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The Effect of Sling Exercise on Muscular Strength and Range of Motion in Female Patients who Received Total Knee Replacement

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슬링 운동이 무릎관절 전치환술을 시행한 여성 환자의 근력과 관절가동범위에 미치는 영향

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Abstract The purpose of study was to compare the effectiveness of sling exercise on the muscle strength and range of motion in female patients who received a total knee replacement. The participants were allocated randomly into 2 groups: sling exercise group (n=15) and control group (n=15). The subjects were evaluated using the Biodex system for the muscle strength test and a goniometer for the range of motion test. The data was analyzed using a paired t-test and independent t-test to determine the statistical significance. As a result, the sling exercise group before and after intervention showed a statistical significance difference in the flexion angle, quadriceps femoris, and hamstring muscle strength. The control group before and after the intervention revealed a statistically significant increase in the flexion & extension angle, quadriceps femoris, and hamstring muscle strength. Muscle strength test and flexion range of motion test in the sling exercise group showed statistical significance differences compared to the control group ($p<.05$). Therefore, the sling exercise group has a positive influence on the muscle strength and ROM in patients with a total knee replacement.

요 약 본 연구의 목적은 무릎관절 전치환술을 시행한 여성 환자에게 슬링 운동을 적용하여 무릎관절의 근력과 관절가동범위에 미치는 영향을 비교하기 위해 실시하였다. 참여자는 2그룹 나누어 슬링 운동군 15명, 대조군 15명으로 무작위로 배정하였다. 대상자들은 근력 검사를 위해 Biodex system를, 관절가동범위 검사를 위해 각도기를 사용하여 평가하였다. 데이터의 분석은 통계적 유의 수준을 결정하기 위해서 대응표본 t-검정과 독립 t-검정을 이용하였다. 본 연구의 결과 슬링 운동군은 중재 전후 굽힘 각, 넙다리네갈래근, 뒤넙다리근 근력이 통계학적으로 유의한 증가를 보였고, 대조군은 중재 전후 굽힘 각, 폄 각, 넙다리네갈래근, 뒤넙다리근 근력이 통계학적으로 유의한 증가를 보였다. 무릎관절 근력과 굴곡 관절 가동범위는 슬링 운동군이 대조군에 비해 통계학적으로 유의하게 증가하였다. 슬링 운동법이 무릎관절 전치환술 환자의 근력과 관절 가동범위에서 긍정적인 영향이 있음을 알 수 있었다.

Key Words : Muscular Strength, Range of Motion, Sling Exercise, Total Knee Replacement

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1. Introduction

Osteoarthritis is one of the most common chronic diseases, accounting for the largest percentage of muscular skeletal diseases [1]. Although it may occur in all types of joints, the most frequent area is the knee joint [2]. In addition to pain, osteoarthritis can lead to physical disability and lower quality of life [3]. Thus, most people with severe knee osteo- arthritis undergo total knee replacement surgery [4]. Implanting an artificial knee joint decreases the driving force when moving forward and causes mechanical stress [5], leading to biomechanical changes in the knee joint [6].

Exercises for patients who undergo total knee replacement surgery are expected to offer the following benefits: recovery of range of motion (ROM), reduction of pain, recovery of muscular strength, and prevention of cardiac arrhythmia and thrombosis [7]. Even if the patient's ROM is improved after surgery, lower muscular strength and functional issues remain. Therefore, exercise treatment with physical therapy intervention is thought to be key to recovery after surgery[8]. Although total knee replacement surgery alleviates the knee pain [9], declines in muscular strength due to the incision of the quadriceps femoris muscle can cause severe pain. Thus, exercises to reduce pain and to strengthen the quadriceps femoris muscles during walking are necessary [10].

Previous study emphasized that early muscle strength in TKA and had various strengthening exercises for knee joint. This study was used alteration of axis for training the body which did not tried with sling in existing method. The sling exercise, induced dynamic movement was more effective in muscle strength and ROM than static and persistent exercise [11].

And has advantage of antigravity exercise which can attain aquatic exercise therapy, mobility, stretching, sensory-motor training, stability of muscle, muscle strength, improving endurance, and relaxation [12]. Sling exercise had been applied to lower back pain for middle aged females [13], scoliosis [14], neck pain [15], and chronic stroke patients [16] but few study applied sling exercise for TKR. Therefore, this study aimed to identify the effects of sling exercise group (SEG) on the knee strength and ROM of patients following total knee replacement surgery.

2. Methods

2.1 Subjects

This study was conducted with 30 patients aged 55 to 75 years who underwent total knee replacement surgery at G Hospital in U City from August 16 to December 15, 2013. Those who participated in the study explained the objectives and methods to the patients, and the study was conducted to people agreed to be selected. A coin was tossed to randomly assign 15 patients to the control group (CG) and another 15 to the sling exercise group (SEG), depending on heads or tails of the coin. Total knee replacement surgery patients with fractures of the knee or those with neurological damage due to rheumatoid arthritis or a spinal disorder were excluded from the experiment. There were no significant differences between the two groups with respect to general characteristics, and they satisfied homoscedasticity and normality assumptions ($p>.05$)[Table 1].

2.2 Research Design

Two weeks after the surgery, the CG (control group) engaged in exercises three times a week for six weeks using a TENS (transcutaneous electrical nerve stimulation) 15 minutes, CPM(continuous passive motion) 20 minutes, cold pack 15 minutes for 50 minutes a day, and the SEG engaged in joint mobilization to improve their ROM and strength exercises for muscular strength and endurance training for 50 minutes a day, three times a week for six weeks. To determine the subject's muscular strength, quadriceps muscle and hamstring muscle strength tests were conducted with the subject's knee joint at an

angle of 45 degrees during isometric contraction. To determine the subject's ROM, a total knee flexion and extension test was conducted using a joint angle indicator (Goniometer 662M4, Orthesen Orthosis, Germany). The strength test and the ROM test were conducted two weeks after the total knee replacement surgery, and the ROM and the muscle strength tests were performed six weeks after the surgery.

2.3 Exercise program

The program consists of warm-up exercise, the main exercise, and warm-down exercise. The warm-up and cool-down exercises involved stretching and self joint mobilization before and after the main exercise.

Subjects trained for quadriceps femoris, hamstring, gluteus maximus, erector spine, adductor with sling of 3 times a week which strength muscle without risk and chronic fatigue [17]. According to exercise prescription principle for progressive resistance, the exercise program was set with individually modified, intensity was set with rating perceived exertion. Exercise program was set as 10 seconds for maintain posture, 10 seconds for resting time between exercise set, 60 seconds for movement resting time [Table 2][Fig. 1].

(a) Knee extension

(b) Hip extension

(c) Hip adduction

(d) Cross bridge

(e) Sling leg press

[Fig. 1] Sling exercise

2.4 Experimental tools and instruments

2.4.1 Muscular strength test

The warm-up exercise was conducted before measurement using a strength measuring device (Biodex System Ⅲ, USA). Each subject was seated on the Biodex testing board with their knee motion axis matching the motion axis of the machine, and their torso, waist, and ankles were fixed using straps. To prevent the weight of the subject's pelvic limb from affecting the peak torque angle of the knee joint, the gravity effect torque was measured and input in the computer [18].

In the test protocol, the joint angle was revised and complemented due to ROM limitations and pain of the patients to conduct an isometric strength testing on quadriceps muscle and hamstring muscle at a knee flexion angle of 45 degrees. The muscle contraction time was 6 seconds, and the measurement was done three times after a 5-second break.

2.4.2 Range of motion (ROM) test

The ROM test is intended to manually measure the knee flexion and extension range. The control group and the sling exercise group were informed of accurate test positions, and clothing and jewelry that could affect the measurement were removed.

Range of motion was measured with a joint protractor as described by Beaupré et al [19] while the subjects voluntarily maximized their total knee flexion and extension in a supine position. The axis of the joint protractor was fixed to the lateral tibia and the knee joint, and the fixed arm was placed along the centerline of the subject's thigh. The Biodex arm was placed along the lateral centerline of the lower leg toward the lateral malleolus. The average value of the angles measured three times by the same tester was used. The reliability and the validity of the knee joint angle measurement have been verified by Gogia et al [20] and Rothstein et al [21].

2.5 Data processing

The data obtained were statistically processed using SPSS 20.0 for Windows, and the average of each group and the standard deviation of all the variables were calculated through descriptive statistics. Differences in the knee strength and the ROM of each group before and after the exercises were verified through a paired t-test. The differences in the knee strength and the ROM between the two groups were analyzed with an independent t-test. The significance level of statistical verification was set at 0.05.

3. Results

3.1 General characteristics of subjects

The participants were divided randomly as sling exercise group (n=15), control group (n=15). The general characteristics of the research subjects are shown in [Table 1].

3.2 Results of flexion and extension angle of the sling exercise and control groups before and after the exercise

The changes in the flexion and the extension angle of the sling exercise and control groups before and after the exercise are shown in [Table 3]. There were statistically significant increase in the sling exercise group's flexion angle and the control group's flexion and extension angle ($p<.05$). However, there were no statistically significant differences in the extension angle of the sling exercise group ($p>.05$).

3.3 Results of muscular strength in the sling exercise and control groups before and after the exercise.

The changes in the quadriceps muscle and hamstring muscle strength in the sling exercise and control group before and after the exercises are shown in [Table 4]. There were statistically significant increase in the quadriceps muscle strength and the hamstring muscle strength of both groups after the exercise ($p<.05$).

3.4 Results of ROM and muscular strength after exercise between the groups

The changes in the quadriceps muscle and hamstring muscle strength between the two groups are shown in [Table 5]. There were no statistically significant differences between the groups before the exercise in any of the variables measured ($p>.05$), but there were significant differences in the flexion ROM between the two groups after the exercise ($p<.05$). However, there were no significant differences in the extension ROM ($p>.05$). There were statistically significant increase in the quadriceps muscle and hamstring muscle strength ($p<.05$).

[Table 1] Baseline characteristics of subjects

	SEG	CG	t	p
Gender	Female : 15	Female :15		
Age(yr)	67.42±5.78	65.50±4.10	0.937	.359
Height(cm)	156.75±4.47	157.17±3.33	-0.725	.476
Weight(Kg)	61.42±2.50	62.25±1.36	-1.014	.325
BMI(Kg/m²)	25.49±1.89	25.16±1.24	0.516	.611

M±SD: Mean±standard deviation
SEG: Sling Exercise Group, CG: Control Group

[Table 2] Exercise program

Level	Item	Muscle	Intensity	Time
Warm up	Self stretching	Hamstring, Calf, TFL, Gluteus maximus, adductor	30sec/2set	5min
	Mobilization	Flexion & extension	1min/5set	5min
Main training	Knee extension	Quadriceps femoris	12-15RM/3set (1~2weeks)	30min
	Hip extension	Hamstring & gluteus maximus		
	Hip adduction	Adductor	10-12RM/3set (3~4weeks)	
	Cross bridge	Erector spine, gluteus medius		
	Sling leg press	Quadriceps & hamstring	8-10RM/3set (5~6weeks)	
Cool down	Stretching	Hamstring, Calf, TFL, Gluteus maximus, adductor	10sec/2set	5min
	Mobilization	Flexion & extension	1min/5set	5min

TFL: Tensor Fasciae Latea

[Table 3] Comparison of pre-test and post-test for flexion and extension angle (unit: °)

Category	Group	Period	M±SD	t	p
Flexion	SEG	Pre	68.75±12.64	-13.72	.000
		Post	110.42±11.77		
	CG	Pre	70.83±8.75	-7.19	.000
		Post	99.33±13.20		
Extension	SEG	Pre	-7.00±4.90	-2.96	.130
		Post	-3.25±2.42		
	CG	Pre	-9.00±5.74	-3.33	.000
		Post	-5.08±4.08		

$p<.05$

[Table 4] Comparison of pre-test and post-test for muscular strength (unit: %)

Category	Group	Period	M±SD	t	p
Quadriceps	SEG	Pre	38.52±17.50	-5.89	.000
		Post	68.08±19.85		
	CG	Pre	28.52±14.91	-5.44	.000
		Post	39.37±20.65		
Hamstring	SEG	Pre	30.65±15.39	-6.33	.000
		Post	47.74±13.30		
	CG	Pre	25.08±8.41	-5.14	.000
		Post	28.30±9.51		

$p<.05$

[Table 5] Comparison of muscular strength and ROM between the groups

Category	Group	M±SD	t	p
Flexion	SEG	110.42±11.77	2.17	.041
	CG	99.33±13.21		
Extension	SEG	-3.25±2.42	1.34	.194
	CG	-5.08±4.08		
Quadriceps	SEG	68.08±19.85	3.47	.000
	CG	39.37±20.65		
Hamstring	SEG	47.74±13.30	4.12	.000
	CG	28.30±9.51		

$p<.05$

4. Discussion

Total knee replacement surgery led to positive outcomes by alleviating the knee pain of most patients and restoring knee functions [9]. The goal of managing patients who undergo total knee replacement surgery is to prevent complications and help them return to their daily routines as soon as possible. Therefore, the core components of post- operative management should be recovery of muscle strength and knee ROM and alleviation of pain and anxiety [22].

In the current study, the subjects were divided into an sling exercise group and a control group who received treatment three times a week for six weeks after total knee replacement surgery. In effectiveness of exercise program for TKR, Strength of knee extensor was significantly increased in isometric with theraband [23], lower extremity strength was significantly difference in 8 weeks aqua complex exercise [24], and home rehabilitation program in TKA also reduced pain and increased the active ROM and strengthening lower extremity [25]. In sling exercise, lower back muscle which not for knee joint was significantly increased with 12 weeks training for middle aged females [13], researched trunk muscle 18.3% flexors, 28.0% extensor strength were increased. Thus previous studies were not for knee joint but sling exercise showed improvement of muscle strength.

This study showed that the variation of muscle strength after TKA had significantly difference both groups ($p<.05$), quadriceps and hamstring strength were greatly improved in sling exercise group. This solved muscle strength which osteoarthritis reduced strength through sling exercise.

In research of ROM after TKA, Chung [26] reported that lower extremity strength exercise program was induced quickly the timing of raised involved leg and attained the goal ROM, Shin [27] showed that there

was significantly effective in ROM after rehabilitation program, Han [28] tried muscle strength and found ROM was increased and reduced stiffness in osteoarthritis. Same as previous study, this study also showed that both knee flexion and extension were significantly increased in sling exercise group($p<.05$), but knee flexion was only significantly increased in control group ($p<.05$). This results were suggested that sling exercise group and CPM for control group were effective positively.

In terms of the limitation of this study, except experimental program, it did not control physical activities, and also did not control physiological and psychological factors either. In addition, the research findings cannot be generalized because the subjects were limited to patients who underwent total joint arthroplasty at G Hospital in U City. Therefore, studies incorporating a variety of exercise therapies with more participants are necessary.

5. Conclusion

This study intended to identify the impact of sling exercise and control groups by applying them to two different groups who underwent total knee replacement surgery. In terms of ROM, there were statistically significant differences in the flexion of the a SEG and in the flexion and the extension of the CG ($p<.05$), whereas there were no statistically significant differences in the extension of the SEG ($p>.05$). When the two groups were compared, there were significant differences in the flexion ($p<.05$). In terms of changes in the muscle strength within each group after the total knee replacement surgery, both groups showed significant differences ($p<.05$), and there were significant differences between the two groups ($p<.05$).

The results suggest that SEG has a more positive impact on knee muscle strength and ROM after total knee replacement surgery. Therefore, SEG can help patients return to their daily routines as soon as possible by quickly restoring their knee ROM and strength after total knee replacement surgery.

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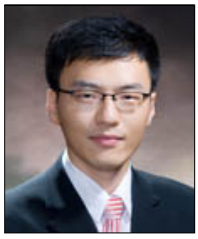

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