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CLINICAL RESEARCH

Patient Activity After TKA Depends on Patient-specific Parameters

Cornelia Lützner Dipl-Päd, Stephan Kirschner Dr med, PD, Jörg Lützner Dr med, PD

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Abstract

Background Most patients expect an improvement of walking ability and an increase in activity levels after TKA. Unfortunately, few studies report qualitative and quantitative activity improvements after TKA.

Questions/purposes The aims of this study were (1) to evaluate quantity and quality of physical activity before and after TKA with an accelerometer, and to compare activity level with that of an age-matched control group without lower-extremity disorders. (2) Improvement in measured steps per day after TKA and the ability to meet physical activity guidelines were evaluated. (3) The influence of patient-specific and implant parameters were assessed.

Patients and Methods An accelerometer was used to measure activity in 97 patients who were assessed before TKA and 1 year after TKA. The measurements included the total number of steps, moderate to vigorous activity defined as at least 100 steps per minute, and time spent lying, sitting/standing, or walking. We then calculated the proportion of patients who met the 10,000 steps per day guideline recommendation and determined factors that predicted failure to meet that goal. Thirty-nine age-matched control subjects without lower-extremity disorders were selected and underwent the same assessments using the accelerometer for comparison with patients 1 year after TKA.

Results Measured steps per day improved from a mean of 5278 (SD, 2999) preoperatively to 6473 (SD, 3654) postoperatively (effect size, 1.23; 95% CI, 1.10–1.35; $p < 0.001$). Moderate to vigorous steps per day improved from a mean of 1150 (SD, 982) to 1935 (SD, 1728; $p < 0.001$). Times spent in lying, sitting, or standing position or during walking did not change after TKA. For all measured parameters, activity of the patients after TKA was considerably less than that of the age-matched control subjects, who walked a mean of 13,375 (SD, 4614) steps per day ($p < 0.001$), performed a mean of 6562 (SD, 3401) vigorous steps per day ($p < 0.001$), and spent a mean of 2.9 hours (SD, 1.1) per day walking ($p < 0.001$). Only 16 patients (16.5%) met physical activity guidelines after TKA. BMI ($p = 0.017$), sex ($p = 0.027$), and comorbidities (American Society of Anesthesiologists Grade, $p = 0.042$) were independent factors associated with steps per day after TKA.

Conclusions One year after TKA, patients had increased walking and moderate to vigorous steps. However, only 16.5% achieved the guideline recommendations for walking activity. BMI, sex, and comorbidities are patient factors

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
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C. Lützner, S. Kirschner, J. Lützner (✉)
Department of Orthopaedic Surgery, University Hospital Carl Gustav Carus, TU Dresden, Fetscherstr. 74, 01307 Dresden, Germany
e-mail: Joerg.Luetzner@uniklinikum-dresden.de

that are associated with activity after TKA. Even with improvements in walking, activity level after TKA remains less than that seen for age-matched control subjects. Surgeons should be aware of this when counseling patients undergoing TKA.

Level of Evidence Level III, therapeutic study. See the Instructions for Authors for a complete description of levels of evidence.

Introduction

Deterioration of physical activity is common in patients with osteoarthritis of the knee. Most patients expect improvement of walking ability and an increase in activity levels after TKA [26, 29, 42]. Fulfillment of these expectations has an effect on patient satisfaction after surgery [42].

Physical activity has a positive effect on prevention of several chronic diseases [11, 55]. National guidelines recommend a certain amount of physical activity to obtain beneficial effects on general health [15, 41, 44, 49, 50]. These are mostly step based, and there is a consistent direction of a total number of 10,000 steps per day with a minimum of 30 minutes per day (or 150–210 minutes per week) of moderate to vigorous physical activity [15, 41, 44, 49, 50]. Moderate to vigorous activity is defined as more than 100 steps per minute [30, 37, 49]. Some studies report on physical activity in patients with osteoarthritis and after TKA [35, 54], but few report on step-based activity measurements before and after TKA [2, 53]. Although self-reporting of activity levels is commonly used (and is a part of many outcomes scoring instruments), self-reported data are subjective, not verifiable, vulnerable to recall bias, and therefore not very reliable [4, 17, 34]. More objective instruments involve the use of physical activity monitors, such as pedometers and accelerometers. A wide variety of these monitors are available commercially; we believe accelerometers are preferred as they measure activity more accurately [10, 23, 24, 38]. Patients with osteoarthritis had lower physical activity compared with control subjects [3, 6, 18, 56] and mainly were not able to meet physical activity guidelines [8]. Furthermore a relationship between age, obesity, inadequate diet, pain, and knee dysfunction with inactivity has been reported [18, 25, 36]. Studies regarding physical activity of patients before and after TKA showed an inconsistent increase of physical activity in the majority of their patients [2, 6, 20, 48, 51, 52]. One recent study did not find any improvement in accelerometer recorded physical activity in a cohort of 25 patients 6 months after TKA [14]. The authors concluded that patients did not necessarily change their physical activity behavior even if pain reduction and better function were accomplished. This suggests that patient-specific parameters might influence the amount of physical activity after TKA.

We therefore aimed to objectively quantify the influence of patient-specific parameters on activity before and after TKA through accelerometer recordings. Specific aims were to evaluate: (1) changes after TKA in terms of total numbers of daily steps, percent of moderate to vigorous steps, average times spent lying, sitting, standing, and walking, and to compare patients who had TKA after a year of recovery with an age-matched control group without lower-extremity disorders; (2) what proportion of patients who had TKA met physical activity guidelines of 10,000 steps per day including a minimum of 30 minutes of moderate to vigorous activity; and (3) factors that were associated with physical activity.

Patients and Methods

Study Design and Setting

For this prospective assessment of activity, patients included in a randomized study comparing two TKA implants were used [28]. Activity was measured with an accelerometer preoperatively and 1 year postoperatively. The results were compared with those of age-matched control subjects who had no lower-extremity pain or injury.

Study Participants

Between March 2009 and September 2011, all patients referred to our department for an unconstrained TKA (n = 638) were screened. Patients with varus or valgus malalignment greater than 15° were excluded (n = 76) as were patients who were involved in another study (n = 135) or were not able to understand and/or to comply with the study protocol (n = 51). All other patients were asked to participate; 44 declined, 200 had an implant or surgeon preference or needed a higher constraint implant, leaving 132 patients who consented to participate and who were included. All patients were interviewed by a trained study nurse 1 week preoperatively and 1 year postoperatively. The Knee Society Score [19] which consists of the Knee Score and the Function Score, each with a maximum of 100 points, was obtained by the same study nurse. Sociodemographic data (Table 1), operative details, and adverse events were documented for all patients. All patients were asked to wear an accelerometer 1 week preoperatively and at the 1-year followup. Patients were

excluded from this study if preoperative activity data were incomplete, as there could be no comparison second measurement. At followup, patients with incomplete or lost activity data were asked to wear the monitor a second time (n = 42). Ninety-seven patients had complete preoperative and postoperative activity data that could be evaluated (73%) (Fig. 1).

Physical activity was compared with that of an age-matched control group of 39 subjects who did not report any pain or previous surgeries in the lower extremities. These volunteers were recruited from a community-based exercise class. The Knee Society Function Score was obtained for comparison to that of the patients (Table 1).

Table 1. Demographic data of the patients with TKA and control subjects*

Variable	Patients with TKA (n = 97)	Control subjects (n = 39)	p value
Sex			
Male	52 (53.6%)	16 (41.0%)	0.703
Female	45 (46.4%)	23 (59.0%)	
Age (years)	68.9 (67.2–70.6)	67.9 (65.3–70.7)	0.568
BMI (kg/m^2)	31.3 (30.3–32.3)	24.1 (23.0–25.2)	< 0.001
ASA			
Grade 1 or 2	50 (51.5%)	39 (100%)	< 0.001
Grade 3 or 4	47 (48.5%)	0	
Implant			
Standard	43 (44.3%)	NA	NA
High flexion	54 (55.7%)	NA	NA
Knee Society Knee Score			
Preoperative	45.9 (42.8–49.0)	NA	NA
Postoperative	87.1 (84.6–89.6)	NA	NA
Knee Society Function Score			
Preoperative	52.5 (49.3–55.6)	NA	NA
Postoperative	72.8 (69.3–76.5)	97.7 (96.1–99.3)	< 0.001

* Mean (95% CI) for continuous variables, and absolute and relative frequencies for categorical variables; ASA = American Society of Anesthesiologists; NA = not applicable.

Description of Experiment, Treatment, or Surgery

All operations were performed with the use of a tourniquet after one dose of antibiotics. A medial parapatellar approach with a measured resection technique was used in all cases. All components were cemented. Patellar resurfacing was not performed in any of the procedures. Implants were classified as standard and high-flexion (Scorpio and Scorpio NRG, Stryker, Mahwah, NJ, USA), which are FDA approved.

Variables, Outcome Measures, Data Sources, and Bias

Activity Measurement

The activPAL™ activity monitor (PAL Technologies, Glasgow, UK) is a comprehensively validated accelerometer [5, 12, 39, 45], lightweight (20 g), and measuring

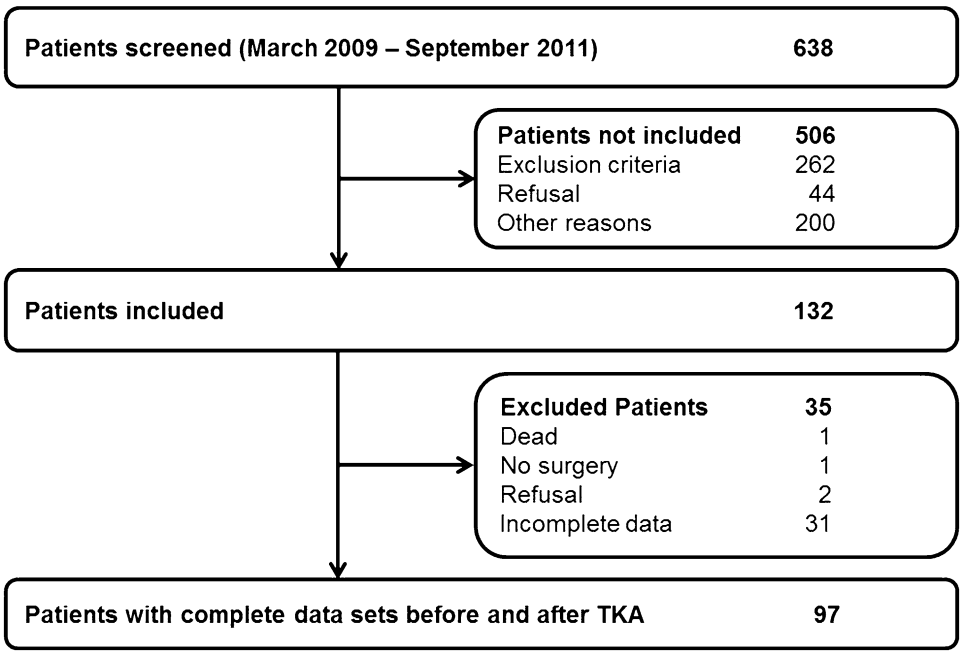

Fig. 1 A flowchart of our patient selection is shown.

53 × 35 × 7 mm. It includes an inclinometer. The accelerometer was attached over the anterolateral tibia, an appropriate position if the main outcome parameter is step number [27]. Preoperatively, the patients were instructed to wear the monitor for 4 consecutive days while awake and while sleeping (however, not during washing, showering, or bathing) under their clothes and secured by adhesive tape. They were briefed by a trained study nurse, given an additional instruction sheet, and returned the monitor on the day of their surgery. One year postoperatively, the monitor was sent to the patient 1 week before the followup.

Before each measurement, the monitor was charged and activated using the proprietary software package (activPAL™ Professional Research Edition). The software uses proprietary algorithms to transform the activity records into graphic or numeric formats, which can be exported to Microsoft Excel allowing detailed analyses [12]. For each measured day the summary of recorded steps and the time spent in lying, sitting and standing, or walking were analyzed. Furthermore the algorithms provide a division of the recorded steps owing to their intensity in decades, eg, number of steps in the intensity of 100 to 110 steps per minute. From this extended analyses the numbers of steps performed in moderate to vigorous activity (more than 100 steps per minute) could be calculated.

During the duration of the study, 16 separate monitors were used. Three monitors had to be replaced owing to technical errors. During all measurements (n = 301[132 measurements preoperative, 127 measurements postoperative, 42 repeated measurements – some of these repeat measurements were attributable to the activity data not being reproducible or the break between activity counts was too long]), 62 data sets were not recorded because of technical failure or lack of patient compliance, representing a 20.6% loss from the data collection. In the control group four of 43 measurements could not be analyzed, representing a 9.3% loss from the data collection.

Statistical Analysis, Study Size

Statistical Analysis

After each sampling the recorded data from each activPAL™ device was exported to Microsoft Excel (Microsoft Corp, Redmond, WA, USA) using proprietary software. For comparison to other studies, valid days have been defined as the continuous measure of activity counts during a minimum of 10 hours with an interruption less than 3 hours [9, 31, 32, 46]. All data were transferred to a database and analyzed using SPSS release 21 for Windows (SPSS Inc, Chicago, IL, USA). Endpoints of this investigation were differences in steps per day, moderate to vigorous intensity steps per day before and after surgery, and meeting the guideline on health-enhancing activity as described before. For the comparison of presurgical with postsurgical values, a one-sample paired t-test was used. Comparisons between groups were based on t-tests for continuous variables and on chi-square tests for categorical variables, respectively. The influence of different patient characteristics was evaluated by linear and logistic regression analysis, including age, sex, BMI, and type of implant. Results of these significance tests were summarized as p values, where a probability less than 0.05 indicates statistically significant differences between groups.

Results

Patients' activity levels increased after compared with before TKA, but one year postoperative patients still had lower activity levels than age-matched control subjects. Overall, measured steps per day improved from a mean of 5278 (SD, 2999) preoperatively to 6473 (SD, 3654) postoperatively (effect size, 1.23; 95% CI, 1.10–1.35; $p < 0.001$). This is an improvement of 1195 steps per day (SD, 3224) and results in approximately 2.4 million steps per year (SD, 1.3 million steps). Moderate to vigorous steps per day improved from a mean of 1150 (SD, 982) to 1935 (SD, 1728; $p < 0.001$). This results in approximately 19 minutes of moderate to vigorous activity per day. Times spent in lying or sitting and standing positions or during walking did not change after TKA. Lying time was a mean 12.2 (SD, 2.4) hours per day preoperatively and 12.2 (SD, 2.7) at followup ($p = 0.982$). Sitting and standing time was a mean 10.8 (SD, 3.7) hours per day preoperatively and 10.3 (SD, 2.6) at followup ($p = 0.258$). Walking time was a mean 1.4 (SD, 1.3) hours per day preoperatively and 1.5 (SD, 0.8) hours at followup ($p = 0.586$). For all measured parameters, activity of the patients after TKA was considerably less than that of the age-matched control subjects (Table 2). The control subjects walked a mean of 13,375 (SD, 4614; $p < 0.001$) steps per day which represents approximately 4.9 (SD, 1.7) million steps per year. Furthermore they performed a mean of 6562 (SD, 3401) vigorous steps per day ($p < 0.001$) which results in approximately 66 minutes of moderate to vigorous activity per day. Control subjects spent a mean of 11.2 hours per day (SD, 1.5) in the lying position ($p = 0.030$), 9.9 hours (SD, 1.5) in sitting or standing position ($p = 0.605$), and 2.9 hours (SD, 1.1) walking ($p < 0.001$).

The majority of patients did not meet health-enhancing physical activity guideline recommendations. After TKA, only 16 patients (16.5%) achieved the recommended quantity and quality of activity. An additional four patients

achieved at least 80% of the recommended activity (8000 steps per day including 2400 moderate to vigorous steps), which means that 79.4% of all patients did not achieve at least 80% of the recommended activity after TKA.

Patient factors had an influence on activity after TKA (Table 3). In a linear multivariate model BMI ($p = 0.017$), sex ($p = 0.027$), and comorbidities (American Society of Anesthesiologists [ASA] Grade, $p = 0.042$) were independent factors associated with the number of steps per day after TKA, but not age at surgery ($p = 0.071$) or implant type ($p = 0.970$). The proportion of moderate to vigorous activity was not different after surgery after stratification for these parameters (Table 4). Taking recommended health-enhancing physical activity as outcome parameter, fewer comorbidities (ASA Grade 1 or 2, $p = 0.007$) and male gender ($p = 0.043$) were independent factors associated with achieving this goal.

Table 2. Physical activity of the patients and control subjects

Variable	Patients with TKA n = 97 Mean (95% CI)	Control subjects n = 39 Mean (95% CI)	p value
Steps per day	6473 (5737–7210)	13,375 (11,879–14,871)	< 0.001
Proportion of moderate to vigorous activity	26.7% (23.2–30.1)	47.6% (43.6–51.7)	< 0.001
Hours lying	12.2 (11.6–12.7)	11.2 (10.6–11.7)	0.030
Hours sitting and standing	10.3 (9.8–10.8)	10.1 (9.6–10.6)	0.605
Hours walking	1.5 (1.3–1.7)	2.7 (2.5–3.0)	< 0.001

Table 3. Number of steps per day

Patient factors	Amounts per factor Mean (95% CI)		p value
	Male (n = 45)	Female (n = 52)	
Sex			
Preoperative	6026 (5083–6968)	4630 (3867–5394)	0.022
Followup	7471 (6294–8648)	5610 (4718–6501)	0.012
Age	≤ 70 years (n = 49)	> 70 years (n = 48)	
Preoperative	5688 (4693–6682)	4859 (4161–5557)	0.175
Followup	6716 (5449–7983)	6225 (5443–7008)	0.511
BMI	< 30 (n = 42)	≥ 30 (n = 55)	
Preoperative	5445 (4548–6342)	5150 (4309–5990)	0.634
Followup	7387 (6177–8598)	5775 (4873–6677)	0.031
Comorbidities	ASA Grade 1or 2 (n = 50)	ASA Grade 3 or 4 (n = 47)	
Preoperative	5841 (4966–6715)	4679 (3849–5508)	0.056
Followup	7676 (6530–8822)	5194 (4401–5987)	0.001
Implant	Standard (n = 43)	High-flexion (n = 54)	
Preoperative	5490 (4516–6465)	5108 (4323–5894)	0.536
Followup	6330 (5289–7371)	6587 (5527–7648)	0.732

ASA = American Society of Anesthesiologists.

Discussion

Improvement in physical activity is a major expectation of patients undergoing knee surgery [26, 29, 42], and fulfillment has an influence on patient satisfaction [42]. Therefore it is important to know if and how activity improves after major surgery such as a TKA. Although some studies have looked at objectively measured activity levels after knee arthroplasty [22, 40, 43, 48, 58], others have compared measurements before and after TKA [2, 6, 14, 16, 33, 51–53]. These studies were limited by the number of patients, short postoperative followup, and few were step based [2, 51, 53]. We therefore used accelerometer-based activity measurements to evaluate changes in step number and intensity after TKA and to compare these patients after a year of recovery with an age-matched control group without lower-extremity disorders. Furthermore we evaluated what proportion of patients who had TKAs met physical activity guidelines and which patient-specific factors were associated with physical activity.

Limitations of this study include increased inaccuracy of the activity monitor at very slow velocities. However, these measurements have greater accuracy than self-reported activity questionnaires. The activity on the recorded days might not always reflect typical days. However, a 3- to 7-day monitoring period has been suggested to provide sufficient data regarding activity behavior [31, 47]. Patients taking part in a study about activity might change their normal behavior and measurements might not always reflect the real activity. Furthermore, 20.6% of the data could not be analyzed owing to technical errors or inadequate patient compliance. However, the number of patients is greater than in previous studies reporting longitudinal data [2, 6, 14, 51–53] . The 1-year followup might not always reflect maximum functional benefit after TKA, but for most patients this is sufficient time to assess major functional improvement. Finally, there is a risk of selection bias as many eligible patients were not included for different reasons.

Improvement in the number of steps per day was 22.6% in our patients. This is consistent with the results of Brandes et al. [2] who reported an 18.8% improvement in the number of steps of 44 patients from preoperative to 1 year after TKA. Walker et al. [53] measured steps in 19 patients before and 3 and 6 months after TKA and reported a 55% improvement in the total number of steps per day at

Table 4. Proportion of moderate to vigorous activity per day (%)

Patient factors	Amounts per factor Mean (95% CI)		p value
	Male (n = 45)	Female (n = 52)	
Sex			
Preoperative	21.1 (17.8–24.3)	18.2 (14.7–21.7)	0.233
Followup	27.8 (23.7–31.8)	25.7 (20.2–31.2)	0.559
Age	≤ 70 years (n = 49)	> 70 years (n = 48)	
Preoperative	21.4 (18.0–24.7)	17.7 (14.2–21.1)	0.126
Followup	27.6 (22.7–32.4)	25.8 (20.7–30.8)	0.613
BMI	< 30 (n = 42)	≥ 30 (n = 55)	
Preoperative	19.2 (15.4–22.9)	19.8 (16.6–23.0)	0.790
Followup	29.7 (24.4–35.1)	24.3 (19.8–28.8)	0.120
Comorbidities	ASA Grade 1or 2 (n = 50)	ASA Grade 3 or 4 (n = 47)	
Preoperative	21.9 (18.7–25.1)	16.9 (13.4–20.5)	0.040
Followup	29.6 (25.2–34.1)	23.5 (18.2–28.9)	0.079
Implant	Standard (n = 43)	High-flexion (n = 54)	
Preoperative	21.7 (17.9–25.6)	17.8 (14.7–20.8)	0.100
Followup	26.0 (21.3–30.8)	27.2 (22.2–32.2)	0.736

ASA = American Society of Anesthesiologists.

the latest followup. However, measurements were performed for one day only, which is less than recommended. Other studies measured steps after TKA only [33, 40, 43, 48, 58]. The total numbers of steps per day varied from 3518 [48] to 15,641 [53] at different followup periods. Some of these studies used pedometers which are considered less accurate in detecting step numbers [10, 24, 38]. Furthermore, measurements early after TKA might not always reflect full recovery. A followup of at least 1 year has been suggested to be sufficient [57]. Daily time of activity did not change after surgery in our patients, which is consistent with the results of other studies [7, 14, 51]. In comparison to patients who had TKAs, the age-matched control subjects were considerably more active. The total number of 13,375 steps per day is consistent with other studies that had a control group [3, 56]. This suggests that although patients benefit from TKA in terms of pain relief and functional improvement, this does not result in activity comparable to that of control subjects. Although moderate to vigorous walking ability increased, patients might not be willing to change their activity behavior [14].

The total number of steps taken at followup was considerably fewer than guideline recommendations [15, 41, 44, 49, 50]. Moderate to vigorous activity, as part of the recommendation for health-enhancing activity, showed more pronounced improvement but still was less than the recommended 30 minutes per day at followup. Only 16.5% of our patients reached the recommended activity. A recent study [14] reported that only one of 52 patients met American Physical Activity Guidelines after THA or TKA. The total number of steps per day reported in other studies was considerably below the recommended number [33, 40, 43, 48], as in our patients. The mean number of steps was reported as being greater than the recommended 10,000 steps per day in only two studies [2, 53]. Therefore the majority of patients might not reach recommended health-enhancing activity levels after TKA. Two studies that used questionnaires to assess physical activity postoperatively found nearly ½ of the observed patients who had TKAs met recommended activity guidelines [13, 21]. As self-reported data are more unreliable, these data should be viewed with caution as reported before [53].

In all studies the standard deviations of step-based measured activity are large, suggesting there are considerable differences between patients. In our study obesity, female sex, and comorbidities were related to reduced activity, measured as total step number. While the increase in step number per day was approximately the same for male and female patients, there was a more pronounced increase in nonobese compared with obese patients and patients with fewer comorbidities (ASA Grades 1 and 2) compared with those with more comorbidities (ASA Grades 3 and 4). This is consistent with previous studies that have reported age, sex, and BMI to be associated with activity [33, 40, 58]. Although one recent study showed decreased activity with increasing age [1], this was not an independent factor for step-based activity in our patients. This is consistent with the results of another study of objectively measured activity level after TKA [51] which did not find any difference related to age. Improvement in moderate to vigorous activity was consistent for all patients in our study. This suggests that all patients, regardless of BMI, sex, comorbidities, or age, benefited from TKA, but not all were willing to change their activity behavior in terms of walking more steps per day. This is consistent with the results of Harding et al. [14], who did not find any change in activity after TKA.

Our study showed moderate improvement in the total number of steps and moderate to vigorous walking but no change in daily walking time. After 1 year, the patients who had a TKA walked only approximately ½ as many steps as the age-matched control subjects. Most patients did not meet the recommendation for health-enhancing activity levels. Female sex, obesity, and comorbidities were found to be predictive factors that were associated with daily step number after TKA. This should be kept in mind when counseling patients before TKA. To avoid overextended expectations surgeons should consider a patient's motivation to participate in a more active lifestyle. Further research is required to better understand the factors influencing physical activity after successful surgery.

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