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Research Article

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Immediate Effect of Intermittent Versus Continuous Hamstring Static Stretching on the Muscle Tone and Range of Motion

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| Abstract |

PURPOSE: This study examined which stretching exercise had the most positive effect on increasing the range of motion (ROM) of the knee joint in healthy people and whether there was a difference between continuous stretching and intermittent stretching.

METHODS: This study included 30 healthy university students from OOO University. The subjects were asked to sit on a mat and perform hamstring-stretching exercise during which the ROM and muscle tone were measured with pre and post-tests. Each subject was assigned randomly to a continuous stretching group (stretching without relaxation time group, n=10, G1) or intermittent stretching group (stretching with 10s relaxing time group, n=10, G2; and stretching with 20s relaxing time group, n=10, G3). The participants conducted hamstring stretching exercises with a sit-and-reach box at three different rest times (0s, 10s, and 20s). Subsequently, they underwent passive knee extension (PKE) tests, in which the ROM of the knee joint was measured with a goniometer, and the muscle tone was evaluated using a MyotonPro.

RESULTS: Significant differences in muscle tone, stiffness, and ROM were observed between pre-test and post-test in each groups ($p<.05$). Although the post hoc tests indicated no significant differences in muscle tone and ROM between the continuous stretching group and intermittent stretching group ($p>.05$), the rate of change of the ROM showed that the intermittent stretching group developed more effective maintenance of the hamstring flexibility.

CONCLUSION: No significant differences in the muscle tone of the hamstring and ROM of the knee joint were observed according to the hamstring stretching exercises with three different rest times. On the other hand, the rate of change of the ROM showed that intermittent stretching maintained the hamstring flexibility more effectively.

Key Words: Muscle stretching exercise, Muscle tone, Range of motion

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Ⅰ. Introduction

Appropriate flexibility is necessary to improve the level of human activity. Hamstring flexibility is an important part of good health and is considered a sign of good health and quality of life [1]. Flexibility training is incorporated into training programs because achieving flexibility can reduce the risk of injury, alleviate pain, and improve athletic performance [2,3]. Most experts consider the loss of flexibility to decrease the muscle performance. Moreover, a lack of flexibility has been shown to reduce muscle ability, limit the body from moving, and induce muscle injury [4].

As reported previously [5,6], hamstring muscles are important contributors to the control of human movement. Moreover, hamstring flexibility is important to general health and physical fitness because hamstring muscles have a wide range of activities, ranging from jumping to forward ending during sitting or standing, running, and many postural control actions [7,8]. Therefore, the hamstrings play important roles in effective walking and running, and stretching has significant effects on increased the hamstring flexibility [9]. A lack of flexibility or poor flexibility of the hamstring reduces the performance of various daily living activities by patients, and reduced hamstring flexibility increases the risk of damage to the musculoskeletal system [10]. Accordingly, hamstring flexibility is an important matter in the context of physiotherapy.

Meroni [11] and Kang [12] reported that hamstring flexibility is improved by stretching. Stretching is one of the most popular methods to increase muscle flexibility [13]. because it increases the hamstring flexibility immediately and improves the hip joint proprioception [14]. Static stretching, which has been used to increase flexibility [15], is one method of rehabilitation and an integral component of sports-conditioning programs. Two common forms of static stretching exercise include continuous and intermittent modalities [16-18]. A comparison of different periods of stretching exercise (15s, 30s, 60s, 90s, and 120s) revealed significant increases in the ROM without any differences between them [19]. The change in flexibility appeared to be dependent on the duration and frequency of stretching [20]. Each type of static stretching exercise can have a range of effects, and different results are obtained when diverse stretching programs are applied to the same muscle group.

The passive knee extension (PKE) test is used frequently to stretch hamstrings and assess the hamstring flexibility [21,22]. Previous research has demonstrated that active knee extension (AKE) only measures the 'initial hamstring length', and PKE measures the 'maximal hamstring length' [23]. Muscle tone characterizes the tone (intrinsic tension on the cellular level) of a muscle in its passive or resting state without voluntary contraction. An abnormally high muscle tone is a serious and sometimes insurmountable challenge [24], and causes faster muscle fatigue and slows muscle recovery.

Many studies have investigated the increased flexibility of hamstrings after stretching, but few studies have examined the effects of varying the rest times between stretches on the hamstring flexibility. Moreover, few studies have compared the effects of continuous stretching and intermittent stretching in the same stretching exercise for the same exercise time. Moreover, almost no studies have examined the relationship between muscle tone and the ROM based on the PKE test during stretching to have positive effects on the hamstring flexibility.

Therefore, this study compared the effects of muscle tone and the ROM of the knee joints on the hamstring flexibility when different frequencies of the total time were used in conjunction with the same stretching exercise. Furthermore, the effects of continuous and intermittent stretching were compared.

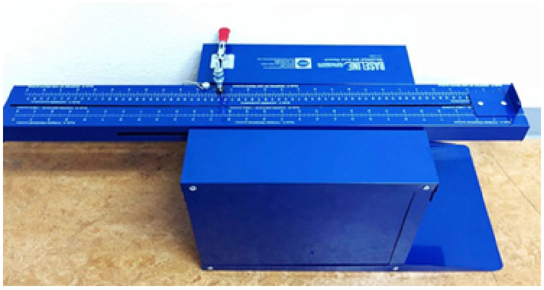

Fig. 1. Hamstring stretching exercise using the Sit-and-Reach box.

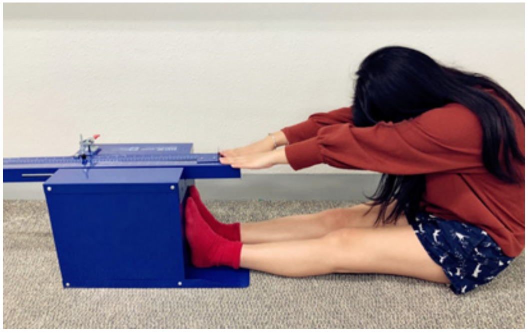

Fig. 2. Experimental posture.

Ⅱ. Methods

1. Participant

This study examined 30 healthy university students from OOO University, Korea. The inclusion criteria were as follows: non-professional sports students, no pain or any significant history of the pathology of the hip, knee, or thigh within the last six months, and less than 70° passive knee extension (PKE) test. The exclusion criteria were as follows: 1) prior history of musculoskeletal injury or surgery of the lower limbs; 2) aching pain in the lower limbs and lumbar spine; and 3) hamstring injury (hamstring muscle strain, hamstring spasm, or tendinopathies).

2. Ethics

Before the start of this study, all subjects were explained the study content and signed an informed consent form. The ethical committee of Daegu University approved this study (IRB number 1040621-201811-HR-045-02).

3. Study Protocol

This study employed a pre-test and a post-test design, and all assessments were performed on the left leg. For randomization, sealed envelopes were prepared in advance and marked inside with G1, G2, or G3. The three groups were one continuous stretching group (stretching without relaxation time group, n=10, G1) and two intermittent stretching group (stretching with 10s relaxing time group, n=10, G2; and stretching with 20s relaxing time group, n=10, G3). A third party unaware of the nature of the study performed the randomization procedure.

All participants performed a hamstring stretching exercise with a sit-and-reach device and the evaluations in one day. The program for each group was conducted in the following three steps. In the first step, a pre-test, five minutes sitting was performed to relax the hamstring muscle group followed by the PKE test to measure the ROM using a goniometer. Subsequently, the biceps femoris and semitendinosus were measured using a MyotonPro device. In the second step, during the 60-second hamstring stretching exercise with a sit-and-reach box (Fig. 1), static stretching was performed with each prescriptive relaxation time (no relaxation, 10s relaxation, and 20 s relaxation) (Fig. 2). G1 performed static stretching continuously for 60 s. G2 performed static stretching for 30 s, rested for 10 s, and performed the exercise again for 30 s. G3 performed static stretching for 20 s, rested for 10s, stretched for 20 s, rested for 10 s, and finally stretched for 20 s. In the third step, the post-test, after 60 s of hamstring stretching exercise, a PKE test was conducted immediately to measure the ROM, and the muscle tone was evaluated with the MyotonPRO. All outcome measures obtained before and after treatment were assessed using a physical therapist, who was blinded to the treatment allocations. A physical therapist, who was not involved in subject assessment, performed the intervention was performed by

Table 1. General Characteristics of the Subjects (n=30)

	G1 (n=10)	G2 (n=10)	G3(n=10)
Age (year)	22.5±1.35$^{\alpha}$	23.3±.82	23.4±1.26
Height (cm)	164.5±6.84	169.0±9.46	166.9±10.57
Weight (kg)	55.9±7.23	63.8±16.4	58.4±11.17

$^{\alpha}$Mean±SD
G1: hamstring stretching without relaxing time
G2: hamstring stretching with 10s relaxing time
G3: hamstring stretching with 20s relaxing time

Physical therapist, who was not involved in subject assessment. The physical therapist was instructed not to communicate the study goals or treatments with the subjects.

Kay et al. [25] reported that 30s and 45s of stretching is safe and effective during pre-exercise, but more than 60s of stretching can cause impaired muscle strength. Therefore, 60s was chosen as the exercise time for this study.

4. Measurements

The muscle tone, stiffness, and ROM were measured in this study. Each subject underwent each measurement in a random order. All measurements were performed before and after the intervention. The pre-test and post-test measurements were as follows: 1) ROM of the knee joint in the PKE test, and 2) muscle tone measurements of the semitendinosus and biceps femoris before hamstring stretching. The post-test was performed after the intervention to compare the immediate effects.

The muscle tone of the biceps femoris and semitendinosus on the affected side was measured using MyotonPRO. MyotonPRO (Myoton AS, Tallinn, Estonia) was used to quantify the mechanical muscle properties objectively, and the measurement method was based on a registration of the oscillation acceleration signals and subsequent computing of the parameters reflecting the tone, dynamic stiffness, elasticity, and mechanical stress relaxation time. The principle behind the myotonometer was to apply multiple short impulses over the muscle bulk via the testing probe to generate oscillations in the muscle fibers [25]. Willy [27] reported a good to excellent confidence level of knee ROM measurements made using a goniometer.

5. Statistical analysis

SPSS version 21.0 (IBM Corporation, Armonk, NY, USA) was used for statistical analysis. The Shapiro-Wilk test was used to determine the normality of the distribution; all data were distributed normally. One-way ANOVA was used to compare the changes in the muscle tone and the ROM according to hamstring stretching with different rest times (no relaxation, 10s relaxation, and 20s relaxation) in each subject, while a paired t-test was used to compare the intra-group differences. LSD was used for the post-hoc tests. The null hypothesis of no difference was rejected if p-values were <.05.

Ⅲ. Results

The results revealed significant differences in muscle tone and stiffness between the pre-test and post-test in each groups (p<.05)(Table 2-5). The results revealed significant differences in the ROM of the knee joint between the pre-test and post-test in each group (p<.05)(Table 6).

Table 2. Comparison of the Pre and Post Muscle Tone of the Biceps Femoris (unit: Hz)

Group	Pre	Post	*t*	*p*
G1	14.867±1.5[α]	14.102±1.343	3.403	.00*
G2	15.746±1.92	14.021±1.384	5.361	.00*
G3	15.265±1.63	13.692±1.195	5.891	.00*
F	.68	.28		
p	.52	.76		

[α]Mean±SD,
*p<.05

Table 3. Comparison of the Pre and Post Stiffness of the Biceps Femoris (unit: N/m)

Group	Pre	Post	*t*	*p*
G1	252.002±41.812[α]	232.04±38.062	2.621	.03*
G2	280.821±42.542	240.313±42.524	6.512	.00*
G3	265.202±34.841	222.921±40.174	6.323	.00*
F	1.312	.474		
p	.29	.63		

[α]Mean±SD,
*p<.05

Table 4. Comparison of the Pre and Post Muscle Tone of the Semitendinosus (unit: Hz)

Group	Pre	Post	*t*	*p*
G1	14.351±1.454[α]	13.735±1.157	2.934	.02*
G2	14.782±1.235	13.824±1.192	6.373	.00*
G3	14.342±1.056	13.293±.952	9.312	.00*
F	.407	.662		
p	.67	.52		

[α]Mean±SD,
*p<.05

Ⅳ. Discussion

A 60-second stretching exercise program was conducted in this study. Many studies of hamstring flexibility have shown that 30s~60s of stretching is sufficient to increase the ROM [20]. Although the post hoc test showed that the intervention did not produce a difference in muscle tone, hamstring stiffness, and knee joint ROM among G1, G2, and G3, the rate of change of the ROM was approximately 16.34% higher in G3 than in G1, whereas it increased by approximately 1.05% relative to G2. Gomes [28] reported that intermittent stretching did not reduce muscle endurance. A previous study reported that intermittent stretching could improve the muscular condition by maintaining the stiffness of the muscle-tendon units, thereby improving the stretching flexibility.

Table 5. Comparison of the Pre and Post Stiffness of the Semitendinosus (unit: N/m)

Group	Pre	Post	*t*	*p*
G1	229.023±41.843$^{\alpha}$	210.704±35.541	2.631	.03*
G2	259.812±36.991	227.032±31.671	5.432	.00*
G3	264.532±31.801	215.503±31.962	5.973	.00*
F	1.732	.644		
p	.20	.54		

$^{\alpha}$Mean±SD,
$^{*}p<.05$

Table 6. Comparison of the Pre and Post ROM of the PKE Test (unit: °)

Group	Pre	Post	*t*	*p*
G1	52.702±8.153$^{\alpha}$	62.702±8.273	-10.111	.00*
G2	46.802±9.212	61.343±9.035	-17.446	.00*
G3	43.612±7.011	61.512±7.381	-9.892	.00*
F	3.191	.091		
p	.06	.92		

$^{\alpha}$Mean±SD,
$^{*}p<.05$

Moreover, intermittent stretching may help prevent the ROM from decreasing by keeping muscles in a plastic elongation state [29]. Donti [30] reported that intermittent stretching was more effective than continuous stretching for both long-term and acute ROM enhancement in preadolescent female athletes. This explains the results of the study, in which intermittent stretching increased the ROM significantly, leading to the maintenance of hamstring flexibility.

Compared to the method used in the present study, Sato [31] reported that an analysis of the changes in hamstring muscle tone and stiffness is a simple and effective way to evaluate stretching for hamstring flexibility. Neumann [32] suggested that increases in muscle length during stretching affect the force-length relationship. When evaluating the principal muscle and stiffness outcome-interpretation criteria, higher F and S values are associated with greater tension and stiffness of the soft tissue structure, respectively, at the dedicated body measurement points (MPs) [33]. The human resting muscle tone is the passive tension and resistance to stretching that continue postural stability in balanced positions [34]. The muscle tone and properties could be used to evaluate the effects of pathology [35,36] and sports-related injury [37].

From a clinical and practical perspective, although post hoc tests showed that the intervention did not produce a difference in the hamstring muscle tone, and the stiffness or ROM of the knee joint between continuous stretching and intermittent stretching, the rate of change of the ROM showed that intermittent stretching was more effective for maintaining the hamstring flexibility. Gajdosik [38] reported that patients might be more likely to participate in a stretching program with less time than continuous stretching, but is still as effective as continuous stretching and may lead to a lower risk of re-injury. Intermittent stretching may be a particularly good choice for older patients [39].

This study had several limitations. First, this study only investigated individuals. Second, the sample size was small. Third, only the range of motion and the quality of muscles were evaluated. Therefore, there was no functional evaluation of the subjects. Finally, this study could not identify the clinical effect and long term. Given these limitations, additional research, including a follow-up study of the continuous effects and investigations of the clinical effects in patients, is warranted.

Ⅴ. Conclusion

Based on the muscle tone and ROM, a significant difference and instant relief in hamstring flexibility occur after continuous stretching and intermittent stretching, with intermittent stretching having a more positive effect.

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