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Instrument-assisted soft tissue mobilization and proprioceptive neuromuscular facilitation techniques improve hamstring flexibility better than static stretching alone: a randomized clinical trial

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ABSTRACT

Objectives: Tight hamstrings contribute to inefficiency of movement and increased risk for injury. Static stretching is the most common intervention for this problem, but the use of alternatives like instrument-assisted soft tissue mobilization (IASTM) and proprioceptive neuromuscular facilitation (PNF) is increasing among clinicians. This study examined two prospective studies with the common aim of demonstrating the effectiveness of IASTM or PNF over static stretching for improving hamstring tightness.

Methods: Nondisabled adults were recruited on a university campus. IASTM study: $N = 17$ (11 males and 6 females). PNF study: $N = 23$ (7 males and 16 females). Hip flexion range of motion was measured with a passive straight leg raise (for IASTM) or active straight leg raise (for PNF) before and after stretching. Participants performed a self-static stretch on one leg and received the alternative intervention on the contralateral leg. The two studies were analyzed separately for reliability indices and significant differences between interventions.

Results: Hip flexion measures showed good reliability in both studies (intraclass correlation coefficient = 0.97) with a minimal detectable change of <4.26. Both studies showed significant interactions between time and intervention ($p < 0.05$). Follow-up analyses revealed PNF and IASTM interventions resulted in greater increases in hip flexion range than static stretching.

Discussion: These findings demonstrate the effectiveness of PNF and IASTM techniques over static stretching for hamstring flexibility. These interventions provide more efficient alternatives for improving flexibility in the clinic, allowing greater progress in a shorter period of time than an equivalent static stretching program.

Level of Evidence: 1b.

KEYWORDS
Flexibility; range of motion; knee flexors; active straight leg raise; passive straight leg raise; hip flexion; lower extremity; digital inclinometer

Introduction

The hamstring muscles are the primary muscles responsible for flexion of the knee, and as such play a significant role in normal performance of functional activities [1,2]. This muscle group resides in the posterior compartment of the thigh and consists of the semitendinosus, semimembranosus, and biceps femoris muscles [1]. Mobility can become inefficient and overuse syndromes can result when the biomechanics of shortened hamstrings result in imbalanced forces on the joints of the lower extremity [3–7]. During running, poor hamstring flexibility results in larger loads on the knee joint due to increased passive tensioning and compensatory activation of the knee extensors [4,6]. Multiple studies have linked a deficit in hamstring length to an increase in risk for hamstring strain [2,8–10]. Decreased hamstring extensibility may also lead to the development of low back pain as the hamstrings pull the pelvis into posterior rotation and result in spinal compensations [11–13].

Due to their ease of implementation, static stretching interventions have long been the standard intervention for muscle tightness. However, the efficacy of static stretching has inconclusive support in the literature [14–18]. Variables such as type, frequency, duration, intensity, and position generate conflicting evidence for best practice and render clinical decision-making uncertain. While this ambiguity exists for static stretching interventions, alternative methods for improving hamstring length are becoming popular.

Proprioceptive neuromuscular facilitation (PNF) techniques have been shown to increase hamstring length as effectively as, or more effectively than, comparable static stretching interventions in several studies[19–28] but other studies have found it is less effective [29]. PNF stretching is based upon the physiological reflex mechanism responsible for activating the Golgi tendon organ and causing autogenic inhibition in the agonist muscle [30]. There is a dearth of quality evidence specifically addressing the effectiveness of PNF stretching for

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the hamstrings, and this intervention warrants further investigation.

Another technique used to complement stretching interventions is instrument-assisted soft tissue mobilization (IASTM). The Graston Technique® is the most researched method for performing this intervention [31]. This technique is intended to promote connective tissue remodeling by releasing adhesions using stainless steel tools and eliciting a local inflammatory response [32–34]. Several case studies have been published documenting successful improvement in range of motion (ROM) following IASTM [35,36]. However, this intervention is underresearched and the evidence is inconclusive, largely due to variations in technique, tools, and duration of application [37]. Furthermore, a gap in the literature exists comparing the effectiveness of IASTM with other common interventions for improving tissue extensibility.

The purpose of this study was to examine the interventions of PNF stretching and IASTM to determine the effectiveness of these techniques on improving hamstring ROM in comparison to static stretching. Two separate prospective studies with the common aim of comparing either PNF or IASTM with static stretching were analyzed for significant effects on hamstring active and passive ROM. Based on previous studies, it was hypothesized that both IASTM and PNF stretching would result in greater improvements in hamstring length than static stretching alone.

Methods

Participants

Forty-eight total participants were recruited by word of mouth on the university campus to participate in interventions consisting of self-static stretching (SS), IASTM with static stretching (IASTM), or PNF stretching (PNF) for the hamstring muscles. Sample sizes were calculated a priori based on power and effect size. All data were collected in the university's physical therapy lab. Participants for the PNF study were recruited in August of 2016, while participants in the IASTM group were recruited in August of 2012. Participants in the PNF study ranged from age 21–65 years (32 ± 14.2, mean ± SD), and participants in the IASTM study ranged from age 20–30 (24 ± 2.0) (Table 1). Each participant received two interventions, either IASTM or PNF to one lower extremity and SS to the other lower extremity. Study inclusion required a clinical deficit in ROM as indicated by hip flexion of <80° measured by a straight leg raise test. Potential participants were excluded if they had recent history of trauma, open wounds, serious pathology, or anticoagulant medications. Each participant provided written informed consent through a protocol approved by the university Institutional Review Board.

Table 1. Baseline demographics.

Number of participants	PNF $n = 23$	IASTM $n = 17$
Age (years)		
$\bar{x}$	32	24
SD	14.2	2.0
Range	21–65	20–30
Sex		
Male	7	11
Female	16	6

$\bar{x}$, mean; SD, standard deviation.

Design

Participants were instructed to abstain from stretching or physical activity on the day of testing to prevent confounding effects. Each lower extremity was considered separately in data analysis, with the participants receiving PNF or IASTM on one lower extremity and SS on the other lower extremity. The right lower extremity was treated first for all participants, but the intervention completed on each leg was randomly assigned through use of a blinded card draw administered to participants by the primary investigator, allocating participants to either group 1 or group 2 (Figure 1). The examiners taking measurements were blinded to the interventions performed; only the primary investigator was aware of which lower extremity received which intervention.

Testing procedure

In the IASTM study, hip flexion was measured bilaterally with a passive straight leg raise (PSLR) using an inclinometer (Figure 2). A mark was placed 15 cm below the tibial tuberosity of each leg for reliability of inclinometer placement. With the participant in supine and the contralateral leg strapped to the table to minimize compensations, the inclinometer was 'zeroed out' on the lower extremity being measured. One examiner lifted the lower extremity off the table, maintaining knee extension, and stopped as soon as passive knee flexion was observed. At this point the other examiner recorded the value from the inclinometer. After recording baseline values for both legs, the participant received either IASTM with static stretching or the self-static stretching intervention on the right extremity and immediately returned for measurement of that leg. The alternate intervention was then administered to the left leg and the participant returned for measurement of that extremity. Each measurement was performed three times, with the latter two measures averaged for use in data analysis.

In the PNF study, hip flexion was measured bilaterally with an active straight leg raise (ASLR). Participants were positioned supine with the left leg stabilized on the table by an examiner to prevent pelvic rotation. A

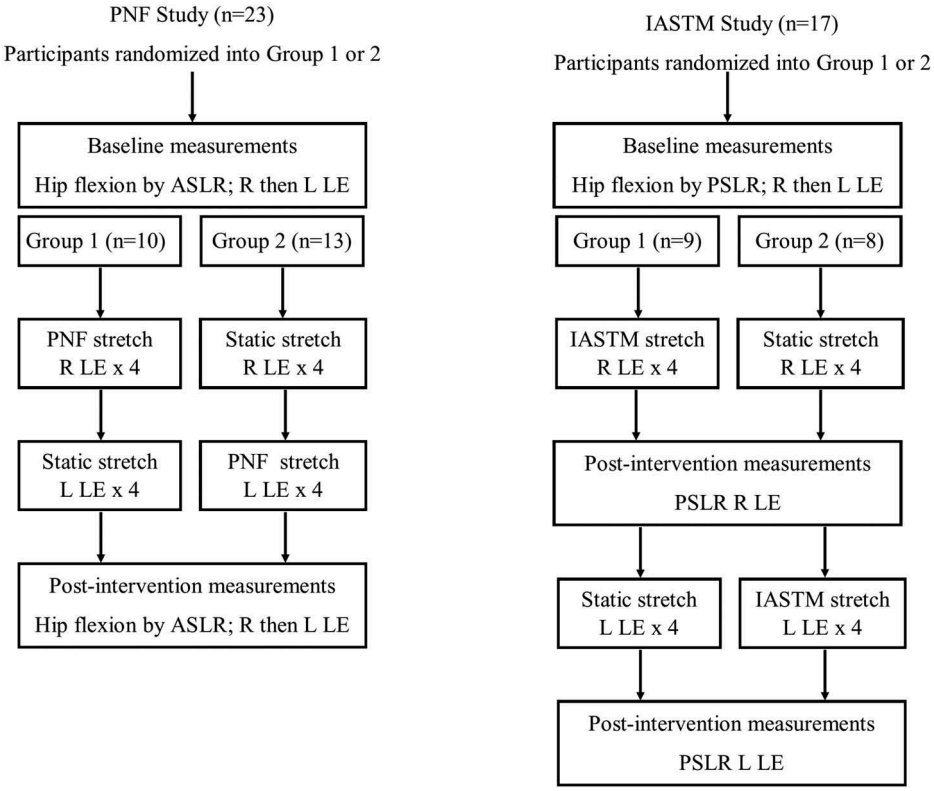

Figure 1. Flow chart of study procedures in each study. R, right; L, left; LE, lower extremity; *n*, number of participants; ASLR, active straight leg raise; PSLR, passive straight leg raise.

Figure 2. Measuring position for passive straight leg raise test (PSLR).

mark was placed 15 cm distal to the tibial tuberosity on each leg to ensure reliable placement of the inclinometer throughout the study. The inclinometer was 'zeroed out' on the participant's tibia prior to each measurement. The participant was then instructed to keep his or her leg as straight as possible and perform a straight leg raise as high as he or she could. Once the participant stated they had reached their maximum range, the examiner holding the inclinometer maintained the ROM by cupping his hand under the participant's heel, and the other examiner recorded the measurement. After participants received the PNF and SS interventions to each leg, hip flexion was measured in the same manner. For reliability, each examiner performed the same task for each participant, and the examiner assisting with the straight leg raise was blinded to measurement results. Each measurement was performed three times, with the latter two measures averaged for use in data analysis.

Interventions

All interventions were performed in a private treatment room by the primary investigator, a licensed physical therapist with 27 years of experience and Orthopedic Clinical Specialist, Fellow of the American Academy of Orthopedic Manual Physical Therapists, and Manual Therapy Certified credentials. Examiners were blinded to intervention leg and the primary investigator was blinded to baseline ROM values. After baseline measures, the PNF study participants received interventions on both lower extremities according to random group assignment with no more than a 1-min break between treatments. The participant lay supine for both self-stretching and PNF stretching interventions. The PNF stretch was performed by the primary investigator, who passively stretched the participant's fully extended leg for 30 s at 100% intensity (ascertained by self-determined maximum stretch before the onset of pain)

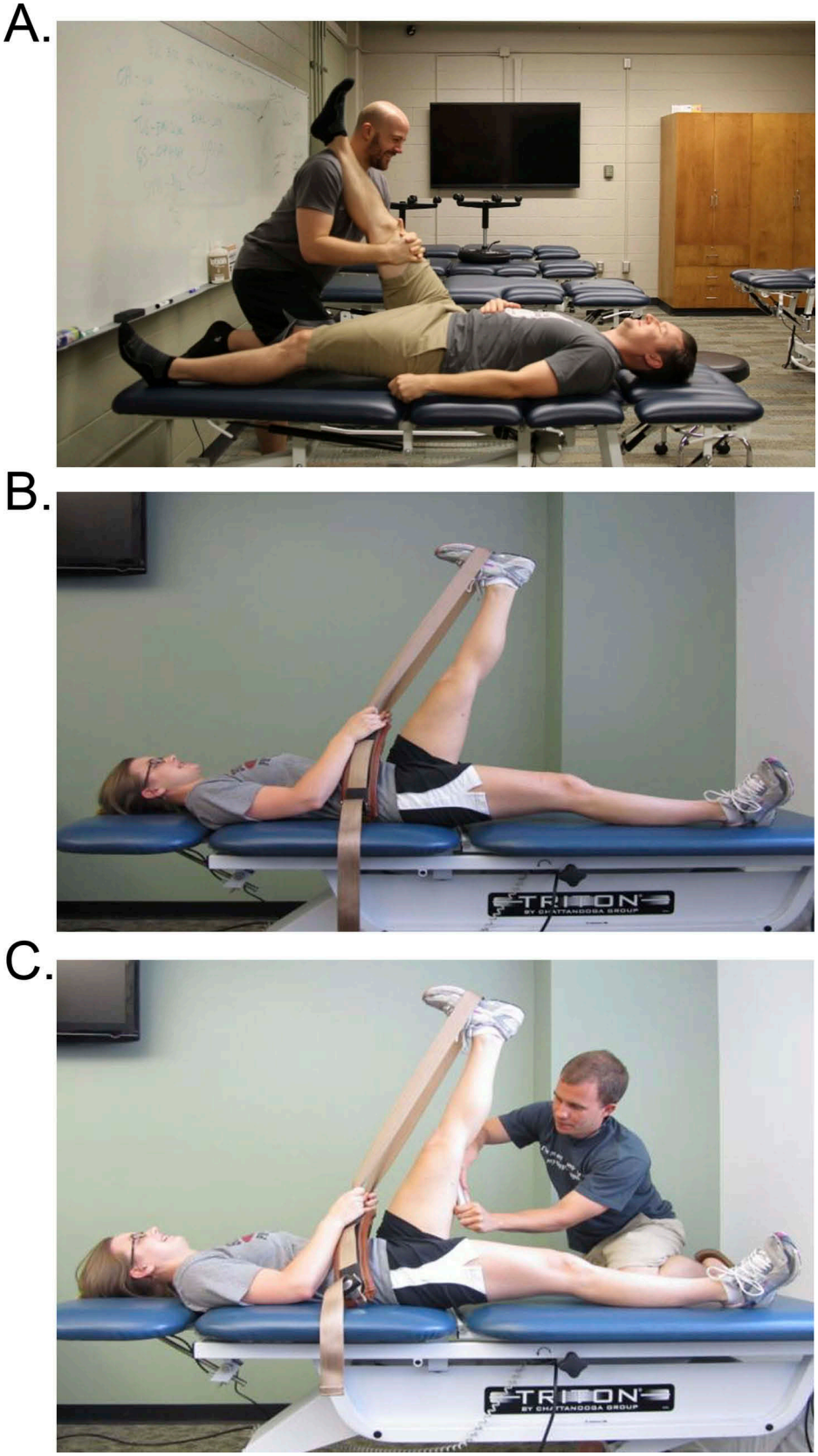

Figure 3. (A–C) PNF stretching, self-static stretching, and IASTM with static stretch.

(Figure 3A). Then the primary investigator instructed the participant to push his or her leg into the investigator's shoulder for 10 s with 20% strength while the investigator met his or her force isometrically. Immediately following the 10-s contraction, the investigator maintained the position, instructed the participant to relax, and passively stretched the extremity until 100% intensity was reached again. This new ROM

was held for 30 s. The intervention was repeated until four consecutive cycles of stretching and contraction were completed.

The self-static stretch was performed on the alternate leg. This stretch was performed in supine with the participant grasping a strap placed across the plantar surface of the foot with both hands and pulling the strap to raise the fully extended leg into hip flexion (Figure 3B). The participant was instructed to lift the leg until 100% intensity was achieved and hold the position for 30 s. The leg was lowered to the table for a 15-s rest, and this self-stretch was repeated until four repetitions had been completed.

For participants in the IASTM study, the IASTM with static stretching treatment was administered by the same primary investigator. Participants performed a self-stretch in the manner previously described. While the participant lay in the self-stretched position, the investigator applied IASTM to the posterior thigh with a contoured stainless steel instrument with consistent pressure from the beveled edge at a 45° angle (Figure 3C). A 'scraping' technique was performed, proceeding from distal to proximal and lateral to medial, mobilizing the entire surface of the hamstring complex for the 30-s duration of the stretch before the participant lowered his or her leg for a 15-s rest period. This process was repeated until four repetitions of the IASTM and rest cycle were completed. The other lower extremity received the SS treatment as described above for a total of four repetitions.

Data analysis

The aim of this paper is to determine the effectiveness of IASTM with static stretching and PNF stretching compared to static stretching alone for improving hamstring length, as assessed by two separate studies. Data were analyzed for normal distribution using the Shapiro–Wilk test. A two-way fixed model intraclass correlation coefficient (ICC), standard error of measure (SEM), and minimal detectable change (MDC) were calculated for each study; the calculated MDC value was used to determine whether a change in ROM was made beyond measurement noise. Each study was analyzed using a two-way repeated measures analysis of variance with factors for time (pre-, post-stretching) and intervention. Significant interactions were further analyzed with a paired *t*-test of ROM change scores from pre- to post-intervention in order to locate the significant difference.

Results

No adverse reactions were reported during the study. One participant in the IASTM group was unable to relax during interventions, resulting in exclusion from the study. When the data for the IASTM study was assessed for normality using the Shapiro–Wilk test, three outliers (participants 1, 4, and 14) were discovered and removed from data analysis, reducing the sample size to 17 subjects. All other data distributions were normal with *p*-values > 0.05. Reliability, precision of measurement and MDC were calculated using ICC and SEM at the 95% confidence interval for both studies; reliability was high (ICC = 0.97) and MDC was < 4.26° (Table 2).

Table 2. Reliability and minimum detectable change at 95% CI.

	PNF Study	IASTM Study
ICC (95% CI)	0.97 (0.943–0.982)	0.97 (0.957–0.979)
SEM (95% CI)	1.53 (3.01)	1.26 (2.47)
MDC_{95}	4.26	3.50

A significant interaction between time and intervention for both the PNF intervention ($p = 0.023$) and the IASTM intervention ($p < 0.005$) (Figure 4) was found. Follow-up analyses indicated that ROM between treatment legs was not significantly different at baseline. In the PNF group, the PNF intervention resulted in a statistically significant increase of 3.26° (95% CI, 0.4251 to 6.09221) ($t(22) = 2.385$, $p = 0.026$, $d = 0.497$) when compared to mean change in the static stretching legs. Based on the calculated MDC, we are 95% confident that 91% of participants (21/23) demonstrated real change after the PNF intervention and 78% of participants (18/23) showed real change after the static intervention. The pre- to post-intervention differences in the IASTM study were not normally distributed, so a Wilcoxon signed-rank test was used instead of a paired *t*-test. In the IASTM group, the Wilcoxon signed-rank test indicated a significant median change of 15° in the IASTM legs when compared to the static stretching legs ($z = 3.425$, $p < 0.005$). Based on the calculated MDC for the IASTM study, we are 95% confident that 94% of participants (16/17) demonstrated real change after the IASTM intervention and 29% of participants (5/17) showed real change after the static intervention.

Discussion

The aim of this study was to determine the effect of two different stretching techniques, IASTM and PNF, on hamstring extensibility when compared to static stretching alone. Both experimental interventions demonstrated a statistically significant greater increase in hip flexion ROM than static stretching. The results of this study are consistent with previous research indicating PNF stretching may be more effective than static stretching [25,26,28] and that IASTM may be an effective method for improving ROM [32,33,37–39]. It demonstrates that IASTM is effective specifically for treating tight hamstring muscles and affirms that PNF is effective

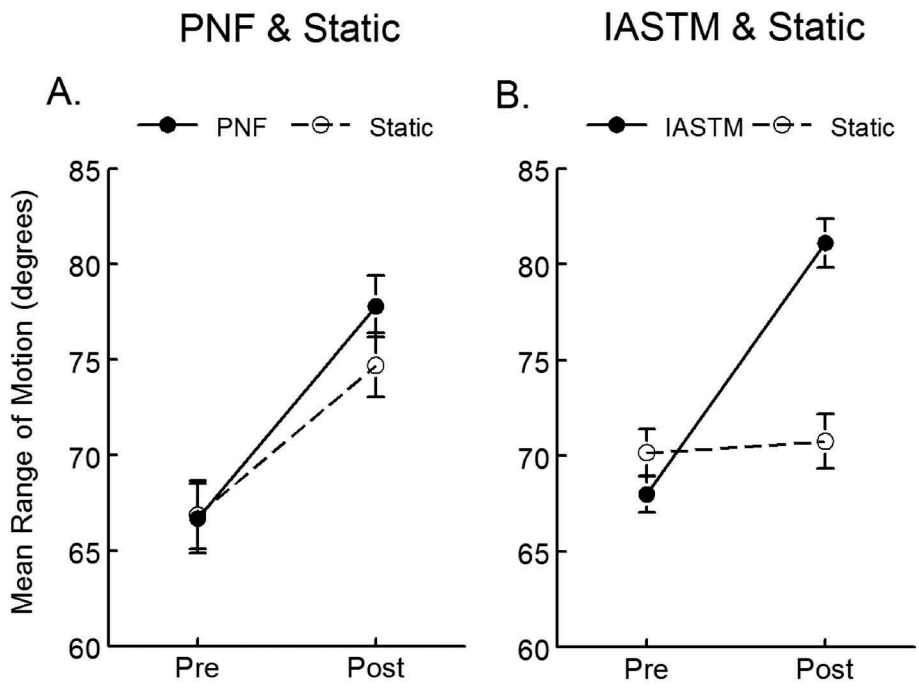

Figure 4. (A, B) Mean (± SEM) changes of hamstring ROM from pre to post in both studies. PNF and IASTM groups improved significantly more than static groups in both studies.

not only for improving passive ROM but also improving active ROM, as indicated by the ASLR test. While this study did not compare PNF and IASTM techniques directly, it provides evidence that both may be used in place of static stretching for more significant increases in ROM.

Objective outcome measures for assessing hamstring flexibility consist of tests that attempt to lengthen the hamstrings maximally in various ways to allow an angular ROM measurement. The PSLR is widely considered the 'gold standard' of tests for hamstring length and is frequently used in studies assessing hamstring length. Although from a clinical perspective the measurement of active ROM rather than passive ROM provides a more functional assessment, the ASLR and PSLR are both frequently used as field tests for hamstring length. Furthermore, one or two studies have suggested the ASLR may be used indistinctly with the PSLR [40,41]. Notably, the MDC values for PSLR and ASLR in our study were quite similar, though further research is needed to fully investigate this relationship.

The mechanisms behind increased ROM observed in therapeutic studies, such as this one, remain unclear. Explanations, such as increased stretch tolerance and muscle lengthening 'creep,' have been proposed to describe the results of acute bouts of stretching [42–44]. Since all interventions in this study included periods of sustained passive stretch that applied constant stress to lengthened muscles, these theories seem to indicate that all interventions should have resulted in similar changes. However, as this study affirmed, it is a common conclusion in the literature that PNF stretching demonstrates significantly greater increases than equivalent applications of static stretching [42,43,45]. Further research is needed to explore the specific effects of PNF versus static stretching to fully understand the reasons for this result. While PNF and static stretching are both stretching-type interventions, the benefits of IASTM are proposed to arise from a different mechanism. IASTM techniques attempt to target and break up structural adhesions within the fascia of muscles, which may be limiting extensibility [31,33,34]. Perhaps, since this study utilized static stretching in conjunction with the IASTM intervention, both of these mechanisms were at play, resulting in an acute, significant increase in hamstring length.

It is interesting to note that the legs receiving self-static stretching did not respond similarly between studies, despite the similarity of the self-stretching protocol. Within the PNF study, the static stretching resulted in significant change, while in the IASTM study it did not. This could potentially be attributed to differences in group demographics since the PNF study included more females (n = 16) than males (n = 7), whereas the IASTM study included more males (n = 11) than females (n = 6). Not only does the literature indicate that females tend to be more flexible at baseline than males[16,43,46,47] but there is increasing evidence showing females respond to acute bouts of stretching with significantly greater rates of change than males [44,48]. If this is the case, the higher number of females in the PNF static stretching group may have resulted in a higher mean change after static stretching than the IASTM

static stretching group with fewer females (individual ROM values linked with participant characteristics may be found in appended Supplementary Data).

Another possible reason behind the difference in change between static stretching groups is the lack of blinding of participants to intervention. While the examiners and primary investigator were blinded to the intervention and its effects, respectively, participants were not blinded to the stretching intervention they received, which may have resulted in subject bias. This could theoretically have impacted the PNF study more than the IASTM study since the test used for this study was an ASLR initiated and limited subjectively by the participant rather than objectively by the examiner.

The results of this study are relevant to clinicians seeking to improve hamstring flexibility because they demonstrate a more effective alternative to typical stretching interventions. IASTM techniques and PNF stretching produced greater immediate increases in passive and active hip flexion range than static stretching alone, indicating that choosing either of these interventions rather than an equivalent static stretching program could result in meeting flexibility goals more quickly. Improved flexibility provides the clinician a better opportunity to strengthen the extremity in the new range during a treatment session, perhaps resulting in more lasting flexibility effects. A more efficient method of improving flexibility is also beneficial for the use of home programs, allowing patients to make greater improvements while they practice stretching techniques at home.

There are some limitations to this study. While both PNF stretching and IASTM with static stretching produced significantly greater changes in hamstring length, our study does not provide evidence for which of these interventions is more effective. However, contraindications for IASTM are more extensive than those for PNF stretching, so IASTM may be less appropriate for some individuals [49]. From a clinical perspective, PNF stretching may be recommended as a home program to maintain benefits, while IASTM of the hamstrings requires a trained clinician for effective application [49]. All of our participants were also healthy, so it is difficult to generalize our results to individuals with pathological conditions that may be encountered in a therapeutic setting.

Conclusion

Both PNF stretching and IASTM techniques resulted in significant improvements to hip active and passive ROM, respectively, when compared to static stretching alone. These studies were performed reliably and precisely, with high ICC (ICC = 0.97) and low SEM values. MDC values < 4.26° indicate even a small change in ROM is indicative of true change with both the ASLR and PSLR. Both interventions are effective alternatives to conventional static stretching and are likely more effective for improving both active and passive hip flexion ROM.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

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