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Original Article

Effects of static and dynamic stretching techniques on muscle function

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Abstract. [Purpose] To examine the effects of a combination of static stretching (SS) and dynamic stretching (DS) on muscle function. [Participants and Methods] There were 32 healthy male participants. The hamstrings were the target muscles. Flexibility was measured using the straight leg raise test and muscle output was measured using a manual muscle force meter. The two measurements were compared before and after stretching, and between the group that first performed SS and the group that first performed DS. [Results] Flexibility improved significantly after stretching compared to the level before stretching when either SS or DS was performed first. However, there were no significant differences in muscle output or in between-group comparisons for any indicator. [Conclusion] There were no differences between the stretching techniques, suggesting that either combination of stretching may improve flexibility but with little effect on muscle output.

Key words: Static stretching, Dynamic stretching, Technique

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INTRODUCTION

In Japan, the importance of static stretching (SS) was recognized with the publication of the book Stretching (1975) by Bob Anderson and became widely accepted by both athletes as well as the general public[1)]. This is due to the fact that high-level training in terms of quality and quantity became common in the 1970s, and sports injuries due to the overuse of muscles and joints were frequent[2)]. Stretching has garnered attention in order to prevent and treat those sports injuries, and stretching has now become a part of life for patients as well as sports enthusiasts. SS as put forth by Anderson is a method of slowly stretching muscles without bouncing and maintaining that body position for a certain amount of time. This contrasts with dynamic stretching (DS), which is a method of using rhythmic movements to stretch muscles via the stretch reflex of the nervous system. Numerous studies of these methods have been conducted thus far[3–15)], and they have found that both methods improve flexibility. SS in particular is considered to be more effective than DS[1)] at improving muscle flexibility, so SS has been effective at improving joint range of motion in the field of medicine. That said, a study has noted that SS sedates the neuromuscular system, which decreases muscle output[16)]. This leads to a decrease in athletic performance, sp there are negative views on incorporating SS in warming up in sports[17)]. In contrast, several studies have reported that DS improves joint range of motion and it increases muscle output as well[10–15)]. This is why DS is used as a form of warming up in sports.

In the field of physical therapy, various stretching techniques are used to improve joint range of motion, and other techniques such as range of motion exercises, joint mobilization, and manipulation are also used to improve joint range of

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motion[18, 19]. Stretching in particular has demonstrated its effectiveness by improving the flexibility of soft tissues such as muscles and tendons[4–10]. In contrast, muscle strengthening exercises performed in the field of physical therapy include methods that induce isometric muscle contraction, resistance exercises using loads, and plyometrics that use a muscle's stretch-shortening cycle[20]. However, these exercises are intended to increase muscle output over the long term and are not expected to immediately increase muscle output. As mentioned earlier, DS has been found to increase muscle output, but this is believed to be due to an increase in muscle temperature, which decreases muscle viscosity and smoothes contraction, and to an increase in the speed of nerve stimulus conduction, which is immediate. The immediate effect of increased muscle output is advantageous in competitive sports, so mainly DS is incorporated in warming up in the field of physical therapy and particularly in the field of sports.

Thus, previous studies have revealed the effects of SS or DS on the body, and both forms are widely used in clinical and sports settings. That said, combining SS and DS has also been proposed[21], such as performing SS as a warm-up followed by DS that takes into account the characteristics of the given sport. Even when DS is combined with SS or their order is reversed, SS does not reduce DS' effectiveness at improving muscle function nor does it produce a synergistic effect, as a study has reported[22]. However, a study reported that sprint times were slower when SS was performed after DS compared to only warming up without stretching[23]. Thus, there is no consensus on the effects of SS and DS combined on athletic performance. To extent known, no studies have examined whether the order in which SS and DS are performed leads to differences in the extent of changes in terms of both joint range of motion and muscle output. Moreover, there are few studies on the combined use of these forms of stretching, so there is ample room for discussion.

Thus, the aim purpose of the current study was to determine the effects of the order of SS and DS on muscle function and to ascertain several aspects of that combination in the area of conditioning.

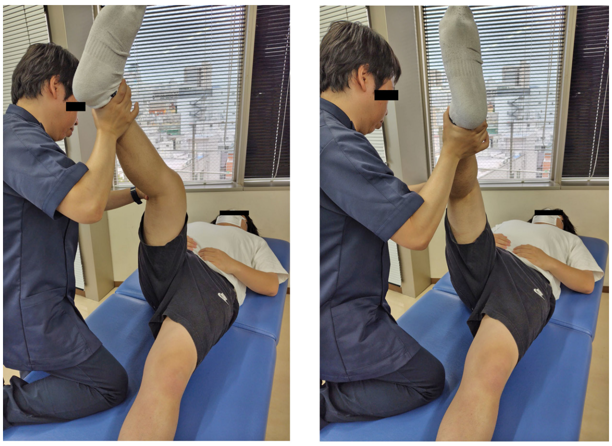
PARTICIPANTS AND METHODS

Participants were 32 healthy adult males with no orthopedic disorders of the lower limbs. The participants' age, height, and weight were 20.4 ± 1.8 years, 171.6 ± 4.4 cm, and 63.5 ± 7.8 kg, respectively (mean ± standard deviation).

All participants were informed of the details and risks of this study both verbally and in writing before participation. All participants signed a consent form attesting that they understood the details of this study and then participated in this study. This study underwent an ethical review for research involving human participants and was approved (approval no. T24-02) by the Ethics Committee of Shujyukai, an incorporated medical association.

Joint range of motion and muscle output were measured in all participants before and after stretching. Participants were divided into 2 groups: one performed SS followed by DS (the group that performed SS first) and the other performed DS followed by SS (the group that performed DS first). In order to prevent the first stretching method from affecting the results of the second stretching method, the order of the stretches was decided at random, and the interval between stretches was at least one day, in accordance with previous studies[3, 9].

The limb and target muscle for both forms of stretching were the dominant leg (the leg most likely to kick a ball) and the hamstring, as in a previous study[16]. SS is shown in Fig. 1. SS of the medial and lateral hamstrings was performed using individual muscle stretching, which is also used in the field of rehabilitation[1]. To stretch the medial hamstrings, the participant assumed a supine position with the hip in flexion, adduction, and internal rotation. The leg was extended while the knee remained in moderate flexion, and the heel was pulled upward parallel to the long axis of the trunk. To stretch the lateral



Medial hamstrings Lateral hamstrings

Fig. 1. Individual muscle stretching (static stretching).

hamstring, the participant assumed a supine position with the hip in flexion, abduction, and external rotation. The leg was extended while the knee remained in moderate flexion, and the heel was pulled upward parallel to the long axis of the trunk.

Stretching was performed by the same examiner, who was a different physical therapist from the authors, and the intensity of the stretching was until the participant began to feel muscle pain. One set of stretching lasted 20 seconds, and a total of 3 sets was performed for the medial hamstrings and lateral hamstring[3)]. DS is shown in Fig. 2. This technique is based on a previous study[23)]. The starting limb position was the resting standing position. The hip was voluntarily flexed to its maximum while the anterior-posterior tilt of the pelvis remained in an intermediate position and the leg remained extended. The participant was instructed to stabilize his balance by placing one hand on a desk for support. The pace was 1 set per second using a metronome (60 bpm), and a total of 20 sets was performed[24)].

The range of motion was measured using the SLR (straight leg raise) method by the same examiner, who is a physical therapist other than the author. The participant assumed a supine position with the leg extended, and the range of motion was measured using a goniometer (Medica) while the hip was passively flexed. The basic axis and axis of movement for measurements were in accordance with the Japanese Orthopaedic Association and the Japanese Association of Rehabilitation Medicine[25)]. To ensure accuracy, measurements were performed by two persons while confirming the results.

Muscle output was measured using the Mobie (MT-100, Sakai Medical Co., Tokyo, Japan). Measurement was in accordance with a previous study[26)]. The starting position was a seated position with both the hip and knee flexed 90° and both upper limbs crossed in front of the chest. A belt was attached to the distal one-third of a line connecting the lateral compartment of the knee and the lateral malleolus, and the opposite side of the belt was secured in a horizontal position. The hamstrings were exercised for 5 seconds in 1 set, and a total of 3 sets was performed. The maximum value served as the measured muscle output.

For statistical processing, a paired t-test was performed to compare measurements from each group before and after stretching to compare groups in terms of the extent of changes before and after stretching. SPSS Statistics 25.0 for Windows (IBM Japan, Ltd., Tokyo, Japan) was used as the software for statistical analysis, and the significance level was set at 5%.

RESULTS

Results for the joint range of motion (SLR) are shown in Table 1. In the group that performed SS first, joint range of motion was 67.5 ± 8.7° before stretching, 72.1 ± 9.1° after stretching, and the extent of changes was 4.6 ± 5.8. In the group that performed DS first, joint range of motion was 65.8 ± 6.7° before stretching, 70.9 ± 5.7° after stretching, and the extent of changes was 5.1 ± 4.5. In both groups, significant improvement in joint range of motion after stretching was noted compared to that before stretching ($p<0.05$). The results of muscle output are shown in Table 2. In the group that performed SS first, muscle output was 24.1 ± 5.3 kgf before stretching, 28.9 ± 7.5 kgf after stretching, and the extent of changes was 4.8 ± 6.8. In the group that performed DS first, muscle output was 24.6 ± 6.7 kgf before stretching, 27.8 ± 5.7 kgf after stretching, and

Fig. 2. Dynamic stretching for hamstrings.

Table 1. Changes in flexibility due to different stretching methods

	Hip flexion range of motion (SLR)		
Group	Pre	Post	Amount of change
SS first	67.5 ± 8.7	72.1 ± 9.1*	4.6 ± 5.8
DS first	65.8 ± 6.7	70.9 ± 5.7*	5.1 ± 4.5

n=32, Unit: °, Mean ± standard deviation, *p<0.05 (pre vs. post).
SS first: SS+DS, DS first: DS+SS.
SLR: straight leg raise, SS: static stretching; DS: dyanamic stretching.

Table 2. Changes in muscle output due to different combinations of stretching methods

	Muscle output (hamstrings)		
Group	Pre	Post	Amount of change
SS first	24.1 ± 5.3	28.9 ± 7.5	4.8 ± 6.8
DS first	24.6 ± 6.7	27.8 ± 5.7	3.2 ± 5.5

n=32, Unit: kgf, Mean ± SS, p>0.05 (pre vs. post).
SS first: SS+DS, DS first: DS+SS.
SS: static stretching; DS: dyanamic stretching.

the extent of changes was 3.2 ± 5.5. Significant improvement in muscle output after stretching was not noted in either group (p=0.07). A comparison of the extent of changes also revealed no significant differences in joint range of motion or muscle output in the two groups (p>0.05).

DISCUSSION

The current study compared the effects of SS and DS combined and their order on joint range of motion and muscle output.

Results suggested that the range of joint motion (flexibility) improved significantly in both the group performing SS first and the group performing DS first, but there were no significant differences in the extent of changes in the range of motion. Typically, changes in joint range of motion with SS are presumed to be the result of improved muscle flexibility due to Ib inhibition[3–9]. When a muscle is continuously stretched, the Golgi tendon organs, which are abundant in the muscle-tendon transition zone, receive the stretching stimulus, and the received stimulus is transmitted to the dorsal horn of the spinal cord via afferent Ib fibers. This information is transmitted via interneurons to the anterior horn cells of the spinal cord, where interneurons inhibit depolarization of the anterior horn cells, resulting in decreased muscle tone in the stretched muscle and improved joint range of motion[1]. In contrast, changes in joint range of motion due to DS are mainly due to reciprocal inhibition and the effects of increased muscle temperature[10, 12]. Reciprocal inhibition is a response in which the nerves innervating a muscle are inhibited by stimulating contraction of its antagonist, resulting in decreased tension in the muscle and improved joint range of motion[24]. In addition, an increased muscle temperature is considered to be due to muscle pumping action and sympathetic nerve action being promoted by repeated muscle contraction and relaxation, resulting in increased blood flow in the muscle. Increased muscle temperature decreases muscle rigidity and increases muscle extensibility, presumably improving joint range of motion[9]. As mentioned earlier, the physiological contexts in which SS and DS contribute to joint range of motion differ, but they both work to improve joint range of motion. Therefore, even if the order of SS and DS were switched, both would presumably result in improved joint range of motion. This may be why there were no significant differences in the extent of changes in joint range of motion between the two groups in the current study.

The results of switching the order of SS and DS on the muscle output of the hamstrings were determined. Results indicated that muscle output tended to increase in both the group that performed SS first and the group that performed DS first, but significant differences in the extent of changes were not noted. Studies have noted that SS decreases muscle output by decreasing the level of excitation of the neuromuscular system due to Ib inhibition and by decreasing the viscoelasticity of muscle and tendon tissue[1, 3]. Nonetheless, a previous study has reported that the level of neuromuscular excitation in the motor nerves decreases during SS for 30 seconds but that it returns to its previous level immediately after stretching[27]. Another study has reported that the viscoelasticity of muscle and tendon tissue decreases during SS but that it returns to its previous level after 30 seconds[28]. In other words, one can surmise that combining SS for less than 30 seconds, as was done in the current study, has little effect on subsequent performance. There is speculation that DS involves post-activation potentiation, in which the muscle function of a muscle group used in an exercise increases temporarily due to activation of the muscle group at a high intensity beforehand[29]. In addition, a previous study reported that post-activation potentiation lasts up to 18.5 minutes[30]. In the current study, muscle output was measured immediately after both forms of stretching, so one could surmise that the factors by which DS improved muscle function in both groups may have persisted until output was measured. These findings suggest that when SS and DS are combined, SS does not reduce the improvement of muscle function by DS. In the current study, muscle output tended to improve in both groups, but there were no differences in the extent of changes between the two groups. This partially corroborates the study by Utsumi et al[22]. Therefore, the current results suggested that improved muscle output due to DS may have been maintained in both groups, and thus explain why there were no significant differences in the extent of changes between the two groups. In this study, we examined the effects of combining stretching, but in clinical practice, it is thought that SS is rarely used after DS. On the other hand, in sports settings, including those involving top athletes, a method is also used in which DS is used to check the condition of one's own body using a series of movements, and then, after narrowing down the target, SS is switched to the affected area. At present, there are many different conditioning methods in use, so it is necessary to consider the best method from a scientific and multifaceted perspective.

Finally, the current study did not examine the physiological changes that occur when SS and DS are both performed or performed in combination. In order to examine the current results in more detail, changes in neuromuscular activity, muscle blood flow, and muscle temperature need to be examined from multiple perspectives.

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Conflicts of interest

There are no conflicts of interest to disclose.

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