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Randomized Controlled Trial

Efficacy of instrument-assisted soft tissue mobilization in comparison to gastrocnemius-soleus stretching for dorsiflexion range of motion: A randomized controlled trial

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ABSTRACT

Objectives: To determine the efficacy of IASTM of the gastrocnemius-soleus complex in comparison to a traditional stretching intervention on dorsiflexion ROM.
Methods: Sixty healthy participants were randomly allocated to one of 3 groups: IASTM ($n = 20$), stretching ($n = 20$), or control group ($n = 20$). The dependent variables for this study was dorsiflexion range of motion (ROM) via three measurement methods which included Modified root position 1- knee extended (MRP1), Modified root position 2- knee flexed (MRP2), and weight bearing lunge test (WBLT). A multivariate analysis of variance (MANOVA) was utilized to analyze the ROM differences between the groups (IASTM, stretching, and control groups), with a post-hoc Tukey and pairwise least significant difference tests to assess individual pairwise differences between the groups.
Results: The MANOVA found significant ROM differences between the three intervention groups ($F_{6,110} = 2.40$, $p = .032$). Statistically significant differences were identified between both the IASTM and control as well as the stretching and control group through the WBLT and MRP2 assessments, but not in the MRP1 assessment. Further, there was no statistically significant difference between the IASTM and stretching groups using any of the three methods.
Conclusion: A single session of IASTM or stretching increased ankle dorsiflexion ROM in WBLT and MRP2. No significant difference was noted in the MRP1. Both IASTM and stretching appear to have a greater effect on soleus muscle flexibility as evidenced by ROM gains measured with the knee in a flexed position. No clinically significant difference was identified between the intervention groups in weight-bearing conditions; thus empowering patients with the use of self-stretching would seemingly be reasonable and efficient. Combined effects of stretching and IASTM warrant further investigation for increasing dorsiflexion range of motion as a summative effect is unknown.

1. Introduction

Sufficient range of motion (ROM) of the ankle (talocrural) joint is required for a variety of functional activities such as walking, running, and squatting (Gunther and Blickhan, 2002; Kang and Oh, 2017; Macrum et al., 2012; Mueller et al., 1995). When ankle motion is limited, specifically in dorsiflexion, impairments and activity limitations may result. Impaired dorsiflexion ROM may predispose an individual to knee pathology, gait abnormalities, balance deficits, impaired dynamic activity, and an increased risk of ankle sprains (Basnett et al., 2013; Bowers and Castro, 2007; Drewes et al., 2009; Goff and Crawford, 2011; Malliaras et al., 2006; Ota et al., 2014; Tabrizi et al., 2000). Decreased ankle dorsiflexion ROM may result from tightness in the gastrocnemius and soleus muscles, inherent ankle joint stiffness, or as a result of ankle sprains (Backman and Danielson, 2011) and improving ankle dorsiflexion ROM has become a common treatment goal for rehabilitation professionals.

An intervention commonly utilized to improve dorsiflexion ROM is stretching of the gastrocnemius-soleus muscle complex

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(Condon and Hutton, 1987). The specific type of stretch and appropriate dosing to maximize gains in ankle ROM has been investigated in the literature (Condon and Hutton, 1987; Radford et al., 2006). Stretching interventions range from basic static stretching to proprioceptive neuromuscular facilitation methods that involve isometric contraction and relaxation of agonist and antagonist muscle groups. When comparing four stretching techniques (static, agonist contraction, hold relax, and hold relax-agonist contraction) of the soleus muscle in the sagittal plane, all groups showed increased dorsiflexion ROM, and no significant differences were found between the different groups, thus, indicating that each method was effective in increasing ankle dorsiflexion ROM (Condon and Hutton, 1987).

Soft tissue mobilization (STM) is another treatment method used to assist in improving ankle dorsiflexion ROM. STM is often used to reduce pain, increase soft tissue mobility, and restore functional activity (DeLuccio, 2006). Instrument-assisted soft tissue mobilization (IASTM) is a specialized therapeutic soft tissue mobilization technique that utilizes instruments to apply a longitudinal pressure along muscle fibers. The instruments allow the clinician to detect altered tissue properties via mechanical vibration within the instrument and to facilitate patient awareness of altered sensations in the treatment area (Baker et al., 2013). The vibrations also allow the clinician to isolate adhesions and restrictions and treat them precisely (Crothers et al., 2008). Furthermore, use of the instrument enables the clinician to achieve greater depth of mechanical force transmission while reducing compressive stresses to the clinician's hands. Microtrauma is induced from IASTM, which has potential to cause a local inflammatory response. This local inflammatory response promotes the breakdown of scar tissue, release of adhesions, synthesis of new collagen, and remodeling of connective tissue (Baker et al., 2013; DeLuccio, 2006). The instruments are thought to activate fibroblasts which, in turn, induce collagen synthesis (Hammer, 2005; Kline, 2010).

IASTM used in the treatment of tendinopathies has resulted in pain resolution, improved ROM, and a faster return to normal function when compared to natural healing and other traditional therapeutic interventions (Baker et al., 2013). Instruments have been developed for use with soft tissue mobilization that vary in material, shape, and size but are each designed to enable a clinician to enhance STM. The Edge Mobility Tool is one such instrument that is a stainless steel tool with multiple sharp and dull edges that contour the body for superficial and deep tissue work.

The current treatment protocols for treating patients with limited ankle dorsiflexion ROM typically includes a stretching protocol of the gastrocnemius-soleus complex. Although the amounts of time for stretching and rest breaks vary among the literature, weight-bearing static stretches have shown statistically significant improvements in dorsiflexion range of motion (Radford et al., 2006). While IASTM has become an intervention of choice with soft tissue injury, its utility in improving ankle dorsiflexion ROM has yet to be investigated. Therefore, the aim of this study is to determine the immediate effects of IASTM in comparison to stretching of the gastrocnemius-soleus muscle complex on dorsiflexion ROM.

2. Methods

2.1. Participants

Sixty healthy individuals meeting inclusion criteria were enrolled in the study. Recruitment occurred via email notification, flyers, and word-of-mouth throughout the local university. Inclusion criteria were: between 18 and 65 years of age, no acute knee, ankle or foot pathology, and no positive responses on health history questionnaire or Physical Activity Readiness Questionnaire (PAR-Q). Exclusion criteria included conditions where IASTM or stretching are contraindicated and positive responses to the PAR-Q due to the potential health implications of the warm-up activity. Contraindications specific to stretching included presence of a bony block limiting joint motion, recent fracture with incomplete bony union, acute inflammatory or infectious process, a sharp or acute pain with joint movement or muscle elongation, hematoma or other indication of tissue trauma, hypermobility of a joint if shortening soft tissues provide necessary joint stability, shortened soft tissues that enable patients with paralysis or other significant muscle weakness to perform specific functional skills (Kisner and Colby, 2012). Contraindications for IASTM include a history of arteriosclerosis, thrombosis, embolism, severe varicose veins, acute phlebitis, cellulitis, synovitis, abscesses, skin infections, cancers, and acute inflammatory conditions (Prentice, 2011). All participants signed an informed consent form prior to participation. The study was approved by the Institutional Review Board at the University of Central Florida.

2.2. Experimental design

Each participant performed an initial warm-up consisting of 2 min of step taps on a 12-inch box to promote activation of the gastrocnemius-soleus complex and increased circulation (Fig. 1). Immediately following the warm-up, pre-intervention dorsiflexion ROM was measured in both weight-bearing (WB) and non-weight bearing (NWB) positions. The measurements were performed sequentially three times each and with short rest periods. The warm-up and pre-intervention dorsiflexion ROM measurements were conducted by the first researcher who was blinded to the randomly assigned group selection by opaque envelope of each of the participants: IASTM, stretching, or control. Participants were then directed to another room where an additional researcher performed the interventions. Both researchers had the same level

Fig. 1. Warm-up including 2 min of step taps.

of experience and training prior to the study including completion of the training guide provided by The Edge Mobility Tool. The first intervention consisted of IASTM delivered to the entire length of the gastrocnemius-soleus complex with The Edge Mobility Tool (Fig. 2). The area was prepared with massage cream lubricant. Then, the researcher applied the tool in alternating proximal and distal directions parallel to the muscle fibers for 2 min (Fig. 3).

Participants in the second group performed 3 bouts of 30-s passive static stretching against a wall with the knee extended (Fig. 4) followed by 3 bouts of 30- second stretching with the knee flexed (Fig. 5). Participants were instructed to lean forward while keeping the heel on the floor until a light pull was felt in the back of the leg. The control group received no intervention for 3 min. Following the intervention, dorsiflexion ROM was reassessed by the initial researcher, who was blinded to the intervention delivered.

Fig. 3. Instrument-assisted soft tissue mobilization.

2.3. Outcome measures

Multiple procedures have been used to quantify ankle dorsiflexion ROM. Key differences amongst these procedures include weight-bearing status, knee position, and instrument used to record the measurement. The length and elasticity of the gastrocnemius-soleus muscle complex directly influence the amount of dorsiflexion ROM available at the ankle joint. The gastrocnemius is a two-joint muscle which crosses both the knee and ankle joints, therefore, the position of the knee effects the amount of ankle dorsiflexion ROM (Bowers and Castro, 2007). Typically, measurement of ankle dorsiflexion ROM with the knee fully extended assesses the influence of the gastrocnemius, whereas measurement with the knee flexed is more reflective of soleus influence (DiGiovanni et al., 2002). Greater ankle dorsiflexion ROM is typically noted when the knee is flexed since the gastrocnemius is taken off maximum stretch at both joints (DiGiovanni et al., 2002; Krause et al., 2011).

The weight-bearing lunge test (WBLT) was one of two dorsiflexion ROM assessments chosen for this study. It has high reliability (ICC = right 0.96; left 0.97) with digital inclinometer (Konor et al., 2012) and utilizes a functional position of dorsiflexion seen during closed-chain gait (Bennell et al., 1998; Grindstaff et al., 2009; Konor et al., 2012; Krause et al., 2011). In accordance with the protocol utilized by Konor et al., ankle dorsiflexion ROM was measured with a digital inclinometer while the participant performed a WBLT (Konor et al., 2012). Participants were instructed to assume a lunge position against a wall while maintaining heel contact with the ground (Fig. 6).

A Baseline® digital inclinometer (3B Scientific, Tucker, GA, USA) was placed at the tibial tuberosity to measure the angle of the tibia relative to a vertical point perpendicular to the ground (Konor et al., 2012). The WBLT places the knee in a flexed position and, therefore, primarily assesses the muscle length of the soleus and its contribution to ankle dorsiflexion ROM.

Fig. 2. The edge mobility tool.

Fig. 4. Stretching of gastrocnemius.

Fig. 5. Stretching of soleus.

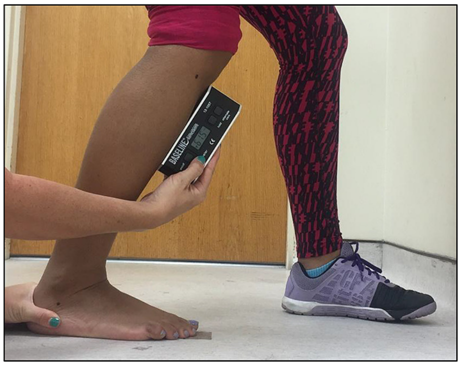

Fig. 6. Weight bearing lunge test.

The Modified Root protocol was also used to measure passive dorsiflexion ROM. A standard Baseline® goniometer (3B Scientific, Tucker, GA, USA) was used to assess ankle dorsiflexion ROM in two NWB positions: with the knee extended to 0° in the Modified Root Position 1 (MRP1), and with the knee flexed to 90° in the Modified Root Position 2 (MRP2) (Figs. 7 and 8). The goniometer axis was placed just inferior to lateral malleolus with the stationary arm aligned parallel to the fibula, pointing toward head of fibula. The movable arm was positioned parallel to longitudinal axis of the fifth metatarsal (Krause et al., 2011). To improve accuracy in measurement, landmarks were marked on the body in attempt to enable consistency between pre- and post-intervention measurements (Weaver et al., 2001). Assessment of joint ROM with goniometry has been found to have greater intra-rater reliability than inter-rater reliability, therefore, one blinded tester performed all ROM testing before and after the interventions (Boone et al., 1978). Passive ROM was collected from each participant using the aforementioned three methods during three trials prior to, and after the interventions. Each trial was recorded and average ROM scores were calculated.

2.4. Statistical analysis

At baseline, between-group comparisons of characteristics were analyzed using a one-way analysis of variance (ANOVA) for continuous data and with a Pearson chi-square for gender (Table 1). To assess group ROM changes with the intervention for each group, a two-way, factorial ANOVA was conducted with the intervention as the between-subject variable and time (pre/post-intervention) as the within-subject variable. Last, a multivariate analysis of variance (MANOVA) was conducted to assess ROM change scores collected via the three methods between the intervention groups (IASTM, stretching, and control). A post-hoc

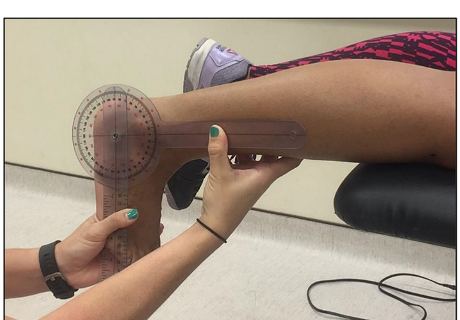

Fig. 7. Modified Root Position 1 (0 degrees of knee flexion).

Fig. 8. Modified Root Position 2 (90 degrees of knee flexion).

Tukey test was then conducted to assess individual pairwise comparisons between the intervention groups. Statistical analyses were performed utilizing IBM SPSS Statistics for Windows or Macintosh, Version 22.0 (IBM Corp, Armonk, NY) with alpha levels set to equal to or less than 0.05. Prior to conducting the primary analyses, assumptions for multivariate procedures were assessed. This included checking data for normality, linearity of dependent variables, equality of variance and covariance matrices, multicollinearity, and detection of univariate and multivariate outliers. An *a priori* power analysis for the MANOVA statistic was calculated using G*Power 3 (Heinrich-Heine-Universität, Düsseldorf, Germany). Results indicated that a sample size of 57 would be sufficient based on an alpha of 0.05, power of 0.80, with an estimated medium effect size ($f = 0.25$).

3. Results

Sixty individuals met the inclusion criteria and provided informed consent to participate in the study. ROM improved in both the IASTM and stretching groups across the three measures of ROM (Table 2). The group receiving IASTM increased their ROM by a mean of 1.81° in the WBLT measure, 2.35° in the MRP1 measure, and 3.43° in the MRP2 measure. The group receiving stretching increased their ROM by a mean of 1.60° in the WBLT measure, 2.33° in the MRP1 measure, and 3.15° in the MRP2 measure (Fig. 9). The control group changed by less than 1° in the WBLT and MRP2 measures, and just under 2° in the MRP1 measure (Table 3).

The MANVOA found a statistically significant difference in ROM changes between the three groups (Wilks' Lambda = .782, $F_{6,110} = 2.40$, $p = .032$). Between subjects effects were statistically significant for the intervention group assignment based on the WBLT mean change ($F_{2,57} = 4.89$, $p = .011$) and the MRP2 mean change ($F_{2,57} = 3.68$, $p = .031$) but not the MRP1 mean change score. Post-hoc testing found a statistically significant difference in the ROM changes between the ISTM and control group in the WBLT ($p = .018$, 95% CI of change .35 to 4.34) and the MRP2 assessments

Table 1
Baseline characteristics of study participants.

	Overall n = 60 Mean (SD)	IASTM group n = 20 Mean (SD)	Gastrc/Soleus Stretch Group n = 20 Mean (SD)	Control group n = 20 Mean (SD)	P-value (Between Groups at Baseline)
Age (years)	25.8 (6.7)	24.7 (2.1)	25.8 (4.0)	27.0 (10.8)	.563
Gender (% female)	63.3	50.0	75.0	65.0	.256
Height (cm)	176.7 (47.9)	172.2 (11.6)	170.0 (7.3)	188.0 (82.0)	.437
Body mass (kg)	72.4 (17.4)	68.4 (12.5)	71.7 (14.5)	77.1 (23.0)	.285
BMI	24.2 (5.4)	22.9 (2.1)	24.7 (3.8)	25.1 (8.3)	.402

Table 2
Group comparisons of range of motion before and after intervention (ANOVA).

	IASTM group (N = 20) Mean (SD)		Gastrc/Soleus Stretch Group (N = 20) Mean (SD)		Control Group (N = 20) Mean (SD)			
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	P value (Between groups at baseline)	P value (Time-by group interaction)
Weight Bearing Lunge (Degrees)	40.2 (8.3)	42.0 (8.7)	41.2 (5.9)	42.8 (7.0)	40.6 (6.2)	40.1 (6.4)	.890	.011*
Modified Root Position 1 (Degrees)	9.2 (6.0)	11.6 (6.6)	7.5 (3.8)	9.8 (5.0)	5.4 (5.1)	7.4 (4.9)	.067	.943
Modified Root Position 2 (Degrees)	18.0 (9.4)	21.4 (8.7)	16.2 (5.3)	19.4 (5.9)	17.0 (6.0)	17.3 (6.2)	.734	.031*

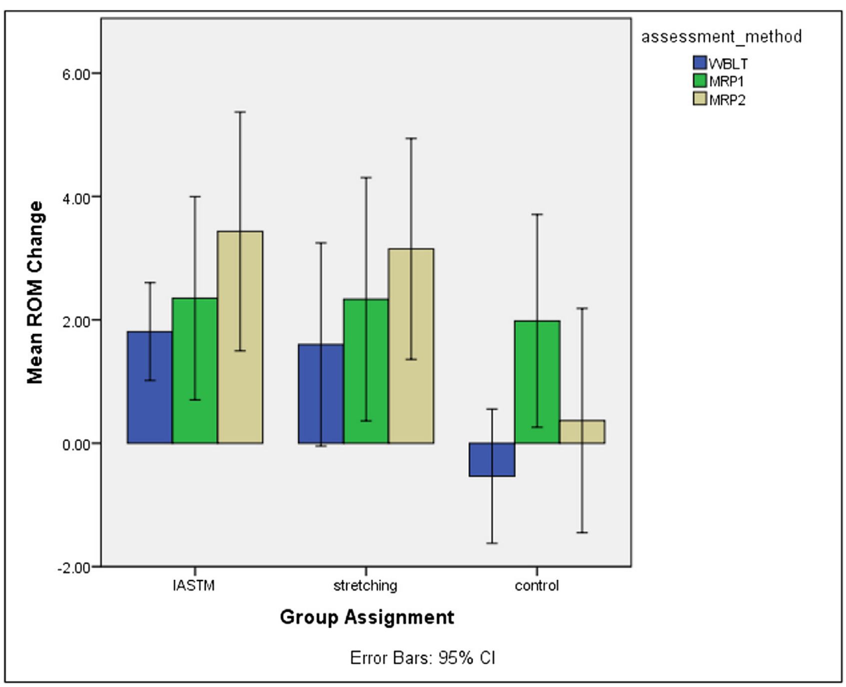

Fig. 9. Mean ROM change based on group assignment.

(p = .045, 95% CI of change .060 to 6.07). In addition, statistically significant differences in the ROM changes were found between the stretching and control group in the WBLT (p = .034, 95% CI of change .140 to 4.13). For the MRP2 assessment, the differences between the stretching and control groups approached statistical significance (p = .075, 95% CI of change −.224 to 5.79) in the Tukey test (Table 4). Pairwise comparisons for main effects of group mean differences, however, found statistically significant differences between the stretching and control groups in the MRP2 measure (mean difference 2.78, p = .03, 95%CI of change .281 to 5.29) (Table 5). There were no statistically significant differences in ROM changes between the IASTM and stretching groups using any of the three methods of assessment.

4. Discussion

The purpose of this study was to examine the effect of IASTM on ankle dorsiflexion ROM in comparison to standard stretching

Table 3
Mean dorsiflexion change for IASTM, stretching, and control interventions (MANOVA).

	IASTM Mean ± SD 95% CI	Stretching Mean ± SD 95% CI	Control Mean ± SD 95% CI
Weight Bearing Lunge Mean Change	1.81 ± 1.70 0.63–2.99	1.60 ± 3.52 0.42–2.78	−0.54 ± 2.33 −0.71–0.64
Modified Root Position 1 Mean Change	2.35 ± 3.52 0.64–4.06	2.33 ± 4.21 0.62–4.04	1.98 ± 3.68 0.27–3.69
Modified Root Position 2 Mean Change	3.43 ± 4.13 1.66–5.20	3.15 ± 3.83 1.38–4.92	0.37 ± 3.88 −1.40–2.14

Table 4
Between group comparison of mean change (Tukey HSD).

		WBLT P value 95% CI	MRP1 P value 95% CI	MRP2 P value 95% CI
IASTM	Stretching	.965 −1.79–2.21	1.00 −2.89–2.92	.972 −2.72–3.29
	Control	.018* 0.35–4.34	.950 −2.54–3.27	.045* 0.06–6.07
Stretching	IASTM	.965 −2.21–1.79	1.00 −2.92–2.89	.972 2.72–5.79
	Control	.034* 0.14–4.13	.955 −2.55–3.25	.075 −0.22–5.79
Control	IASTM	.018* −4.34 – (−0.35)	.950 −3.27–2.53	.045* −6.07 – (−0.06)
	Stretching	.034* −4.13 – (−0.14)	.955 −3.25–2.55	.075 −5.79–0.22

Table 5
Pairwise comparisons of mean change.

		IASTM		Stretching		Control	
		Stretching	Control	IASTM	Control	IASTM	Stretching
Weight Bearing Lunge Mean Change	Mean Difference	0.21	2.35*	−0.21	2.14*	−2.35*	−2.14*
	95% CI for Difference	−1.45–1.87	0.68–4.01	−1.87–1.45	0.47–3.80	−4.01 – (−0.68)	−3.80 – (−0.47)
	p-value	0.80	0.007	0.80	0.013	0.007	0.013
Modified Root Position 1 Mean Change	Mean Difference	0.17	0.37	−0.17	0.35	−0.37	−0.35
	95% CI for Difference	−2.40–2.43	−2.05–2.78	−2.43–2.40	−2.07–2.77	−2.78–2.05	−2.77–2.07
	p-value	0.989	0.762	0.989	0.773	0.762	0.773
Modified Root Position 2 Mean Change	Mean Difference	0.283	3.07*	−0.28	2.78*	−3.07*	−2.78*
	95% CI for Difference	−2.22–2.79	0.56–5.57	−2.79–2.22	0.28–5.29	−5.57 – (−0.56)	−5.59 – (−0.28)
	p-value	0.821	0.017	0.821	0.030	0.017	0.030

interventions for the gastrocnemius-soleus complex. Use of IASTM as a standalone intervention for improving ankle dorsiflexion ROM has yet to be investigated. This study showed significant improvements in dorsiflexion ROM with both standard stretching as well as IASTM when ROM was measured in the weight bearing position. The importance of WB measurements resides in evidence that WB ankle dorsiflexion is more closely related to gait (Kang and Oh, 2017). Significant changes were exclusively seen in the IASTM group when ROM was measured in the Modified Root Position 2. These findings are consistent with previous studies that have found stretching to be an effective technique for improving ankle dorsiflexion ROM. A meta-analysis by Radford et al. examined the utility of static stretching to improve ankle dorsiflexion ROM. It was concluded that calf stretching increased ankle dorsiflexion ROM when compared to controls regardless of total duration of stretching: stretching less than 15 min, between 15 and 30 min, and longer than 30 min were all beneficial in improving ankle dorsiflexion ROM. Furthermore, ROM gains with increased duration of stretching time were only small & clinically insignificant (Radford et al., 2006). Therefore, this study's use of intermittent 30-s bouts of stretching of the gastrocnemius-soleus complex was sufficient to provide a statistically significant change in dorsiflexion ROM.

Although this study used the Edge Mobility Tool rather than other STM tools to improve joint ROM, the statistically significant increase in ankle dorsiflexion ROM is consistent with other studies where IASTM was used to improve ROM (Baker et al., 2013; Crothers et al., 2008; DeLuccio, 2006; Hammer, 2005; Kline, 2010; Looney et al., 2011). The available IASTM studies have not investigated IASTM as a standalone technique to improve ROM and generally use stretching as a follow-up method to increase ROM. Although, participants in this study are considered healthy, increased vibrations throughout the tool were noted indicating areas of possible restrictions during the performance of IASTM. The common method of localizing tissues with increased adhesions was not used due to the intervention goal of assessing if the use of IASTM is able to improve ankle dorsiflexion ROM and not to perform a specific treatment targeted to one area. A consistent pressure in a parallel direction was used to target the entire length of the triceps surae.

A limitation of this study is that it was conducted on healthy individuals with ROM values that met or exceeded normal values for published dorsiflexion ROM ranges from 0° to 13.1° with the knee extended and 5° to 22.3° with the knee flexed (Baggett and Young, 1993; DiGiovanni et al., 2002; Jordan et al., 1979; Kim et al., 2011; Van Gheluwe et al., 2002). The high initial values for ROM may have impacted the potential for change and the ability to reach minimal detectable change (MDC) values as needed to exceed the threshold of error in the measurements. Further research is necessary to determine whether subjects who demonstrate limited dorsiflexion may experience greater gains in dorsiflexion ROM following IASTM or stretching interventions.

The study only investigated immediate improvements in ROM following a single intervention. Further examination of the effects of multiple intervention sessions and a combination of IASTM and stretching is warranted. Another limitation of this study is the effect of having therapist delivered interventions versus participant delivered. In this study a researcher performed and dictated the intensity of the intervention received for participants who were in the IASTM group, whereas participants in the stretching group determined the level of intensity for the wall stretch.

Based on the results of the study, both IASTM and stretching are effective interventions for improving ankle dorsiflexion ROM in weight bearing conditions. Although statistically significant, the mean changes achieved by each intervention group (IASTM $1.81 \pm 1.70°$; Stretching $3.15 \pm 3.83°$) do not meet or exceed established minimal detectable change (MDC) values for the WBLT. Konor et al. concluded that the MDC for a novice rater ranged from 3.7°– 3.8° using a digital inclinometer (Konor et al., 2012). According to Krause et al., the MDC for the modified lunge was 6.1° and 6.4° for the two examiners (Krause et al., 2011). The IASTM group also reached a statistically significant increase in dorsiflexion ROM when measured with the MRP2 method. The mean change experienced by this group was $3.43 \pm 4.13°$ in comparison to the MDC values ranging from 6.5° to 7.9° (Krause et al., 2011). Finally, the lack of significant findings with MRP1 measurements suggests limited improvement in gastrocnemius muscle flexibility as a contributor to overall ankle dorsiflexion ROM. The clinical value of IASTM as an alternative to stretching of the gastrocnemius-soleus complex may reside in populations with conditions that may worsen with sustained stretching such as Haglund deformity or insertional tendinopathy (Chimenti et al., 2017).

5. Conclusion

Both IASTM and stretching of the gastrocnemius-soleus muscle complex may be effective for increasing weight-bearing ankle dorsiflexion ROM. Both IASTM and stretching resulted in significant increases in WB ankle dorsiflexion ROM, however, the increase did not meet the MCD values established in previous studies. While there were no significant differences between IASTM and stretching in WB, significant differences were found only for IASTM compared to stretching when measuring ankle dorsiflexion ROM in NWB with the knee flexed, suggesting that IASTM may have greater effects on the soleus muscle flexibility. Further investigation on the effectiveness of IASTM alone and in combination with stretching to improve ankle dorsiflexion ROM is warranted.

Conflicts of interest

None.

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