OPEN

Effects of Instrument-assisted Soft Tissue Mobilization on Musculoskeletal Properties

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ABSTRACT

IKEDA, N., S. OTSUKA, Y. KAWANISHI, and Y. KAWAKAMI. Effects of Instrument-assisted Soft Tissue Mobilization on Musculoskeletal Properties. *Med. Sci. Sports Exerc.*, Vol. 51, No. 10, pp. 2166–2172, 2019. **Purpose:** Instrument-assisted soft tissue mobilization (IASTM) has been reported to improve joint range of motion (flexibility). However, it is not clear whether this change in the joint range of motion is accompanied by any alterations in the mechanical and/or neural properties. This study aimed to investigate the effects of IASTM in plantarflexors and Achilles tendon on the mechanical and neural properties of them. **Methods:** This randomized, controlled, crossover study included 14 healthy volunteers (11 men and 3 women, 21–32 yr). IASTM was performed on the skin over the posterior part of the lower leg for 5 min and targeted the soft tissues (gastrocnemii, soleus, and tibialis posterior muscles; overlying deep fascia; and Achilles tendon). As a control condition, the same participants rested for 5 min between pre- and postmeasurements without IASTM on a separate day. The maximal ankle joint dorsiflexion angle (dorsiflexion range of motion), the peak passive torque (stretch tolerance), and the ankle joint stiffness (slope of the relationship between passive torque and ankle joint angle) during the measurement of the dorsiflexion range of motion and muscle stiffness of the triceps surae (using shear wave elastography) were measured before and immediately after the interventions. **Results:** After IASTM, the dorsiflexion range of motion significantly increased by 10.7% ± 10.8% and ankle joint stiffness significantly decreased by −6.2% ± 10.1%. However, peak passive torque and muscle stiffness did not change. All variables remained unchanged in the repeated measurements of controls. **Conclusion:** IASTM can improve joint range of motion, without affecting the mechanical and neural properties of the treated muscles. **Key Words:** SHEAR WAVE ELASTOGRAPHY, PLANTARFLEXOR MUSCLES, JOINT AND MUSCLE STIFFNESS, ELECTROMYOGRAPHY, STRETCH TOLERANCE, RANGE OF MOTION

Parameters of joint flexibility such as the joint range of motion and muscle "stiffness" are indicators of its physical condition. Instrument-assisted soft tissue mobilization (IASTM) is used in the field of sports as one of the methods for improving the physical condition. IASTM is also an effective method for the treatment and rehabilitation of athletes and nonathletes who suffer from repetitive and cumulative injuries because it changes the structure and nature of the existing tissue to resolve the adhesion of tissues and restriction of fascia mobility (1,2,3). IASTM involves repeated mechanical stimulations, such as compression and shear stress, of soft tissues (muscles, overlying deep fascia, and tendons) at various intensities by stroking the skin with a bar or spurtle (1,2,3). IASTM is said to be able to cause greater effects on flexibility than manual mobilization without using the instrument because pressure is applied to the deeper parts of the soft tissues by using these tools (2). However, there are only few studies on the effects of IASTM. Some previous studies reported that the joint range of motion was improved by IASTM (4,5), whereas another study reported no significant improvement in flexibility after IASTM (6).

The joint range of motion is known to be influenced by many factors such as stiffness of the joint capsule and ligaments and elongation of the muscle–tendon unit (MTU) across the joint (7). Improvements in the joint range of motion result from the reduction of joint stiffness due to the decrease in the stiffness of muscles and tendons (7,8). On the other hand, changes in neural properties, such as stretch reflex or sensation of MTU elongation, pain, and maximum tolerable stretch (stretch tolerance), have been reported to improve the joint range of motion as well (8,9,10). Previous studies have suggested that manual and roller massages increase stretch tolerance or

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inhibit pain perception (11,12). In other words, repetitive mechanical stimulation over the skin can be assumed to increase joint range of motion by inhibiting muscle activity or modulating the central nervous system by altering the response of mechanoreceptors in the target muscle. Therefore, it is expected that joint range of motion is improved by decreasing joint and muscle stiffness and altering stretch tolerance by repetitive mechanical stimulation in IASTM.

This study aimed to investigate the effects of IASTM over the plantarflexor muscles and Achilles tendon on the mechanical and neural properties of the triceps surae muscles. We hypothesized that IASTM would improve joint range of motion while decreasing joint stiffness by 1) reducing muscle stiffness and 2) increasing the stretch tolerance of the central nervous system.

METHODS

Subjects

The subjects were 14 healthy volunteers (11 men and 3 women; age [mean ± SD], 24 ± 4 yr; height, 1.68 ± 0.08 m; body mass, 60.3 ± 7.3 kg) with no disturbances of motor function and no history of orthopedic injury (injury to muscles, tendons, joint capsules, or ligaments; or peripheral neuropathy) in their lower limbs. The subjects also demonstrated no restriction of coupled posterior glide of the talus during dorsiflexion; therefore, there was no bony restriction of the ankle dorsiflexion range of motion in the anterior talocrural joint. The subjects were examined preliminarily for whether bone collision pain occurred at the anterior talocrural joint during ankle dorsiflexion during the posterior glide of the talus test (by the tendon of the flexor pollicis longus muscle). All subjects provided written consent to participate in this study after they were informed of the contents, the purpose of this study, and the benefits and risks associated with it. The present study was conducted after being reviewed and approved by the Ethics Committee on Research Involving Human Subjects of the affiliated institution.

Study Design

In all subjects, assessments were conducted on the right leg in two separate conditions: IASTM over the posterior surface of the lower leg and no IASTM (control). The ankle dorsiflexion range of motion, the peak passive torque and ankle joint stiffness of passive dorsiflexion, and the muscle stiffness of triceps surae were measured before and after intervention. The subjects were tested in both conditions (IASTM intervention and control) in a random order, with at least 3 d between the tests.

IASTM protocol. The IASTM protocol included soft tissue mobilization techniques and Fascia Slick Technic with an instrument (ScandSlick Pro; Graston Technique Japan Inc., Tokyo, Japan; Figure 1). A therapist who has a doctor of chiropractic degree with 8 yr of experience with IASTM after completing IASTM (Graston Technique®) Module 1 (basic training) and Module 2 (advanced training), a registered massage therapist, and a Judo therapist performed IASTM in all the subjects. For the intervention, with the subject on a bed in the prone or supine position and a pea-sized lubricant applied on the working surface, IASTM was performed on the skin over the posterior part of the lower leg for 5 min and targeted the tissue structures (medial gastrocnemius [MG], lateral gastrocnemius [LG], soleus [SOL], and tibialis posterior muscles, the deep fascia overlying those muscles, and Achilles tendon) (Figure 2).

FIGURE 1—The instrument used in IASTM in this study.

IASTM intervention for the calf included gentle and firm strokes that applied compression and shear stress to produce a pulling force in the engaged tissues around the edges of the instrument (5). IASTM was performed with the therapist moving the knee and ankle joints to arbitrary joint angles according to the target tissue condition so that the position of the soft tissues ranged from a slightly extended position to a slightly shortened position (knee joint: 90° flexion to fully extended [0°]; ankle joint: resting position of plantarflexion [approximately 30°] to anatomical position [0°] and anatomical position to valgus (pronation) of approximately 5° in conjunction with the knee joint angle). Occasionally, IASTM was performed while moving the ankle and knee joints so that the soft tissues were slowly stretched from a slightly shortened position to a slightly extended position. The intervention was aimed at reducing fascia gliding limits as follows: first, very superficial light strokes were performed with the edge of the instrument on the skin to the subcutaneous structures, which was imbricated consecutive strokes; then similar but slightly deeper strokes were performed on the gastrocnemius; subsequent targets involved the SOL fascia and deeper to the posterior tibialis and flexor pollicis longus; finally, strokes were performed at the boundary of the posterior and lateral compartments and medial margin of tibia with the contiguous soft tissue.

The strokes of IASTM were concentrated between each calf muscles and the adjacent (contiguous) tissues, the muscle belly of each muscle, the boundaries between the muscles, and the muscle–tendon junction. The imbricated consecutive strokes were longitudinal straight or drawing an arc shape crossing the muscle or tendon fibers. Stroke pressure and speed were adjusted according to the subject's tolerance so as not to cause pain. To evaluate subjective pain, we used scores of 1–5 on the visual analog scale (1, no pain at all; 5, intolerable discomfort; 0.5 increments), and IASTM was performed with scores <4 (discomfort [defined as feeling pain]). In clinical practice, IASTM is sometimes performed while maintaining the joint angle at which the muscles and tendon are stretched. In this study, we proceeded from the surface to the deeper structures with IASTM; however, we were careful to avoid the effects of stretching (e.g., the ankle was passively moved from the resting position to the neutral position without resulting in dorsiflexion). As the control condition, the subjects rested on a bed in the prone or supine position for 5 min between before and after measurements without IASTM while maintaining the plantarflexors in the relaxed state (knee joint

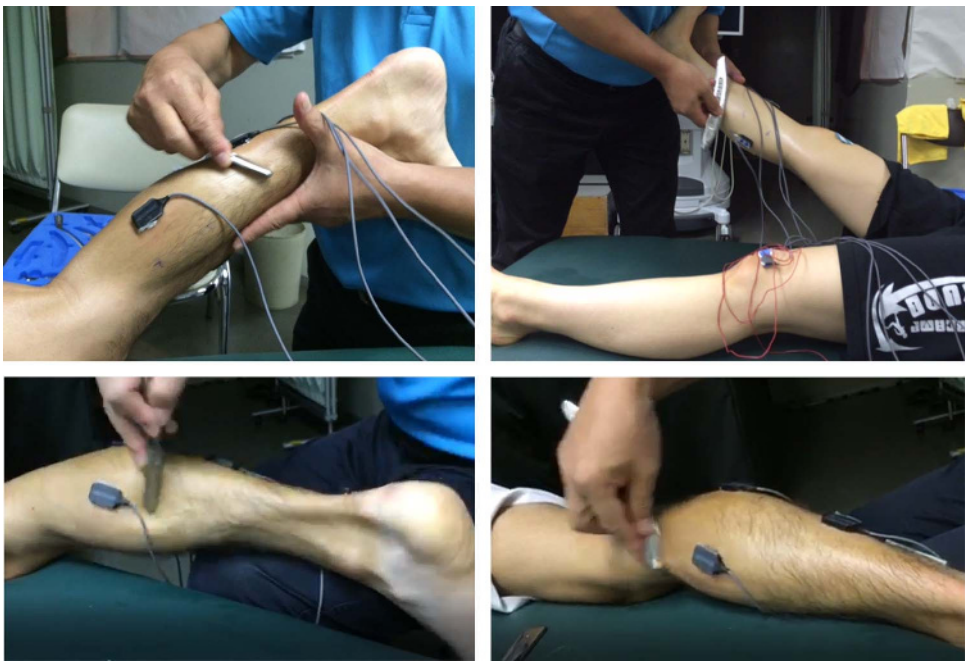

FIGURE 2—Illustration of the process of IASTM.

angle, slightly flexed; ankle joint angle, approximately 30°) to avoid their stretching.

Dorsiflexion range of motion and ankle joint stiffness. The ankle dorsiflexion range of motion and the ankle joint stiffness were measured with an isokinetic dynamometer (Biodex System 3; Biodex Medical Systems, Shirley, NY). The subject was seated with the knee fully extended (hip joint angle, 60° flexion), and the thigh and foot were fixed to the dynamometer with a belt. The ankle joint was dorsiflexed from 0° (anatomical position) to the angle at which the subject felt discomfort (peak dorsiflexion angle) at a velocity of $2°\cdot s^{-1}$; the range from 0° to the peak dorsiflexion angle was defined as the dorsiflexion range of motion. Visual analog scale (described above) was used for subjective pain assessment (4, discomfort). Torque in the direction of plantarflexion during peak dorsiflexion was defined as peak passive torque. This measurement was repeated twice; if there was a difference of ≥10% in the dorsiflexion range of motion, the measurement was performed a third time. The two values obtained for the dorsiflexion range of motion were averaged, as were the two values obtained for peak passive torque; these means were used as representative values. The subjects were instructed to relax during the measurements without resisting passive dorsiflexion. The output of torque and ankle joint angle signals by the isokinetic dynamometer were converted to digital signals at 2 kHz via an analog-to-digital converter (PowerLab/16SP; ADInstruments, Sydney, Australia) and recorded on a personal computer (FMV Lifebook, Fujitsu, Japan) using an analysis software (LabChart 7, ADInstruments).

The activities of the lower leg muscles while measuring the dorsiflexion range of motion were recorded with surface electromyography. Electromyograms were obtained using a Delsys EMG data acquisition system (Bagnoli-8; Delsys, Inc., Boston, MA). Active surface electrodes (interelectrode distance of 10 mm, DE-2.1; Delsys, Inc.) were lightly polished and cleaned with ethyl alcohol and were attached to the muscle bellies of the MG, LG, SOL, and tibialis anterior. As with the dynamometer data, these electromyogram signals were converted to a digital format at a sampling frequency of 2 kHz using an analog-to-digital converter and were then recorded on a personal computer using the same analysis software (data smoothing on the software: band-pass filter, passband at 25–450 Hz). Root mean square (RMS) values of muscle activity during passive dorsiflexion were determined from four joint angle ranges (described above) from the electromyogram signals. These RMS values were normalized according to the RMS value during maximum voluntary contraction (MVC) of ankle plantarflexor and dorsiflexor muscles. To measure the RMS value during MVC of ankle plantarflexors and dorsiflexors, the maximal strengths of plantarflexion and dorsiflexion were evaluated using a dynamometer (described above), with the knee fully extended in the sitting position and the ankle at 0°. Before evaluating the maximal strength of plantarflexion, the subjects were instructed to practice and produce force less than that required during maximal effort (80% of maximum) twice. After at least 1-min rest, the subjects performed two exertions of maximal strength of plantarflexion with 1-min rest between trials. Peak torque was analyzed, and the RMS value of the trial with the higher peak torque was used for normalization. Ankle dorsiflexion MVC was also similarly performed. On the basis of these tests, rest of more than 15 min was provided between MVC and preintervention measurements to minimize the effect of MVC measurement procedures on the ROM and muscle stiffness measurements.

Ankle joint stiffness was calculated from the torque and joint angle obtained while measuring the dorsiflexion range

of motion. On the basis of a previous study (13), with the peak dorsiflexion angle in each dorsiflexion range of motion measurement defined as 100%, we determined joint angles at 0%, 33%, 66%, and 100% as well as the passive torque at each of these angles. With these joint angles defined as angles 1–4, the respective mean joint angles were as follows: 1) 0° ± 0°, 2) 11° ± 3°, 3) 22° ± 7°, and 4) 32° ± 10°. The slope of the dorsiflexion angle-passive torque relationship at angles 1–4 was defined as ankle joint stiffness. This analysis was conducted for the two trials that adopted the dorsiflexion range of motion; ankle joint stiffness was defined as the mean of values obtained in these two trials.

Muscle stiffness. The stiffness of MG and SOL were measured using shear wave elastography (Aixplorer MSK mode; SuperSonic Imagine, Aix-en-Provence, France) (Figure 3). For the measurement, the ankle joints were at 0° and 25° dorsiflexion, based on a previous study (14), while the subjects were in the same posture as they were during the dorsiflexion range of motion measurement. The shear modulus of MG was measured at the center of the muscle belly (at 30% of the proximal length of the leg), and the shear modulus of SOL was measured near the distal end of the muscle belly of MG. The preintervention measurement sites were marked with a marker, and a linear ultrasound probe (frequency, 4–15 MHz; scan width, 50 mm; SL15-4, SuperSonic Imagine) was placed at that site during the postintervention measurement. The shear moduli of MG and SOL were measured five times each; the highest and the lowest values were excluded, and the mean of the remaining three values was used as the representative value. To determine the shear modulus, Young's modulus obtained from the shear wave elastography device was divided by 3 ($E = 3\rho c^2$; Young's modulus, E; tissue density, ρ; shear wave velocity, c). The region of interest of shear modulus was defined as a circle with a diameter of 5 mm (15).

Statistical Analysis

All data are expressed as mean ± SD. Two-way repeated-measures ANOVA (IBM SPSS statistics 24; SPSS Japan, Japan) for all pre- and postintervention measurements was performed by intervention condition (IASTM and control)–time (pre- and postintervention) interaction. If an interaction or a main effect of time was observed, the paired t-test was performed for each condition. The paired t-test was also performed to confirm that there were no differences in any preintervention measured values between the conditions. As the effect size, Cohen's d (for *post hoc* comparisons) was calculated by the following formula: $d = M_{diff}/SD_{pooled}\ \sqrt{2}\ [1 - r]$, where M_{diff} is the difference between mean pre- and postmeasurement value and r is the correlation between means (16). As a result of *a priori* statistical power analyses, it was estimated that 14 subjects were required for this study design in each of the two conditions (repeated-measures ANOVA within factors; effect size, 0.4; power, 0.8; alpha level, 0.05 [(17)]); using G*power 3). The effect size (d) of the paired t-test was calculated by dividing the difference between the average values of the pre- and postmeasurement values by the SD of the premeasurement value. The effect size was defined as follows: |0.20|–|0.50| small effect, |0.50|–|0.80|

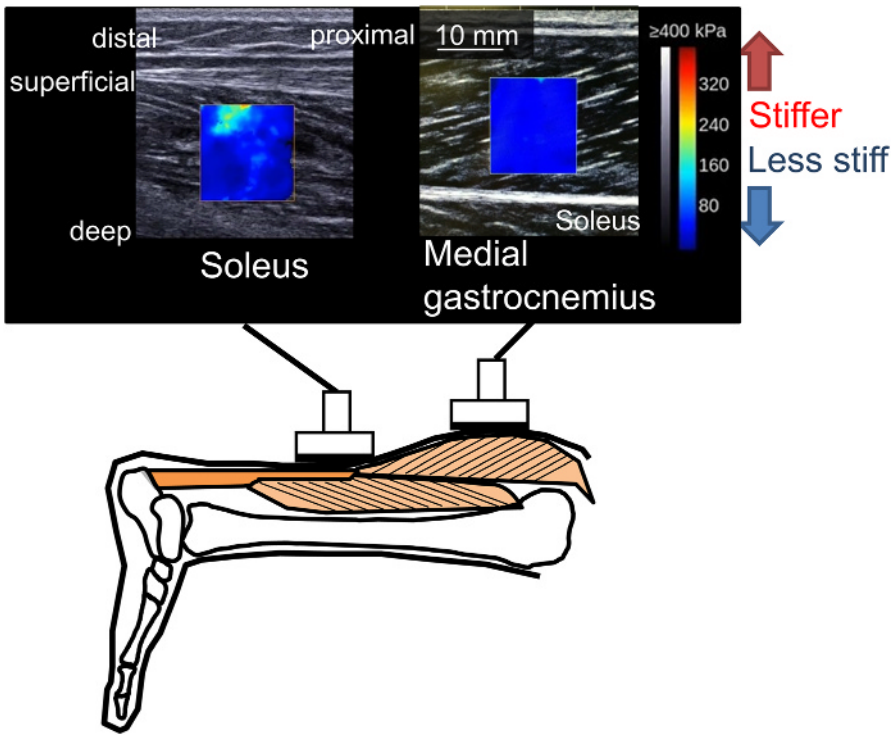

FIGURE 3—Illustration of muscle shear modulus measurement.

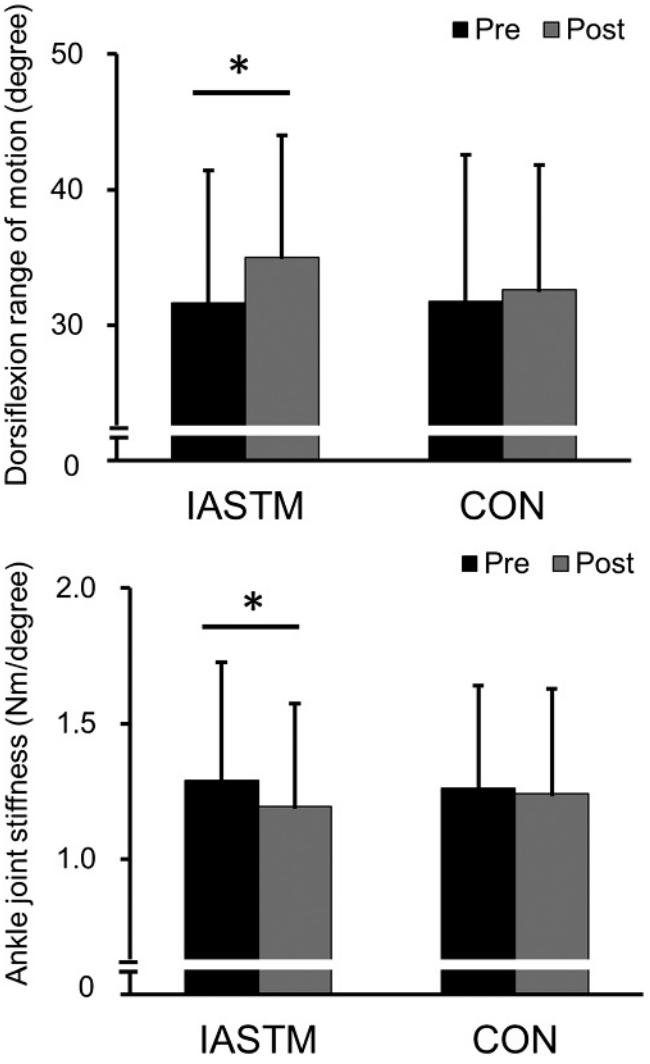

FIGURE 4—Changes in the dorsiflexion range of motion and ankle joint stiffness during passive dorsiflexion in each condition (CON, control; pre, preintervention; post, postintervention). *Significantly changed compared with preintervention measurement ($P < 0.05$). Values are presented as mean ± SD.

medium effect, and |0.80|< large effect (17). The level of statistical significance was set at $P < 0.05$.

RESULTS

An interaction between condition and time was observed in the dorsiflexion range of motion ($P = 0.018$, $\eta p^2 = 0.36$), which significantly improved after IASTM (31.6° ± 9.8° to 35.0° ± 9.0°, $P < 0.01$, $d = 1.15$) but was not observed in the control condition (31.7° ± 10.8° to 32.6° ± 9.2°, $P = 0.15$) (Figure 4). At peak passive torque, there was no interaction between condition and time or main effect of time; no changes in peak passive torque were observed in any condition (interaction: $P = 0.67$, $\eta p^2 = 0.015$; main effect of time: $P = 0.23$, $\eta p^2 = 0.11$) (Table 1). A main effect of time was observed in ankle joint stiffness ($P = 0.035$, $\eta p^2 = 0.30$), which decreased significantly after IASTM (1.29 ± 0.44 N·m·deg^{-1} to 1.19 ± 0.38 N·m·deg^{-1}, $P = 0.047$, $d = -0.62$), but did not change in the control condition (1.26 ± 0.38 N·m·deg^{-1} to 1.24 ± 0.39 N·m·deg^{-1}, $P = 0.20$) (Figure 4).

In muscle stiffness of MG at joint angles of 0° and dorsiflexion of 25°, no interaction was observed between condition and time, and no main effect of time was observed; there were no changes in either condition (0°; interaction: $P = 0.15$, $\eta p^2 = 0.16$; main effect of time: $P = 0.89$, $\eta p^2 < 0.01$) (dorsiflexion 25°; interaction: $P = 0.44$, $\eta p^2 = 0.047$; main effect of time: $P = 0.88$, $\eta p^2 < 0.01$) (Table 1). Similarly, in muscle stiffness of SOL at joint angles of 0° and dorsiflexion of 25°, there were no changes in any condition (0°; interaction: $P = 0.76$, $\eta p^2 < 0.01$; main effect of time: $P = 0.60$, $\eta p^2 = 0.022$) (dorsiflexion 25°; interaction: $P = 0.67$, $\eta p^2 = 0.015$; main effect of time: $P = 0.54$, $\eta p^2 = 0.030$) (Table 1).

DISCUSSION

This study demonstrated that IASTM increases the dorsiflexion range of motion and decreases ankle joint stiffness. In addition, this study clarified that peak passive torque during the measurement of the dorsiflexion range of motion and muscle stiffness of MG and SOL was not affected by IASTM.

Some previous studies have reported that IASTM improves joint range of motion (4,5). The results of this study support the results of the previous studies. However, another previous study reported that IASTM (Graston Technique®), which was performed on the posterior part of the lower leg similar to that in the present study, resulted in no improvement in the dorsiflexion range of motion (6). Therefore, we believe that the dorsiflexion range of motion was improved by IASTM in this study as the participants were healthy without a clinical level of joint range of motion restriction. Further studies are

TABLE 1. Changes in peak passive torque, and muscle shear modulus of the MG and SOL in each condition.

	IASTM		Control Group	
	Preintervention	Postintervention	Preintervention	Postintervention
Peak passive torque (N·m)	48.6 ± 16.3	50.3 ± 16.9	47.2 ± 14.9	48.1 ± 16.7
Muscle shear modulus				
Joint angle: 0°				
MG (kPa)	19.0 ± 5.9	18.2 ± 4.7	19.2 ± 6.0	20.2 ± 6.4
SOL (kPa)	10.8 ± 5.7	11.0 ± 4.3	8.6 ± 2.6	9.4 ± 5.6
Joint angle: dorsiflexion 25°				
MG (kPa)	112.3 ± 39.5	107.4 ± 31.5	108.4 ± 40.0	111.5 ± 37.5
SOL (kPa)	24.8 ± 11.8	26.8 ± 12.4	22.1 ± 9.2	22.5 ± 10.3

These parameters did not significantly change from preintervention values in any condition ($P > 0.05$). Values are expressed as mean ± SD.
DF, dorsiflexion.

TABLE 2. Muscle activities of triceps surae and tibialis anterior during the dorsiflexion range of motion measurement.

	Angles 1–2	Angles 2–3	Angles 3–4
MG (%MVC_{RMS})	1.6 ± 1.1	1.4 ± 0.9	4.4 ± 5.9
LG (%MVC_{RMS})	1.7 ± 1.4	1.6 ± 1.3	1.8 ± 1.4
SOL (%MVC_{RMS})	3.1 ± 2.3	3.3 ± 2.4	4.9 ± 3.4
Tibialis anterior (%MVC_{RMS})	1.9 ± 1.2	1.3 ± 0.7	1.9 ± 1.9

Values are the average of the pre- and postintervention values of the two conditions. Values are expressed as mean ± SD.

required to clarify whether the magnitude of the effect of IASTM on flexibility is related to the previous level of flexibility of the subject. The activations of the triceps surae muscles during ankle dorsiflexion were quite low in pre- and postintervention measurements (Table 2). This result demonstrates that there was almost no input from the central nervous system to the triceps surae. In addition, the dorsiflexion range of motion improved by 10.7% ± 10.8% after IASTM, which is approximately 16% lesser than that reported in some previous studies that measured it after static stretching (18,19). This may be because IASTM (−6.2% ± 10.1%) results in a lesser reduction in ankle joint stiffness than static stretching (approximately −12%) (19). Furthermore, unlike static stretching, IASTM does not change the stiffness of the muscle belly and stretch tolerance. However, it has been reported that IASTM (Graston Technique®) effectively improves the flexibility of the hip joint in patients with chronic low back pain in comparison with static stretching (20). Therefore, IASTM appears to be less effective in improving flexibility than static stretching, and it depends on the target sites and subjects.

It is believed that reduction in joint stiffness is secondary to a decrease in the stiffness of the muscles and tendons constituting the MTU across the joint (7,8). The results of the present study revealed that IASTM reduces joint stiffness, which contributes to the improvement of joint range of motion. However, muscle stiffness of MG and SOL was unchanged after IASTM. In this study, IASTM was not performed over the feet and ligaments of the ankle joint. Therefore, we believe that the stiffness of soft tissue other than that of the muscle belly of the triceps surae (such as the Achilles tendon) decreased after IASTM. One of the physiological hypotheses regarding IASTM is reduced sliding resistance that occurs between muscle and deep fascia when the muscle contracts or stretches (21), which could be one of the causes of decreased joint stiffness in the present study.

Previous studies have suggested that manual and roller massages increase stretch tolerance or inhibit pain perception (11,12). However, in the present study, peak passive torque during ankle dorsiflexion remained unchanged after IASTM, indicating that IASTM did not change the perception of pain caused by stretching the MTU (stretch tolerance). This suggests that the stroking action of IASTM resulted in only shallow penetration of the muscle and, therefore, did not change the sensitivity of the mechanoreceptors. Stretch tolerance is known to increase after static stretching (stretching stress load to the MTU) (8,9). Therefore, the results of this study suggest that IASTM does not induce stretching stress over the MTU, which affects stretch tolerance. In addition, it is expected that a combination of IASTM and stretching could have greater effect on flexibility than IASTM or stretching alone. Changes in the stretch-reflex sensitivity (H-reflex) are also considered a part of the mechanism for improvement in the joint range of motion (7,8). Previous studies have reported temporary decreases in the H-reflexes of target muscles during manual and roller massages (12,22). These studies have suggested that massaging increases Ib afferent inhibition and presynaptic inhibition by modulating the sensitivity of the Golgi tendon organs and pressure sensitive receptors of the skin and muscle (12,22). Therefore, further studies are required to clarify the effects of IASTM on H-reflex.

It has been found that static stretching reduces neuromuscular activity and maximal voluntary force production (8,10). These negative effects after stretching are presumed to be secondary to changes in neural properties such as reduced central drive, lowered stretch-reflex sensitivity, and increased stretch tolerance (8,23,24). On the other hand, IASTM was found to improve joint range of motion without changing stretch tolerance in this study. In the present study, we prioritized the verification of the effects of IASTM on ankle joint range of motion and neuromechanical properties of the triceps surae and did not measure muscle strength or power. Further studies are required to clarify whether IASTM affects muscular performance such as strength and power.

In the present study, the pressure or force of the instrument was not measured; therefore, future studies should evaluate them quantitatively and objectively elucidate the effective stroke intensity. The intensity of IASTM was determined by the therapist and the respective subject in this study. It should be noted that these findings were obtained as a result of the use of IASTM alone in healthy subjects by an experienced therapist. In routine practice, IASTM is sometimes combined with compressive myofascial release such as massage and stretching. Therefore, IASTM in routine practice may have a greater effect on joint mobility than that observed in this study.

CONCLUSION

This study revealed that IASTM over the posterior part of the lower leg can improve the ankle joint dorsiflexion range of motion and stiffness, without affecting stretch tolerance, and muscle stiffness of MG and SOL.

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The authors declare no conflict of interest. None of the authors has a professional relationship with any company or manufacturer who will benefit from the results of the present study.

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