome measures and devices used to measure PA contribute to contradictory results in PA reporting by published studies.

Methods

Operational definition of physical activity

For the purposes of this review, PA was defined as any body movement that works muscles, and requires more energy than resting [18]. This was extrapolated to include activities such as walking, gardening, swimming, dancing and cycling. We included active recreation within our definition of PA.

Identification and selection of studies

A literature search of several electronic databases was performed including PubMed, Embase, Medline, CINAHL and Scopus from the earliest record to March 2017. The search strategy used MeSH headings such as; hip arthroplasty, knee arthroplasty, hip replacement, knee replacement, hip prosthesis, knee prosthesis and physical activity. As well as keywords; recreational activity; climb*; cycl*; jog*; jump*; run*; swim*; walk*; danc* and garden*. A sample search strategy for a single data base is included as supplementary data A. Reference lists of all manuscripts selected for full text review were hand searched for any missed publication. Titles and abstracts were screened then full text of publications meeting the selection criteria were retrieved. The literature search and selection process were conducted by two reviewers (CD; BF); the latter of whom was blinded to author; title and journal of publication. Inclusion in the review was via predetermined criteria. Studies needed to be prospective human case control; observational or randomised control trials of individuals undergoing unilateral or bilateral TKA or THA. PA; measured by accelerometer; pedometer or patient reported outcome (PRO) needed to occur prior to surgery and either 6-months or 12-months post surgery. Disagreements between the two independent reviewers were resolved by a third; blinded reviewer (KM or JN). No restrictions were placed on language or date of publication.

Quality assessment

A modified version of Downs and Black Quality Assessment Tool was utilised to assess methodological quality of included papers [19,20]. The modified version contains 16 items assessing reporting (items 1 to 3, 5 to 7 and 10), internal validity (items 11 and 12) and external validity (items 15, 16, 18, 20 to 22 and 25) and excludes items relating the validity and delivery of an intervention. The tool awards 1 point for each item, with the exception of item 5 where 2 points are awarded for “yes” and 1 for “partial”. No points are scored for negative items or when items are unable to be determined. Quality assessment was performed by 2 reviewers (KM and BF) the latter of whom was blinded to authors, title and journal. Disagreements between authors were settled by consensus with those not resolved being referred to a third reviewer (JN) for adjudication.

Data synthesis

Data extraction was performed by one reviewer (KM) using a pre formulated standardized data extraction form and checked by a second reviewer (JN). Data extracted

included: (1) participant demographics (sex, age, body mass index (BMI) and joint replaced); (2) study characteristics (design, sample size, country of origin); (3) pre-operative assessment time, and; (4) length of follow-up. Specific measurement characteristics were also extracted, including: (1) the outcome measure used to quantify physical activity (2) the measurement tool used e.g. motion sensor or questionnaire and subsequent design/manufacturer (3) pre- and post operative levels of physical activity (as point estimates of effect and standard deviation) (4) length of time activity was measured. For reporting purposes, we categorised each outcome measure into four primary domains of PA: frequency, duration, intensity and type. For empirical measures, when the outcome measure crossed multiple domains, the primary domain of interest, as nominated by the authors, was used for categorisation. Questionnaires designed to capture multiple PA domains were sequestered from those designed to capture a specific PA domain.

The change in PA (and 95% confidence intervals) from pre to post surgery was calculated by subtracting pre surgery activity levels of PA from 6- or 12-month post surgery levels. Data from individuals undergoing THA or TKA were extracted and reported separately. When data from both surgeries were presented together, we contacted the authors to retrieve differentiated data. Where studies presented central tendencies as medians and range, the mean and standard deviation were calculated using methods defined by Hozo *et al.* [21] Studies reporting on individuals with the same joint replaced, using the same type of outcome measure (e.g. patient reported outcome or device), at the same follow-up period (6- or 12-months) were considered for meta-analysis. When performed, meta-analysis of the standardized mean difference was conducted using RevMan V5 (Cochrane collaboration). A random effects model was chosen to pool data as it was assumed that the activity levels being estimated may not be the same across the studies, but would follow the same distribution [22]. The I^2 statistics was used as a measure of unexplained variance within the meta-analysis. The metric is ratio of how much variance is due to within-study variation (typically due to differences between the participants of an individual study) compared with between study variation. Lower values indicate that all of the variability in the point estimates of effect is due to variation with the individuals studies rather than methodological differences between studies [23]. Ranges of low, moderate, substantial and considerable heterogeneity between studies were interpreted as 0 to 40%, 30% to 60%, 50% to 90% and 75% to 100% respectively [22,23]. Publication bias would be assessed if ten or more studies were eligible for inclusion.

The study protocol was registered on the PROSPERO systematic review register (CRD42015029686). The PRISMA statement [24] was used to conduct the review and report the findings.

Results

The initial search retrieved 8695 titles. After deletion of duplicates and Abstract screening, 32 full-text publications underwent further review. Of these, 11 studies were found to be eligible (Fig. 1). Seven of the included studies were observational cohorts and four compared activity levels in individuals undergoing arthroplasty with age matched peers [25–28]. Only the arthroplasty group's data were extracted in the latter studies. Of the four studies examining only participants with THA, three examined physical activity changes at 6-months [26,27,29] and two examined changes at 12 months [27,30]. This was also the case for the four studies that only examined participants with TKA [25,28,31,32]. The three remaining studies examined both TKA and THA; two did so at 6 months post surgery [33,34] and the other at 12 months [35]. Across all studies, data from 277 THA and 406 TKA recipients were able to be analysed for changes in PA (Table 1).

Methodological quality

The quality assessment tool scores ranged from 9 to 16 points (supplementary data A), indicating that the studies' quality ranged from low to high. No study received a point for blinding the assessors who were measuring the primary outcome of the study. While this is impractical for cohort study designs, no comparative study reported attempts to blind assessors pertaining to individuals undergoing arthroplasty and healthy controls. Only three studies [25,31,35] adequately reported confounding factors, such as co-morbidities and BMI, and controlled for them in their analysis, with the remaining studies scoring "unable to determine" (supplementary data A).

Study characteristics

Quantifying physical activity

The two methods used to quantify PA were accelerometers and recall questionnaires. Six studies only used accelerometers [25–29,31], three studies used accelerometers and questionnaires [30,33,34] and two studies only used questionnaires [32,35]. Accelerometers were uniaxial [33], bixial [27,28,30] or triaxial devices [25,29]. Multi sensor systems were also utilised [26,31,34]. Placement of the devices varied between studies, but were confined to the lower limb, waist and sternum (Table 1).

Three recall questionnaires were utilised to capture self-reported PA: The Physical Activity Scale for the Elderly (PASE) (12 items), the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) (13-items) and University of California, Los Angeles (UCLA) activity scale (10-items). In all PROs, higher scores indicate greater PA. The PASE and its derivative, PASIPD, assess the type of activity across occupational, household and leisure pursuits, and uses the frequency, duration and intensity level of each

Table 1
Study demographics.

Authors	Country	Study design	Joint replaced	Cohort demographics	Pre-operative data collection	Post operative follow-up	Physical activity measurement device	Device placement	Data collection period
Brandes 2011 [31]	Denmark	Prospective observational	Knee	$n = 53$ Female = 34 Baseline age: 65.8 (5.8) years Baseline BMI: 30.7 (4.1) kg/m^2	3 weeks	6 months 12 months	1. Multi sensor Accelerometer: 3 × uniaxial (DynaPort ADL Monitor, McRoberts) 2. Accelerometer: bi-axial (Step Activity Monitor, OrthoCare Innovations)	1. Bilateral thigh and waist 2. Ankle	7 days (average 12 hours/daily)
Fujita 2013 [27]	Japan	Prospective comparative	Hip	$n = 38$ Females = 38 Baseline age: 60.9 (9.1) years Baseline BMI: 23 (3.6) kg/m^2	1 month	6 months 12 months	Accelerometer: uniaxial (Lifecorder EX, Suzuken, Nagoya, Japan)	Hip	7 days (average: 14 hours/daily)
de Groot 2008 [34]	Netherlands	Prospective observational	Hip Knee	THA $n = 36$ Female = 23 Baseline age: 61.5 (12.8) years Baseline BMI: 26.6 (4.2) kg/m^2 TKA $n = 44$ Female = 24 Baseline age: 62.1 (9.7) years Baseline BMI: 32.1 (5.3) kg/m^2	3 months	6 months	1. Multi sensor Accelerometers: 4 × uniaxial (Temec Instruments, Kerkrade, the Netherlands) 2. Physical Activity Scale for Individuals with Physical Disabilities (PASIPD)	Bilateral lateral aspect of the thigh, 2 × placement on sternum	2 days
Harding 2014 [33]	Australia	Prospective observational	Hip Knee	THA $n = 19$ Female = 10 Baseline age: 69.4 (8.9) years Baseline BMI: 30.5 (5.0) kg/m^2 TKA $n = 25$ Female = 17 Baseline age: 68.6 (8.2) Baseline BMI: 32.2 (5.9) kg/m^2	58 days (2 to 227)	6 months	1. Accelerometer: uni-axial (ActiGraph, LLC, FL, USA) 2. University of California, Los Angeles Activity Scale (UCLA)	Close as possible to the centre of mass	7 days (average: 14 hours/daily)
Kuhn 2013 [30]	USA	Prospective observational	Hip	$n = 37$ Females = 25 Baseline age: 42.1 (7.2) years Baseline BMI: 29 (5.6) kg/m^2	3.6 to 2.4 months	12 months	1. Accelerometer: bi-axial (StepWatch Activity Monitor 3.0, SAM; Cyma Corp., WI USA) 2. University of California, Los Angeles Activity Scale (UCLA)	Ankle	4 days (minimum 10 hours/day)

Table 1 (*Continued*)

Authors	Country	Study design	Joint replaced	Cohort demographics	Pre-operative data collection	Post operative follow-up	Physical activity measurement device	Device placement	Data collection period
Lin 2013 [29]	China	Prospective observational	Hip	$n = 12$ Female = 12 Baseline age: 58.2 (3.7) years Baseline BMI: 23.4 (4.1) kg/m^2	1 month	6 months	Accelerometer: tri-axial (RT3, Stay Healthy Inc, CA, USA)	Waist	7 days (average 8 hours/daily)
Lützner 2014 [25]	Germany	Prospective comparative	Knee	$n = 97$ Females = 45 Baseline age: 68.9 (8.5) years Baseline BMI: 31.3 (5) kg/m^2	1 week	12 months	Accelerometer (ActivPal, Pal Technologies, Glasgow, UK)	Anterior lateral tibia	4 days (minimum of 10/daily)
Smith 2017 [35]	USA (OAI dataset)	Prospective cohort	Hip Knee	THA $n = 105$ Females = 60 Baseline age: 62.2 (9.3) years Baseline BMI: 28.8 (4.2) kg/m^2 TKA $n = 116$ Females = 68 Baseline age: 67.3 (8.3) years Baseline BMI: 30.1 (4.9) kg/m^2	Not detailed	12 months	Physical Activity Scale for the Elderly (PASE)	NA	Recall over past 7 days
Tsonga 2011 [32]	Greece	Prospective observational	Knee	$n = 52$ Females = 52 Baseline age: 72.6 (5.9) years Baseline BMI: 29.8 (5.3) kg/m^2	1 week	6 months	Physical Activity Scale for the Elderly (PASE)	NA	Recall over past 7 days
Vissers 2011 [26]	Netherlands	Prospective comparative	Hip	$n = 30$ Females = 19 Baseline age: 60.3 (13) years Baseline BMI: 26.4 (3.4) kg/m^2	6 weeks	6 months	Mutli-sensor Accelerometer: 4 × uniaxial (Temec Instruments, Kerkrade, Netherlands)	Bilateral lateral aspect of the thigh, 2 × placement on sternum	1 to 3 days (average: 15.4 hours)
Walker 2002 [28]	England	Prospective comparative	Knee	$n = 19$ Female = 10 Baseline age = 69 (9.3) years Baseline BMI: NR)	1 month	6 months	Accelerometer: bi-axial (Numact activity monitor)	NR	1 day

OAI—osteoarthritis initiative; BMI—body mass index; TKA—total knee arthroplasty; THA—total hip arthroplasty.

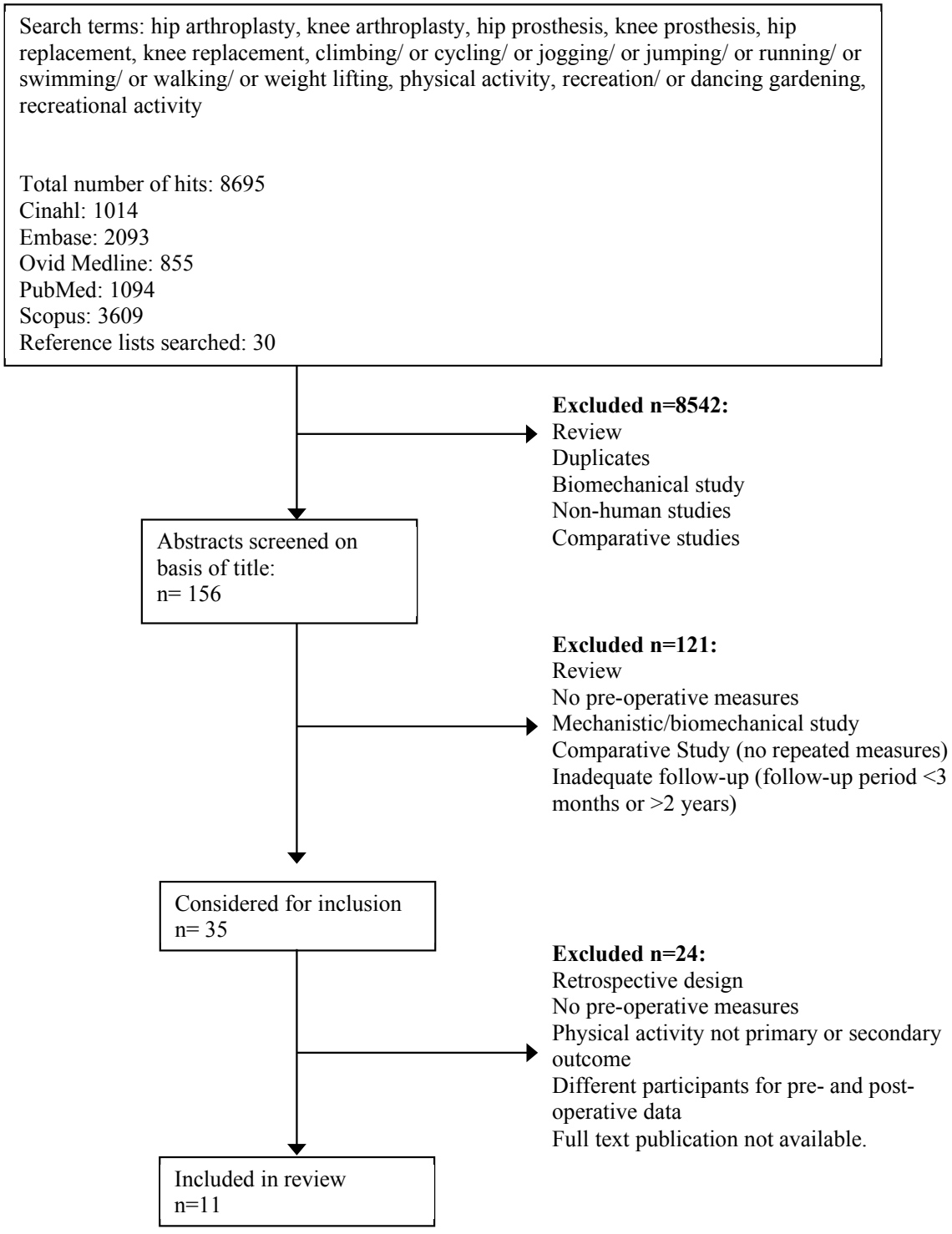

Fig. 1. Flow chart of search strategy.

activity over the previous week to assign a score [36,37]. Total PASE scores range of 0 to 793, and are computed by multiplying the amount of time spent in each activity by pre determined weights and summing over all activities [37]. Similarly, the PASIPD is scored by multiply the average hours per day for each item by a pre determined MET value for that item and summing over all activities for a total out of 199.5 MET hour/day [36]. The UCLA is scored out of 10 and while there is a frequency component to each score, scores are based on participation in the highest rated type of activity regardless of the intensity or duration of participation [38].

Length of time activity was measured

The shortest total period of data collection within a study was 15 hours [26]. Studies requiring participants to wear devices across multiple days asked participants to remove accelerometers during showering, bathing or swimming. Therefore, total data collection time per day ranged from 10 to 14 hours. One study [34] required participants to wear their device for 2 days, two studies required participants to wear devices for 4 days [25,30] and four studies asked participants to wear devices for 7 consecutive days (Table 1) [27,29,31,33].

For the PROs, all 3 scales ask participants to consider the past 7 days.

Changes in physical activity

Patient reported outcomes

Three studies reported changes in PA using patient reported outcomes. Two studies present a single number to represent change in type, frequency and duration of PA in individuals 6-months post-TKA and THA [34] and in a cohort who were 6-months post-TKA [32]. Both studies indicated moderate-to-large increases compared with pre surgery scores. Smith *et al.* [35] also presented a single PASE value for cohorts that were 12-months post-TKA and THA and indicated no overall change (supplementary data B). However, the authors also itemized the scale, such that changes in PA frequency, duration and type could be included here (reported below).

Frequency

Steps, strides and gait cycles per minute or day were the most prevalent outcome measure used to quantify the frequency of PA in both TKA and THA cohorts [25–27,30,31]. The only other outcome used to quantify the frequency of PA was activity "counts". A "count" is a unit-less output generated from technical specifications unique to each accelerometer brand [39].

Meta-analysis of steps per day was possible for individuals 12-months post surgery. Individuals 12-months post-TKA exhibited a small increase in steps per day (SMD 0.44 [0.2, 0.67] $I^2 = 0\%$) [25,31] and individuals 12-months post-THA exhibited a moderate increase (SMD 0.65 [0.32, 0.97] $I^2 = 0\%$) [27,30] (Fig. 2). Patient reported data indicated what while the frequency of walking episodes in the past 7 days significantly increased 12-months post-TKA ($P < 0.001$), there was no change for people post-THA ($P = 0.379$) [35].

No data could be pooled for PA frequency on 6-months. From non-pooled data, two studies displaying markedly different study cohorts and using different accelerometer designs, reported an increase in step frequency at 6-months post-THA [26,27]. Despite reporting this increase in step frequency, Fujita *et al.* [27] simultaneously reported no change in the number of walking periods. Two other studies reported no increase in the number of steps post-TKA (503 gait cycles/day [−362.79, 1368.79] SMD 0.24) [31] and no changes in activity counts post-TKA or THA (supplementary data B) [33]. In addition to using a different metric, the latter study [33] recruited a population that had notably higher BMI than studies reporting increases in PA frequency (Table 1).

Duration

The duration of PA was quantified as either a proportion or rate of time throughout the data collection period. Despite demonstrating no change in PA duration 6-months post-TKA, pooled data of the proportion of time spent active [33,34] and the proportion of time spent in locomotion [31,34] exhibited moderate to substantial variability (SMD 0.05 [−0.42, 0.52] $I^2 = 46\%$ and SMD 0.5 [−0.17, 1.16] $I^2 = 75\%$ respectively) (Fig. 2). Participants of the studies included in both meta-analyses were similar on the basis of age, BMI and sex-ratio. Harding *et al.* [33] and de Groot *et al.* [34] differed in the accelerometer design, placement and data collection period. In contrast, the only notable difference between de Groot *et al.* [34] and Brandes *et al.* [31] was the data collection period (Table 1).

At 12-months post-TKA, results could not be pooled and were contradictory. While Brandes *et al.* [31] reported a moderate increase in proportion of time spent in locomotion (3.6% [1.55, 5.65] SMD 0.85), Lützner *et al.* [25] found no change in time spent walking per day (0.1 hour/day [−0.2, 0.4] SMD 0.09) (supplementary data B). Accelerometer design, placement and data collection period were notable difference between these studies as they exhibited similar cohort demographic profiles (Table 1). Patient reported data supported findings by Lützner *et al.* [25] with no reported change in walking hours per day 12-months post-TKA ($P = 0.931$) [35].

Duration of PA in individuals post-THA has only been investigated at 6-months post surgery, but findings between studies appears consistent. Pooled data from four studies [26,29,33,34] revealed no change in time spent active (SMD 0.03 [−0.31, 0.25] $I^2 = 0\%$). Similarly, pooled data from two studies [26,34] found no different in time spent walking (SMD 0.03 [−0.34, 0.4] $I^2 = 7\%$) (Fig. 2). While all of these studies differed with respect to their data collection period, one study [33] included a smaller number of participants, who exhibited higher BMI than the studies included in this meta-analysis. This study also used a single uniaxial accelerometer rather than tri-axial or multi sensors (Table 1). Sensitivity analysis, removing this latter study, demonstrated wider confidence intervals but no effect on the overall point estimate of effect. These objective results differ to patient reported data collected at 12-months post THA, where a significant increase in the duration of walking periods was reported ($P = 0.001$) [35].

Intensity

For individuals with TKA, intensity of PA was quantified using a gait-based proxy, namely the proportion of time moving at a particular stride frequency [25,30,31,33]. For individuals with THA, either the gait-based proxy or

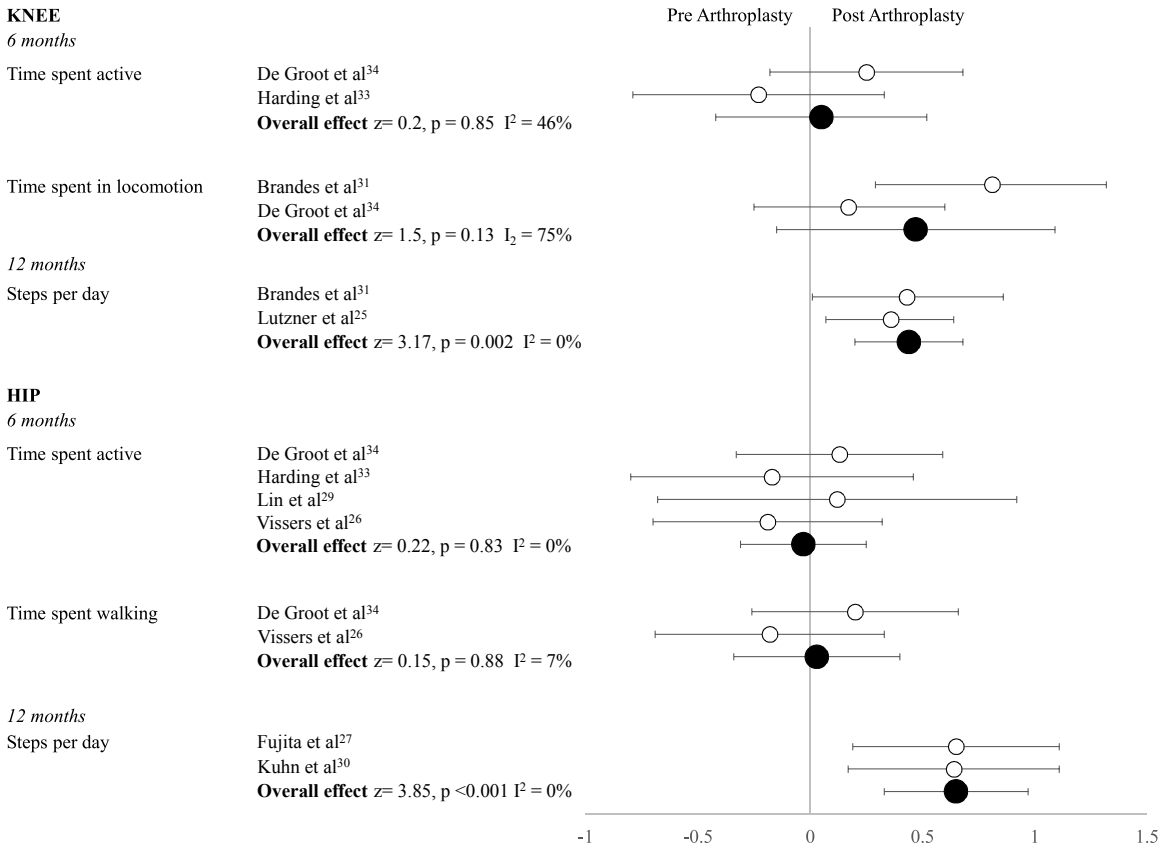

Fig. 2. Forest plot of pooled outcome measures for individuals who underwent TKA and THA. Filled circles indicate data from individual studies. Open circles indicate pooled data. Data is displayed as standardised mean difference (mean difference divided by pooled standard deviation).

metabolic equivalents tasks (METS) were used [27,29]. No data pooling was possible for either TKA or THA cohorts at 6- or 12-months.

Data from individuals 6-months post-TKA showed that while there was a decrease in low intensity gait cycles (−2.9 cycles/minute [−5.26, 0.54] SMD 0.36) [31], there was no change in higher gait intensity or time spent being moderately active (supplementary data B) [31,33]. At 12-months post-TKA, the small reduction in low intensity gait cycles was accompanied by a moderate increase in moderate intensity gait cycles (2.1 cycles/minute [0.68, 3.52] SMD 0.61) and small increase in very high intensity cycles (0.7 cycle/minute [0.05, 1.35] SMD 0.32) [31].

Two studies, that only included females in their cohort, reported moderate-to-large increases in moderate intensity activity at both 6- [27,29] and 12-months [27] post-THA when presented as METS or MET hour/day (supplementary data B). Further, the energy cost of moderate/high intensity PA increased by a large amount 6-months post surgery (0.3 METS hour/day [0.2, 0.4] SMD 1.48) [29]. However, when intensity of PA was examined as a function of gait cycle frequency in a mixed gender sample, with higher BMI, no change was found at 6-months post-THA [33], and only small increases were observed at 12-months [30]. At 12-months, patient reported outcomes revealed increases in light (THA $P = 0.018$, TKA $P = 0.002$), moderate (THA $P = 0.018$, TKA $P = 0.002$) and strenuous PA episodes (THA $P = 0.018$, TKA $P = 0.002$), but no change in the duration of these episodes [35].

Type

The only outcome measure that exclusively captured changes in the type of PA post-TJA was the UCLA questionnaire. This was reported by one study examining changes in individuals 6-months post-TKA and THA [33], which found no change in PA type. A further study examined changes in individuals 12-months post-THA [30] and reported that individuals self-reported undertaking higher impact or more demanding types of PA (1.2 points [0.32, 2.08] SMD 0.61) (supplementary data B). This is supported by itemised PASE scores, which revealed that individuals who had undergone either THA or TKA reported increases in the frequency of muscle strength and endurance PA episodes (THA $P = 0.036$, TKA $P = 0.003$) and significant increases in the duration of these episodes ($P = 0.01$, 0.037 respectively) [35].

Discussion

The findings of this review highlight the inconsistencies when measuring the levels of PA in people who have undergone TKA or THA compared with their pre surgery levels.

Based on the available literature, it appears that individuals who undergo TKA require 12-months to make notable changes in their PA. At 12-months, increases in PA were confined to frequency and intensity of PA, while the duration and type of PA appears to remain unchanged. In contrast, improvements were evident in the frequency and intensity of PA in individuals 6-months post-THA. These improvements were retained at 12-months and there was also a self-reported change in type of PA for both surgeries to more demanding tasks focusing on muscle strength and endurance exercises.

It is evident from this review that sample characteristics influence changes in PA post arthroplasty. Studies that only included females, and those with samples whose BMI was $<30\,kg/m^2$ reported increases in PA more often than those with mixed gender and high BMI. However, these differences do not explain all difference in results. The metric used profoundly influences whether PA appears to increase or not. For example, drawing from the same sample, Fujita *et al.* [27] reported an increase in step frequency but no change in the number of walking periods. The former implies an improvement in PA frequency while the latter indicates no change. Similarly, Brandes *et al.* [31] utilised a proportion of time and Lützner *et al.* [25] utilised a rate of time to quantify duration of PA. The resulting findings were contradictory. Different accelerometer design and data collection period could also explain the heterogeneity found in meta-analysis, and subsequently needs to be considered in future studies.

Results from a prior study [40] demonstrated clear disparity between concurrent measurement of patient-reported and objectively measured activity. However, when patient-reported outcomes were itemised, there was agreement with objective outcomes. The meta-analysis from the current review and the patient-reported findings of Smith *et al.* [35] indicate an increase in PA frequency, specifically walking, 12-months post-TKA. Similarly, no changes in the duration of walking per day has been reported objectively [25] and via patient reported outcomes [35]. As such, it could be concluded that patient-reported and objective outcomes are comparable, when they are measuring the same construct. While accelerometers can provide estimates of activity duration, frequency and intensity, they are limited to ambulatory activity. This negates activities such as muscle strength and endurance, swimming, cycling, which may be important to people with arthroplasty [41] and have been found to significantly increase post arthroplasty [35]. Due to this, it is likely that objective measures underestimate PA for post arthroplasty cohorts. It is also likely that over-estimation of PA is prevalent in patient-reported outcomes [40]. The actual PA levels post arthroplasty is likely a confluence of objected and reported outcomes. As such, both appear to be required when establishing PA levels post arthroplasty.

Even when measuring PA using accelerometers, significant discrepancies exist with how different brands calculate PA [42]. This is due to the specific design features of each device, including the number of transducers, placement on the body, data acquisition of acceleration signals and unique algorithms utilised to convert signals into usable outputs. Most current accelerometers lack the sensitivity to partition non-physiological noise from slow movements and subsequently apply aggressive filtering that cancels these movements out [43]. This loss of sensitivity appears to be worse when accelerometers are worn on the waist or hip [43], as done by four of the seven studies reviewed here that used accelerometers. Device placement also appears to have a larger impact on vector magnitude (accelerations) than measurements of steps [44], possibly because brand-specific algorithms convert signal to activity "counts" in different ways [42]. These issues may further explain why PA frequency differed between outcome measures that quantified PA frequency as steps per day [26,27,31] and activity counts per minute [33] or number of walking periods [26]. It may also explain the discrepancies in PA intensity between studies that used gait-based proxies [27,30] and METS or proportion of time [29,33]. A recent Delphi consensus recommends that MET-min/week become the standard measure when examining PA in people with OA [17]. We suggest that the same metric be adopted to measure individuals post arthroplasty for consistency. The results of this review also indicate that care must be taken when selecting the device and its placement when designing a study or monitoring patients, as these appear to interact and ultimately influence how PA is interpreted.

Regardless of the tool used, the activity levels reported or observed at both 6- and 12-months fall short of the recommended guidelines for activity [45]. We contend then that whilst arthroplasty has the potential to improve the health profile of the individual via exercise-induced improvements in metabolic and physiological performances, this is not likely to be realised for the majority. Questions then arise as to why this is the case. A potential reason for arthroplasty recipients attaining sub-optimal levels of PA is the presence of significant complications, like joint instability or co-morbidities. Co-morbidities, such as cardiovascular disease, contra-lateral joint pain or back pain are common amongst arthroplasty recipients [46]. These, as well as complications, were under-reported and not controlled for by the majority of studies in this review [28–32]. Further, problematic pain can persist for approximately 10% of THA and 20% of TKA patients [47]. This is despite consistent reports of improvement in overall quality of life [27,31–33,48]. This may culminate in many individuals reporting lower satisfaction with their functional ability post surgery and many expressing the desire to not engage in PA [49]. As such, the lack of increase in PA post surgery, the slower increase in PA levels in individuals who undergo TKA as opposed to THA, and the lack of correlation between quality of life measures and PA [27,31] may be a consequence of ongoing physical impairment and functional limitation.

Key messages

- This review is the first to comprehensively review how different domains of physical activity change post lower limb arthroplasty using both accelerometery and patient reported data.
- This review highlights the need for increasing consistency in reporting PA outcomes and the importance of accounting for type of PA undertaken.
- Individuals may require up to 12-months post-TKA to change PA whereas change is evident 6-months post-THA.
- Patient reported data indicates individuals are increasing non-ambulatory (e.g. strength-based) PA post arthroplasty more than they increase gait-based activity.

The meta-analyses here combine data across studies in order to improve the precision of point estimates of effect. However, given the differences in study design and quantification of PA, few analyses were possible. Further, there was marked heterogeneity in samples, specifically in individuals who underwent TKA, serving as another indication that the patient populations and outcome definitions are not the same across studies, even when reported using the similar metrics. This hampers the synthesis and subsequent interpretation of the included studies. By dividing PA metrics into widely used domains – frequency, duration, intensity and type – this review assists interpretation and provides clinicians with useful information as to *how* PA may increase post surgery. However, our review also illuminates the increasing need for consensus on how PA is measured and reported in orthopaedic patient populations.

Conclusion

An increase in PA following TKA or THA is theoretically desirable as greater PA may address the many health problems evident in people who have undergone arthroplasty. However, accurate capture of changes in PA remains elusive. Current evidence, objectively obtained, suggest that PA does not increase substantially after either surgery, but the tools used to quantify PA systematically fail to capture all forms of activity. Thus, the true extent and nature of PA changes post surgery remain unclear.

Conflict of interest: None declared.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.physio.2018.04.003.

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