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Original Article

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Effects of Flossing Band Technique, Static and Dynamic Stretching on Hamstring on Knee Range of Motion, Muscle Activity, and Proprioception

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Purpose: This study aimed to compare the lasting effects of the flossing band technique, dynamic and static stretching on hamstring on range of motion (ROM), muscle activity, and proprioception to identify the most effective pre-exercise method for preventing injuries.
Methods: Thirty participants were randomly assigned to the flossing band (FB), dynamic stretching (DS), and static stretching (SS) groups, with 10 subjects in each. Measurements included muscle activity of the biceps femoris vis surface electromyography, knee ROM and proprioception during active knee extension and flexion using a smart joint goniometer. Assessments were conducted before, immediately after, 15, and 30 minutes after each intervention.
Results: Proprioception showed no significant differences among groups at any time point. Significant differences in knee ROM were observed in the FB group (except between 15 and 30 minutes after), DS group (except between immediately after and 15 minutes after, and between 15 and 30 minutes after), and SS group (except between before and 15 minutes after, and between before and 30 minutes after). Muscle activity in the FB (except between before and 30 minutes after, and between 15 and 30 minutes after) and SS (between before and immediately after, between immediately after and 30 minutes after, and between 15 and 30 minutes after) groups showed significant differences, while the DS group exhibited no significant changes.
Conclusion: Although direct comparisons did not establish superiority, within-group analyses indicated that the flossing band technique exhibited longer-lasting effects than dynamic and static stretching, providing valuable insights for injury prevention program design.

Keywords: Dynamic stretching, Static stretching, Hamstring, Proprioception

INTRODUCTION

The most common injury in sports is a hamstring injury.[1] Specifically, studies have reported a significant correlation between low flexibility of the hamstrings and the occurrence of hamstring muscle strain in soccer players.[2,3] Additionally, the injury rate in individuals with a normal range of motion (ROM) was found to be 12.4% lower than in those with limited ROM due to decreased hamstring muscle flexibility.[4] Stretching is generally known to address limited ROM, thereby reducing the risk of injuries.[5,6]

Moreover, the voodoo flossing band technique presents an alternative method to improve limited ROM.[7] This technique involves tightly wrapping a joint or muscle, applying passive twisting and active movements, and then removing it within 2 minutes.[8] Widely utilized in athletic training and clinical settings, the flossing technique is defined as a joint mobilization technique that integrates and compresses all movable tissues simultaneously.[9,10] This compression facilitates the return of tissues within a joint to their functional position and increases joint lubrication, stimulating the production of synovial fluid.[11]

Furthermore, the compressive force exerted by the flossing technique extends beyond the joints, reaching tissues under the skin. This helps eliminate adhesion between layers, such as the skin and fascia, during passive and active exercises, thereby improving pain, stiffness, and muscle weakness. Mechanoreceptors in the fascia of the treated area respond to the flossing technique, increasing joint ROM.[12] A previous study demonstrated that

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applying the flossing technique to the hamstring significantly increased passive torque and maximal eccentric knee flexion contraction. Additionally, in comparison to dynamic stretching, the flossing technique improved the passive knee extension range by 2.1 times and the maximal eccentric knee extension contraction.[13,14] These findings suggest that the flossing technique on the hamstring muscle might be more beneficial than dynamic stretching in terms of increasing joint ROM and muscle movement, thus aiding in injury prevention. Static stretching is the traditional method of remaining motionless for a period and holding the same movement for about 15 to 60 seconds. Dynamic stretching, on the other hand, involves repeatedly stimulating a specific area with dynamic joint movements. The twisting and pulling motions increase the range of motion of the joint. Stretching is known to help prevent injury by preventing the risk of injury due to muscle shortening and improving chronically stiff range of motion.[15]

This study applies the flossing band technique, dynamic, and static self stretching interventions to the hamstring, the most commonly injured muscle during exercise. The aim is to compare joint ROM, muscle activity, and proprioception, and to examine the lasting effects up to 30 minutes after interventions. The goal is to determine the most suitable pre-exercise method for preventing injuries. This study also seeks to determine the association between stretching and joint range of motion, muscle activation, and proprioception.

METHODS

1. Subjects

The subjects of this study were a total of 30 adults-15 men and 15 women-in their 20s attending D University. They were individuals who had received a comprehensive explanation of the experiment in advance and had given their consent. Subsequently, they were randomly assigned, with

Table 1. General characteristics of subjects (n=30)

	FB (n=10)	DS (n=10)	SS (n=10)	p
Gender (male/female)	5/5	5/5	5/5	
Age (years)	24.3±1.5	22.9±1.2	24.4±1.7	0.100
Height (cm)	167.8±8.8	167.0±5.9	169.5±9.2	0.780
Weight (kg)	65.1±12.1	64.0±11.5	69.4±16.6	0.650

Values are mean±SD. FB: Flossing Band, DS: Dynamic Stretching, SS: Static Stretching.

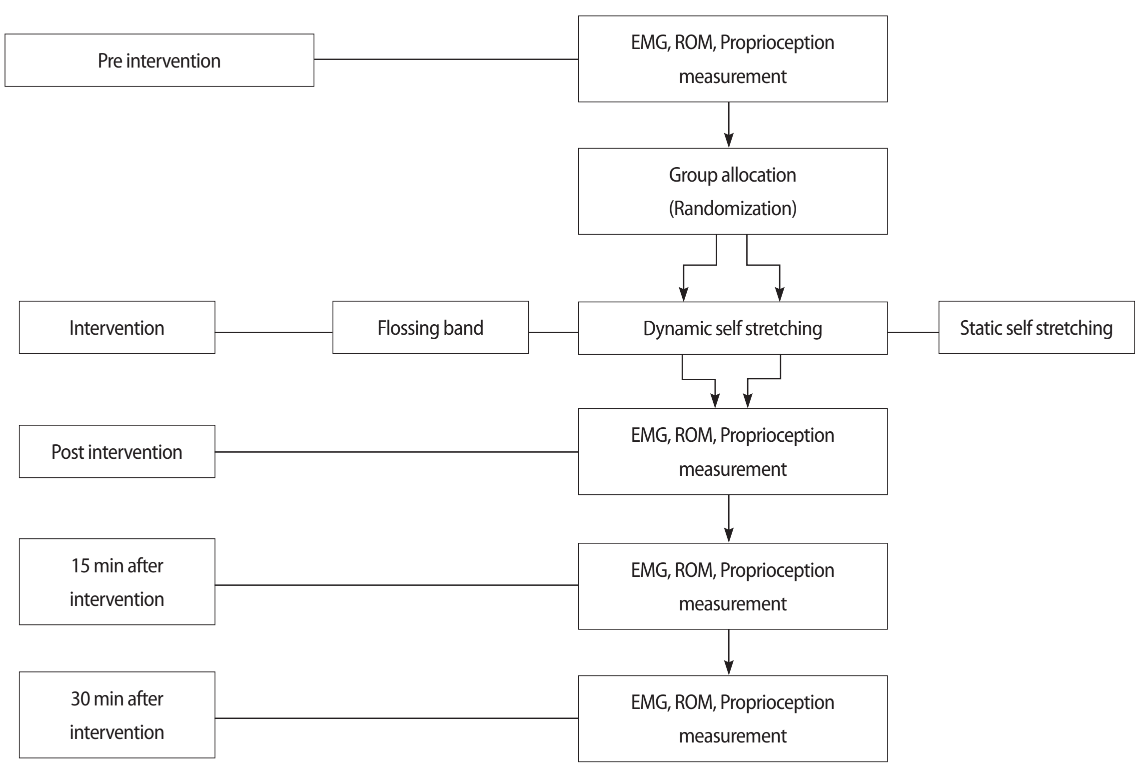

Figure 1. Flow chart

10 participants in each of the flossing band (FB), dynamic stretching (DS), and static stretching (SS) groups.

The criteria for selecting candidates were as follows: 1) absence of vascular abnormalities such as thrombus or hypersensitivity to rubber, and 2) right leg dominance (Table 1). The dominant foot selection criterion was the preference for the right leg when performing kicking movements.[16]

2. Experimental methods

1) Interventions

The subjects for this study were fully informed and consented to participate in the experiment. Each subject was divided into FB, DS, and SS groups using a random sampling method (Figure 1).

(1) FB group

Subjects in the FB group applied a flossing band to their dominant leg and then stood upright against a wall. With the knee joint extended, the hip joint of the leg to which the flossing band was applied was bent 90 degrees with as little sway as possible. Verbal feedback was provided to minimize sway and encourage leg extension (Figure 2).

(2) DS group

Subjects in the DS group stood against the wall with their knees extended. With the knee extended, the hip joint of the dominant leg was bent 90 degrees with as little sway as possible. Verbal feedback was provided to minimize sway and promote leg extension (Figure 2).

(3) SS group

Subjects in the SS group placed their legs on a footstool with their knees extended. While looking straight ahead, the trunk continued to bend without any sway. The height of the footstool was set to hip joint height. Verbal feedback was provided to prevent the subject's trunk from tilting (Figure 2).

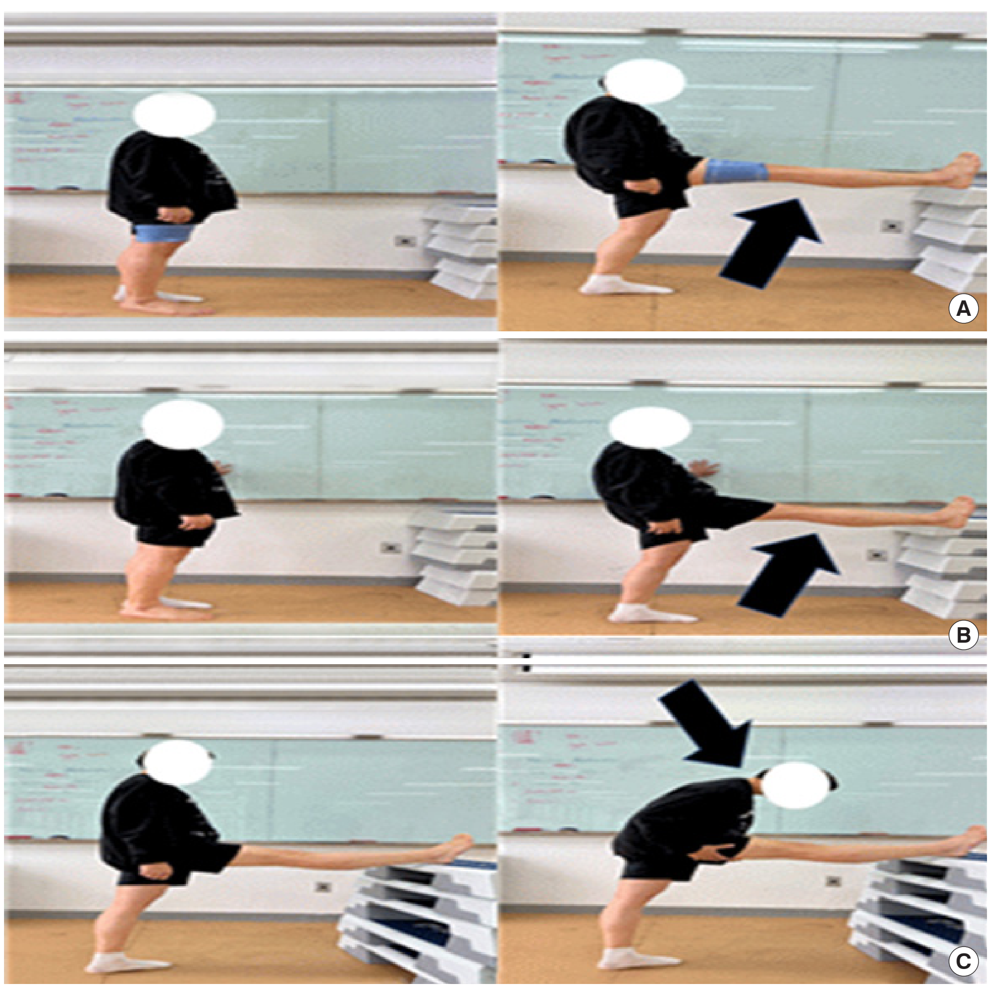

Figure 2. The picture of intervention method for FB, DS, SS. (A) Flossing band, (B) Dynamic stretching, (C) Static stretching.

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2) Measurement

(1) ROM

To measure knee joint ROM, an active knee extension (AKE) test was performed in which the subject maintained the hip joint at 90 degrees while lying down and actively extended the knee. A smartphone joint goniometer (Setsquare, ver 1.7) was used, following a previous study that found no difference in reliability between a regular joint goniometer and a smartphone joint goniometer.[17] The goniometer was fixed parallel to the fibula and measured a total of 5 times, with the average value calculated.

(2) Muscle activity

A WEMG-8 (LAM5308, LAXTHA, USA) was used to measure muscle activity, and the sampling rate for the electromyographic signal was set to 1,024Hz, with notch filters at 60Hz, 120Hz, and 180Hz that could affect the collected data. The electrode pad was placed at the midpoint between the fibular of head and the ischial tuberosity to measure the muscle activity of the biceps femoris.

Maximum voluntary isometric contraction (MVIC) was measured five times for 5 seconds, and bridge exercise was performed to measure the maximum voluntary contraction (MVC). According to previous research demonstrating that compression bridge exercise is more effective than general bridge exercise in increasing hamstring and lower extremity strength, subjects maintained a knee bend of 90 degrees and lifted the buttocks as if pressing with the entire sole of the foot.[18]

(3) Proprioception

To measure proprioception, repositioning error was measured at 30, 60, and 90 degrees of knee flexion while the subject was lying prone. For this purpose, the subject was asked to maintain each angle for 10 seconds, then return to the extended position and find the angle again. The smartphone joint goniometer was fixed parallel to the fibula. After measuring five times, the average value of each error value was calculated. A five-minute break was provided after the first measurement to prevent subjects from accumulating fatigue.

3. Statistical analysis

IBM SPSS ver 19.0 (IBM SPSS Statistics 19.0 Inc., USA) was utilized to compare the mean and standard deviation of the measurement data collected in this study. One-way analysis of variance (ANOVA) was employed to compare the effects among the three groups (FB, DS, and SS) before, immediately after, 15 minutes after, and 30 minutes after the intervention. Additionally, one-way repeated measures ANOVA was applied to examine the lasting effect within each group.

Furthermore, Mauchly's sphericity test was used. In the case of a significant difference in the sphericity test, the Greengouse-Geisser correction was employed for the within-subject effect test. If the sphericity assumption was not violated, the results of the within-subject effect test were reported as sphericity assumed.

Post hoc analysis was conducted through pairwise comparisons using the Least Significant Difference (LSD) method. The level of statistical significance was set at $\alpha = 0.05$.

RESULTS

1. Comparison of proprioception by time point among groups

There was no significant difference in proprioception among the FB, DS,

Table 2. Comparison of proprioception among FB, DS, IS groups (Unit: degree)

		FB	DS	SS	F	p
Pre	30°	4.92±0.80	4.28±0.89	4.68±2.19	0.50	0.610
	60°	5.90±3.80	5.88±2.52	6.26±2.61	0.05	0.950
	90°	6.28±1.68	6.88±4.08	6.36±1.84	0.14	0.870
Post	30°	2.60±1.64	3.00±0.80	2.90±0.95	0.31	0.740
	60°	2.98±1.03	4.40±3.12	5.00±2.08	2.13	0.140
	90°	3.84±2.25	4.76±3.42	4.54±2.00	0.80	0.460
After 15 min	30°	3.72±1.95	3.76±1.66	4.06±1.45	0.12	0.890
	60°	3.68±1.58	4.42±2.03	4.40±1.64	0.57	0.570
	90°	3.36±2.00	4.88±4.59	4.06±2.33	0.57	0.570
After 30 min	30°	2.98±1.56	3.44±1.69	4.46±1.89	2.19	0.130
	60°	4.24±2.27	4.26±2.06	5.10±2.38	0.48	0.630
	90°	3.96±1.70	4.20±3.96	4.58±1.55	0.14	0.870

Values are mean±SD. FB: flossing band, DS: dynamic stretching, SS: static stretching.

Table 3. Comparison of range of motion within groups FB, DS, SS (Unit: degree)

	Pre	Post	After 15 min	After 30 min	F	p
FB	136.32±10.50†,‡,§	149.68±13.98∥,¶	145.72±14.40	146.02±13.65	0.06	<0.001*
DS	133.16±11.04†,‡,§	140.70±10.87¶	138.72±10.25	137.94±9.51	1.19	<0.001*
SS	133.78±12.48†	138.14±12.57∥,¶	136.15±3.85**	133.96±11.91	1.09	0.010*

Values are mean±SD. FB: flossing band, DS: dynamic stretching, SS: static stretching. *p<0.05. †: Significant difference between pre and post, ‡: Significant difference between pre and after 15 min, §: Significant difference between pre and after 30 min, ∥: Significant difference between post and after 15 min, ¶: Significant difference between post and after 30 min, **: Significant difference between after 15 min and after 30 min.

Table 4. Comparison of biceps femoris muscle activity within groups FB, DS, SS (Unit: %MVIC)

	Pre	Post	After 15 min	After 30 min	F	p
FB	28.48±12.52†,‡	43.19±24.21§,∥	40.50±24.06	39.45±23.60	6.24	0.03*
DS	27.05±9.09	25.19±13.39§,∥	23.09±12.64	22.46±12.22	1.32	0.28
SS	27.93±13.72†	31.63±16.88∥	29.17±13.93¶	25.72±13.32	4.34	0.04*

Values are mean±SD. FB: flossing band, DS: dynamic stretching, SS: static stretching. *p<0.05.†: Significant difference between pre and post, ‡: Significant difference between pre and after 15 min, §: Significant difference between post and after 15 min, ∥: Significant difference between post and after 30 min, ¶: Significant difference between after 15 min and after 30 min.

and SS groups before, immediately after, 15 minutes after, and 30 minutes after the intervention at each time point ($p > 0.05$)(Table 2).

2. Comparison of knee joint ROM at each time point within the group

Significant differences were observed in the FB group ($p < 0.05$), except between 15 and 30 minutes after intervention ($p > 0.05$). In the DS group, there were significant differences ($p < 0.05$), except between immediately after and 15 minutes after the intervention, and between 15 and 30 minutes after the intervention ($p > 0.05$). The SS group exhibited significant differences ($p < 0.05$), except between before and 15 minutes after, and between 15 and 30 minutes after the intervention ($p > 0.05$)(Table 3).

3. Comparison of biceps femoris muscle activity at each time point within the group

In the FB group, there were significant differences ($p < 0.05$), except between before and 30minutes after, and between 15 and 30minutes after the intervention ($p > 0.05$). The DS group showed no significant difference ($p > 0.05$). In the SS group, a significant difference was observed between before and immediately after, between immediately after and 30minutes after, and between 15 and 30minutes after intervention ($p < 0.05$)(Table 4).

DISCUSSION

There are various ways to prevent injuries, but one of the most common methods is stretching. According to a previous study by Ekstrand et al.[19], when comparing the stretching group and the non-stretching group, the stretching group showed a 25% reduction in injuries, in other words, stretching before exercise can be effective in preventing injuries.[6] Furthermore, one of the important factors in preventing injuries is proprioception. Proprioception is the body's memory of its position and affects balance. A deficiency in this sense can lead to injury. In this way, injuries can be prevented through stretching by increasing joint ROM and proprioception. Additionally, as a result of comparing dynamic and static stretching, research has reported that dynamic stretching increases joint ROM more than static stretching.[21] The flossing band technique is a new method to increase joint ROM and reduce pain.[13]

In this study, 30 men and women in their 20s were enrolled to determine which of the three intervention methods - flossing band, dynamic self stretching, and static self stretching - improved joint ROM, muscle activity, and proprioception the most and to compare the lasting effect over time. As a result of comparing proprioception among groups at before, immediately after, 15, and 30 minutes after each intervention, no significant differences were found. However, when measuring repositioning error at 90° to determine proprioception, the FB group had the smallest error range compared to the DS and SS groups at all time points, showing that proprioception was maintained for the longest in the FB group. This is consistent with a previous study that compared the flossing band technique with dynamic self stretching and found that joint ROM and muscle torque increased more when using a flossing band than with dynamic self stretching.[14] In addition, according to previous research showing that among the types of stretching, dynamic stretching provides a similar or

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greater rapid increase in flexibility than static stretching, in this study, when comparing the DS group and SS group for the repositioning error by time point at 60°, the DS group showed smaller errors than the SS group.[22] Through this, it was found that proprioception increased in the order of intervention of the FB, DS, and SS methods. This is consistent with previous research showing that both static and dynamic stretching improve knee joint position sense as part of a pre-exercise warm-up procedure.[23] Due to the thixotropic nature of the muscle fuselage, stretching may enhance the proprioceptive input of muscle receptors.[24]

As a result of comparing the difference in AKE ROM between before and 30 minutes after intervention within the group, the FB group showed the greatest increase in ROM, with 9.7 degrees in the FB group, 4.78 degrees in the DS group, and 0.18 degrees in the SS group. Additionally, within the FB group, significant differences were observed between all time points except between 15 and 30 minutes after the intervention, and the FB group showed the longest-lasting effect. In the case of the DS group, there were significant differences between all time points except immediately after and 15 minutes after, and between 15 and 30 minutes after intervention. Through this, it was found that the increased ROM in the FB and DS groups continued 30 minutes after the intervention, while in the SS group, there was a temporary increase in ROM immediately after the intervention, but it returned to the same level as before the intervention 15 minutes later. The effect of the flossing intervention on muscle movement and flexibility results from temporarily impeding the shear force of the fascia and blood flow to the muscle.[10,23] Fascia is composed of multiple layers of fibrous and collagenous connective tissue that surround and infiltrate skeletal muscles, joints, organs, nerves, and blood vessels.[24] Smooth sliding between flowing layers of fascia allows muscles to contract or stretch.[27] Flossing provides strong mechanical pressure on the muscles and covers the entire limb due to close contact with the skin, and the resulting compression of the muscles generates heat by retaining the heat associated with the increase in intramuscular pressure and the resulting muscle contraction, thereby generating heat and reducing fascial viscoelasticity potentially.[28] The resulting heat or mechanical pressure reduces fascial viscoelasticity, making it easier for muscles to stretch. It is thought that flossing increases stretching tolerance by increasing the ROM, such as straight leg raise test and passive knee extension range, compared to static stretching.[29] Another study found that the flossing intervention method was effective in increasing the dorsiflexion ROM of the ankle joint and that this increased the ability to perform single-leg jumps.[23] Through this, a sufficient range of joint motion can be achieved through the flossing band intervention before and after exercise and can help prevent injuries.

Lastly, in comparing the muscle activity of the biceps femoris muscle within the group over time, there were significant increases in all cases in the FB group, except between before and 30 minutes after and between 15 and 30minutes after the intervention. The SS group showed significant increases between before and immediately after, between immediately after and 30minutes after, and between 15 and 30 minutes after intervention. In addition, the muscle activity in the FB group increased immediately after the intervention but decreased when measured 15 and 30 minutes later. However, compared to before the intervention, an increase in muscle activity could still be observed even 30 minutes later. In the DS group, there was no increase in muscle activity and no lasting effect compared to before the intervention. The flossing intervention has the effect of smoothing muscle contraction and increasing muscle contractility by reducing fascial viscoelasticity, which activates metabolic activity while increasing muscle temperature due to increased blood circulation.[30] Additionally, flossing involves contraction of the target muscle under pressure, whereas dynamic stretching involves contraction of the antagonist muscle of the target muscle.[31] This is consistent with the research results showing that the FB group had greater muscle activity and longer-lasting effects than the DS group.

In this study, FB, DS, and SS were applied to the hamstring muscles, and joint ROM, proprioception, and muscle activity were measured and compared before, immediately after, 15, and 30 minutes after the intervention to determine which intervention had a more lasting effect. As a result, the proprioception observed at 30°, 60°, and 90° knee flexion had the smallest repositioning error in the flossing band group, and the effect persisted over time. When comparing joint ROM, it was found that flossing bands and dynamic self stretching had greater lasting effects than static self stretching. Among the three intervention methods, the muscle activity of the biceps femoris was also increased the highest with the flossing band, and static self stretching showed higher muscle activity than dynamic self stretching. However, the flossing group showed the greatest lasting effect.

Therefore, applying a flossing band before exercise appears to be more effective than dynamic or static self stretching for injury prevention and exercise performance. This is expected to provide useful data for designing injury prevention programs before exercise in the future. However, generalization may be limited as this study involved a small number of healthy adults (30 men and women). Additionally, due to the short interval for repeated measurements, it is necessary to investigate longer-lasting effects in future studies.

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