Effect of preoperative sedentary behavior on clinical recovery after total knee arthroplasty: a prospective cohort study

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(Degree)
博士（保健学）

(Date of Degree)
2021-03-25

(Date of Publication)
2022-03-01

(Resource Type)
doctoral thesis

(Report Number)
甲第8058号

(URL)
https://hdl.handle.net/20.500.14094/D1008058

博士論文

Effect of preoperative sedentary behavior on clinical recovery after total knee arthroplasty: a prospective cohort study
（人工膝関節全置換術患者の術前の座位行動が術後の身体機能回復に与える影響
―前向きコホート研究―）

令和 3 年 1 月 13 日

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Introduction

Knee osteoarthritis (OA) is a common orthopedic disease and a leading cause of pain and disability among the elderly adults. Total knee arthroplasty (TKA) is a common surgical treatment for end-stage knee OA and a cost-effective intervention for releasing knee pain and improving knee and physical function [14]. However, some patients experience persistent chronic pain (10%–34%) and insufficient improvement in their physical function after TKA [2, 3, 33], which contributes to patient dissatisfaction [4] and lower physical domains of health-related quality of life [31]. As the number of TKA operations continuously increases with the aging population [16], it is important to identify the factors affecting clinical outcomes after TKA.

Sedentary behavior (SB) is defined as the participation during waking hours in activities, such as sitting and reclining, which do not substantially increase energy expenditure [23]. Prolonged SB is associated with declines in physical function and is a risk factor for physical function loss and frailty in knee OA adults [26, 29]. SB may also affect improvements in physical function among adults with knee OA following surgical treatment, such as TKA. One study reported no effect of preoperative physical activity on improvements in knee function after TKA [25]; however, it did not evaluate SB and relied on self-reported physical activity, which is subject to recall bias that can result in overestimation [9]. It is necessary to obtain an objective measure of preoperative SB in order to evaluate its effect on the recovery of physical function after TKA.

The objective of this study is to examine the effect of preoperative SB on improvements in clinical outcomes after TKA, including knee-specific functional outcomes and gait function. We hypothesized that the patients with high proportion of preoperative SB have small improvement in clinical outcomes after TKA.

Materials and Methods

Study design and setting

A 6-month prospective cohort study was conducted between June 2017 and June 2019. In total, 115 adults with knee OA, who had a planned TKA, were recruited from an orthopedic outpatient clinic in Kobe city, Hyogo prefecture, Japan between September 2017 and December 2018. Data collection was conducted 1 month preoperatively, and 3 and 6 months postoperatively. The rationale for the follow-up duration was based on evidence that improvements in knee and gait function plateau 6 months after TKA [19].

Participants

Participant inclusion criteria were (i) completion of primary TKA for knee OA that was graded 3 or 4 based on the Kellgren and Lawrence radiographic grading system [13] (performed by an independent experienced assessor (TO); (ii) being able to walk free or with a cane; and (iii) provision of informed consent to participate in the study. Exclusion criteria were (i) diagnosis of systemic disease such as rheumatoid arthritis, (ii) the presence of neurological conditions affecting gait ability, such as Parkinson disease and lumber spinal canal stenosis; (iii) total joint arthroplasty within 6 months in another area of the lower-limb; (iv) invalid accelerometer data (described in detail below); and (v) other reasons, such as fracture. All the procedures followed the medial parapatellar approach, and the patella was replaced with prothesis. Eight trained therapists (T.O., O.W., T.K., Y.T., Y.Y., D.K., T.Y., and C.S.) performed all the instructions and measurements.

The ethics committee of the Anshin Hospital approved all procedures before starting the study (approval protocol number: 61; date of approval: April 26th, 2017) and all individuals provided written informed consent before participating in accordance with the Declaration of Helsinki.

Rehabilitation protocol

All patients received 6–8 days of standard inpatient rehabilitation and weekly outpatient rehabilitation for 12 weeks (supplemental file). During their postoperative stay in the hospital, all patients were treated twice daily for 40 min by physical therapists. Inpatient rehabilitation comprised passive knee range of motion (ROM) exercises; patellofemoral joint mobilization, as needed; lower extremity flexibility exercises for the quadriceps, calves, and hamstrings; icing; gait training; and functional training for stair climbing and descending. The type of ROM exercise was passive, and the type of resistance training was non-weight such as isometric quadriceps setting. Both exercises were performed 20 times at an intensity that could be tolerated by the patients in terms of pain. After discharge from the hospital, patients received outpatient physical therapy once or twice per week for 12 weeks. Outpatient rehabilitation comprised passive and active knee ROM exercises, quadriceps strengthening, gait training, and activities of daily living training (i.e., climbing and descending stairs). The type of ROM exercises was passive and active. The type of resistance training was non-weight and free weight such as squatting that were performed 20 times during each visit. Both exercises were performed for 20 times × 2 sets at an intensity that could be tolerated by the patient in terms of pain. After 1 month, the type of ROM exercise was the same as that within 1 month, and the type of resistance training was free weight and against gravity such as stair up and down exercise. The number of repetitions and sets were the same as those within 1 month. Additionally,

all patients were prescribed a standard home exercise program to be performed twice daily. The home exercise program included active knee ROM exercises and strengthening exercises for the quadriceps, hip abductors, and hip extensors in both weight-bearing and non-weight-bearing conditions.

Knee-specific functional outcomes

The new knee society score (KSS) questionnaire was used to assess knee-specific functional outcomes [10, 28]. The new KSS consists of four categories: symptoms (3 items, 25 points), patient satisfaction (5 items, 40 points), patient expectations (3 items, 15 points), and functional activities (19 items, 100 points), which is divided into walking and standing (5 items, 30 points), standard activities (6 items, 30 points), advanced activities (5 items, 25 points), and discretionary activities (3 items, 15 points). High scores represent less pain and greater patient satisfaction, expectations, and physical functioning. The new KSS is a validated and reliable instrument for use before and after TKA [20].

Gait function

The timed-up-and-go (TUG) test was used to evaluate the time it takes to rise from a chair, walk 3 meters, turn around, and return to a seated position [24]. Participants were instructed to walk as fast as possible, and completed two trials each; the fastest time was used for analysis.

Physical activity

We measured step count and physical activity intensity using an accelerometer (Active Style Pro HJA-350IT, Omron Healthcare, Kyoto, Japan). The detailed algorithm and validity of the accelerometer device have been described [17, 21, 22]. The device measured anteroposterior (x-axis), mediolateral (y-axis), and vertical (z-axis) acceleration

signals. Patients were instructed to wear the accelerometer on their waist for at least 7 days, except when sleeping or during water-based activities such as bathing, showering, and swimming. The device estimates the intensity of activity by metabolic equivalents (METs). The algorithm for the prediction of METs was established by the Douglas bag method in a controlled laboratory setting [21, 22]. Physical activity intensity was classified into three categories based on METs: SB (≤1.5 METs), light physical activity (LPA; >1.5 to <3.0 METs), and moderate to vigorous physical activity (MVPA; ≥3.0 METs) [5, 34]. The data were collected in 60-s epochs. Non-wear time was defined if no acceleration signal was obtained for more than 60 minutes. To provide a sufficient estimation of physical activity, accelerometer data for more than 4 valid days, with at least 10 wearing hours per day, were required from each participant [34].

Sociodemographic and clinical descriptive variables

We collected sociodemographic data such as sex, age, weight, height, body mass index (BMI), smoking, bilateral KL grade, and frequency of outpatient rehabilitation from medical records. Knee ROM was measured using a standard 2-arm plastic goniometer, with the axis placed over the lateral epicondyle of the femur, the proximal arm aligned with the greater trochanter of the femur, and the distal arm aligned with the lateral malleolus of the ankle. The maximal isometric strength of the knee extensors was measured by using a hand-held dynamometer (μTas F1; ANIMA, Chofu, Japan). The peak torque (Nm) was estimated as the product of force and lever-arm length. Two attempts at maximal contraction were performed, and the greater value was recorded and normalized according to body weight (Nm/kg) [12].

Statistical analysis

We calculated the sample size using G*power. The following assumed parameters were used: two-sided α-level, 0.05; β, 80%; and medium effect size f^2, 0.15. The required sample size was estimated to be 55 patients. For adjusting the potential confounders, we found that a sample size of at least 80 patients was required.

Participant characteristics represented by continuous variables were expressed as means ± standard deviations after confirming normal distributions of their data using the Shapiro–Wilk test. Those represented by categorical variables were expressed as frequencies and percentages.

Physical activity intensity was converted into a ratio, which was calculated as the duration of each intensity divided by total accelerometer wearing time. The time course of clinical outcomes and physical activity were analyzed using repeated one-way analysis of variance, and the mean differences between preoperative, and 3 and 6 months postoperative scores were analyzed using a Bonferroni post hoc test.

We performed multiple linear regression analyses to investigate the impact of preoperative SB on the improvement of clinical outcomes (new KSS and TUG) after TKA. The dependent variable was the change in each outcome preoperatively to 6 months postoperatively and the independent variable was the proportion of preoperative SB. In Model 1, multiple linear regression analysis was performed to adjust for preoperative dependent variable scores. In Model 2, multiple linear regression analysis was performed by adjusting for potential confounders including sex, age, BMI, KL grade on the bilateral side, the proportion of preoperative MVPA, and the preoperative score for the dependent variable (KSS or TUG as relevant). We selected potential confounders on the basis of clinical knowledge and evidence reported in previous studies of their effects on clinical outcomes after TKA [27].

The statistical significance level was set at $p<0.05$ for all analyses, which were performed using SPSS for Windows 21.0.0 version (IBM, Tokyo, Japan).

Results

Of the 115 identified patients, 33 (28.7%) were excluded from the study. Reasons for exclusion were undergoing total arthroplasty on the contralateral side within 6 months (n = 10), invalid accelerometer physical activity data (n = 20), symptoms of lumber spinal canal stenosis (n = 2), and the fracture of the ankle (n = 1). Therefore, data for the remaining 82 patients were included in the study (Figure 1).

Patient characteristics assessed preoperatively are summarized in Table 1. The age was 72.1 ± 5.9 years and 67 participants were female (84%). The time course of clinical outcomes and physical activity are shown in Table 2. The new KSS scores reflecting symptoms, patient satisfaction, and functional activities, knee extensor strength on the surgical side, TUG score, and knee flexion ROM were significantly improved at the 6 months postoperative assessment compared to the preoperative assessment. Patient expectations, knee extension ROM, and knee extensor strength on the non-surgical side were not significantly different between time points. Regarding the assessment of physical activity, step count improved from the preoperative to 6-months postoperative assessment. There were no significant improvements in any measures of physical activity intensity between time points.

Results of multiple linear regression analysis are shown in Table 3. In Model 1, the preoperative scores of SB were not significantly associated with any dependent variable. In Model 2, higher preoperative scores of SB reduced the improvement in new KSS total scores [$\beta = -0.83$, 95% confidence interval (CI): −1.53 to −0.13, $p = 0.02$], symptoms ($\beta = -0.15$, 95% CI: −0.28 to −0.02, $p = 0.03$), patient satisfaction ($\beta = -0.22$, 95% CI: −0.42 to −0.02, $p = 0.03$), and

functional activities ($\beta = -0.40$, 95% CI: −0.76 to −0.04, $p = 0.03$) after adjusting for potential confounders (Table 3).

Patient expectations and TUG were not significantly correlated with preoperative SB.

Discussion

We investigated the effect of preoperative SB on improvements of clinical outcomes (knee-specific functional outcomes and gait function) after TKA. This study demonstrated that a high proportion of preoperative SB negatively effects the improvement of knee-specific functional outcomes measured by the new KSS, including symptoms, patient satisfaction, and functional activities after adjusting for potential confounders. This is the first to clarify the effect of SB on clinical outcomes after TKA, which is rarely investigated despite the importance of SB as a target for improving physical function.

A high proportion of preoperative SB reduced improvements in symptoms, patient satisfaction, and functional activities after TKA, which supported the hypothesis of the present study. A previous study reported that a high proportion of SB was negatively associated with physical function and knee pain in older adults [26]. Additionally, one longitudinal study reported that baseline SB time was related to persistent pain, physical function loss and frailty after 2 years in adults with knee OA [29]. In the present study, the proportion of SB did not change before and after TKA, which is consistent with evidence from systematic reviews [6, 11]. This finding suggests that preoperative SB had a negative effect on symptoms (including pain) and functional activities after TKA. In addition, the effect of preoperative SB on patient satisfaction may have been influenced by pain and functional activities after TKA, which were associated with this outcome [1, 7]. Therefore, preoperative SB may contribute to worsened pain, patient satisfaction, and functional activities after TKA.

Based on multiple linear regression analysis, preoperative SB had a negative effect on the improvement of knee function in Model 2, whereas significant effect was not observed on any variable in Model 1. The possible explanation for these results is the effect of gender and KL grade at surgical side as suppressors. Although females are less active than males among the elderly [8], the proportion of SB in males was higher than that in females in this study (data not shown). Similarly, as the severity of knee OA at surgical side becomes severe, it is thought that the proportion of SB becomes higher due to pain and disability in this population; however, a negative correlation was observed in the present study (data not shown). Thus, the patients with a high proportion of preoperative SB include several male patients with less severity of knee OA. Therefore, the effect of preoperative SB on the clinical outcome after TKA was not observed in Model 1.

By contrast, preoperative SB had no significant effect on improvements in TUG scores, which does not support the hypothesis of the study. This contrasts with finding from a previous study, which reported that TUG scores were associated with SB in community-dwelling adults [34]. A potential explanation is that TUG scores after TKA indicated relatively high gait function in the patients in the present study, which might have contributed to a floor effect. Specifically, TUG scores at the 6 months postoperative assessment (mean 8.2 s) were better than the cut-off value of this measure used to represent good physical function after TKA in a previous study (8.8 s) [15]. Therefore, it cannot be concluded that preoperative SB had no significant effect on improvement in TUG scores based on results of the present study. Further studies should be conducted including participants with a wide range of TUG scores to determine whether the results can be generalized.

To prevent poor functional recovery after TKA, it is essential to understand the preoperative lifestyle factors and to take action in reducing the proportion of SB in such individuals. White et al. reported that replacing SB with LPA preserved physical function regardless of the severity of knee OA [32]. Engaging in MVPA preoperatively is difficult in patients with knee OA due to pain; therefore, LPA may be a feasible activity intensity for this population. Further studies should be conducted in a wide range of patients to determine whether the results of the present study can be generalized and whether replacing SB with LPA improves the clinical outcomes after TKA. In addition, preoperative SB may be a predictor for preventing poor functional recovery. Clinicians and therapists may intervene proactively during the acute postoperative phase in patients with a high proportion of SB.

Strengths of this study included the use of an objective measure of SB using accelerometry, which enabled a precise evaluation, and a longitudinal study design, which allowed us to demonstrate the impact of preoperative SB on outcomes after TKA. However, this study also had several limitations. First, 33 participants (28.7%) dropped out, suggesting a possibility of selection bias. However, the baseline characteristics and physical function of participants who dropped out and those who remained in the study were not significantly different (data not shown). Second, the accelerometer used in this study could not capture water-based activities such as bathing, swimming, and underwater walking. Therefore, the results may underestimate physical activity levels. Third, home exercise was not definitely confirmed and no instructions for an aerobic exercise such as walking were provided. A previous study reported that promoting aerobic exercises lead to improved gait function after TKA [30]. Therefore, these factors might affect the results of the study. Finally, femoral–tibial alignment and depression status, which could be a confounding factor based

on a previous study that reported its association with chronic pain and functional activities after TKA, were not evaluated [18]. Although no participants had a diagnosis of depression, a more robust assessment is required to evaluate this condition and future research should consider its potential influence.

In conclusion, this study demonstrated that a high proportion of preoperative SB reduced the improvement of knee-specific functional outcomes after TKA in adults with knee OA. When considering clinical outcomes after TKA, clinicians should closely monitor patients with high proportions of preoperative SB to prevent poor functional recovery.

Acknowledgments

We acknowledge all subjects and medical staff members for their assistance in collecting the clinical information used in this study: Daiki Kawazoe, Takeru Yagihashi, and Chisato Shindo (Anshin Clinic, Kobe).

This study was supported by research grants from the association of Hyogo prefecture physical therapy.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Fig. 1 Flow diagram illustrating participant selection and assessment

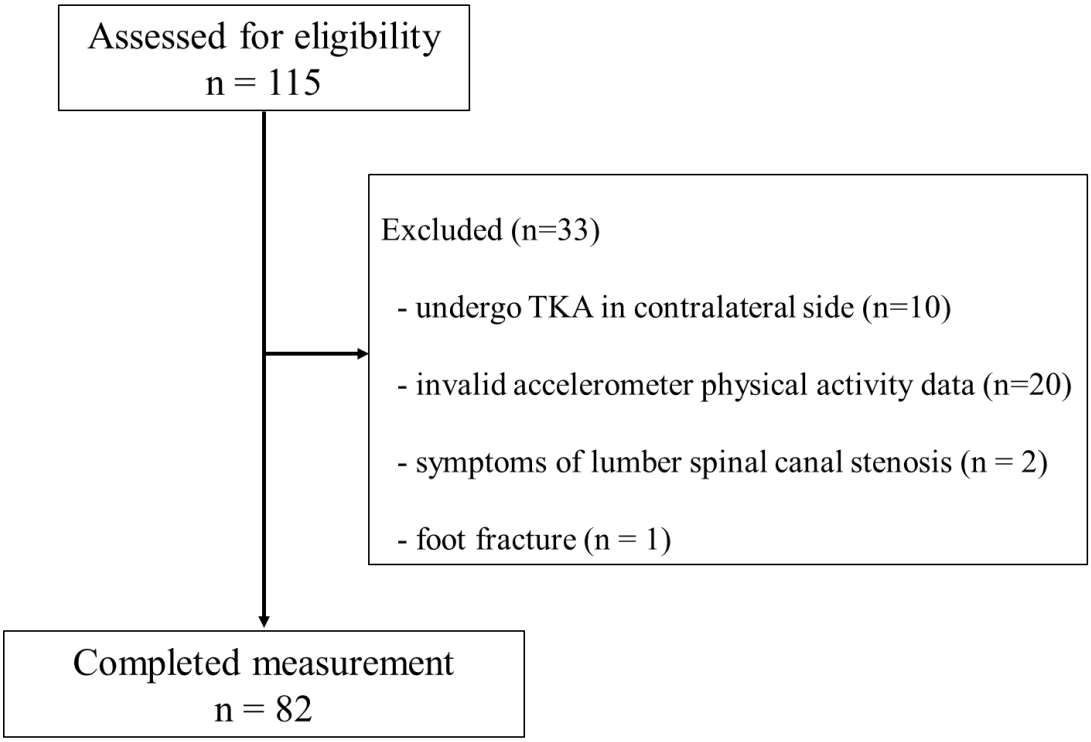

Table 1. Participant sociodemographic and clinical characteristics

Variable	Value
Female sex, n (%)	67 (82)
Age, years	72.1 ± 5.9
Height, cm	152.8 ± 6.8
Weight, kg	61.1 ± 9.6
BMI, kg/m^2	26.1 ± 3.7
Grade of OA in the surgical limb, n (%)	
3	15 (18.7)
4	67 (81.3)
Grade of OA in the non-surgical limb, n (%)	
1	8 (9.8)
2	22 (26.8)
3	25 (30.5)
4	27 (32.9)
Positive smoking status, n (%)	12 (14.6)
Frequency of outpatient rehabilitation per week	
Once, n (%)	79 (96.3)
Twice, n (%)	3 (3.7)

Data reflect 82 participants; data are expressed as means ± standard deviations.

BMI, body mass index; OA, osteoarthritis.

Table 2. Clinical outcomes and physical activity scores assessed preoperatively and 3 and 6 months postoperatively

Assessments	Preoperative	3 months postoperative	6 months postoperative	P value
Knee range of motion (flexion) °	121.5 ± 12.0	118.2 ± 9.8	118.3 ± 10.9	0.14
Knee range of motion (extension) °	−10.9 ± 7.7	−1.2 ± 12.7	−2.2 ± 3.5	< 0.01[*,†]
Knee extensor strength (surgical limb), Nm/kg	0.83 ± 0.37	0.78 ± 0.29	0.95 ± 0.33	< 0.01[†]
Knee extensor strength (non-surgical limb), Nm/kg	0.98 ± 0.33	0.97 ± 0.34	0.99 ± 0.32	0.91
New knee society score				
Total score	82.9 ± 26.5	117.7 ± 21.8	127.7 ± 24.5	< 0.01[*,†]
Symptoms	9.1 ± 4.5	18.7 ± 4.5	19.0 ± 5.1	< 0.01[*,†]
Patient satisfaction	13.1 ± 5.3	24.2 ± 7.2	29.3 ± 25.2	< 0.01[*,†]
Patient expectations	13.3 ± 2.7	9.1 ± 2.7	10.0 ± 2.9	< 0.01[*,†]
Functional activities	49.2 ± 15.5	65.8 ± 12.3	71.6 ± 13.6	< 0.01[*,†]
Timed up and go test, s	10.2 ± 3.0	8.6 ± 2.4	8.2 ± 2.2	< 0.01[*,†]
Physical activity				
Number of valid days of data	9.2 ± 2.4	9.1 ± 2.7	9.0 ± 2.7	0.83
Waking wear time, min/day	801 ± 100	801 ± 110	812 ± 119	0.32
SB, % awake wear	54.8 ± 10.6	56.6 ± 10.6	56.5 ± 11.0	0.23
LPA, % awake wear	41.1 ± 9.4	39.5 ± 10.1	39.4 ± 10.5	0.31
MVPA, % awake wear	4.2 ± 3.7	3.9 ± 2.7	4.2 ± 2.9	0.32
Steps, number/day	3724 ± 1996	3604 ± 2000	4020 ± 2351	0.03[†]

The time course of clinical outcomes and physical activity were analyzed using repeated one-way analysis of variance, and the mean differences between the preoperative and 3 and 6 months postoperative scores were analyzed using a Bonferroni post-hoc test.

Data are expressed as means ± standard deviations.

SB, sedentary behavior; LPA, light physical activity intensity; MVPA, moderate-to-vigorous physical activity intensity.

Time course of clinical outcomes for physical activity were analyzed using repeated one-way analysis of variance.

*Significant difference between the preoperative and 3 months postoperative assessments.

†Significant difference between the preoperative and 6 months postoperative assessments.

Table 3. Results of multiple regression analyses evaluating the effects of preoperative sedentary behavior on knee-specific functional outcomes and gait function after total knee arthroplasty

Dependent variables	Model 1		Model 2	
	β (95% CI)	p-value	β (95% CI)	p-value
Δ KSS total	−0.29 (−0.82 to 0.24)	0.28	−0.83 (−1.53 to −0.12)	0.02
Adjusted R^2			0.34	
Δ KSS symptom	−0.04 (−0.15 to 0.07)	0.47	−0.15 (−0.28 to −0.02)	0.03
Adjusted R^2			0.42	
Δ KSS patient satisfaction	−0.07 (−0.23 to 0.09)	0.37	−0.22 (−0.42 to −0.02)	0.03
Adjusted R^2			0.27	
Δ KSS patient expectations	−0.006 (−0.07 to 0.06)	0.85	−0.03 (−0.11 to 0.05)	0.47
Adjusted R^2			0.47	
Δ KSS functional activities	−0.12 (−0.41 to 0.16)	0.40	−0.40 (−0.76 to −0.04)	0.03
Adjusted R^2			0.42	
Δ TUG	0.002 (−0.04 to 0.05)	0.92	0.007 (−0.05 to 0.06)	0.81
Adjusted R^2			0.50	

In Model 1, multiple linear regression analysis was performed adjusting for preoperative dependent variable scores.

In Model 2, multiple linear regression analysis was performed adjusting for age, gender, body mass index, preoperative moderate to vigorous physical activity, bilateral grade of knee osteoarthritis and preoperative dependent variable scores.

Δ, change from the preoperative to the 6 months postoperative assessment. CI, confidence interval; new KSS, new knee society score; TUG; timed up and go test