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The Effect of adding Hip Abductor Strengthening to Conventional Rehabilitation on Muscular Strength and Physical Function following Total Knee Replacement

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Objective: This study aimed to investigate the effect of adding hip abductor strengthening to conventional rehabilitation on muscle strength and physical function following total knee replacement (TKR) for knee osteoarthritis.

Design: Randomized controlled trial

Methods: Thirty-five participants were randomly allocated to exercise groups I (n=18) and II (n=17). Group I underwent hip abductor training and conventional rehabilitation for 30 min per day, 5 days per week for 4 weeks. Group II underwent conventional rehabilitation for 30 min per day, 5 days per week for 4 weeks. The participants in both groups also received continuous passive motion therapy for 15 min per day, 5 days per week for 4 weeks. To investigate the effect of the intervention, the Biodex dynamometer was used to measure the peak torque of both knee extensors and hip abductors. This study used the Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS) to assess physical function, as well as the figure-of-8 walk test (F8W) and the stair climb test (SCT).

Results: According to the interventions, exercise groups I and II showed significantly improved muscle strength and KOS-ADLS, F8W, and SCT scores ($p < 0.001$). Compared with that of exercise group II, exercise group I showed significantly improved hip abductor strength ($p < 0.001$) and KOS-ADLS, F8W, and SCT scores ($p < 0.05$).

Conclusions: The results of this study indicate that the combination of hip abductor strengthening and conventional rehabilitation is an effective exercise method to increase hip abductor muscle strength and physical function after TKR.

Key Words: hip joint, gait, knee joint, osteoarthritis, total knee replacement

Introduction

Total knee replacement (TKR) is a safe and generalized surgery for patients with knee osteoarthritis with severe symptoms [1]. However, problems such as subcutaneous tissue, joint capsule, and skin adhesions may occur after TKR [2]. In particular, approximately 62% of the muscle strength of the quadriceps muscle is lost after surgery, and the activities of daily living are limited due to weakened muscle strength [3]. Among these limitations are typical movements,such aswalking and climbing and descending the stairs [4]. Previous studies have revealed a correlation between knee extensors and physical function post-TKR [5,6]. Therefore, the conventional rehabilitation program recommended for patients post-TKR has focused on the improvement of physiological parts such as joint range of motion and functional parts such as walking and climbing/descending the stairs through strengthening of the knee extensors [7].

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However, in addition to the knee extensor, weakness of the hip abductor muscle and mechanical damage to the joint are common in patients with knee osteoarthritis [8]. The hip abductor muscle plays an important role in providing trunk stability and controlling extremity movement during functional tasks [9]. The weakened hip abductor muscle reduces the stability of the hip joint, causing imbalance during weight-bearing and loosening of the connective tissue around the knee joint, accelerating osteoarthritis [10]. Hinman et al. [11] reported that weakening of the hip abductor muscle causes both overactivity and shortening of the iliotibial band and tensor fasciae latae, thereby causing knee osteoarthritis due to the lack of lateral stability of the knee joint. Thus, it is important to evaluate hip abductor strength because the abductor muscle is the key to reducing pain and improving physical function in patients with knee osteoarthritis [12].

Piva et al. [13] reported that hip abductor muscle strength greatly contributed to physical function than that of knee extensor muscle strength in patients who underwent TKR for knee osteoarthritis. Thus, the contribution of the hip abductor muscle to functional limitation is more relevant than that of the knee extensor muscle, and increased abductor muscle strength improves physical function [14,15]. However, few studies have evaluated the effects of hip abductor strengthening on post-TKR rehabilitation.

Therefore, this study aimed to investigate the effects of 4 weeks of a combination of knee extensor and hip abductor strengthening on lower extremity muscle strength and physical function in patients who underwent TKR for osteoarthritis.

Methods

Participants

A total of 40 participants were recruited for this study. Participants were inpatients who underwent TKR for knee osteoarthritis between June and September 2016 in a hospital in Bundang-gu, Gyeonggi-do. The sample size was calculated using G*Power software (version 3.0.1; Franz Faul, University of Kiel, Kiel, Germany). Based on a previous study, the effect size, power, and alpha error were set to 0.84, 0.8, and 0.05, respectively, and the calculated total sample size was 38 [16].

The inclusion criteria wereas follows: (1) patients who did not undergo any surgery on the knee before TKR, (2) those who did not have neurological or muscular damage to the lower extremities, (3) those aged 45–75 years, and (4) those with visual analog scale ≥25 mm for knee pain before surgery.

Patients with the following conditions were excluded from the study: (1) history of knee joint surgery within 6 months, (2) receiving nonpharmacological treatment, (3) spine disease, and (4) rheumatoid arthritis.

This study was approved by the Bioethics Committee of Shamyook University Center (approval no. 2-1040781-AB-N-01-2016036HR). The study participants understood the purpose of the study and voluntarily agreed to participate. Written informed consent was obtained from all participants.

Procedures

All participants were randomly divided into two groups—20 people in exercise group I (conventional rehabilitation with hip abductor exercise) and 20 people in exercise group II (conventional rehabilitation)—using an Excel random number table after performing a pretest. After group assignment, two people from exercise group I and three people from group II dropped out due to early discharge. Finally, there were 18 participants in exercise group I and 17 in exercise group II.

Both groups performed each exercise program for 30 min a day, 5 days per week for 4 weeks, and continuous passive motion (CPM) as general physical therapy for an additional 15 min a day, 5 days per week for 4 weeks. The lower extremity muscle peak torque was measured using a dynamometer [17], whose function was measured using the Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS), figure-of-8 walk test (F8W), and stair climb test (SCT).

Intervention

The two types of hip abductor exercises were selected based on previous studies [18, 19]:

(1) Side-lying hip abduction: Participants took a side-lying position with the affected knee on top. During side-lying, the participants' hip joints

were slightly extended through the midline. Then, the lower knee was flexed to balance in the side-lying position, and the upper knee was extended. Both knees were wrapped with an elastic band to provide resistance during hip abductor exercises. The participants then abducted the hip joint at 45° without external rotation [19] (Figure 1).

(2) Standing hip abduction: The participants stood upright with a fixed pole positioned next to the healthy knee joint. One side of the elastic band was wrapped around a fixed pole, and the other side was wrapped around the ankle of the affected knee joint, and the hip joint was abducted up to 45° without external rotation and maintained for 2 s [19] (Figure 2).

The intervention was performed 10 times daily per set for three sets (1-min rest between sets), 5 days per week for 4 weeks. A yellow elastic band (THERA-BAND, Hygenic Corp., USA) with the lowest resistance was used in elderly patients. The bands were used to increase the resistance strength [18].

Conventional rehabilitation after TKR includes ankle pumps, straight leg raises, short-arc knee extension, and seated single-leg knee extension [20]. (1) Ankle pumps are performed through repeated maximum dorsiflexion of the ankle for 10 s and plantarflexion for a maximum of 10 s (Figure 3). (2) Straight leg raiseis an exercise in which the operated leg is lifted while maintaining maximum extension (Figure 4). (3) Short-arc knee extension contracts the knee extensor muscle of the operated leg and presses the knee toward the bed for 5 s. At this time, the knee is extended as much as possible (Figure 5). (4) Seated single-leg knee extension extends the operated knee as much as possible while sitting in a chair (Figure 6).

CPM is a general physical therapy used to improve the mobility of the operated knee joint, and in this study, it was performed for 15 min a day [21].

Each exercise included three sets of 10 repetitions and was performed 5 days per week. In exercise group II, conventional exercise for the knee joint was performed with five sets of 10 repetitions to match the total amount of exercise as that of exercise group I.

Figure 1. Side-lying hip abduction

Figure 2. Standing hip abduction

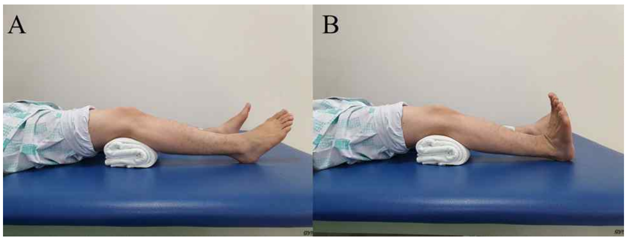

Figure 3. Ankle pump

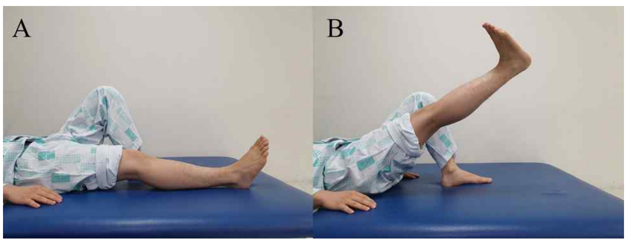

Figure 4. Straight leg raise

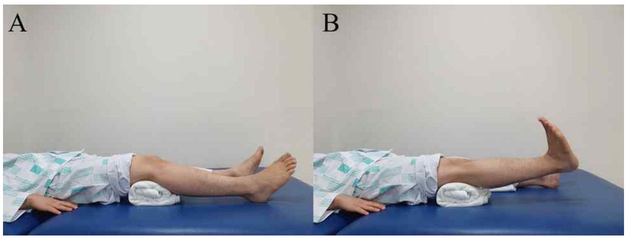

Figure 5. Short-arc knee extension

Figure 6. Seated single-leg knee extension

Outcome measure

To measure lower extremity muscle strength using a Biodex dynamometer (Biodex System 3 PRO, Biodex Medical Systems Inc., USA), a control strip was fixed on the chest, abdomen, and thigh. The measurement method was accomplished following the Biodex system operation manual. To measure the strength of the knee extensor, a strap was tied at a point 1 cm above the ankle joint, and the maximum knee extension was measured. To measure the strength of the hip abductor, the pelvis and lateral epicondyle of the femur were fixed with a strap in a standing position. Following the measurement ofmaximal contraction for five times, with a rest period of 2 min between measurements,the average value was analyzed. The angular velocity during contraction was set to 60/s, and the angle was set to 10–90°.

The KOS-ADLS considers the patient's knee symptoms and conditions. Knee symptoms included general items of daily living ability (six items). To assess the knee condition, a 14-item scale was used to evaluate the effect of specific functional tasks on performance ability (eight items). Questionnaires were prepared before and 4 weeks after exercise. The total score was divided by 70 and then multiplied by 100 to give an overall percentage rating [22].

The F8W was performed to measure the time and number of steps required to walk around two cones spaced 1.5-m apart in a figure-of-8 shape. Hess et al. [23] evaluated the walking ability in elderly individuals. This test assessed the turning task of walking, including curves in the clockwise, counterclockwise, and linear directions. The average execution time and number of steps were measured in two runs after one exercise.

The SCT assesses lower extremity function by measuring the time required to ascend and descend the stairs. The number of stairs depends on the individual situation and is performed using handles. The test starts by supporting two feet on the floor and asking the participants to ascend as safely and quickly as possible and then return. The time elapsed from starting until the second foot touched the starting point was measured [24].

Statistical analysis

Data were analyzed using SPSS (version 19.0, SPSS Inc., USA), and Shapiro–Wilk tests were used to test the normality of the general participant characteristics. Independent t-tests and chi-square tests were used to test the homogeneity between groups. Changes in dependent variables before and after exercise were analyzed using paired t-tests, whereas independent t-tests were used to compare the effects between groups. *P*-values <0.05 were considered statistically significant.

Results

Data from 35 participants were analyzed. General participant characteristics are shown in Table 1.

Knee extensor strength was significantly improved after exercise in both groups ($p<0.001$). However, no significant differences were observed between groups. Hip abductor strength was significantly improved after exercise in both groups ($p<0.001$). A significant improvement in group I was found compared to that in group II ($p<0.001$) (Table 2).

Both groups showed significant improvement after exercise in KOS-ADLS, F8W, and SCT scores ($p<0.001$).

Table 1. General participant characteristics (N=35)

	Exercise group I (n=18)	Exercise group II (n=17)
Sex (male/female)	3/15	2/15
Operation side (right/left)	9/9	10/7
Age (year)	65.50 (5.20)	64.82 (5.33)
Height (cm)	156.44 (4.85)	158.65 (3.97)
Weight (kg)	62.56 (6.67)	63.82 (5.55)
BMI	25.55 (2.34)	25.35 (1.84)
Lower extremity length (cm)	81.70 (3.45)	83.05 (3.24)

Values are presented as number or mean (standard deviation).
BMI: body mass index.

Table 2. Comparisons of muscle strength and function (N=35)

	Exercise group I (n=18)		Exercise group II (n=17)	
	Pretest	Posttest	Pretest	Posttest
Quadriceps (Nm)	55.01 (9.44)	65.74 (9.45)***	53.53 (11.11)	63.89 (8.68)***
Hip abductor (Nm)	53.13 (10.55)	64.67 (10.08)***	50.71 (11.60)	53.62 (11.34)***†††
KOS-ADLS (%)	51.61 (7.50)	71.89 (8.38)***	51.12 (8.60)	68.65 (8.80)***†
F8WT (s)	10.89 (2.01)	9.01 (1.00)***	11.52 (2.14)	10.42 (0.52)***†
F8WS (n)	23.17 (2.96)	20.83 (2.33)***	23.00 (2.83)	21.29 (2.44)***†
SCT (s)	21.85 (4.36)	17.10 (4.36)***	20.87 (2.74)	16.92 (2.05)***†

Values are presented as mean (standard deviation).
KOS-ADLS: knee outcome survey of the activities of daily living scale, F8WT: figure-of-8 walk time test, F8WS: figure-of-8 walk step test, SCT: stair climbing test.
Between the group († p<0.05, †† p<0.01, ††† p<0.001), within the group (* p<0.05, ** p<0.01, *** p<0.001)

Compared to that in exercise group II, exercise group I showed significant improvement in KOS-ADLS, F8W, and SCT scores ($p<0.05$) (Table 2).

Discussion

This study evaluated the effect of 4 weeks of adding hip abductor strengthening to conventional rehabilitation on lower extremity muscle strength and physical function in patients who underwent TKR. The results showed that this exercise program significantly improved hip abductor muscle strength and physical function.

In the present study, the strength of the lower extremities improved significantly ($p<0.001$) in both exercise groups, whereas exercise group I showed significantly improved hip abductor strength compared to that in exercise group II ($p<0.001$). Bade and Stevens-Lapsley [20] reported a significant improvement in the quadriceps strength of patients who underwent TKR through a total of 25 knee joint strengthening exercises for 12 weeks. Sled et al. [25] reported that hip abductor muscle strength was significantly improved in the experimental group comprising of 80 patients with knee arthritis who underwent a hip abductor program along with general rehabilitation training for 8 weeks compared to that in the control group who received only general rehabilitation training. In this study, as in previous studies, it is thought that the program with the addition of hip abductor strengthening exercise directly affected the hip abductor compared to that in the general knee rehabilitation program.

In this study, both groups showed significant changes in KOS-ADLS scores, which measured physical function ($p<0.001$). After exercise, group I showed a significant improvement in KOS-ADL scores compared to that in group II ($p < 0.05$). A previous study reported a significant correlation between hip abductor strength, knee joint pain, and physical function in 25 patients with knee osteoarthritis [26]. Moreover, the hip abductor affects the contralateral pelvic drop and hip adduction angle and contributes to lateral stability in activities of daily living, such as walking [26, 27]. Similarly, in this study, it is thought that improvement in hip abductor strength may have had an effect on knee symptoms and activities of daily living.

In this study, both exercise groups showed significant improvement in F8W after exercise ($p < 0.001$). A significant improvement was found in group I compared to that in group II ($p < 0.05$). Hess et al. [23] reported that it was possible to determine the hesitancyof a participant when turning a corner by measuring the number of steps as well as the walking speed through the F8W. In previous studies, not only the weakening of quadriceps in patients after TKR, but also the "stiff-knee pattern" appeared due to abnormal muscle activation during gait as well as a decrease in stride length during gait [3,28]. Conversely, Iijima et al. [29] reported that the turning task during gait was related to the hip abductor and that the strengthening of the hip abductor is considered a modifiable risk factor for gait function, such as turning movement. Moreover, Piva et al. [13] reported that F8W was highly correlated with the muscle strength of the hip abduction muscle than that of the quadriceps muscle. Therefore, in this study, it was considered that hip abductor strength training along with conventional rehabilitation would improve gait function through improvement of the hip abductor muscle compared to that of conventional rehabilitation alone.

Both groups in this study showed significantly decreased SCT times ($p < 0.05$). A previous study reported that functional performance, including stair climbing after TKR, was highly correlated with the quadriceps [30]. In this study, both groups showed significant improvement because the participants inboth groups underwent a conventional rehabilitation program, including knee extensor strengthening. However, Schache et al. [16] reported significantly decreased SCT times after the application of strengthening exercises of the hip joint for 42 weeks in patients who underwent TKR. In this study as well, a significant improvement in SCT was found in group I, where hip abductor strengthening was performed along with conventional rehabilitation, compared to that in group II, where only conventional rehabilitation was performed, which is similar to a previous study.

This study has some limitations.It is difficult to generalize due to the small number of participants as well as to determine the long-term effect of the intervention because follow-up after 4 weeks of exercise was not performed. Therefore, in a follow-up study, a clear mechanism for improving physical function should be identified through a long-term exercise plan of >8 weeks and physiological evaluation of the whole body, including the lower extremities, in patients who underwent TKR.

The present study aimed to improve the outcomes of patients with TKR and evaluate better rehabilitation programs. The results of this study showed that the combination of hip abductor strengthening and conventional rehabilitation significantly increased hip abductor strength and physical function. Therefore, adding hip abductor strengthening to conventional rehabilitation can be suggested as a treatment method to improve abductor muscle strength, daily living ability and function after TKR.

Conflict of Interest

The authors have no competing financial interests or personal relationships to declare that could influence the work reported in this paper.

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