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Original Article

Effects of incorporating elliptical trainer exercise during rehabilitation on physical function and self-reported outcomes after total hip arthroplasty: a randomized controlled trial

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Abstract. [Purpose] To investigate the effects of incorporating elliptical trainer exercise in early rehabilitation after total hip arthroplasty on physical function and self-reported outcomes. [Participants and Methods] Participants with independent gait prior to total hip arthroplasty underwent conventional postoperative physiotherapy and were divided into two groups. The intervention group additionally underwent elliptical trainer exercise, while the control group underwent a walking program. The main outcomes were low back and hip region pain, lower limb muscle strength, single-leg stance time, Timed Up & Go Test results, 10 m walking test results, hip disability and osteoarthritis outcome score, and modified fall efficacy scale score. These outcomes were evaluated preoperatively, at discharge, and at 1 and 3 months postoperatively. [Results] Fifty participants (including 40 females; age, 68.3 ± 10.8 years) participated in this study. Physical function evaluations showed a significant improvement in hip region pain during walking at discharge. Knee extensor strength, single-leg stance time, stride length, and walking speed were significantly greater in the intervention group at discharge and at 1 and 3 months postoperatively. The modified fall efficacy scale score significantly improved in the intervention group 1 month postoperatively. [Conclusion] Elliptical trainer exercise and conventional physiotherapy in the early postoperative period contribute to improved physical function and walking ability and improvement in the fear of falling.
Key words: Total hip arthroplasty, Elliptical trainer, Self-reported outcome

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INTRODUCTION

Hip osteoarthritis is widely known to cause pain, limitation of range of motion[1], reduced quality of life (QOL), and adversely affects the lumbar spine[2]. Total hip arthroplasty (THA) is a standard surgical treatment for severe osteoarthritis, and many previous studies have shown this procedure improves pain[3, 4], physical function[5], and QOL[6–9]. With respect to physical function after THA, recovery in knee extensor muscle strength, and walking ability take time to improve beyond preoperative values[10–12]. This might explain why even one year after surgery, there is a higher risk of falls than in healthy able-bodied people[13]. In addition, persistent dysfunction that occurs after THA can lead to an increased risk of falls[14].

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The hip disability and osteoarthritis outcome score (HOOS) is used to measure QOL following THA. This questionnaire was developed as a disease-specific evaluation scale based on the Western Ontario and McMaster Universities osteoarthritis index (WOMAC), which is generally used as a QOL evaluation scale[15)]. The HOOS is useful for inactive patients with a hip injury or hip osteoarthritis and has been used to track outcomes after THA[16)]. To increase applicability to younger people after THA, and therefore divergent to the WOMAC questionnaire, questions about sports and recreation are included in the HOOS questionnaire[17)]. In addition, the Fall efficacy scale is generally used to evaluate fear of falling. It has been reported that elderly people with activity restrictions due to fear of falling have lower physical functions, activities of daily living (ADL) and instrumental activities of daily living (IADL) after 3 years than those who do not[18)], suggesting the importance of evaluation.

In recent years, it has been reported that walking ability and health-related QOL are improved after performing ergometer cycling early after THA[19, 20)]. However, it is not possible to directly link the effects of ergometer cycling to changes in walking ability. Exercising on elliptical trainer is used in physical therapy rehabilitation of various central nervous system and orthopedic diseases[21–23)]. Elliptical trainer exercise has many similarities to walking, but has the benefits of being more stable with hand support, allowing increased confidence in the ability to exercise. No studies have examined the effects of including elliptical trainer exercise in the early stages of rehabilitation after THA.

This study sought to examine the effects of adding elliptical trainer exercise to early rehabilitation after THA on physical function, health-related QOL, and self-efficacy.

PARTICIPANTS AND METHODS

The participants were 57 patients hospitalized for unilateral THA from July 2020 to June 2021 and suitable for postoperative physiotherapy. The exclusion criteria were inability to achieve independent gait for 10 m preoperatively, THA for hip fracture, patients with limitation of ADL, severe cognitive impairment (Hierarchic Dementia Scale-Revised score of ≤5), and those who did not provide consent to participate. Participants were randomly allocated using a random number table by the principal investigator into an intervention group receiving standard postoperative physiotherapy with the addition of elliptical trainer exercise. A control group received standard physiotherapy and additional walking exercise after THA (25 in each group). As an ethical consideration, patients were provided a verbal explanation of the study content, and consent was obtained to participate. This study was conducted with the ethics review committee's approval at Saitama Medical University Saitama Medical Center (No. 2375). The conduct of all investigations in this study conformed to the protocol of ethical and humane principles in research and was registered at the University Hospital Medical Information Network Center (000040477).

Participants' characteristics including age, gender, Body Mass Index (BMI), preoperative Hip Japanese Orthopedic Association (JOA) Score, hip disorder duration, surgery time, and intraoperative bleeding volume were collected.

The following tests of physical function were assessed preoperatively, at discharge, as well as postoperatively at 1 and 3 months for each group: pain (low back/hip region during rest and walking) using a Visual Analog Scale (VAS), single-leg stance time on the surgical side, knee extensor strength on the surgical side, Timed Up & Go Test (TUG), and 10 m walking test. In addition, hip abduction strength on the surgical side was measured preoperatively, as well as postoperatively at 1 and 3 months. The VAS pain score (0–100) was rated from no pain at all to "100" being the worst pain they had ever felt. The distance to the mark was then measured. Knee isometric extensor strength and hip isometric abductor strength were measured using a manual muscle strength meter (µTas F-1, manufactured by Anima) in the same manner as in previous reports[24, 25)]. The maximum isometric effort of knee extension and hip abduction over 5 sec was undertaken twice with an interval of 30 sec. The maximum value was used for the analysis and normalized according to body weight (kg). The TUG was measured according to the principle of Podsiadlo et al.[26)], and the 10 m walking test consisted of walking time and number of steps to complete a 10 m walking task[27)]. Each test measured maximum walking speed. The single-leg stance time, TUG, and 10 m walking test were measured twice using a digital stopwatch. As a representative value, the maximum measurement time was used for the single-leg stance time, and the minimum measurement time was used for the TUG and 10 m walking test.

Evaluation of physical function was carried out by the physiotherapist in charge of the patient. The physiotherapist and the attending physician were blind to treatment group allocation. Self-Reported Outcomes included the HOOS and the modified fall efficacy scale (MFES). HOOS is a 40-item questionnaire constructed to assess patient-relevant outcomes in five separate subscales: Pain, symptoms, ADL, sport and recreational activities (Sport/Rec), and hip related quality of life (QOL). A normalized score was then calculated for each subscale, with 100 indicating no symptoms and 0 indicating extreme symptoms[28)]. The MFES scale is an evaluation method that quantitatively evaluates the fear of falls and self-efficacy related to falls for 10 items based on ADL[29)]. Compared to the Falls Efficacy Scale, which is a scale specific to indoor activities, MFES is an evaluation scale that includes indoor and outdoor activities in line with the lives of the elderly[30)].

Routine postoperative physiotherapy was performed according to the hospital clinical pathway with the following goals: wheelchair use and practice walking with the aid of a frame from postoperative day 1; walking with a cane as soon as possible; achieving independent walking with a walking frame in the wards by postoperative day 3; achieving independence in walking with the aid of a cane in the ward by postoperative day 10; and discharge home by postoperative day 14–21. Postoperative physiotherapy from day 1 onwards included hip ROM exercise, hip and knee muscle strengthening exercise using body weight, and walking/activity of daily living.

From postoperative day 3, the intervention group trained on an elliptical trainer (Horizon Cross trainer, ANDES 3, Johnson Health Tech Japan, Tokyo, Japan) for 20 min daily for 7 days in addition to the above mentioned standard post operative physiotherapy. The control group undertook walking practice for 20 min daily for 7 days together with standard post operative physiotherapy. If participants complained of fatigue, they were encouraged to rest. The principal investigator managed the post operative intervention training.

Statistics software of SPSS statistics ver. 26.0 (IBM Corp. Released 2020. IBM SPSS Statistics for Macintosh, Version 26.0., IBM Corp, Armonk, NY, USA) was used to analyze the data. Measured values were recorded as mean ± standard deviation and 95% confidence interval. We studied variables obtained for each period by two-way repeated measures ANOVA with time as within factor and Intervention group versus Control group as grouping factor. Intergroup comparison was evaluated using independent t-test or Mann–Whitney U test, and intragroup comparison was evaluated by Bonferroni analysis. P-values were Bonferroni corrected to adjust for multiple comparisons. The analysis was based on an intention-to-treat principle, but there were no patient crossovers between the two treatment groups. The level of statistical significance was set at $p<0.05$.

RESULTS

Of the 50 patients, excluding the 7 who met the exclusion criteria, 25 were allocated to the intervention group and 25 to the control group. There were no dropouts in the follow-up period. The intervention compliance rate was 100% in both groups.

There were no significant differences between groups in demographic characteristics (Table 1). The surgical procedure was an anterolateral-supine approach (ALS approach). The results of the two-way ANOVA and post-hoc test of physical function evaluations are shown in Table 2. The main effect was observed in all physical function evaluations compared to measurement time, and the main effect was observed in Single-leg stance time, TUG, Stride length, and Walking speed. The interaction was observed in Low back and Hip region pain during walking and Single-leg stance time. In the comparison between groups at each measurement point, there was a significant difference at discharge, postoperatively at 1 month, and postoperatively at 3 months in knee extension strength, single-leg stance time, stride length, and walking speed. Hip region pain during walking and TUG was significantly different only at discharge.

For the HOOS score, both groups showed significant improvement at discharge on the subscale excluding sport/Rec compared to preoperatively, and all subscales of the intervention group showed significant improvement postoperatively at 1 month after discharge compared to discharge (Table 3). However, there was no significant difference in the comparison between groups. The MFES score improved above the preoperative value at 1 month postoperatively, and was significantly higher in the intervention group than in the control group.

DISCUSSION

This study compared changes over time in physical function and health-related QOL with and without exercise on an elliptical trainer in the early postoperative period following THA. Both groups improved over time up to 3 months postoperatively compared to preoperatively. In particular, the intervention group showed significantly higher MFES values postoperatively at 1 month, and knee extensor strength, stride length, and walking speed were significantly higher postoperatively at 1 month and 3 months compared to the control group.

The positive results for recovery following elliptical trainer exercise may be due to similarity between this form of exercise and walking[31)]. During this exercise, knee extensors muscle activation[32)] and lower limb load are increased when compared to walking with a frame, and enhanced proprioceptive sense can be expected[33)]. In addition, knee extensor strength, stride length, and walking speed were significantly higher in the intervention group up to 3 months postoperatively. It has been reported that walking speed is related to age and knee extensor strength[34)]. In elliptical training, muscle activity of the knee

Table 1. Demographic characteristics of patients in the intervention and control groups

	IG (n=25)	CG (n=25)
Age (years)	69.3 ± 8.7	67.3 ± 12.8
Gender (female, n)	18	22
Height (cm)	156.9 ± 9.7	152.2 ± 8.9
Weight (kg)	57.7 ± 10.0	54.5 ± 11.6
BMI (kg/m^2)	23.4 ± 3.1	23.4 ± 4.1
Preoperative hip JOA score	50.0 ± 15.2	43.1 ± 13.5
Surgery time (hours)	102.9 ± 22.5	106.8 ± 32.2
Intraoperative bleeding volume (mL)	430.0 ± 200.3	342.0 ± 234.1

IG: Intervention group; CG: Control group; JOA: Japanese Orthopedic Association.

extensors is greater than that during walking on level overground, and proprioceptive awareness is promoted. From the results of this study, knee extensor strength was significantly greater in the intervention group. From this, it is considered that muscle strength was improved by repeating the knee extensor muscle activity at a greater level than walking, which had the positive effects on stride length and walking speed.

Outcomes are not always the same when determined by medical staff compared to the patient's own report, so it makes sense that evaluation is determined from the patient's perspective[35]. It has been reported that patients have high expectations for improvement in pain, physical function, psychological improvement and participation in social activities after THA surgery[36]. Our study found that both groups improved over time when comparing discharge to preoperatively, but there was no difference between the two groups. We evaluated the HOOS score and lower limb muscle strength in people post THA, which decreased postoperatively at 1 month but improved over time after that. Interestingly, lower limb strength remained inferior to healthy subjects even at 1 year postoperatively. This would suggest that early rehabilitation in the early postoperative period is essential to minimize the decrease in physical function capability post THA[12]. In addition, Dayton et al. investigated the correlation between TUG, Stair Climbing Test, 6 Minute walking test and HOOS, and found no significant correlation between these measures and changes in the HOOS score. It is suggested that both self-report and physical function need to be evaluated[37]. In addition, self-reported measures may overestimate patients' true functional abilities[38], hence a more comprehensive evaluative strategy is needed. In both groups, pain and physical function after THA were improved, and mental background may have also affected these results. Therefore, the self-reported results suggested the need to consider approaches other than physical function.

In the results of this study, the MFES score was significantly higher in the intervention group only by 1 month postoperatively. McAuley et al.[39] suggested that fall self-efficacy is a predictor of fall fear and noted that although they are related, fall self-efficacy is not a surrogate for fall fear. Tinetti et al.[40] investigated the association of four variables: fall fear, fall self-efficacy, fall experience, and physical function. Fall self-efficacy was found to be the most powerful predictor of current

Table 2. Physical function for the intervention and control group in each assessment period

		Preoperatively	Discharge	Postoperatively 1 month	Postoperatively 3 months
Low back pain	IG	23.1 ± 28.0 (11.5–34.7)	3.9 ± 9.0† (0.2–7.6)	2.5 ± 4.0 (0.8–4.1)	3.4 ± 9.3 (−0.5–7.3)
during rest (cm)	CG	24.2 ± 2.6 (13.4–35.0)	8.8 ± 13.5‖ (3.2–14.3)	5.7 ± 12.3 (0.6–10.7)	4.8 ± 9.5 (0.8–8.7)
Hip region pain	IG	30.2 ± 24.8 (20.0–40.5)	5.4 ± 10.3† (1.2–9.7)	2.8 ± 4.2 (1.0–4.5)	2.2 ± 3.6 (0.7–3.7)
during rest (cm)	CG	28.3 ± 27.4 (17.0–39.6)	9.2 ± 9.7‖ (5.2–13.2)	8.5 ± 15.9 (2.0–15.1)	3.6 ± 4.9 (1.6–5.6)
Low back pain	IG	42.0 ± 32.8 (28.5–55.6)	7.5 ± 12.4† (2.4–12.6)	5.2 ± 8.2 (1.9–8.6)	7.2 ± 13.7 (1.5–12.8)
during walking (cm)	CG	35.1 ± 31.0 (22.3–47.9)	19.6 ± 22.9‖ (10.1–29.0)	15.6 ± 23.0 (6.1–25.1)	8.9 ± 14.5 (2.9–14.9)
Hip region pain	IG	66.0 ± 20.9 (57.3–74.6)	15.0 ± 15.5*† (8.7–21.4)	9.0 ± 12.6‡ (3.8–14.2)	5.4 ± 6.0 (2.9–7.9)
during walking (cm)	CG	56.2 ± 31.5 (43.3–69.2)	26.7 ± 22.1‖ (17.6–35.9)	16.2 ± 21.3 (7.4–25.0)	6.1 ± 7.4 (3.1–9.2)
Hip abduction strength	IG	2.5 ± 1.0 (2.1–2.9)	–	2.7 ± 0.8 (2.4–3.0)	3.1 ± 0.9§ (2.7–3.4)
(kgf/kg)	CG	2.1 ± 0.9 (1.8–2.5)	–	2.4 ± 0.7 (2.1–2.7)	2.7 ± 1.0 (2.3–3.1)
Knee extensor strength	IG	4.3 ± 1.3 (3.8–4.8)	3.7 ± 1.0*† (3.3–4.1)	4.4 ± 1.2*‡ (3.9–4.9)	5.2 ± 1.3*§ (4.7–5.8)
(kgf/kg)	CG	4.1 ± 1.6 (3.4–4.7)	3.0 ± 1.0‖ (2.6–3.4)	3.7 ± 1.2¶ (3.2–4.1)	4.5 ± 1.6# (3.8–5.2)
Single-leg stance time	IG	94.2 ± 12.6 (89.0–99.4)	99.0 ± 7.1 (96.1–101.9)	101.4 ± 7.4 (98.3–104.5)	104.8 ± 7.1§ (101.9–107.8)
(sec)	CG	91.8 ± 22.8 (82.4–101.2)	99.4 ± 9.1 (95.7–103.1)	101.0 ± 8.7 (97.4–104.6)	104.0 ± 7.6# (100.9–107.2)
TUG (sec)	IG	10.9 ± 3.2 (9.6–12.3)	9.3 ± 1.9* (8.6–10.1)	8.0 ± 1.4‡ (7.4–8.6)	7.0 ± 1.1§ (6.5–7.4)
	CG	13.2 ± 7.2 (10.3–16.2)	12.0 ± 3.6 (10.5–13.5)	9.7 ± 3.1¶ (8.4–11.0)	8.2 ± 2.2# (7.3–9.1)
Stride length (cm)	IG	60.2 ± 9.8 (56.2–64.3)	58.9 ± 6.4* (56.2–61.5)	64.9 ± 6.5*‡ (62.2–67.6)	68.8 ± 6.8*§ (66.0–71.6)
	CG	53.6 ± 13.7 (48.0–59.3)	51.6 ± 10.4 (47.3–55.9)	57.4 ± 11.6¶ (52.6–62.2)	61.8 ± 10.9# (57.3–66.3)
Walking speed (m/sec)	IG	1.4 ± 0.4 (1.3–1.6)	1.3 ± 0.2* (1.2–1.4)	1.5 ± 0.3*‡ (1.4–1.6)	1.7 ± 0.2*§ (1.6–1.8)
	CG	1.2 ± 0.4 (1.1–1.4)	1.1 ± 0.3 (1.0–1.3)	1.3 ± 0.4¶ (1.1–1.4)	1.5 ± 0.3# (1.3–1.6)
Walking rate (steps/sec)	IG	2.42 ± 0.3 (2.2–2.5)	2.2 ± 0.3 (2.1–2.4)	2.3 ± 0.3 (2.2–2.4)	2.5 ± 0.3§ (2.4–2.6)
	CG	2.3 ± 0.3 (2.1–2.4)	2.1 ± 0.3 (2.0–2.3)	2.2 ± 0.3 (2.2–2.3)	2.4 ± 0.3# (2.3–2.5)

Values are mean ± SD for each variable (95%CI).
IG: Intervention group; CG: Control group.
*Difference between groups at each assessment period using a 2-sample t-tests or Mann–Whitney U test.
†Difference between preoperatively and discharge in the IG group.
‡Difference between discharge and 1 month postoperatively in the IG group.
§Difference between 1 month postoperatively and 3 months postoperatively in the IG group.
‖Difference between preoperatively and discharge in the CG group.
¶Different between discharge and 1 month postoperatively in the CG group.
#Different between 1 month postoperatively and 3 months postoperatively in the CG group.

Table 3. Self-reported outcomes for the intervention and control group in each assessment period

			Preoperatively	Discharge	Postoperatively 1 month	Postoperatively 3 months
HOOS	Pain	IG	53.0 ± 17.3 (45.9–60.1)	74.7 ± 11.7† (69.9–79.5)	85.2 ± 12.4‡ (80.1–90.3)	87.7 ± 14.6 (81.7–93.7)
		CG	51.4 ± 14.4 (45.4–57.4)	77.0 ± 14.9‖ (70.8–83.2)	81.4 ± 16.4 (74.6–88.2)	88.5 ± 12.7 (83.2–93.8)
	Symptom	IG	47.4 ± 21.9 (38.4–56.4)	69.0 ± 15.4† (62.6–75.4)	76.2 ± 14.8‡ (70.1–82.3)	81.8 ± 13.0 (76.4–87.2)
		CG	48.4 ± 18.1 (40.9–55.9)	69.8 ± 17.1‖ (62.7–76.9)	73.6 ± 15.7 (67.1–80.1)	79.2 ± 17.2 (72.1–86.3)
	ADL	IG	53.9 ± 19.8 (45.7–62.0)	73.7 ± 12.8† (68.4–79.0)	83.5 ± 10.3‡ (79.2–87.7)	86.8 ± 10.4 (82.5–91.1)
		CG	49.6 ± 18.5 (42.0–57.2)	71.8 ± 16.8‖ (64.9–78.8)	77.3 ± 14.9 (71.1–83.4)	82.4 ± 13.8 (76.7–88.1)
	Sport/Rec	IG	38.0 ± 20.8* (29.4–46.6)	46.3 ± 25.3 (35.8–56.7)	66.0 ± 19.8‡ (57.8–74.2)	77.0 ± 13.2*§ (71.5–82.5)
		CG	22.8 ± 18.4 (15.2–30.3)	43.8 ± 28.9‖ (31.8–55.7)	53.8 ± 28.1 (42.2–65.3)	62.5 ± 27.5 (51.1–73.9)
	QOL	IG	40.8 ± 18.2 (33.2–48.3)	56.5 ± 18.8† (48.7–64.3)	70.8 ± 16.9‡ (63.8–77.7)	78.3 ± 16.3 (71.5–85.0)
		CG	30.0 ± 13.5 (24.4–35.6)	53.0 ± 24.5‖ (42.9–63.1)	60.8 ± 23.6 (51.0–70.5)	69.3 ± 20.8 (60.7–77.8)
MFES		IG	113.9 ± 23.7 (104.1–123.6)	105.9 ± 31.3 (93.0–118.8)	122.6 ± 27.3*‡ (111.4–133.9)	130.1 ± 17.4 (123.0–137.3)
		CG	98.7 ± 35.9 (83.9–113.5)	88.6 ± 37.8 (73.0–104.2)	109.0 ± 31.0¶ (96.2–121.8)	121.0 ± 24.6 (110.9–131.2)

Values are mean ± SD for each variable (95%CI).
IG: Intervention group; CG: Control group; HOOS: Hip Disability and Osteoarthritis Outcome Score; MFES: Modified fall efficacy scale.
*Difference between groups at each assessment period using a 2-sample t tests or Mann–Whitney U test.
†Difference between preoperatively and discharge in the IG group.
‡Difference between discharge and 1 month postoperatively in the IG group.
§Difference between 1 month postoperatively and 3 months postoperatively in the IG group.
‖Difference between preoperatively and discharge in the CG group.
¶Different between discharge and 1 month postoperatively in the CG group.
Different between 1 month postoperatively and 3 months postoperatively in the CG group.

physical function. Since HOOS did not show a significant difference in the comparison between groups, it is considered that improvement of physical function rather than functional self-efficacy may be related to improvement of MFES score.

We propose that the improvement of pain, knee joint extension muscle strength, and walking ability as a consequence of elliptical trainer contributed to the improvement of fear of falling. Still, it is possible that fall self-efficacy was influenced by various factors as there was no significant difference 3 months postoperatively.

This study has some limitations. All study participants were able to walk preoperatively without a cane, and the effect of elliptical training exercise in those with more severe hip joint disease is unknown. Additionally, the content of conventional physiotherapy in both groups may vary slightly from patient to patient, affecting training effectiveness.

In conclusion, adding exercise on an elliptical trainer to conventional physiotherapy in early postoperative rehabilitation after THA improves the MFES score at 1 month postoperatively as well as knee extensor strength, stride length, and walking speed at 1 and 3 months postoperatively. This suggests that exercise on an elliptical trainer in the early postoperative period following THA contributes to the improvement seen in physical function in the medium to long term as well as a lessening in the patients anxiety of falling.

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The authors declare no funding and conflict of interest.

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