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Effects of the Active Static Stretching and Eccentric Exercise of Hamstring Muscles on Flexibility, Strength, and Agility Performance

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Abstract

Purpose : The hamstring is a group of three muscles, biceps femoris, semitendinosus, and semimembranosus, placed behind the thigh. The hamstring is one of the most commonly injured muscles and usually occurs during high-speed, high-intensity exercise. The purpose of this study was to investigate the effect of static stretching and eccentric exercise of hamstrings on flexibility, strength, and functional performance.

Methods : This study was conducted on 28 healthy adults. Subjects were divided into a static stretching group (n=15) and an eccentric exercise group (n=13). Subjects measured hamstring flexibility (active knee extension test), hamstring strength (concentric and eccentric peak torque), and functional performance (triple hop for distance and modified 20 m sprint). The intervention was conducted three times a week for six weeks. To compare the difference between values before and after the intervention, paired t-test was used, and an independent t-test was used to compare between groups.

Results : In both groups, the active knee extension test, concentric peak torque, triple hop test, and 20 m sprint significantly increased after the intervention compared to before the intervention ($p<.05$). However, no significant difference was found in eccentric peak torque after intervention in both groups ($p>.05$). No significant difference was found between the two groups in the effect on the variables ($p>.05$).

Conclusion : Both interventions were found to be effective for flexibility, concentric strength, and functional performance. Eccentric exercise and static stretching are recommended to improve the flexibility and functional performance of the hamstring. This study's results will be considered essential data on the effectiveness of static stretching and eccentric exercise.

Key Words : eccentric exercise, flexibility, hamstring, static stretching, strength

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Ⅰ. Introduction

In modern society, a sedentary lifestyle often causes hamstring shortening. Reduced hamstring flexibility can lead to physical disabilities such as back pain, poor posture, and gait disorder (Kisner et al., 2020). It is also one of the leading causes of hamstring injuries (Ruslan et al., 2014). The hamstring is a group of three muscles, biceps femoris, semitendinosus, and semimembranosus, placed behind the thigh (Woodley & Storey, 2013). The hamstring is one of the most commonly injured muscles and usually occurs during high-speed, high-intensity exercise (Kisner et al., 2020).

The definition of flexibility is the ability to stretch a muscle and move a joint or a series of joints over their original range of motion (Weppler & Magnusson, 2010). Flexibility is the main factor that keeps the appropriate posture of the body, increases exercise capability, and prevents possible injuries from exercise or daily life (Abdel-Aziem et al., 2018). Decreased flexibility harms the activity of muscles and damages the musculoskeletal system (Weppler & Magnusson, 2010). The advantages of high flexibility are reducing the possibility of injuries, relaxation of pain, and better performance ability in exercises (Abdel-Aziem et al., 2018). Thus, it is essential to improve one's flexibility to prevent muscle stiffness and injuries (Espejo-Antunez et al., 2016). One of the main interventions to improve flexibility is stretching (Espejo-Antunez et al., 2016).

Stretching is an action that stretches soft tissues such as muscles and tendons and has been reported to have various benefits, including increased flexibility, improved performance, faster running, injury prevention, and recovery from injury (Medeiros et al., 2016). Static stretching is one of the most widely used stretching methods as a way to stretch and maintain a muscle to its maximum length (Medeiros et al., 2016). It is often used because it is time-efficient and has a positive effect on flexibility with few side effects (Medeiros et al., 2016).

Nordic hamstring exercise or straight leg raise exercise using the Thera-band can be used for the eccentric exercise of the hamstring (Petersen et al., 2011). Eccentric hamstring exercises have been reported to reduce the risk of hamstring injuries (Delvaux et al., 2020). Eccentric muscular exercises not only increase flexibility but also improve muscle strength (O'Sullivan et al., 2012). Therefore, eccentric exercises are usually used to improve the range of motion around the joints and the overall performance (Gerard et al., 2020).

The functional performance cannot detect abnormalities in the body, but it is helpful to evaluate physical function (Dean, 2018). Moreover, functional performance tests can measure the performances without any devices (Dean, 2018). Functional performance tests are used in various methods, such as hopping tests and modified 20 m sprints (Dean, 2018). Recently, the importance of such functional performance has been emphasized. Regardless of the increased range of motion, there is no practical evidence that increased flexibility leads to increased performance (Gerard et al., 2020).

If eccentric exercise improves flexibility to the same level as static stretching and can additionally induce improvement in muscle strength and functional performance, it can be considered a more effective intervention for hamstrings. However, although the effectiveness of each intervention has been reported, studies comparing the two interventions are rare. Therefore, the purpose of this study was to investigate the effect of static stretching and eccentric exercise of hamstrings on flexibility, strength, and functional performance.

Ⅱ. Methods

1. Subjects

On the basis of reported data on differences in flexibility according to static stretching and eccentric exercise (Nelson, 2006), a power analysis (α =.05, power (1-β -error)=.95, effect size=1.22) was performed using statistical software (G-Power 3.1.9.7, Düsseldorf, Germany) required sample size of n=10 in each group. To account for dropouts and increase power, we recruited 28 participants. This study was conducted on 28 healthy young adults. Before the experiment, the aims and procedures of this study were sufficiently explained to the participants. All subjects consented to participate in this study with written informed consent. The exclusion criteria included previous musculoskeletal surgery and injury, cardiovascular disorders, or neurologic disorders. This study was approved by Sunmoon University Institutional Review Board (SM-202104-043-2).

2. Experimental procedures

1) Procedure

Subjects were randomly assigned to a static stretching group and an eccentric exercise group. This study was a pre-post control group design. Pre- and post-measurements were carried out in the same way. Interventions were performed three times a week for 6 weeks.

2) Measurements

(1) Active knee extension test

In the supine position, the subject flexed the hip and knee by 90 degrees, and the ankle was placed in a neutral position (Fig 1) (Nelson, 2006). The lateral epicondyle of the femur was established as the axis. Subjects were asked to extend the knee joint. The femur's greater trochanter and lateral malleolus were marked, and the knee joint angle was measured using an electric goniometer (Baseline, Digital Absolute Axis Goniometer 12-1027, USA).

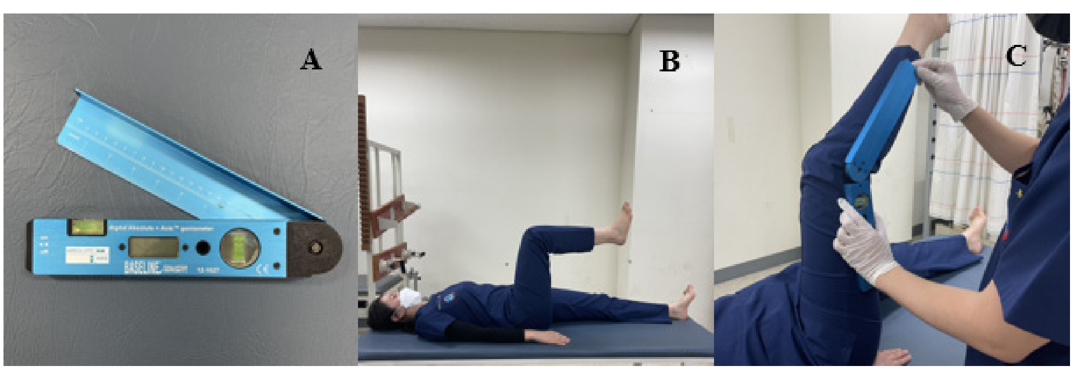

Fig 1. Active knee extension test, SLR 90/90 test
A; digital goniometer, B; supine and hip 90 ° knee 90 ° , C; AKET

(2) Hamstring strength

An isokinetic dynamometer (HUMAC Norm; CSMI Solutions, Stoughton, Massachusetts) was used to measure the knee flexion strength (Fig 2) (Barbosa et al., 2020). In the starting position, the hip is flexed 85 degrees. The trunk and thighs were fixed using straps. Subjects performed 3 submaximal contractions as a practice trial. It was repeated 3 times at an angular velocity of 60/s. Concentric and eccentric strength were measured, and 3 min rest was given between the two strength tests. The average of the three measured peak torque values (Nm) was used for the analysis.

Fig 2. Peak torque (isokinetic dynamometer)
A; isokinetic dynamometer, B; starting position, C; leg starting position

(3) Triple hop test

Subjects put their dominant foot's thumb toe at the starting line (Fig 3). When they are ready, they jump forward three steps, landing with their dominant foot. During the test, the movement of arms was allowed, and subjects were equipped with athletic shoes. After the three jumps, the distance between the starting line and the heel of the dominant feet was measured. Practice sessions were limited to three to prevent exhaustion and adaptation to the test. When the subject lost their balance and landed with the other foot, the test was done again, and three tests were conducted, with the highest value as the measuring data. After triple hop for the distance test, two minutes of resting time was given before moving on to a modified 20m sprint (Barbosa et al., 2020).

Figure 3. Triple hop for distance
A; 10 m tapeline, B; starting position, C; triple hop

(4) Modified 20 m sprint

A turning point was placed at 10m after the starting line (Fig 4). Subjects started 0.5 m before the starting line and were instructed to start accelerating with only the non-dominant leg. Subjects ran as fast as they could, running a total of 20 m back and forth from the starting and the turning point. After two practice sessions and with some adaptations, the test was conducted with two trials. Between trials, 2 minutes of resting time was given. The faster record was recorded (Barbosa et al., 2020).

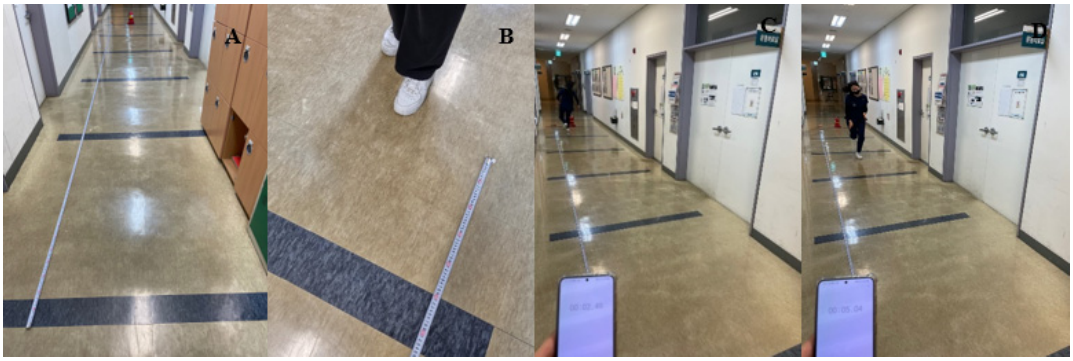

Figure 4. Modified 20 m sprint

3) Intervention

(1) Static stretching

Subjects were asked to place their legs on a table at knee height while maintaining ankle dorsiflexion and knee extension. After that, hold the lumbar in a neutral position and flex the torso until mild pain in the hamstring is felt. This posture was sustained for 30 seconds and repeated three times per week for six weeks (Fig 5).

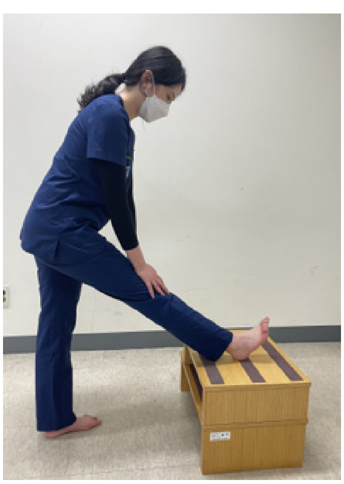

Fig 5. Static stretching

(2) Eccentric exercise

In a supine position, the subject wrapped his heel with the Thera band and held the end of the Thera band with both hands (Fig 6). In the starting position, the knee joint was in full extension. Using a Thera band, the hip joint was flexed while resisting by eccentrically contracting the hamstring over the entire range of the hip joint. Subjects were asked to apply sufficient force to feel a contraction of the hamstrings. The subject was told to put enough force to overcome eccentric force from the hamstring and used about 5 seconds to finish the entire hip flexion range. After, softly it can be extended. Without any rest, six tests were conducted, and a total of 30 seconds were used.

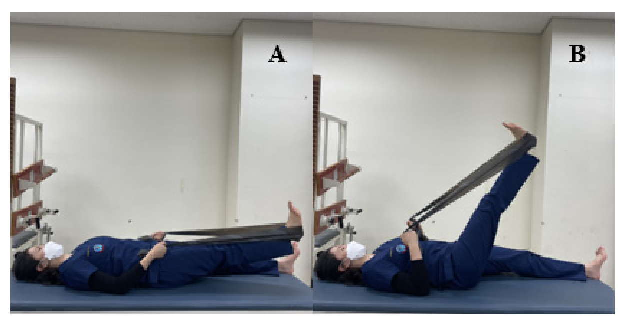

Fig 6. Eccentric exercise
A; starting position, B; full hip flexion

3. Statistical Analysis

This experiment used descriptive statistics to compute mean and standard deviation values from the variables. All statistical analyses used SPSS/PC ver.20.0 for Windows (SPSS INC, Chicago, IL), and the normality was tested using Shapiro-Wilk. To compare the difference between values before and after the intervention, paired t-test was used, and an independent sample t-test was used to compare between groups. A significance level of α =.05 was used.

Ⅲ. Results

The general characteristics of the participants are shown in Table 1. No differences were found between the two groups at baseline. Table 2 shows a pre- and post-comparison of static stretching and eccentric exercises for the AKET, strength, triple hop test, and 20 m sprint. In both groups, AKET, concentric peak torque, triple hop test, and 20 m sprint significantly increased after the intervention compared to before the intervention ($p<.05$). However, no significant difference was found in eccentric peak torque after intervention in both groups ($p>.05$). No significant difference was found between the two groups in the effect on the variables ($p>.05$, Table 3).

Table 1. General characteristics of subjects (n=28)

Characteristics	Static stretching group	Eccentric exercise group	*p*
Sex (male / female)	8 / 7	7 / 6	
Age (years)	20.26±1.48	20.46±2.06	.775
Height (cm)	168.80±9.03	168.70±6.76	.977
Weight (kg)	63.90±11.42	64.60±9.72	.867

Mean±standard deviation

Table 2. Comparison of AKET, strength, triple hop test, and 20 m sprint before and after intervention (n=28)

	Static stretching group (n=15)			Eccentric exercise group (n=13)		
	Pre	Post	*p*	Pre	Post	*p*
AKET (Degree)	143.63±14.55	155.62±11.97	.001	146.87±8.31	154.33±6.00	.010
Concentric peak torque (Nm)	75.80±36.74	82.33±27.02	.236	84.76±30.28	100.23±28.55	.020
Eccentric peak torque (Nm)	98.93±27.48	97.53±32.03	.663	114.38±22.01	116.92±29.76	.702
Triple hop test (cm)	430.20±129.67	455.40±111.28	.008	485.92±86.32	527.92±93.04	.003
20 m sprint test (s)	6.29±.97	6.00±.78	.040	5.56±.48	5.14±.38	.002

Mean±standard deviation, AKET: active knee extenstion test

Table 3. Comparison of changes in AKET, strength, triple hop test, and 20 m sprint between groups (n=28)

	Static stretching group (n=15)	Eccentric exercise group (n=13)	t	*p*
AKET (Degree)	11.99±10.89	7.45±8.80	-1.20	.241
Concentric peak torque (Nm)	6.53±20.43	15.46±20.73	1.14	.263
Eccentric peak torque (Nm)	-1.40±12.16	2.53±23.37	.57	.573
Triple hop test (cm)	25.2±31.7	42.0±41.7	1.20	.238
20m sprint test (s)	-.28±.49	-.41±.38	-.71	.479

Mean±standard deviation, AKET; active knee extenstion test

Ⅳ. Discussion

This study investigated the effects of static stretching and eccentric exercise on flexibility, muscle strength, and functional performance in healthy adults. Both interventions were found to be effective for flexibility, concentric strength, and functional performance.

AKET can provide an accurate result of the hamstring flexibility because the trunk flexor muscle cannot interfere (Weppler & Magnusson, 2010; Abdel-Aziem et al., 2018). Bandy divided high school students into two groups, the eccentric exercise group and the static stretching group, and observed the change in the hamstring flexibility (Bandy et al., 1997). As a result, it showed the eccentric exercise group increasing 12.79 ° and the static stretching group by 12.05 °. Moreover, Nelson observed the immediate effect of eccentric exercise and static stretching (Nelson, 2006). From AKET, the first group had a 9.48 ° increase, and the second one had a 5.5 ° increase. Both groups had a significant increase compared to the control group, but there was no significant difference observable (Nelson, 2006). In this study, flexibility increased after the intervention in both groups, which can be assumed as a result of increasing the length of the entire muscle as the muscle spindle adapts and stretches, as suggested in the previous study (Nelson & Bandy, 2004).

20 m sprint and triple hop was used to measure functional performance. The functional performance test is practical when measuring the body's functions and provides reliable data output when using a standard clinical protocol; Caffrey said it is a method of measuring functional performance without a bias (Dean, 2018). In the case of static stretching, there is consistent evidence that it decreases functional performance. However, Barbosa insisted that intentional delay after the static stretching can relieve the negative effect; such static stretching increases performance in the long term (Barbosa et al., 2020). Unick commented that the intentional delay is the resting period of about four minutes after the stretching (Unick et al., 2005). This study takes account of the intentional delay of sufficient resting time, and, therefore, there is a significant difference visible in static stretching. During Kinikli's study, both eccentric and concentric exercises show an increase in functional performance (Kinikli et al., 2014). Eccentric exercise through all range motion theoretically improves not only the hamstring flexibility but also the functionality of the limbs. The results of this study also support the results of previous studies.

Barbosa insisted that eccentric force is one of the main components of exercise execution, and eccentric exercise is considered necessary for recovery from hamstring injuries or training (Barbosa et al., 2020). A lower level of eccentric force is one of the main factors of hamstring injury (Barbosa et al., 2020). Hamstring injuries usually occur in the muscles' high eccentric activity, and the probability of injury increases as the eccentric force decreases (Barbosa et al., 2020). Several studies have shown that rapid static stretching can cause a temporary decrease in maximum contraction and power production. A hypothesis to explain force loss assumes a decrease in tendon stiffness due to less optimal operation points and mechanical changes in the muscle-tendon unit. However, changes in torque-angle relationships can also be affected by neuro and intrinsic muscle characteristics such as calcium release. Another hypothesis is that the decrease in contractile force is partly due to the decrease in motor commands from the central nervous system (Barbosa et al., 2020). For this reason, it is considered that there was no significant difference between the eccentric and concentric peak torque testing results of static stretching.

Parr commented that eccentric-only isotonic exercise results in muscle fiber micro traumatic and DOMS, resulting in strength loss (Xie et al., 2018). As a result, it is considered that there was no significant difference in eccentric peak torque. There was a study on isokinetic peak torque, but the number of comparative studies on the concentric peak torque of Eccentric exercise is insignificant.

However, in this study, the concentric peak torque increase of the eccentric exercise was observable. Eccentric exercise using the Thera band activates muscles as much as possible and dramatically affects exercise at various lower body angles. In addition, since the subject is directly moving their body, the ability to respond to the resistance accounting for the extension of the band and one's body resistance is also increased. Therefore, it is considered that the concentric peak torque showed a significant increase in eccentric exercise.

This study has several limitations. First, the subjects are limited to healthy men and women in their 20s, it is difficult to generalize to patients or all age groups. Second, the values cannot be generalized due to the small number of subjects. It is believed that further study is needed to determine whether eccentric training and active static stretching are effective in the flexibility of other muscles such as the quadriceps femoris, and triceps in addition to the hamstring.

Ⅴ. Conclusion

Eccentric exercise and static stretching are recommended to improve flexibility and functional performance of the hamstring, and eccentric exercise is more effective in improving concentric peak torque. This study's results will be considered essential data on the effectiveness of static stretching and eccentric exercise.

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