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Light intensity physical activity increases and sedentary behavior decreases following total knee arthroplasty in patients with osteoarthritis

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Abstract

Purpose To describe objectively measured changes in the volume and pattern of physical activity and sedentary behavior in patients undergoing total knee arthroplasty for osteoarthritis.

Methods Physical activity and sedentary behavior were measured in patients (13 males, 76 females) with a mean age of 64 years (range 55–80) and end-stage osteoarthritis of the knee, using an accelerometer (ActiGraph GT3X+) for seven consecutive days (24 h/day) prior to, 6 weeks and 6 months after total knee arthroplasty. Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), University of California Los Angeles (UCLA) Activity index and range of motion (ROM) were also assessed.

Results Proportion of time spent in sedentary behavior decreased from baseline to 6 months (mean 70.1 vs. 64.0%; $p = 0.009$) and the interruptions to sedentary behavior improved between baseline and 6 months after total knee arthroplasty (mean 85.0–93.0 breaks/day, $p = 0.014$). Proportion of time spent in light physical activity increased from baseline to 6 months after total knee arthroplasty (29.0 vs. 34.8%; $p = 0.008$). There was no change in time spent in moderate to vigorous physical activity after total knee arthroplasty. WOMAC (median 71.0 vs. 4.0, $p < 0.001$), UCLA (median 2.0 vs. 5.0, $p < 0.001$) as well as ROM [median (0.0°–90.0°) vs. (0.0°–110°), $p < 0.05$] scores improved between baseline and 6 months after total knee arthroplasty.

Conclusion Clinically, functional improvements in patients following total knee arthroplasty may be assessed by objectively measuring changes in low intensity activity behaviors. The use of accelerometers in this study gives new insights into activity accumulation patterns in a clinical population and highlights their use in determining a behavioral response to an intervention.

Level of evidence II.

Keywords Physical activity · Sedentary behavior · Accelerometry · Knee osteoarthritis · Total knee arthroplasty

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Introduction

Knee osteoarthritis (OA) is associated with decreased physical functional ability, poor quality of life, decreased physical activity and increased time spent in sedentary behavior [13, 23, 40]. Based on self-report data and a few studies which have objectively measured activity behaviors, the majority of patients with knee OA are physically inactive [19, 40], that is, they do not accumulate enough moderate and vigorous physical activity (MVPA) to meet the current physical activity guidelines of at least 150 min of MVPA per week [32].

The most definitive and cost-effective treatment for advanced knee OA is total knee arthroplasty (TKA) [33]. The primary aim of TKA is to treat pain and improve functional ability and health-related quality of life [20]. Despite substantial improvements in the patient-reported outcome measures (PROMs) for pain, physical activity, functional performance and quality of life following TKA, some studies report improvements in physical activity and/or sedentary behavior [7, 24, 39], while others show no improvements [15, 18, 38]. A recent systematic review concluded that no change in objectively measured physical activity occurs 6 months after TKA [17].

The apparent contradiction in improvements between objectively measured activity behaviors and PROMs suggest that despite patients reporting improvements in function, surgery may not be effective for improving the total volume of physical activity in patients with end-stage knee OA. Nonetheless, there may be subtleties in the way objective measures of physical activity and sedentary behavior change after TKA that have not been previously described. For example, in addition to low physical activity levels in knee OA patients, the related and yet discrete importance of prolonged periods of inactivity and absence of whole body movement in people with knee OA is becoming increasingly recognized [41]. A few studies have assessed sedentary behavior with physical activity in patients undergoing TKA [15, 18, 24, 38, 41] but none have considered and described the detailed daily patterns of accumulation of both physical activity and sedentary behavior following TKA. An understanding of these patterns may be useful to inform clinicians (1) as to whether the data obtained objectively can provide insight into behavioral responses to TKA, (2) as to whether objective data are useful in their ability to determine the effect of interventions such as TKA and (3) for the development of targeted interventions for improving physical activity and decreasing time spent sedentary postoperatively. With technology, such as accelerometry, that is now available to measure detailed outcomes of the whole spectrum of daily activity behaviors (from sedentary to light to vigorous intensities), studies that harness the detail of these activity behavior data are needed to determine if, when and how patients may change their activity behaviors after undergoing TKA. In the current study, it was hypothesized that overall volume of activity behaviors would not change following TKA; however, the patterns of accumulation of those activity behaviors would change. The primary objective of this study was to describe changes in both the volume and patterns of activity behaviors (PA and SB) using accelerometry in patients undergoing TKA. A secondary objective was to assess changes in PROMs following TKA.

Materials and methods

Patients with advanced knee OA, scheduled for primary TKA at a tertiary hospital in South Africa took part in this study. The patients were recruited and followed up from August 2015 to April 2017. Inclusion criteria for the study were patients who: (1) were between the ages of 55 and 80 years, (2) met the 1986 American Rheumatology Association (ACR) criteria for knee OA [1], (3) had Kellgren and Lawrence grade 3 or 4 radiographic changes [22], (4) were refractory to conservative medical therapy for at least 6 months, (5) were undergoing primary unilateral TKA surgery and (6) were ambulant with or without assistive devices.

Exclusion criteria were: (1) patients having any other form of chronic arthritis [e.g., rheumatoid arthritis (RA)], (2) significant symptomatic chronic OA of the contralateral knee and/or hip, and (3) having co-morbidities or medical conditions that affect PA such as congestive heart failure, neurological problems (such as stroke) and chronic obstructive pulmonary disease (COPD) as determined using a general health questionnaire (GHQ) [29].

The Human Research Ethics Committee of the University of the Witwatersrand approved the study (clearance number: M150323). Written informed consent was obtained from all patients. The study has also been registered on the ClinicalTrials.gov database (Trial reg. no: NCT02675062-4 February 2016).

Study design

This study was a longitudinal observational design and the details of the study protocol have been previously published [29]. Baseline assessments were done 2 weeks prior to TKA, with patients being off prescription pain medication for at least a week. All patients were implanted with cemented posterior stabilized knee prosthesis (Genesis II, Smith and Nephew, Durban, South Africa). Patients underwent standard physiotherapy care after the surgery. Postoperatively, patients were followed up at 6 weeks and 6 months. Briefly, the data that were collected included patient demographics and anthropometrics, self-reported physical function and health-related quality of life, range of motion (ROM) and PA and SB. The assessment time points corresponded to the required appointments for patients to consult with their surgeons.

Patient-reported outcome measures

A general health questionnaire (GHQ) was used to determine the eligibility for the study by obtaining information on health history, history of knee OA, history of medication and smoking, previous or scheduled surgery other than TKA and present or absence of any co-morbidities (not limited to hypertension, diabetes mellitus, high cholesterol, chronic obstructive pulmonary disorders, heart disease and stroke). The socioeconomic status (SES) was determined using a household amenity and education questionnaire (HAQ) [6].

The University of California, Los Angeles (UCLA) activity index was used to assess the self-reported activity level of patients [18].

The Western Ontario and McMaster Universities Osteoarthritis (WOMAC) index was used to assess pain, stiffness and physical function in patients at each timepoint [4].

Anthropometric and range of motion (ROM) measurements

Height was measured to the nearest meter with the patients shoeless using a stadiometer (Seca, model 202, Germany). Weight was measured to the nearest 0.1 kilograms using a scale (Mettler, Model TE120 ME36400, Switzerland) with the patients shoeless and wearing light clothing. Active flexion and extension ROMs of the affected knee were measured using a plastic goniometer.

Objective measurement of physical activity and sedentary behavior

Physical activity and sedentary behavior were objectively measured using a continuous wear (24 h/day) protocol over a 7-day period with the Actigraph GT3X + accelerometer (Actigraph, LLC, Fort Walton Beach, FL, USA). The GT3X + was programmed to record raw data at a frequency of 30 Hz which were later reduced to vertical axis movement counts per 60 s epoch for the purpose of the current analyses. The ActiGraph was attached to an elastic belt, which the patients wore around their waist on the same side of the affected knee. Patients wore the accelerometer for seven consecutive days and the ActiGraph was collected at the next possible visit to the hospital or arrangements were made for collection from patients at a location most convenient to them. The patients were instructed to remove the ActiGraph when showering, bathing or swimming.

The data were downloaded and reduced using a custom built SAS program (v 9.3, SAS Institute, Cary, NC, USA). Sleep periods were either calculated using a validated algorithm [27] or, where distinct sleep times could not be obtained, sleep periods were determined by visual inspection and confirmed from the patient-reported sleep and wake times recorded on the general health questionnaire. Non-wear time was classified as 1 min intervals with consecutive zero counts for a minimum of 90 min (with an allowance of up to 3 min of counts between 0 and 50) [10]. Sleep and non-wear periods were removed from the data, leaving only daily waking wear time. For a day to be classified as valid, a minimum wear time of 10 h (600 min) was required. Only patients with four or more valid days of wear time were included for data analyses. Common cut points were used to classify each minute as sedentary (< 100 counts per minute, cpm) [25], light intensity (100–1951 cpm), moderate intensity (1952–5724 cpm), or vigorous intensity (> 5724 cpm) [14]. Total volumes of activity in the different intensities (sedentary, light and moderate vigorous) as well as patterns of activity (i.e., bouts of time spent in each activity intensity) were the variables that were extracted from the waking wear data.

Statistical analysis

The data were analyzed using SPSS (version 24, SPSS Inc., Chicago, IL, USA). All patients with at least four valid days of ActiGraph data at baseline and/or 6 weeks and 6 months after TKA were included in the analysis. However, patient characteristics (anthropometric, general health and socio-economic data) were reported for all those recruited into the study using descriptive statistics (mean and standard deviation or median and interquartile range or percentages). The amounts of time spent in SB, light physical activity (LPA) and MVPA at baseline and at 6 weeks and 6 months after TKA were presented descriptively (using means and 95% confidence intervals or median and interquartile range). SB and LPA data (which were normally distributed, assessed by Shapiro–Wilks test) between baseline and 6 weeks and 6 months after TKA were compared using a linear mixed model, whereas a generalized linear model was used for MVPA time and the percentages of awake wear times spent in each of the activity behaviors (not normally distributed). Fixed effect used in the models was time and the random effect was subjects. The variance–covariance structures were selected based on Bayes Information Criterion and the unstructured variance–covariance was used. Patients' age, BMI and awake wear times were included in the models as known covariates. Accumulation of activity across categories of intensity and bout duration was also described using exposure variation analysis (EVA) [34]. The hourly variations of the sedentary to light activity ratios were analyzed using a generalized linear model with hour of the day and assessment time points as factors.

Scores for UCLA and WOMAC (calculated by the scoring system) were reported descriptively (with median and interquartile range). Questionnaire scores between baseline, 6 weeks and 6 months after TKA were compared using a generalized linear model. A p value of less than 0.05 was considered significant. An a priori sample size calculation indicated that a minimum sample size of 107, including a 20% drop out rate to follow-up, was required to achieve 2% reduction in sedentary time with a power of 80% [29].

Results

A total of 89 (76 female; 13 male) patients with mean (SD) age of 64.8 (8.7) years ranging from 55 to 80 years and BMI of 34.0 (7.7) kg/m^2 were recruited into the study. Figure 1 is a flow chart showing the total number of patients recruited into the study at baseline and the drop outs to follow-up. Only 73 patients underwent the TKA surgery, while the remaining 15 patients had their surgeries suspended on account of unsatisfactory clinical reports ($n = 14$) and one patient declined to undergo the surgery due to family issues. A further 16 patients were lost to follow-up: six dropped out at 6 weeks post-TKA (three travelled out of Johannesburg, two could not be reached and one opted to continue treatment at a private clinic); and ten dropped out at 6 month post-TKA (four travelled out of Johannesburg, three declined to continue the study, two lost their monitors and one had a faulty monitor).

Table 1 shows the patients characteristics for those who (1) underwent TKA surgery; (2) completed the study 6 months after TKA and (3) had valid or insufficient ActiGraph GT3X + activity data at 6 months after TKA.

Patient and physician-reported outcomes before and after TKA

Self-reported PA was significantly higher at 6 weeks ($p < 0.001$) and 6 months ($p < 0.001$) after TKA compared to baseline (Table 2). Patients reported no pain and stiffness 6 months after TKA compared to baseline ($p < 0.001$).

Both the flexion and extension ranges of motion (ROM) improved significantly 6 months after TKA ($p < 0.001$ and $p = 0.028$, respectively).

Changes in volume of activity behaviors pre and postoperatively

Table 3 shows the comparisons of total volume and patterns of PA and SB of patients before and after TKA. The number of valid days of ActiGraph wear, total awake wear time per day and total activity counts per day and per minute for all awake wear time was not different between baseline and 6 weeks and 6 months after TKA.

The percentage of awake wear time spent in SB ($p = 0.009$) as well as the overall daily sedentary time ($p = 0.03$) decreased significantly from baseline to 6 months after TKA. The total number of breaks from SB significantly increased at 6 months after TKA compared to 6 weeks after TKA ($p < 0.001$) and baseline ($p = 0.022$). The duration of breaks from SB was lower

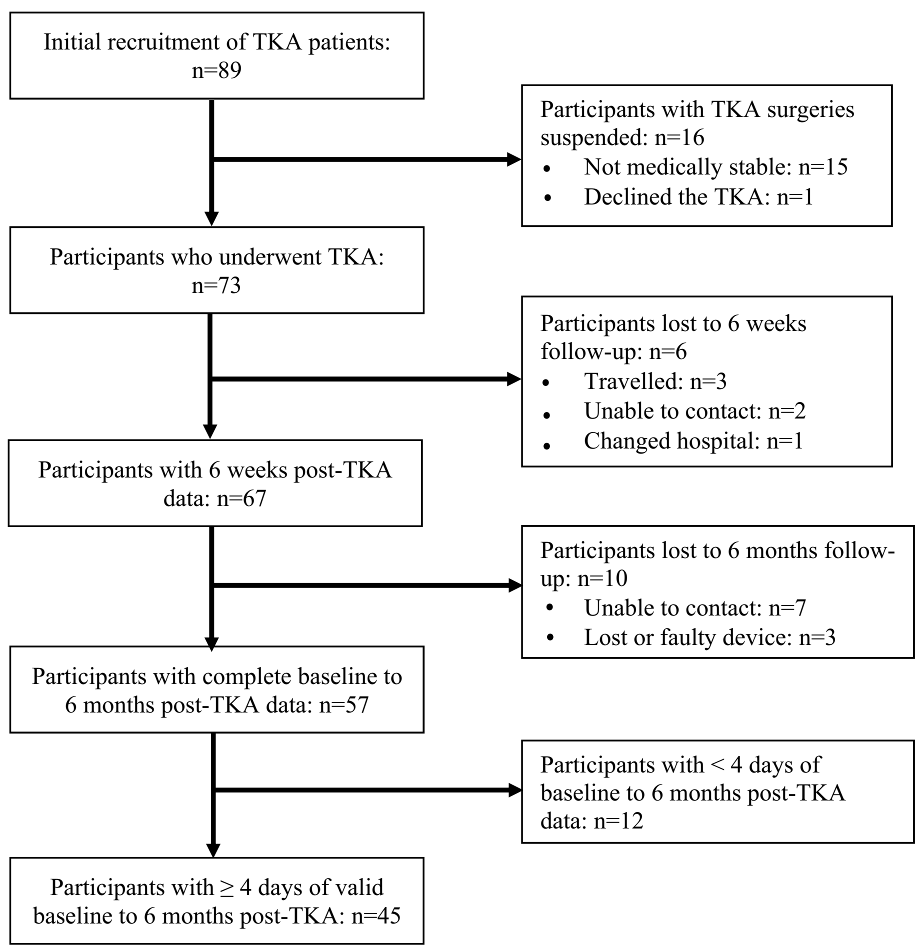

Fig. 1 Flow chart illustrating patient recruitment from baseline to 6 month follow-up

Table 1 Characteristics of patients who underwent TKA, those who completed the follow-up and those who completed the follow-up with and without valid ActiGraph data

	Patients who underwent TKA ($n=73$)	Patients with complete 6 months follow-up data ($n=57$)	Patients with complete 6 months and valid ActiGraph data ($n=45$)	Patients with complete 6 months and insufficient ActiGraph data ($n=12$)
Age (years)	64.0 (8.7)	64.2 (9.0)	63.8 (8.8)	64.3 (9.4)
Gender, *n* (%)				
Females	67 (92)	53 (93)	42 (93)	12 (100)
Males	6 (8)	4 (7)	3 (7)	0 (0)
Race, *n* (%)				
Black	53 (73)	41 (72)	33 (73)	11 (92)
Caucasian	20 (27)	16 (28)	12 (27)	1 (8)
Weight (kg)	84.8 (20.0)	84.3 (20.8)	84.6 (21.0)	87.3 (17.5)
Height (m)	1.6 (0.1)	1.6 (0.1)	1.6 (0.1)	1.6 (0.1)
Body mass index (kg/m^2)	34.2 (7.5)	34.3 (7.9)	34.6 (7.8)	36.6 (7.6)
LHS, median (IQR), (days)	7.0 (3)	7.0 (3)	7.0 (3)	7.0 (5.0)
Side of TKA, *n* (%)				
Left	30 (41)	24 (42)	19 (42)	6 (50)
Right	43 (59)	33 (58)	26 (58)	6 (50)
Smoking (yes), *n* (%)	6 (8)	4 (7)	3 (7)	3 (7)
Diabetes mellitus (yes), *n* (%)	8 (11)	5 (9)	5 (11)	1 (8)
Hypertension (yes), *n* (%)	37 (51)	28 (49)	22 (49)	6 (50)
Dyslipidaemia (yes), *n* (%)	7 (10)	6 (11)	2 (5)	2 (17)
Educational status, *n* (%)				
Below high school	24 (33)	20 (35)	18 (40)	4 (33)
High school complete	37 (51)	30 (53)	20 (44)	7 (58)
Tertiary level complete	12 (16)	7 (12)	7 (16)	1 (9)
SES score	9.9 (2.8)	10.0 (2.9)	9.9 (3.1)	9.7 (3.1)

Age, weight, height, body mass index and SES score are presented as mean (SD), whereas length of hospital stay is presented as median (interquartile range, IQR). The remaining data are presented as frequencies (%)

LHS length of hospital stay, *SES* socioeconomic status, *TKA* total knee arthroplasty

Table 2 Comparisons of patient and physician-reported outcomes before and after TKA

	Baseline ($n=79$)	6 weeks after TKA ($n=62$)	6 months after TKA ($n=45$)	Main effect *p* value	*p* value*
UCLA score	2.0 (1.0)	3.5 (1.0)	5.0 (1.0)	<0.001	<0.001
WOMAC scores					
Total score	71.0 (27.0)	22.5 (19.0)	4.0 (11.3)	<0.001	<0.001
Pain	15.0 (6.0)	3.0 (5.0)	0.0 (2.0)	<0.001	<0.001
Stiffness	6.0 (2.0)	2.0 (1.0)	0.0 (2.0)	<0.001	<0.001
ADL	51.0 (17.0)	16.5 (17.0)	3.5 (9.0)	<0.001	<0.001
ROM					
Flexion (°)	90.0 (10.0)	95.0 (10.0)	110.0 (15.0)	<0.001	<0.001
Extension (°)	0.0 (6.0)	0.0 (4.0)	0.0 (0.0)	0.01	0.012

Data are presented as median (interquartile range). A higher score for WOMAC pain, stiffness and ADL subscales (maximum scores possible were 20, 8, and 68, respectively) indicates a worse outcome. The highest possible score for UCLA is 10, indicating regular participation in impact sports. Normal ROM is 0°–140°; however, ROM of 0°–110° (i.e., 0° extension and 110° flexion) after TKA indicates a good result

**p* value calculated between baseline and 6 months after TKA (Bonferroni)

Table 3 Comparisons of volume of activity behaviors before and after total knee arthroplasty

	Baseline ($n=79$)	6 weeks after TKA ($n=62$)	6 months after TKA ($n=45$)	Main effect p value	p value*
Valid days	5.7 (5.5–5.9)	6.0 (5.8–6.3)	6.0 (5.7–6.3)	0.067	n.s
Waking wear time (min/day)	927.0 (903.2–956.7)	901.7 (874.4–929.0)	927.8 (901.7–953.8)	0.126	n.s
Activity counts, all awake wear time (counts/day)	162,018 (133,675–190,361)	132,094 (109,961–154,227)	196,751 (165,206–228,296)	<0.001	n.s
Activity counts, all awake wear time (counts/min)	170 (143–198)	145 (123–168)	209 (177–242)	0.001	n.s
Sedentary behavior (SB)					
Sedentary time, % awake wear[a]	70.1 (67.5–72.7)	72.0 (69.5–74.9)	64.0 (60.6–67.9)	0.001	0.009
Sedentary time (min/day)	649.7 (622.0–677.3)	649.1 (617.1–681.1)	594.0 (555.9–632.0)	0.033	0.030
Breaks from SB (number/day)	85.2 (80.4–90.1)	82.2 (76.8–87.6)	93.0 (88.1–97.9)	<0.001	0.022
Duration of break from SB (min/break)	3.2 (3.0–3.5)	3.0 (2.7–3.3)	3.7 (3.2–4.0)	0.010	n.s
Light physical activity (LPA)					
Light physical activity, % awake wear[a]	29.0 (26.6–31.4)	27.4 (24.7–30.0)	34.8 (31.3–38.3)	0.001	0.008
Light physical activity time (min/day)	272.8 (247.4–298.2)	245.9 (221.0–279.9)	322.8 (289.0–356.6)	<0.001	0.032
Moderate to vigorous physical activity[a]					
Moderate to vigorous PA, % awake wear	0.1 (0.6)	0.1 (0.5)	0.4 (1.1)	0.266	n.s
Moderate to vigorous PA time (min/day)	2.0 (7.8)	1.4 (4.9)	3.4 (11.6)	0.292	n.s
Steps (number/day)	3677 (3083–4270)	2816 (2355–3278)	4941 (4109–5773)	<0.001	0.015
Meeting PA guidelines, n (%)[a]	7 (8.9)	3 (4.8)	8 (17.8)	0.054	n.s

All data (adjusted for age, body mass index and waking wear time) are presented as mean (95% CI) except for moderate-vigorous physical activity, which are presented as median (interquartile range)

*p value between baseline and 6 months after TKA (Bonferroni)

[a]p value calculated using generalized linear model; remaining data compared using linear mixed model

at 6 weeks compared to 6 months after TKA ($p=0.013$) but was not different between baseline and 6 months after TKA.

Patients spent more of their awake wear time in LPA at 6 months after TKA compared to before ($p=0.008$) and 6 weeks after ($p=0.001$) TKA. Daily LPA time increased from baseline to 6 months after TKA by approximately 50.0 (95% CI 3.2–96.7) min/day ($p=0.032$).

The patients spent less than 1% of their awake wear times in MVPA at all time points (Table 3). Approximately 5–18% of the patients met the current PA guidelines at baseline and after TKA. Patient step count was significantly lower at 6 weeks ($p<0.001$) but significantly higher ($p=0.015$) after surgery compared to baseline.

Patterns of accumulation of activity behaviors before and after TKA

Figure 2 shows comparisons of the accumulation of patients' awake wear times spent in sedentary, LPA and MVPA intensities accumulated for different bout lengths between baseline and 6 months after TKA. There were significant reductions in the percent of time spent in prolonged bouts of SB at 6 months after TKA compared to baseline. Bouts of varying durations of light activity also increased significantly between baseline and 6 months after TKA.

Figure 3 depicts the hourly variation of awake wear time not spent in MVPA (i.e., the sedentary to light activity ratios) over the course of the day. Overall patients were less

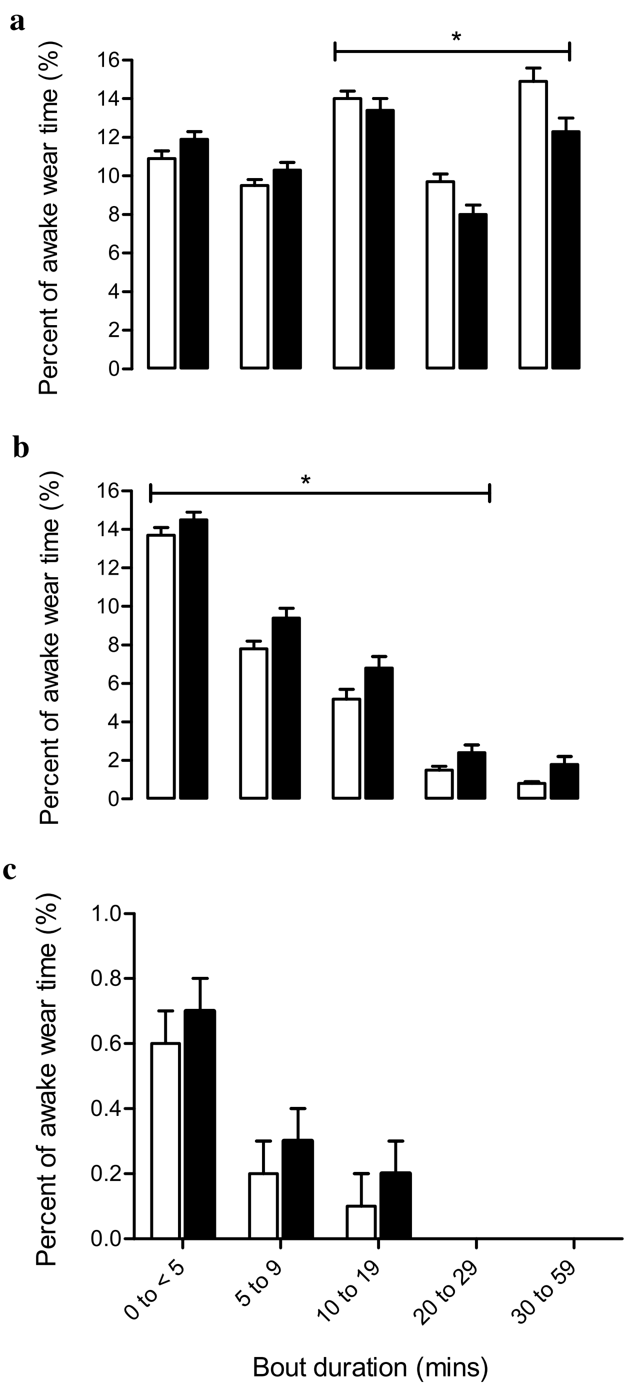

Fig. 2 Percentage of awake wear time spent in **a** sedentary behavior, **b** light physical activity and **c** moderate to vigorous physical activity before (white bars) and 6 months after (black bars) total knee arthroplasty. *$p < 0.05$ for indicated bouts between baseline and 6 months after TKA. Data are presented as mean (SEM)

sedentary in the early hours of the day (6h00–10h00), after which, time spent sedentary gradually increased through the afternoon to late evening (13h00–23h00). The sedentary to light ratio was similar between baseline and 6 weeks after TKA. However, between baseline and 6 months after TKA, there was a significant reduction in sedentariness and an increase in light activity from 09h00 to 19h00 ($p < 0.05$).

Discussion

The most important finding of this study is that overall total daily sedentary time and time spent in light physical activity improved 6 months after TKA with patients showing a reduction in SB of approximately 56 min and an increase in LPA of approximately 50 min per day. The patients also interrupted their sedentary time more frequently after TKA compared to baseline. In conjunction with the changes in objectively measured activity, the patient-reported activity and physical functional levels as well as physician-reported outcome (range of motion) significantly improved from baseline to 6 months after TKA, as was expected.

Although in the current study, the amount of time spent in SB at 6 months after TKA was higher than that of Brandes et al. [7] study (7.0 h/day, 56.5% of awake wear time), and lower than that reported in Harding et al. [18] study (11.6 h/day, 83% of awake wear time), to our knowledge a decrease in sedentary time of this magnitude has not yet been reported in TKA patients following their surgery. With no significant difference being observed in the time our patients spent in MVPA, it is likely that the time spent in prolonged SB decreased at 6 months after TKA, because it was interrupted more frequently with LPA.

Understanding the hourly patterns of SB and LPA provides a useful source of information for physician monitoring and for informing targeted interventions with the ultimate aim of improving overall health and quality of life [9]. The patients in this study accumulated similar volumes of SB and LPA in the early hours of the day (6h00–10h00) before and after TKA. However, there was a noticeable shift in total amounts of sedentary and light activity accumulated over the course of the day following TKA, but particularly at certain times of the day. There was less time spent in SB and more in LPA between 11h00–19h00 at 6 months after TKA compared to baseline. Light PA is associated with purposeful movements accumulated during performances of activities of daily living (ADL) [8]. The improvement in activity behaviors at a time of day when the patients were likely to be engaged in household, social and occupational activities, has implications for quality of life of patients in this study and may offer an explanation as to why such great improvements in activity behaviors were observed following TKA. Patients should be encouraged to engage in more light activity during these times, as the present study has shown that this is a feasible time for targeted interventions. This study supports the notion that targeted interventions may focus on improving activity behaviors of low intensities (SB and

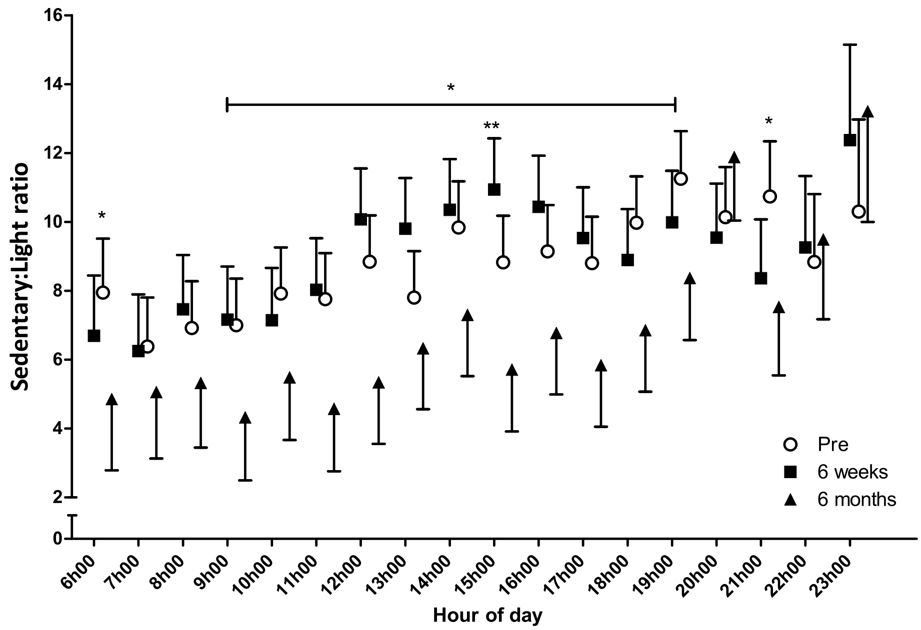

Fig. 3 Average hourly sedentary to light activity ratio between baseline and after TKA. Data are mean (95% CI) sedentary to light ratios per hour of the day for each of the three visits. Data are adjusted for awake wear time. *$p<0.05$ between pre (filled circle) and 6 month post-TKA (filled triangle). **$p<0.01$ between 6 weeks (filled square) and 6 month post-TKA (filled triangle)

LPA), even at 6 months postoperatively, where functional recovery appears to be optimal [2, 11, 36]. Long-term postoperative interventions aimed at offsetting sedentary time with LPA or task-oriented activities performed during ADLs may sustain recovery of functions, quality of life and physical activity in the long term.

The current study is the first to explore activity behaviors in a population living in a low to middle income country (South Africa) and this may also be a reason for the difference between this study and others who have reported no or marginal improvements in activity behaviors following TKA [2, 17]. The present study was conducted in patients of low socioeconomic status (with particularly, low educational background) compared to other studies done in high-income countries. Changes in daily routine and nature of work at home and workplace (due to urbanization and automatism of work and life) may result in a greater time spent being sedentary [16, 21]. Whereas individuals from high-income countries may be able to increase leisure-time PA in case of activity reduction due to work schedules [12], their counterparts in lower income groups (due to poor economic climates) tend to improve PA by performing activities of daily routines related to work, domestic chores and transport [3]. Furthermore, the drive or motivation to change activity behavior in patients with musculoskeletal disorders may vary from one socioeconomic group to the other. Therefore, the inherent motivation to independently perform activities of daily living and return to work postoperatively may have resulted in improved activity behaviors of patients in the present. Herbolsheimer et al. [19] indeed showed that the impact of knee OA on activity behavior patterns varies from one socioeconomic group to the other [19]. In addition, methodological differences across studies may also explain the reason why the findings of the present study are different from the previous studies. The previous studies have either monitored activity of patients in less than 3 days [7, 15, 38, 39] and only a few between 4 and 7 days [18, 24].

The observation of a low accumulation of MVPA is consistent in all of the studies that have assessed PA in patients before and/or after TKA. In our study, less than 1.0% of the daily awake wear time was spent in MVPA at 6 months after TKA and less than a third of the patients met the PA guidelines at baseline and 6 months after TKA. Despite the high rate of success associated with TKA, a lower recovery rate compared to THA, post-surgical pain and quadriceps muscle weakness have all been found to mitigate physical functioning [5, 11, 28, 31]. All of the patients in this study had advanced knee OA prior to surgery and they may have had underlying musculoskeletal damage as a consequence of the knee OA that inhibited more intense movements. Patients were also on average 65 years of age and most older adults do not achieve the recommended PA guidelines even in the absence of a musculoskeletal disorder [35]. However, in this study, the number of steps per day of the patients both at baseline and 6 month post-surgery is consistent with the reported values for healthy 65–69-year adults in the National Health and Nutrition Examination Survey (NHANES) (3302–5269 steps/day) [37]. The patients in this study may, therefore, have already been relatively lightly active and may have been further motivated to increase their activity post-surgery in the lower intensity activities. A longer duration of recovery may allow such patients to adopt a more moderately intensively active lifestyle [15].

There are a few limitations associated with this study. There was high rate of dropout at follow-up, which decreased the total number of patients completing the 6-month follow-up. However, the characteristics of these patients were similar to those included in the analysis. Furthermore, we intended on recruiting 107 patients, but found a significant reduction in SB after preliminary analysis and, therefore, believe that the study was adequately powered. The use of accelerometers comes with the challenge of different algorithms and decision rules for cut points for PA and SB. This makes comparison with other studies limiting; for instance, the ActiGraph GT3X has not been used in patients undergoing TKA in a longitudinal study design before. In addition, waist-worn accelerometers do not always adequately measure activities including upper body activities or upright activity behaviors of low ambulatory components such as cycling [26]. However, in the present study no patient-reported cycling in the UCLA activity index during the activity monitoring periods. Importantly, the same intensity measured by an accelerometer will in reality translate to a different level of cardiorespiratory impact on different people. Thus, it is important to have accelerometer cut point algorithms validated for specific populations (for example, in those with musculoskeletal disorders) [30].

Conclusion

In line with an improvement in patient-reported pain, stiffness and physical function 6 months after total knee arthroplasty, overall objectively measured light physical activity increased and sedentary behavior decreased 6 months after total knee arthroplasty. The way that patients accumulated their activity throughout the day also improved after surgery with patients spending more time in light activity during the active hours of the day. Clinically, functional improvement in patients following total knee arthroplasty may be assessed by objectively measuring changes in low intensity activity behaviors. This comprehensive analysis of detailed daily activity behaviors can be used to inform feasible interventions for increasing the duration of light physical activity bouts and decreasing prolonged sedentary bouts to improve quality of life and overall health following TKA.

Author contributions EF participated in conceptualization of study, development of study design, collecting data, writing of drafts, editing of drafts. JAM participated in conceptualization of study, development of study design, writing of drafts, editing of drafts. DVDJ took part in conceptualization of study, development of study design, editing of drafts. LM took part in conceptualization of study, development of study design, editing of drafts. YSK took part in development of study design, collecting data, editing of drafts. MT took part in conceptualization of study, development of study design, editing of drafts. RMM participated in conceptualization of study, development of study design, writing of drafts, editing of drafts. All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest LM wishes to declare that he has offered consultancy services for Implantcast for the development of a new prosthesis. No money has been paid for these consultancy services. The remaining authors declare that they have no conflict of interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (clearance certificate number M150323) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent An informed consent was obtained from all individuals participants included in the study.

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