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ABSTRACT

Background: Little is known about the long-term changes in physical activity (PA) after total hip arthroplasty (THA). The purpose of this study is to describe the changes in the number of steps and intensity of PA as measured by accelerometers, patient-reported physical function, and health-related quality of life of THA patient preoperatively and at 1 and 3 years after THA.

Methods: This study included 153 patients (mean age, 61.4 years; 86.3% women) who wore an accelerometer for 10 consecutive days and completed the Oxford Hip Score (OHS) and the Short Form 8 at the 5-year follow-up after THA. PA was evaluated based on the mean steps per day and the time spent performing moderate-to-vigorous PA (MVPA) per week.

Results: All 5 indicators had significantly increased at 1 year after THA, although only MVPA and OHS had further increased significantly at the 3-year follow-up. The predictor of improvement in the number of steps from baseline to 1 year post-THA was younger age, while those of improvement in MVPA from baseline to 3-year post-THA were younger age, higher OHS, and better Short Form 8 mental component scores using mixed-model analysis. Participation in the PA measurements was high (69.9%) at the 3-year follow-up. No significant changes were observed for these outcomes in the remaining cohort beyond 3 years after THA.

Conclusion: In post-THA patients, MVPA continued to increase for 3 years postoperatively. Therefore, PA must be measured over the medium term to long term following THA.

Physical activity (PA) after total hip arthroplasty (THA) increases bone quality, improves prosthesis fixation, and decreases the incidence of loosening [1] while also preventing obesity and cardiovascular disease [2]. After THA, physical function [3–5] and walking ability, such as the 6-minute walk test [6], can show dramatic improvement, although PA has been reported to remain at the same level or lower at 1 year postoperatively than that in the preoperative period according to limited evidence from several observational studies [7–9] and systematic reviews [10–12]. There are also limitations arising from differences in study design and the equipment used to measure PA (quantity and intensity) without proper adjustments for potential confounders [13] . Furthermore, most of these studies evaluated the participants' PA for only 1 year. Follow-up periods of 3 years or more are needed to investigate the medium-term to long-term impact of THA on PA levels.

Patient-reported physical function and health-related quality of life (HRQOL) after THA have been reported to improve significantly at 6 months after surgery [3–5] with these recorded at 1 year after THA comparable to those of healthy controls [14]. These outcomes should also be evaluated together to understand the gap between the patient-reported improvement in physical function 1 year after THA and the objective measurement of PA.

The purpose of this prospective study is to evaluate the changes in the number of steps and the intensity of PA as measured by accelerometers, patient-reported physical function, and the HRQOL in THA patients. These parameters were assessed preoperatively and

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at 1 and 3 years after THA to determine the changes, if any, at the various time points. Furthermore, the predictors of changes in PA were explored using the baseline characteristics of the patients.

Materials and Methods

Study Design and Participants

This prospective study included 153 patients scheduled to undergo THA between October 2010 and November 2011 at the university hospital in the Kyushu region. The inclusion criteria were patients scheduled for primary THA who were living independently. Patients who had undergone THA on the contralateral hip or revision within the investigation period were excluded. A sample size of 84 patients (101 patients including a 20% dropout) was required to have the power to detect a type II error (0.95), with an effect size of 0.4 and 5% significance (G*Power v.3.1.9.2; Heinrich-Heine-Universität, Düsseldorf, Germany) [15]. All THAs were performed by the last author (M.M.) and consisted of noncemented Per Fix 910 series prostheses (Kyocera, Osaka, Japan).

Procedure

Patients on the THA waiting list were invited via interview or telephone call to participate in the study at 4 time points: (1) 1 month before THA; (2) 6 months to 1 year postoperatively; (3) 3 years postoperatively; and (4) 5 years postoperatively. The study was approved by our institution's ethics committee before initiation (ID number 29-80). All patients provided informed consent. A research assistant explained the study purposes and research protocol. An investigation request document, consent form, questionnaire, and accelerometer were provided to all eligible patients who had provided verbal consent. The participants then completed the PA measurements using the accelerometer and also completed the self-administered questionnaire.

Physical Activity

The amount and intensity of PA were measured using an accelerometer (Lifecorder EX, size 72.0 × 42.0 × 29 mm, 45 g; Suzuken, Nagoya, Japan) worn on the waist. The participants were requested to wear the accelerometer throughout the day for 10 consecutive days, except during sleeping and bathing. Of these 10 days, data from the first 2 days and the final day were excluded from the analysis, thereby finally estimating 7 days of PA based on a prior recommendation [16]. Previous investigations have shown that the Lifecorder is suitable for research purposes [16,17]. The device is a uniaxial piezoelectronic accelerometer that samples vertical acceleration ranging between 0.06 and 1.94 G at 32 Hz. The epoch length of the device is 4 second, the activity intensity ranging from 1 (minimal intensity of movement) to 9 (maximum intensity of movement) is determined, and the average over 2 minutes is recorded. The time spent at intensity levels 4-9 ($\geq$3.6 metabolic equivalents) was defined in this study as the amount of time (minutes per week) spent at moderate-to-vigorous PA (MVPA) [18]. The measured individual data were analyzed using a PA analysis software package (Liferiser Coach 05; Suzuken, Nagoya, Japan) and Microsoft Excel (Microsoft, Redmond, WA) and stored in a database. Based on a previous study [19], we adopted a wearing time of >10 h/d and the mean duration of continuous activity measurement was 15.2 hour (range, 12.3-18.5 hour).

Patient-Reported Outcomes

Physical function was assessed using the Oxford Hip Score (OHS) tool (Japanese version) [20]. HRQOL was assessed using the 8-item Short Form Health Survey (SF-8) [21], which has 2 categories: a physical component summary (PCS) and a mental component summary (MCS).

Patient Characteristics

The characteristics of the patients, including age, sex, diagnosis, type of THA, and comorbidities, were obtained from their medical records. Employment status was requested on the questionnaire. Body mass index (BMI) was calculated before and after THA using patient height and weight measured during outpatient visits.

Data Analysis

To evaluate potential dropout bias, the participants were aggregated into the following 3 groups according to their PA measurements and questionnaire participation: (1) those who only participated in the baseline survey (baseline-only group); (2) those followed up for 1 year (1-year follow-up group); and (3) those followed up for 3 years (3-year follow-up group).

Descriptive statistics were determined. The differences in categorical variables among these groups were assessed using Pearson's X^2 tests. Kruskal-Wallis tests with a post hoc test were used for nonparametric variables or those with skewed distributions to address multiple comparisons. In addition, we used data from the complete 3-year follow-up participants to describe changes in PA and patient-reported outcomes before and after THA in the 3-year follow-up group. The effect size and 95% confidence intervals were calculated to compare the relative changes in outcomes.

In addition, a mixed linear model was used to predict the changes in the number of steps and MVPA between baseline and the postoperative period using baseline age, BMI, OHS, SF-8 MCS, and employment status as independent variables. SPSS version 23.0 (IBM Corp, Armonk, NY) was used for statistical analyses. $P < .05$ was considered to indicate statistical significance.

Results

A flowchart of the number of participants in the questionnaire survey and the PA measurements at 4 time points is shown in Figure 1. PA measurements had a higher patient attrition rate than those of the postal surveys at each time point. At baseline, 153 participants had complete PA data. The participation rate for PA measurement was 69.9% at the 3-year survey and dropped to 35.3% at the 5-year follow-up. Because of the high attrition rate at 5-year PA survey, we report from baseline to the 3-year survey. The characteristics of the 153 patients are summarized in Table 1. The participants were mostly in their sixties and were nonobese (BMI, 23.1; range, 16-34 kg/m^2). There were no statistical differences in the distributions of age or BMI among the 3 groups. Employment status differed among the 3 groups. The baseline-only group had the highest employment rate, while the rates for the other 2 groups were approximately 30%.

The mean and effect sizes for the 5 outcomes are shown in Table 2. From pre-THA to 3 years post-THA, the mean number of steps taken and MVPA showed statistically significant improvements. Between baseline and 1 year after THA, all 5 outcomes showed significant improvement, although at 3 years after THA, only MVPA and OHS showed further significant changes.

The effect size for the number of steps plateaued at 1 year, whereas that of MVPA continued to increase. The HRQOL improved

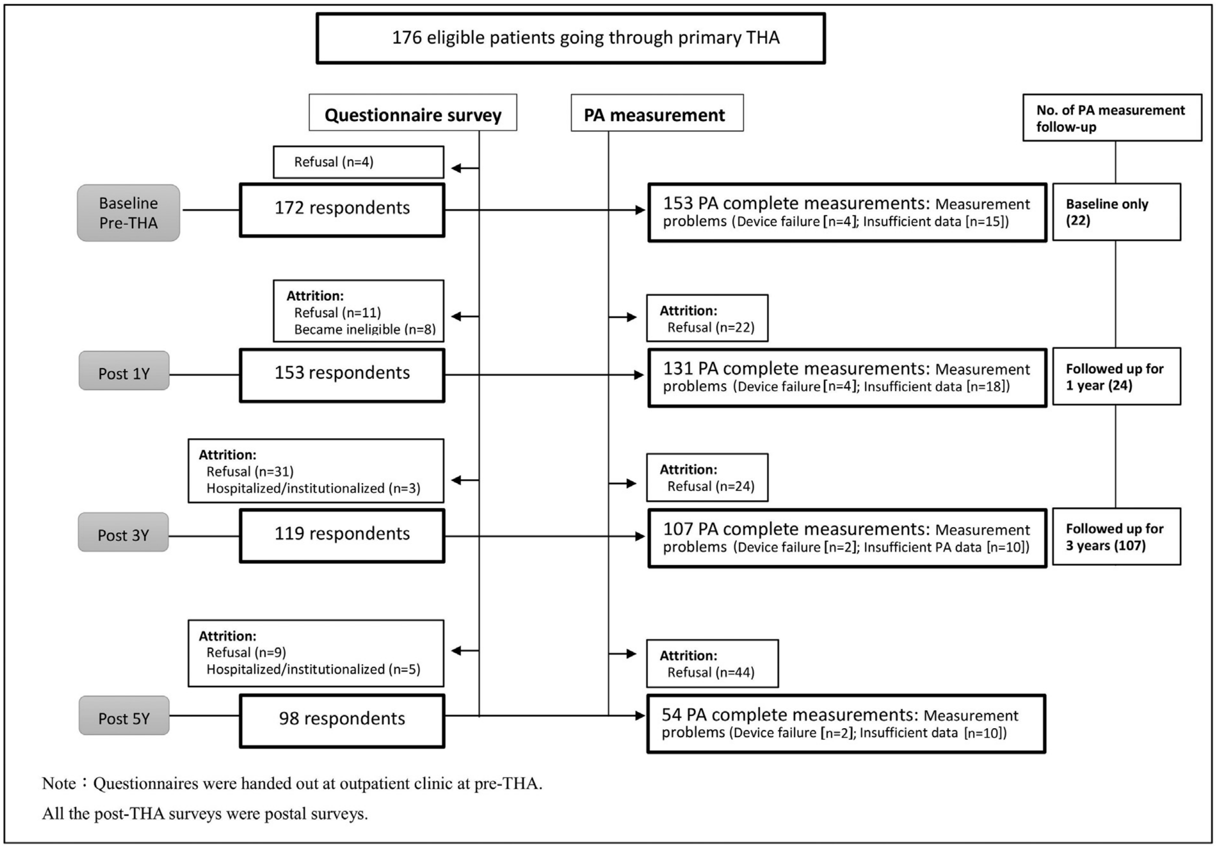

Fig. 1. Flow chart of study participation. PA, physical activity; THA, total hip arthroplasty.

from baseline to 1 year after THA, with the OHS having the highest effect size, followed by the SF-8 PCS and SF-8 MCS. The effect size of the OHS and SF-8 PCS peaked at 3 years after THA. In contrast, the SF-8 MCS effect size showed little change during the 3-year study period.

The median (interquartile range) PA and patient-reported outcomes according to the follow-up status from the preoperative to 3-year postoperative periods are shown in Table 3. Median rather than mean values were used for comparison because some groups had PA outcomes with skewed distributions. Overall, there were no systematic differences in the 5 outcomes among the 3 groups, although the 3-year follow-up group tended to have a higher median number of steps and higher MVPA level than those of the other groups at each time point. The group differences in these 2 indicators, however, reached the levels of significance only at 1 year after THA.

The median OHS at baseline differed significantly, whereas the median scores of SF-8 PCS did not differ at any follow-up point (Table 3). In contrast, the differences in the median SF-8 MCS scores reached significance at 3 years after THA, at which time the 3-year follow-up group had a higher score than those of the other groups.

Participants who dropped out of PA measurement 5 years after THA tended to be older and had a higher proportion of women and more comorbidities (eg, hypertension). The median number of steps, MVPA, OHS, and SF-8 PCS and MCS in the 5-year follow-up group were 6452 steps; 70.0 min/wk; and 46.0, 53.1, and 57.7 points, respectively. No statistically significant changes were observed between 3 and 5 years after THA.

Box plots of the MVPA and OHS data for the 3-year follow-up group are shown in Figure 2. Both indicators continued to improve up to the 3-year follow-up and then stabilized, as shown at the 3-year post-THA evaluation. Only 2.0% of patients reached an

Table 1
Baseline Characteristics of the Participants With Physical Activity Data, According to Follow-Up Status.

Characteristics	Subsections	All Participants (N = 153)	Baseline Only (N = 22)	1-y Follow-Up (N = 24)	3-y Follow-Up (N = 107)
Age in y	Mean ± SD	61.4 ± 8.1	61.4 ± 8.0	60.8 ± 8.7	61.8 ± 7.9
Sex, n (%)	Men	21 (13.7)	4 (18.2)	3 (12.5)	17 (15.9)
	Women	132 (86.3)	18 (81.8)	21 (87.5)	90 (84.1)
Diagnosis, n (%)	Osteoarthritis	149 (97.4)	22 (100)	23 (95.8)	105 (98.1)
	Others	4 (2.6)	0	1 (4.2)	2 (1.9)
Comorbidities, n (%)[a]	Hypertension	37 (24.2)	7 (31.8)	7 (29.2)	25 (23.4)
	Dyslipidemia	17 (11.1)	2 (9.1)	4 (16.7)	13 (12.1)
	Diabetes mellitus	15 (9.8)	2 (9.1)	2 (8.3)	10 (9.3)
BMI, kg/m^2	Mean ± SD	23.1 ± 3.5	24.7 ± 3.4	23.3 ± 3.4	23.0 ± 3.5
Employment, n (%)	Baseline	53 (34.6)	10 (45.5)	8 (33.3)	31 (29.0)

BMI, body mass index; SD, standard deviation.
[a] Multiple comorbidities in some patients.

Table 2
Changes in Mean Physical Activity at 3 Survey Points, According to the Follow-Up Status of Total Hip Arthroplasty Patients.

Parameter	Mean ± SD						Effect Size (95% Confidence Interval)		
	Baseline (Pre-THA)	Post 1 y	Pre vs Post 1 y	Post 3 y	Post 1 y vs 3 y	Main Effect	Pre vs 1 y	1 y vs 3 y	Pre vs 3 y
	N = 153	N = 131	*P*	N = 111	*P*	*P*			
Steps (no./day)	4776 ± 2259	6634 ± 3242	<.0001	6736 ± 3150	.621	<.0001	−0.82 (−1.025 to −0.544)	−0.03 (−0.010 to −0.001)	−0.88 (−1.062 to −0.507)
MVPA (min/wk)	35.4 ± 35.1	58.3 ± 64.6	.003	72.3 ± 67.4	.008	<.0001	−0.65 (−0.950 to −0.320)	−0.22 (−0.458 to −0.018)	−1.05 (−1.480 to −0.717)
OHS	29.4 ± 8.1	42.7 ± 5.0	<.0001	44.8 ± 4.7	.003	<.0001	−1.64 (−1.917 to −1.442)	−0.42 (−1.031 to −0.169)	−1.90 (−2.231 to −1.769)
SF-8 PCS	40.1 ± 7.6	49.9 ± 6.9	<.0001	51.5 ± 6.1	.053	<.0001	−1.29 (−1.428 to −1.211)	−0.23 (−0.690 to −0.164)	−1.82 (−2.069 to −1.564)
SF-8 MCS	49.7 ± 8.2	54.8 ± 6.8	<.0001	55.0 ± 6.2	.816	<.0001	−0.62 (−0.978 to −0.513)	−0.03 (−0.120 to −0.004)	−0.64 (−1.198 to −0.494)

All data are presented as means ± standard deviation (SD). Main effect *P* value was calculated using the linear mixed model with Bonferroni adjustment.
MVPA, moderate-to-vigorous physical activity; OHS, Oxford Hip Score; SF-8, Short Form 8 score; PCS, physical component summary; MCS, mental component summary.

MVPA level of 150 min/wk at baseline, as recommended by the World Health Organization guidelines for PA. However, at the 3-year follow-up, 18.0% of patients had reached this goal.

The results of the mixed linear model to predict changes in the number of steps 1 year after THA are shown in Table 4. One-year follow-up data were chosen because they had reached a plateau. Younger age was the only significant predictor of improvement. The mixed model was also used to predict changes in MVPA. Younger age, higher OHS, and better SF-8 MCS were significant predictors of greater improvement, whereas BMI and employment status were not significant predictors.

Discussion

This 3-year prospective study of patients who underwent THA measured the number of steps, MVPA, and HRQOL. We found differences in the rates of improvement for 2 PA indicators: the number of steps peaked at 1 year after THA, whereas MVPA peaked at 3 years. The predictors of improvement in MVPA from baseline to the 3-year follow-up were younger age, higher OHS, and better SF-8 mental component score, whereas younger age was the only predictor of change in the number of steps. The improvements in the OHS, SF-8 PCS, and SF-8 MCS scores in our patients were comparable to those in previous studies [5,7].

Contrary to our findings, recent systematic reviews on PA in patients with lower-limb arthroplasty found no conclusive evidence of improvement in PA at 1 year after surgery [10,11,13], likely because of differences in patient characteristics between our study and those of the patients in their reviewed studies. In previous reviews, the mean number of steps per day ranged from 5541 to 10,738. In addition, their patients tended to be more obese than our participants [10,13]. The difference in BMI between our study and the reviewed studies was approximately 7.0 kg/m^2 [10,13]. Obesity is associated with worse clinical outcomes of hip or knee arthroplasty in terms of pain, disability, and complications in patients with osteoarthritis [22]. These obesity-related problems may slow the recovery process, which could affect PA outcomes in the post-THA period. The PA at 1 year after THA in the present study was

Table 3
Number of Steps, Moderate-To-Vigorous Physical Activity (MVPA), Oxford Hip Score (OHS), and Short Form 8 (SF-8) at 3 Time Points, by Follow-Up Status in Total Hip Arthroplasty.

Parameter	Baseline (Pre-THA)	*P*	Post 1 y	*P*	Post 3 y
Steps (no./d)					
Baseline only (n = 22)	3778 (2856-5460)		—		—
1-y follow-up (n = 24)	4682 (2840-5035)	.066[a]	5965 (3498-10,859)	.769[a]	—
3-y follow-up (n = 107)	4772 (3393-6426)		6878 (4348-9234)		6469 (4327-8935)
MVPA (min/wk)					
Baseline only (n = 22)	25.0 (4.7-42.6)		—		—
1-y follow-up (n = 24)	19.7 (5.6-44.2)	.452[a]	30.4 (10.9-53.1)[b]	.012[a]	—
3-y follow-up (n = 107)	24.6 (10.3-55.2)		45.4 (18.5-83.2)[b]		66.3 (25.4-106.9)
Oxford Hip Score					
Baseline only (n = 22)	29.0 (25.0-34.0)		—		—
1-y follow-up (n = 24)	24.5 (17.8-29.0)[b]	.019[a]	42.5 (37.0-46.8)	.484[a]	—
3-y follow-up (n = 107)	31.0 (25.0-35.5)[b]		44.5 (40.3-47.0)		46.0 (43.0-48.0)
SF-8 physical component summary					
Baseline only (n = 22)	41.1 (38.0-46.5)		—		—
1-y follow-up (n = 24)	38.9 (32.9-45.0)	.867[a]	47.1 (41.6-55.4)	.604[a]	—
3-y follow-up (n = 107)	40.5 (34.1-45.6)		51.9 (46.7-55.7)		54.1 (48.4-57.3)
SF-8 mental component summary					
Baseline only (n = 22)	53.2 (46.7-56.8)		—		—
1-y follow-up (n = 24)	48.0 (37.4-56.6)	.604[a]	52.4 (44.8-58.6)[b]	.044[a]	—
3-y follow-up (n = 107)	49.4 (44.0-55.2)		58.3 (52.8-59.8)[b]		58.6 (53.4-59.9)

All data are presented as medians (interquartile range).
MVPA, moderate-to-vigorous physical activity; SF-8, Short Form 8 score.
[a] Kruskal-Wallis test.
[b] Post hoc comparison. $P < .05$.

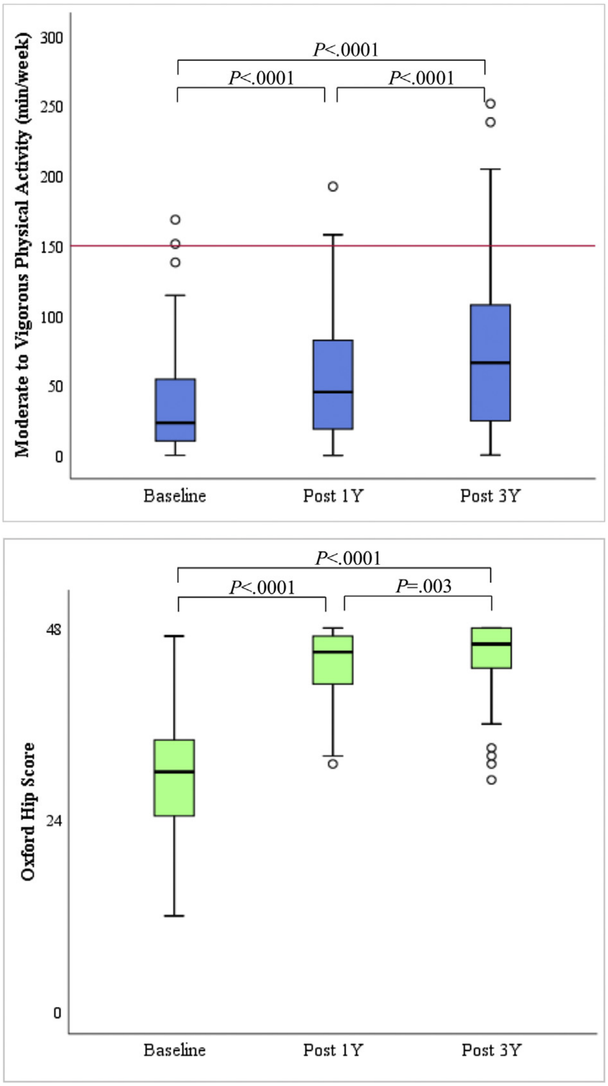

Fig. 2. Box plots of moderate-to-vigorous physical activity (MVPA) and Oxford Hip Score (OHS) for the 3-y follow-up group. MVPA scores and OHS continued to increase up to 3 y postoperatively ($P < .0001$ and $P = .003$, respectively). The MVPA 150 min/wk red line shows the recommended physical activity to promote/maintain good health. Only 2.0% of the THA patients reached an MVPA level of 150 min/wk at baseline. However, at 3 y after THA, 18.0% of the patients had attained this PA level.

comparable to that reported in other studies [14,23] and was maintained without decline until 3 years postoperatively.

The number of steps changed little at 1 year after THA, whereas the MVPA had nearly doubled from preoperatively to 3 years postoperatively. Approximately 20% of our participants reached the MVPA guideline of 150 min/wk of PA recommended by the World Health Organization [2]. This proportion was lower than that reported in previous studies using questionnaire-based PA measurement, which reported that 50%-67% of patients reached the recommended PA guideline after THA [24,25]. This proportion is almost twice as high as that in an accelerometer-based PA of healthy elderly persons [26]. It is possible that the PA measurements on self-administered questionnaires suffered from overestimation and recall bias [27]. PA levels appropriate for THA patients need to be examined in future studies.

The predictive factors for improvement in MVPA from baseline to 3 years after THA were younger age, better OHS for pain and physical function, and better SF-8 mental component score at baseline. Thus, over time, younger participants and those with higher physical function may see further improvement in their abilities to perform more vigorous activities. A review of the impact of mental health on joint arthroplasty found that patients with poor preoperative mental health were less likely to have improvements in physical health [28]. More attention to the mental health of patients during the preoperative phase may be necessary to improve PA after THA.

In contrast to the improvement in MVPA, the number of steps peaked at 1 year after THA, with younger age the only predictor of improvement. Systematic reviews show numerous PA outcomes measured by different types of devices [10,11,13]. Additional studies are needed to determine the best indicators to monitor changes in PA over time and to examine which PA indicators are associated with patient-reported outcomes.

The patient participation rate for PA measurements at 5 years post-THA was low despite our concerted efforts. The attrition rates for studies that evaluated the PA in total joint arthroplasty patients with an accelerometer were 10%-26.5% [7,29] at 1 year after surgery, compared to the 1-year rate in the present study (14.4%). However, the dropout rate at the 5-year follow-up was high, while the attrition rate for the postal survey was much lower. Nevertheless, there were no systematic differences in the 5 outcomes among the 3 participant groups at the 3 follow-up points. In addition, the overlapping interquartile ranges suggest that within-group differences were greater than the differences among the groups.

Finally, this study was a single-center survey. Our tertiary hospital manages the entire episode of care; thus, more variability might be observed in other medical settings.

Conclusion

The number of steps taken by the participants and their MVPA after THA significantly increased and was accompanied by functional improvement. The rate of improvement in MVPA was slower than that in the number of steps, peaking at 3 years after THA. In

Table 4
Predictors of the Change in the Number of Steps and MVPA After Total Hip Arthroplasty.

Baseline Data	MVPA (min/wk) at 3 y[a] after THA		Number of Steps at 1 y[a] after THA	
	Beta (95% CI)	P	Beta (95% CI)	P
Age	−1.137 (−2.204 to −.069)	.037	−82.057 (−124.041 to −40.073)	<.0001
Body mass index	—	.565	—	.067
Oxford Hip Score	1.632 (.696 to 2.567)	.001	—	.081
SF-8 mental component summary	.874 (.038 to 1.709)	.040	—	.475
Employed	—	.878	—	.380

Bata, change in outcome per unit of model element: age (y), body mass index (kg/m^2), Oxford Hip Score (score/48), SF-8 mental component summary (score/100), Employed (0/1). Bata and 95% CI of beta are given (age, BMI, OHS, and SF-8 PCS were adjusted).
THA, total hip arthroplasty; MVPA, moderate-to-vigorous physical activity; CI, confidence interval; SF-8, Short Form 8 score.
[a] The number of steps peaked 1 y after THA, and MVPA peaked 3 y after THA.

addition, the predictors of changes in MVPA from baseline to 3 years after THA in the mixed model were younger age, higher OHS, and better SF-8 mental component scores. This finding suggests the need for at least 3 years of follow-up to monitor PA. Substantial differences in the rates of recovery for PA among participants indicate the need for individual recovery plans. Further studies are necessary to examine the factors associated with the degree and rate of recovery.

Ethical Approval

The ethics committee of Saga University School of Medicine approved this study (approval number 29-80).

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