Research Article

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The Use of Instrument Assisted Soft Tissue Mobilization Verse Massage and Proprioceptive Neuromuscular Facilitation Stretching Techniques on Improving Hamstring Flexibility

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Abstract

Context: *Instrument assisted soft tissue mobilization (IASTM), massage and proprioceptive neuromuscular facilitation (PNF) stretching are interventions commonly used to address chronic muscle tightness and fascial restrictions. The efficacies of these interventions have not been well established.*

Objective: *The purpose of this study was to compare the effectiveness of two manual therapy approaches, IASTM and Massage with PNF stretching (MAS/PNF) in improving hamstring muscle tightness and subjective reporting of tightness in physically active individuals.*

Design: *Single blinded randomized, controlled, repeated-measures design, where group and treated limb were randomized.*

Setting: *University athletic training clinic.*

Participants: *Twenty healthy subjects (8 men, 12 women; mean age, 23.5±7.91 years) with bilateral hamstring tightness (measured using active knee extension (AKE)).*

Intervention: *Subjects were randomly assigned to one of two treatment groups, IASTM (n=12) and MAS/PNF (n=8). Both treatments consisted of a unilateral 10 minutes treatment to the posterior leg. The subject's untreated limb was the control. The authors measured pain levels (Visual Analog Scale (VAS)), general disability (Disablement in Physically Active Scale (DPAS), and perceived improvements in muscle tightness (Global Rate of Change (GRC)) at four different times (Pre, Post, 24hrs, 48hrs). A single blinded assessor collected all measurements.*

Main Outcome Measures: *A repeated measures analysis of variance determined within-subjects factors between AKE and time (Pre, Post, 24hrs, 48hrs), limb (Treated vs. Control), and group (IASTM vs. MAS/PNF). Kruskal-Wallis H test analyzed data collected from the patient reported measures.*

Results: *The authors found significant main effects between time (F=14.386, P< .001), limb (F=4.717, P=.043) and time-by-limb (F=11.233, P<.000), and AKE measurements. The treated limb of both groups demonstrated significant improvements in AKE compared to control limb. However the time by treatment interaction was not significant, indicating that both treatments groups changed similarly over time (P=.078). There was no difference in mean AKE between the treatment groups over time (F=4.717, P=.714). Significant within-subjects differences in VAS score were revealed for time (F=6.51, P=.000) and for time by group (F=4.46, P=.003). A significant treatment-by-time effect was revealed for the VAS during the treatment (F=10.47, P=.005). The IASTM group reported significantly higher discomfort during the treatment compared to the MAS/PNF group (P=.044). There was no statistically significant difference in the DPAS between the IASTM and MAS/PNF treatments, (post, p=.230; 24hrs, p=.475; 48hrs, p=.786). There was also no difference in GRC for perceived muscle tightness between groups over time (post, p=.321; 24hrs; p=.326; 48hrs, p=.609).*

Concusion: *Both IASTM and MAS/PNF interventions were effective in increasing hamstring flexibility immediately post treatment, which was retained for up to 48 hours. There were no significant differences between the magnitudes of improvement, DPAS, or GRC between the interventions, but those within the IASTIM group reported more discomfort during the treatment.*

Introduction

Hamstring muscle tightness and muscle strain injuries are a common phenomenon in physically active individuals [1, 2]. Although a direct causal relationship between hamstring tightness and injury predisposition is debatable, hamstring tightness is considered a risk factor for hamstring muscle injuries and a key element in sport performance. Several research studies have linked limited hamstring flexibility with increased risk of hamstring muscle injuries [3-6], altered trunk positioning during lifting tasks [7], low back pain [8,9], increased knee joint forces during running [10,11], patella-femoral pain syndrome [12-14], and decreased sport performance [15].

Muscle Tightness

Kisner and Colby define flexibility as the, "ability of a muscle and or other soft tissue to yield to a stretch force." [16]. Tissues with greater flexibility elongate more easily under lower force levels and enable unrestricted pain-free range of motion. Several factors have been discussed in the literature as contributing to muscle-tendon unit flexibility including increased passive and active stiffness and stretch tolerance [17].

Interventions

Common intervention used to improve muscle flexibility include static stretching [18-21]; active stretching [22,23], massage [24,25], and instrument assisted soft tissue mobilization (IASTM) [26-28].

Massage is commonly thought to reduce muscle tension and improving muscle compliance via mechanical, reflexive, hormonal, and psychological mechanisms [29]. The application of tensile, compressive and shear forces is thought to decrease tissue adhesions and reduce tissue stiffness by providing compressive, distractive, shearing and torsional forces to deform and elongate the body's connective tissues. However, research substantiating these effects are limited and their findings are conflicting. The application of IASTM to muscle and connective tissue has been reported useful in decreasing tissue restrictions and improving ROM and altering mechanoreceptor firing thresholds [30, 31].

Rationale for Study

A wide range of soft tissue mobilization and neuromuscular techniques are commonly used to improve extensibility and reduce stiffness of skin, muscle, tendons, and fascial tissues. Instrument Assisted Soft Tissue Mobilization (IASTM) and Proprioceptive Neuromuscular Facilitation (PNF) stretching techniques are commonly used to address chronic muscle tightness and fascial restrictions. Although IASTM and PNF stretching techniques have been shown to yield immediate/short-term improvements in muscle flexibility, there is a potential for adverse effects on muscle performance and pain perception following these treatments. Although temporary, these adverse effects can impact overall performance and perceived readiness for physical activity and therefore should be investigated as part of comprehensive benefits to harm analysis. This study attempts to examine both the potential benefits and possible risk of using these interventions for improving hamstring flexibility in healthy subjects with no reported hamstring pathology.

Purpose: The purpose of this study is to assess and compare the effectiveness of two commonly used manual therapy techniques, IASTM and PNF stretching in improving hamstring muscle tightness in young physically health individuals.

Subjects and Methods

Subjects

Twenty of the 24 healthy subjects with general bilateral hamstring tightness recruited completed the study. Participants for this study were recruited from a university setting and surrounding community via posted flyers, class announcements, and email notices. Inclusion criteria consisted of a bilateral active knee flexion angle of greater than 15◦ on the Active Knee Extension (AKE) Test. Subjects were excluded from the study if they reported hamstring muscle pain or had a history of hamstring injury within the 6 months, were currently taking any medications which altered pain perception or had any known effects on the normal inflammatory response (anti-coagulants, NSAIDs, analgesics) or reported history of any systemic disease or neurological conditions that may increase the risk of potential adverse response to deep tissue mobilization or muscle stretching. Twenty-four subjects scheduled an orientation session and consented to participate. Two subjects were excluded from the study during the initial screening process due to pre-existing conditions. The remaining 22 subjects with general bilateral hamstring tightness not associated with injury were cleared for participation, pre-tested, and randomly assigned to receive either the IASTM or MAS/PNF intervention. Two subjects, one from each group, missed one of the follow-up data collection session (1-the 24hr post session, 1-the 48hr post session). Complete data sets were obtained for 20 subjects (8 men, 12 women) with a mean age of 23.5 ± 7.91 years and an age range of 18-45 years. The majority of the subjects 17/20 (85%) were between the ages of 18-25 years. Baseline demographics are presented in (Table 1) No differences in demographics between the two groups were observed at baseline. The Instructional Review Board approved this study and all subjects provided written informed consent.

Table 1: Subject baseline demographics (N = 20; Mean ± SD[a]

	IASTM (n= 12)	MAS/PNF (n =8)
Age (y)	24.08 ± 7.37	22.75 ± 9.13
AKE Tx limb (deg)	47.05 ± 7.87	44.91 ± 9.64
AKE Control Limb (deg)	45.39 ± 8.05	43.74 ± 12.63
VAS (mm)	3.17 ± 7.96	4.0 ± 6.82
DPAS (range 0-64)	1.92 ± 3.03	3.12 ± 3.83

[a] Indicates no difference between groups at baseline

General Procedures

Individuals indicating interest in participating were sent information which provided an overview of the scope and purpose of the study, a copy of the informed consent and Health History Form and scheduled for the 1st of 3 sessions. During the first session, all participants were given an opportunity to ask questions and informed consent obtained by the PI. Subjects then completed the Health History Form which was individually reviewed by the PI and the initial hamstring tightness screening was completed to determine if they met the minimum hamstring tightness requirement (> 15° knee flexion angle during the AKE).

A single-blinded repeated measures design was used for this study with data collected before, immediately following, and approximately 24 and 48 hours post treatment. All participants meeting the inclusion criteria were then pre-tested and randomly assigned to either the IASTM or MAS/PNF group. The PI served

as the blinded assessor collecting all data measurements over the 3 sessions. After Pre-testing, subjects were taken into another room where the group allocation and limb to be treated was randomly determined by a coin toss. All interventions were administered by licensed clinician's (2 were certified athletic trainers and 1 was a licensed massage therapist) with advanced training in various PNF, massage and IASTM techniques and several years of clinical practice in using these techniques in direct patient/client care. All treatments were delivered unilaterally and data collected on the untreated limb was used as a control limb during statistical analysis. The treating clinicians retained documentation of the subjects' group allocation, limb treated, and the VAS score recorded during treatment until all data collection for the subject was completed.

Following the treatment session, all subjects returned to the data collection area where post treatment data was collected. All subjects were then scheduled for follow-up data collection sessions approximately 24 and 48hrs after the treatment session and asked to refrain from engaging in strenuous physical activities beyond their normal daily activities during the 48-hour data collection period.

Testing Protocol

All data collection sessions used the same testing sequence. Subjects completed a 5-minute warm-up on a stationary bike prior to data collection. Participants were positioned on a stationary bike with the seat positioned affording between 20-30 degree knee bend when the pedal as at its maximal extended position. Subjects were permitted to individually adjust the pedal tension to provide light but comfortable activation of the lower extremity musculature. Subjects were instructed that the purpose of biking was to prepare the muscles for activity; not to fatigue or obtain a strenuous workout.

Data was collected by a single-blinded assessor using same written instructions and general testing orders. Subjects completed the Disablement in Physically Active Scale (DPAS), Active Knee Extension Test (AKE), Visual Analog Scale (VAS), and Global Rate of Change Scale (GRCS). Since the Pre and Immediate Post treatment testing was done on the same day with approximately 20-30 minutes between test and re-test, the DPAS was completed during the pre-testing only and the GRCS was completed during the post-testing only.

The hamstring flexibility data was collected for both the treated and untreated extremities. The untreated leg served as a control extremity. Following the treatments, all subjects' thighs were loosely covered with a 4" stockinet to maintain blinding of the assessor during post-testing.

Measurements

Hamstring Flexibility

The active knee extension test (AKE) is a common method of assessing hamstring flexibility [32-34]. This measurement was taken with the subject lying supine on the treatment table. The subject was instructed to flex the hip of the tested leg to a 90° position. The assessor assisted the subject in positioning the hip by using a 90° wall mount and tape measure placed on table next to the subject and aligned with the greater trochanter (Figure 1). This device served as a vertical reference that was visible to both the subject and the assessor to assist in maintaining the proper hip positioning during the active knee extension test. A variety of similar vertical guides have been used in previous studies to improve consistency of the hip position during testing [9, 35]. This device was readily available, portable, and enabled quick bilateral assessments without requiring patient repositioning. Similar to Norris, 2005, the subjects were also asked to place their hand on the anterior surface of the thigh and instructed to not allow the thigh to move away from the hand while actively straightening the knee [36]. Subjects were also instructed keep the ankle relaxed while extending the knee. A standard 8" EZ Read JAMAR® goniometer was used to measure the subject's available knee active range of motion. The standard landmarks (greater trochanter, lateral femoral condyle and apex of the lateral malleolus) were identified by the assessor and active extension measured in degrees. Full knee extension was referenced as 0◦ with greater values indicating greater hamstring restriction. For all testing the right limb was measured first followed by the left leg, irrespective of which limb received the intervention. Three trials were measured for each limb and the values were averaged. Data collected for the untreated limbs and was later used in the analysis as the control leg.

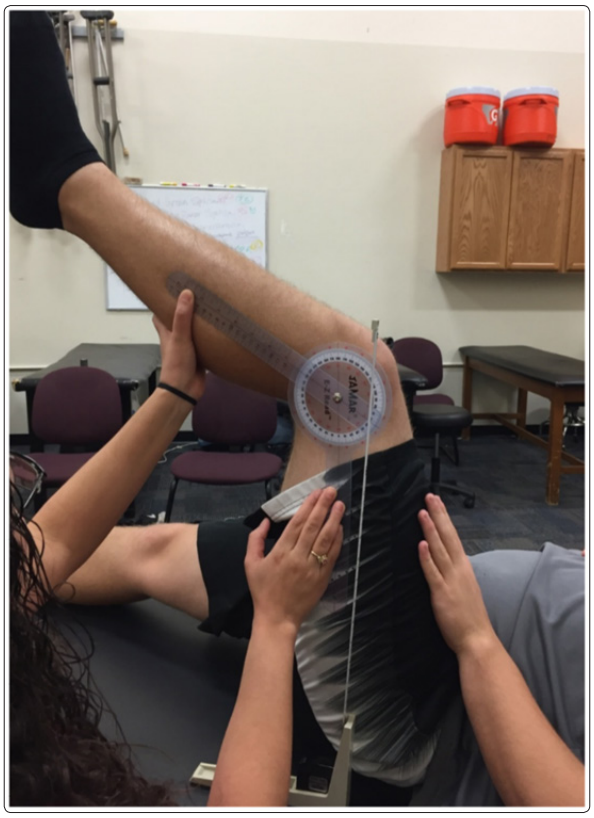

Figure 1

Since the AKE method used in this study was slightly different than those used in other studies, a small a convenience sample of 8 subjects was used to assess the intra-rater reliability of the AKE measurement. In this pilot, participants were assessed during 2 testing sessions separated by a 1 week interval. Three trials were taken during each session and the averaged values was used to establish the test-retest reliability. A two-way mixed model with absolute agreement interclass correlation coefficient (ICC) analysis was used. The ICC value of .86 which indicates "good' reliability, according to the value thresholds recommended by Portney and Watkins [37]. These finding are comparable and consistent with other studies indicating good intra- and inter-rater reliability of the AKE test [32-36].

Discomfort and Perception of Change

During this investigation the researchers were interested in recording subjects' perception of discomfort associated with either treatment as well as their perception of any changes in pain/discomfort, hamstring flexibility, and muscle performance over time.

A basic Visual Analog Scale (VAS) was used to assess participants' pain/discomfort levels at specific points - before, during, post, 24hrs, and 48hrs. The VAS scale used was a 10-cm line with the far left labeled "no pain" and the far right labeled "worst pain imaginable". Subjects were instructed to mark a vertical line indicating their current level of hamstring discomfort. Scores were measured in millimeters from the left ranging from 0-100mm.

A Global Rate of Change Scale (GRCS) was used to gather additional information the subjects' perception of any changes in tightness or restriction. The authors were interested in the subjects' perception of whether the treatment received resulted in improvement or deterioration over time. A 15-point GROC scale that ranged from -7 to +7. The labeling similar scale descriptors as used by Jaeschke, Singer, and Guyatt [38]. Zero on the scale represented no change, positive numbers indicated improvement and negative numbers indicated deterioration. Subject were asked to rate any perceived changes in the treated hamstring immediately post treatment and during the 24 and 48 hour follow-up sessions. Question formatting and administration recommendations described by Kamper, Maher, and Mackay were also used in designing this instrument [39].

The Disablement in Physically Active Scale (DPAS) was collected during Pre-testing and at 24 and 48hr follow-up session. The DPAS is a multidimensional disablement survey that is specifically designed to be used for assessing the level of disability in the physically active populations [40]. The 16-item survey gather patient reported information related to 3 domains: impairments, functional limitations, and disability. This questionnaire uses a 1- 5-point rating scale where a 1 indicates "no problem" and a 5 indicates "the problem severely affects me". Scores are derived by summing the scale values and then subtracting 16 points. Final scores can range from 0-64, with higher scores indicating higher levels of disablement. Vela and Denegar found the DPAS to be a reliable and valid instrument for assessing changes is disablement in physically active individuals with musculoskeletal injuries [41].

Interventions

Subjects were randomly assigned to one of 2 treatment groups, IASTM (n=13) and MAS/PNF (n=9). Both treatments consisted of a unilateral treatment to the posterior leg. The total treatment time for both groups was between 5-10 minutes. All subjects were oriented on what to expect during the treatment, the targeted intensity of the treatment, and how to communicate with the practitioner during the delivery of the interventions. A 10- point discomfort scale was used during all treatments and no treatment was permitted to exceed 6 on this scale. The clinicians conducting the intervention were trained clinicians who closely monitored subject's discomfort and altered the delivery to avoid any excessive discomfort and minimize potential for soft tissue injury.

Massage/PNF

Subjects assigned to this group received 10 minute treatment to the posterior lower extremity which consisted of approximately 5 minutes of massage followed by 5 minutes of PNF stretching. Approximately 3-4 repetition were used for each of the massage and PNF stretching techniques. Subjects were initially positioned prone on the treatment table and the soft tissue assessed and prepared for mobilization using basic effleurage and petrissage strokes. Compressive lengthen strokes along the posterior fascial line were used along with active knee extension to facilitate elongation of the hamstring muscles. The massage component of the treatment was then concluded with some quick jostling and the patient was repositioned to supine. In the supine position the hip and knee were passively ranged to assess the point of bind. The PNF stretching component of the treatment consisted of 3-4 repetition of Hold-Relax and Hold-Relax with Agonist Contraction techniques described by Kisner & Colby [16].

IASTM

Subjects assigned to the IASTM group received a 5-10 minute treatment by a certified athletic trainer who was certified by Tecnica Gavilán method of IASTM. The subjects were positioned prone on the table, lubricant applied and posterior thigh tissues assessed for restrictions using the Ala instrument (Técnica Gavilán, Tracy, CA). The subjects were then repositioned to standing at the edge of the table with the trunk flexed and supported on the table to comfortably elongate the hamstrings. The instrument was then applied parallel to the muscle fibers, both in a distal to proximal and them proximal to distal direction as needed to address restrictions. To reduce risks of adverse effects IASTM instrument was applied for no more than 5 minutes for all subjects in this group. Subjects were then asked to perform some light active ranging of the hamstring muscles by performing forward trunk flexion, standing knee flexion/extension, and squatting immediately following the treatment.

Statistical Analysis

Statistical analysis were completed using IBM SPSS Statistics version 23.0 software (SPSS IBM Inc., Armonk, NY). A 2 x 2 x 4 repeated measures analysis of variance was used to determine within-subjects factors for Time (Pre, Post, 24hrs, 48hrs) and Limb (Tx'ed vs. Control) and between-subjects for Group (IASTM vs. MAS/PNF). The Cohen's d was used to compute the effect sizes of the differences in the dependent variables. Effect size interpretation were: $d \geq .80$ is a large effect, $d = 0.5\text{-}0.79$ is a moderate effect, $d = 0.20\text{-}0.49$ is a small effect, and > 0.2 is a trivial effect. Intent to treat analyses were conducted on the incomplete data sets to determine the impact of missing data. Statistical significance was accepted at the 95% level ($p<0.05$). AKE descriptive data is reported as means and standard deviations (SD). Bonferroni posthoc tests were used for significant main effects and interactions.

Results

Complete data sets were obtained from 20 of the 22 subjects. Of the 2 incomplete data sets, 2 subjects (1 female, 1 male) missed one of the follow-up data collection session (1 – the 24-hrs post session, 1- the 48-hrs post session). An intent to treat analysis using the last observation carried forward method was done to analyze the impact of the missing outcome data. This analysis indicated that the loss of the 2 subjects did not likely have a significant impact on the data analysis. [Within subject-significance was found for Time, Limb, and Time X limb]. Therefore the results presented included only the 20 complete data sets obtained IASTM Group n=12 (8 females, 4 males; mean age, 24 ± 7.3yrs) , MAS/PNF n= 8 (4 females, 4 males, mean age, 23 ± 9.1yrs). No group differences were found in demographics and dependent variables at pre-treatment testing

indicating that randomization was successful.

Hamstring Flexibility

For the AKE variable a repeated measures analysis of variance was conducted to analyze within and between-subject differences in hamstring flexibility. The within-subjects variables were Time (Pre, Post, 24hrs, 48hrs) and Limb (Tx'ed vs. Control). The between-subjects factor was the treatment group (IASTM vs. MAS/PNF).

There were no statistical differences in mean AKE values between the groups or between the control and treated limb at Pre-testing (Table 2).

Table 2: Descriptive statistics ake by group and limb

TIME	IASTM (n=12) Mean (SD)		MAS/PNF (n=8) MEAN (SD)		All (n=20) MEAN (SD)	
	Tx'ed Limb	Control Limb	Tx'ed Limb	Control Limb	Tx'ed Limb	Control Limb
Pre	47.05 (7.89)	45.39 (8.05)	44.92 (9.64)	43.75 (12.63)	46.20 (8.45)	44.73 (9.85)
Post	39.94 (6.67)	44.97 (8.20)	34.13 (9.14)	39.33 (14.83)	37.62 (8.07)	42.71 (11.31)
24-hrs Post	40.64 (8.91)	44.25 (8.44)	38.46 (10.82)	39.12 (13.41)	39.77 (9.51)	42.20 (10.68)
48-hrs Post	41.17 (8.65)	43.97 (7.28)	38.54 (12.63)	40.75 (14.10)	40.11 (10.19)	42.68 (10.32)
Pre→Post	7.11	.4	10.69	4.42	8.58	2.02
Pre→ 24-hrs	6.41	1.14	6.46	4.63	6.43	2.53
Pre -> 48-hrs	5.88	1.42	6.38	3	6.09	2.05

A 2 x 2 x 4 repeated measures analysis of variance was used to determine within-subjects factors for Time (Pre, Post, 24hrs, 48hrs) and Limb (Tx'ed vs. Control) and between-subjects for Group (IASTM vs. MAS/PNF). Main effects were observed for time (F=14.386, P< .001), limb (F= 4.717, P= .043) and time-by-limb (F=11.233, P<.000) were revealed. An interaction was found between the treated limb and the control limb of both treatment groups after treatment. The treated limb of both groups demonstrated significant improvements in AKE compared to the control limb. However the time by treatment interaction was not significant, indicating that both treatments groups changed similarly over time (P= .078). There was no statistical difference in mean AKE between the 2 treatment groups over time (F=4.717, P<.714).

When the groups were combined mean differences in AKE angles of the treated limb were decreased with significance immediately post treatment (P= .000), 24-hrs (P= .001), and 48hrs (P=.015) compared to pre-test Table 3. Further analysis of the pooled group data found that mean AKE values for the treated limbs showed a significantly greater improvement in hamstring flexibility than did the control limbs when comparing pre-test AKE with post-test (8.58, ± 4.97° vs. 2.02 ± 3.52°), 24-hr (6.4 ± 5.05° vs. 2.5 ± 5.17°, and 48-hr (6.1 ± 6.12° vs. 2.1° ± 5.38°) measures (Table 4 and 4b). The effect size for the treated limb over time ranged from large to moderate (post: d= 1.03; 24-hr: d= .715; 48-hr: d= .650) with none of the 95% CIs for crossing zero. Effect sizes for the control limb ranged from small to trivial (post d=0.190, 24-hr: d=0.246, 48-hr: d= 0.203) with 95% CI that crossed zero Table 5.

Table 3: Pairwise comparisons of pooled group data for AKE for TIME

Pairwise Comparisons

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Differenceb	
					Lower Bound	Upper Bound
Pre	Post	5.683*	.695	.000	3.624	7.742
	24 hrs	4.659*	1.000	.001	1.696	7.622
	48 hrs	4.171*	1.189	.015	.649	7.694
Post	Pre	-5.683*	.695	.000	-7.742	-3.624
	24 hrs	-1.023	.813	1.000	-3.433	1.386
	48 hrs	-1.511	1.091	1.000	-4.742	1.720
24 hrs	Pre	-4.659*	1.000	.001	-7.622	-1.696
	Post	1.023	.813	1.000	-1.386	3.433
	48 hrs	-.488	.681	1.000	-2.504	1.529

48 hrs	Pre	-4.171*	1.189	.015	-7.694	-.649
	Post	1.511	1.091	1.000	-1.720	4.742
	24 hrs	.488	.681	1.000	-1.529	2.504

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Table 4a: AKE paired samples T-test -Tx vs. control MEANS
Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean	Cohen's d (effect-size r)
Pair 1	AKE_PRE_Tx	46.1975	20	8.44997	1.88947	1.039
	AKE_Post_Tx	37.6165	20	8.06718	1.80388	
Pair 2	AKE_Pre_Control	44.7320	20	9.84602	2.20164	0.190
	AKE_Post_Control	42.7160	20	11.31052	2.52911	
Pair 3	AKE_PRE_Tx	46.1975	20	8.44997	1.88947	0.715
	AKE_24hr_Tx	39.7650	20	9.50660	2.12574	
Pair 4	AKE_Pre_Control	44.7320	20	9.84602	2.20164	0.246
	AKE_24hr_Control	42.1990	20	10.68328	2.38885	
Pair 5	AKE_PRE_Tx	46.1975	20	8.44997	1.88947	0.650
	AKE_48hr_Tx	40.1150	20	10.19045	2.27865	
Pair 6	AKE_Pre_Control	44.7320	20	9.84602	2.20164	0.203
	AKE_48hr_Control	42.6785	20	10.32378	2.30847	

Cohen's d For Effect Size using Paired Sample T-test data
Effect for Tx'ed between Pre-Post tx:

Table 4b: Paired sample showing significant difference between Tx vs. Control
Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. D eviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	AKE_PRE_Tx - AKE_ Post_Tx	8.58100	4.97309	1.11202	6.25352	10.90848	7.717	19	.000
Pair 2	AKE_Pre_Control - AKE_Post_Control	2.01600	3.52468	.78814	.36640	3.66560	2.558	19	.019
Pair 3	AKE_PRE_Tx - AKE_24hr_Tx	6.43250	5.05369	1.13004	4.06730	8.79770	5.692	19	.000
Pair 4	AKE_Pre_Control - AKE_24hr_Control	2.53300	5.17255	1.15662	.11217	4.95383	2.190	19	.041
Pair 5	AKE_PRE_Tx - AKE_48hr_Tx	6.08250	6.11873	1.36819	3.21885	8.94615	4.446	19	.000
Pair 6	AKE_Pre_Control - AKE_48hr_Control	2.05350	5.38082	1.20319	-.46480	4.57180	1.707	19	.104

Table 5: Time-by-Limb Analysis

7. Time * Limb

Measure: AKE

Time	Limb	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1-Pre	Tx	45.984	1.965	41.855	50.113
	Control	44.568	2.301	39.735	49.401
2-Post	Tx	37.035	1.763	33.331	40.738
	Control	42.152	2.567	36.758	47.546
3- 24 hrs	Tx	39.547	2.214	34.895	44.199
	Control	41.687	2.431	36.579	46.794
4-48 hrs	Tx	39.853	2.369	34.875	44.830
	Control	42.357	2.391	37.334	47.379

Visual Analog Scores (VAS) were recorded in millimeters from the left ranging from 0-100mm. A repeated measures analysis of variance was conducted to analyze within and between subject differences across 5 time points (Pre, during tx, Post, 24-hrs, and 48-hrs). Significant within-subjects differences were revealed for time (F=6.51, P= .000) and for time by group (F= 4.46, P=.003). A significant treatment-by-time effect was revealed for the VAS DURING the treatment (F=10.47, P= .005). Posthoc testing revealed that mean VAS during tx was significantly higher for the IASTM compared to the MAS/PNF. The IASTM group reported significantly higher discomfort during the treatment compared to the MAS/PNF group (IASTM = 21 mm, MAS/PNF= 3.38 mm, P> .044). Table 6

Table 6: Independent t-test for VAS over time

Group Statistics

	Group	N	Mean (mm)	SD	Std. Error Mean
VAS_Pre	IASTM	12	3.17	7.96	2.30
	MAS/ PNF	8	4.00	6.82	2.41
VAS_Post	IASTM	12	3.25	7.02	2.03
	MAS/ PNF	8	1.87	2.75	.972
VAS_24hr	IASTM	12	.500	1.17	.337
	MAS/ PNF	8	.875	1.46	.515
VAS_48hr	IASTM	12	1.00	1.41	.408
	MAS/ PNF	8	.625	.916	.324
VAS_DURING+	IASTM	12	21.00	22.49	6.49
	MAS/ PNF	8	3.38	4.66	1.65
+ significant at .05 level					

DPAS was reported as raw scores minus 16 with a possible score range from 0-64, with higher scores indicating higher levels of disablement. A Kruskal-Wallis H test showed that there was no statistically significant difference in disablement over time between the IASTM and MAS/PNF treatments.

Table 7: DPAS repeated measures data
Tests of Within-Subjects Effects
Measure: DPAS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Sphericity Assumed	28.317	2	14.158	5.314	.010
	Greenhouse-Geisser	28.317	1.696	16.700	5.314	.014
	Huynh-Feldt	28.317	1.957	14.467	5.314	.010
	Lower-bound	28.317	1.000	28.317	5.314	.033
Time * Group	Sphericity Assumed	4.117	2	2.058	.773	.469
	Greenhouse-Geisser	4.117	1.696	2.428	.773	.451
	Huynh-Feldt	4.117	1.957	2.103	.773	.467
	Lower-bound	4.117	1.000	4.117	.773	.391
Error(Time)	Sphericity Assumed	95.917	36	2.664		
	Greenhouse-Geisser	95.917	30.522	3.143		
	Huynh-Feldt	95.917	35.232	2.722		
	Lower-bound	95.917	18.000	5.329		

Descriptive Statistics

	Group	Mean	Std. Deviation	N
DPAS_Pre	1.00	1.9167	3.02890	12
	2.00	3.1250	3.83359	8
	Total	2.4000	3.33088	20
DPAS_24hr	1.00	.5000	1.00000	12
	2.00	1.8750	3.79614	8
	Total	1.0500	2.52305	20
DPAS_48hr	1.00	.8333	1.58592	12
	2.00	1.0000	1.51186	8
	Total	.9000	1.51831	20

Test Statistics[a,b]

	DPAS_Pre	DPAS_24hr	DPAS_48hr
Chi-Square	1.443	.511	.074
df	1	1	1
Asymp. Sig.	.230	.475	.786

a. Kruskal Wallis Test
b. Grouping Variable: Group

A repeated measures analysis of variance was conducted to analyze within and between- subject differences for the 2 treatment groups (IASTM vs. MAS/PNF) over 3 time points (Pre, 24-hrs, and 48-hrs). A significant interaction was found over time (F=5.314, P= .010) but there was no significant difference for time by group (F= .773, P = .469) (TABLE 7). A Kruskal-Wallis H test showed that there was no statistically significant difference in perceived between the IASTM and MAS/PNF treatments, (POST- X2(2)= 1.443, p= .230; 24-hrs- X2(2)=0. .511, p=.475.; 48hr- X2(2)= .074, p= . 786).

Global Rate of Change

Subjects' rated their perceptions of any changes muscle tightness (GRCT) using a 15-point GRCS at 3 time points, Post, 24-hrs, and 48-hrs. A Kruskal-Wallis H test showed that there was no statistically significant difference in perceived between the IASTM and MAS/PNF treatments, (POST- X2(2)= 0.985, p= 0.321; 24-hrs- X2(2)=0.964, p=.326; 48hr- X2(2)=.261, p= .609) (Table 8).

The average GRC scores of the pooled groups indicates that subjects overall reported improvement in muscle tightness with Post scores ranging from 0 -7, mean = 3.05, indicating that subjects perceived their hamstring tightness was somewhat better. No negative values were reported by either group for the GRCT question indicating that no subject reported a perceived worsening of hamstring tightness or restriction Table 9.

Table 8: Global rate of change
Test Statistics[a,b]

	GRC_Post	GRC_24hr	GRC_48hr
Chi-Square	.985	.964	.261
df	1	1	1
Asymp. Sig.	.321	.326	.609

a. Kruskal Wallis Test
b. Grouping Variable: Group

Table 9: Report

Group		GRC_Post	GRC_24hr	GRC_48hr
IASTM	Mean	2.6667	2.4167	2.2500
	N	12	12	12
	Std. Deviation	1.66969	1.78164	2.13733
	Minimum	.00	.00	.00
	Maximum	5.00	6.00	7.00
	Range	5.00	6.00	7.00
	Median	3.0000	2.0000	2.0000
MAS/PNF	Mean	3.6250	2.8750	1.7500
	N	8	8	8
	Std. Deviation	1.76777	1.45774	1.83225
	Minimum	1.00	.00	.00
	Maximum	7.00	5.00	5.00
	Range	6.00	5.00	5.00
	Median	3.0000	3.0000	1.0000
Total	Mean	3.0500	2.6000	2.0500
	N	20	20	20
	Std. Deviation	1.73129	1.63514	1.98614
	Minimum	.00	.00	.00
	Maximum	7.00	6.00	7.00
	Range	7.00	6.00	7.00
	Median	3.0000	2.5000	1.5000

Discussion

The main findings in this study were that an 8-10 minute intervention of either IASTM or massage/PNF were both effective in improving hamstring flexibility and subjective reporting of tightness.

Both IASTM and MAS/PNF interventions were effective in increasing hamstring flexibility immediately post treatment and that this improvement was retained for up to 48 hours post treatment. However, there was no significant differences between the magnitudes of improvement between the 2 treatment interventions. In this study the subject's contralateral limb was used as a control. The treated limb demonstrated significantly improved hamstring flexibility immediately after treatment which was still measureable at 24 and 48hrs post treatment. The greatest improvements were measured immediately post treatment. The IASTM group's AKE angle decreased by an average of 7.11 ° and the MAS/PNF AKE decreased by an average of 10.69°. There were no significant differences between the improvements obtained between the IASTM and MAS/PNF treatments over time. The pooled group data showed greatest improvement in AKE was immediately post treatment for both treatment groups (Mean= 8.58°, SD=4.9, 95% CI= 6.25-10.9). The effect sizes for AKE test ranged from large to moderate with CI's that did not cross zero indicating that both the IASTM and massage/PNF stretching treatments are likely to yield improved hamstring extensibility immediately following treatment. Also found was that although range of motion gained with the single treatment session diminished considerably over time, there was still a moderate improvement in flexibility recorded at 24-hrs (AKE= 6.43 ± 5.05°, d=0.72) and 48-hrs (6.08 ± 6.12°, d= 0.65) post treatment.

These data are consistent with others studies investigating range of motion improvements associated with soft tissue mobilization treatments such as IASTM, massage, and PNF stretching in healthy subjects. Marshall, Cashman and Cheema [21] conducted a randomized control trial investigating the benefits of passive stretching completed 5x/week for 4-weeks. In their study 4 basic hamstring and hip stretches were completed, each stretch was for 30 seconds and repeated 3 times. The authors reported the average time to complete the stretching program was between 12-15 minutes. They reported a 15.9° improvement in hamstring extensibility between baseline and the 4-week follow-up. The improvement seen in our study was considerably less 8.58°, however this improvement was gained from a single 10- minute treatment session. Conducted a pre-post treatment randomized control of found that a single treatment of IASTM to the posterior shoulder resulted in a 11.1° improvement in horizontal adduction and a 4.8° improvement in shoulder internal rotation in healthy asymptomatic baseball players [27]. Similarly in our study the group receiving the IASTM demonstrated a 7.11° improvement in hamstring flexibility immediately following the treat. Our results also demonstrated that this ROM remained significantly improved in comparison to the non-treated control limb at the 24-hr (6.41°) and 48-hr (5.88°) follow-up assessments.

In contrast to our study's findings, Kim et al.,[28] compared the effects of Hold-Relax (HC), Strain-counter strain (SCS), and IASTM techniques on hamstring and quadriceps muscle strength, knee joint passive stiffness, and pain threshold in healthy female subjects with hamstring tightness. They found that the IASTM group showed greater improvements compared to both the HC and SCS groups. In our study the assessor was blinded to the group allocation which reduced the likelihood of bias. Additionally, our MASS/PNF intervention was a more comprehensive intervention protocol that

included components that targeted both neurological and viscoelastic properties of soft tissue that can contribute restricted range of motion. In the present study, both interventions studied incorporated dynamic tissue mobilizations which might be surmised as being a key factor in achieving short-term improvements in muscle flexibility.

Both of the interventions evaluated in this study took between 8-10 minutes to complete and were only repeated once and yielded immediate improvements in hamstring flexibility of 8.58°. Although these gains diminish over time, the effect of this single treatment was still measurable and at 24-hrs (6.43°) and 48-hrs post treatment.

IASTM Treatment more uncomfortable than MAS/PNF Treatment. The subjects in this study were healthy and therefore the VAS scores recorded at baseline indicated subjects reported minimal discomfort in the posterior thigh area (IASM = 3.17, ± 7.96 mm; MAS/PNF =4.0, ± 6.82 mm). During the treatment however, subjects in the IASTM reported a significant increase in VAS scores during the treatment (IASTM= 21 ± 22.49 mm vs. MAS/PNF=3.38 ± 4.66 mm). The VAS rating during the treatment for the IASTM group was highly variable in comparison to VAS ratings given at other time points. Suggesting that the mean value may not be well representative of individual responses. The elevation of VAS score did not remain into the post, 24-hr, and 48-hr assessments which suggests the any discomfort experience with the IASTM was transient.

MAS/PNF stretching may achieve similar benefits without causing discomfort. A few subjects in the IASTM reported experiencing skin bruising following the treatment. No subjects reported discomfort warranting medical treatment.

DPAS

The subjects in this study were health individuals reporting minimal disability as measured by the DPAS. The DPAS collected at pre-test ranged from 0-12 with a mean score for all subjects of a 2.4, SD = 3.33. These scores remained consistent over the 48-hr data collection period indicating that neither treatment resulted in a significant change in overall disability.

GROCS

Overall subjects reported perceived improvement in hamstring tightness immediately following the treatment. GRCT scores POST treatment ranged from 0 (About the same) to a 7 (A very great deal better), with a Mode of 3 (Somewhat better). No negative values were reported by subjects in either group for the GROCT question indicating that no subjects reported a perceived worsening of hamstring tightness or restriction.

Conclusions

Both IASTM and MAS/PNF interventions were effective in increasing hamstring flexibility immediately post treatment, which was retained for up to 48 hours. There were no significant differences between the magnitudes of improvement, DPAS, or GRC between the interventions. The IASTM group reported significantly higher discomfort ratings during the delivery of the treatment; however, the discomfort experienced was mild not significant at the 24 and 48hr post treatment.

Limitations

The subject used in this study were a convenience sample of relatively young population with no history of hamstring pathology. The use of the untreated limb as the control condition left the measured differences susceptible to reporting bias and other biases related to lack of subject blinding.

In review of the descriptive statistics there was a clear difference in the SD and SE values for the 2 treatment groups. The data points were more spread out making the SE and 95% CI intervals larger. Likely due to the fewer number of subjects in the MAS/PNF group. Possibly the limited number of subjects in this group might have resulted in a Type II error with regard to Treatment equality.

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