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The immediate effect of IASTM vs. Vibration vs. Light Hand Massage on knee angle repositioning accuracy and hamstrings flexibility: A pilot study

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ABSTRACT

Introduction: The effectiveness of novel soft-tissue interventions relative to traditional ones requires further exploration. The purpose of this pilot study was to evaluate the immediate effect of Instrument Assisted Soft Tissue Mobilization (IASTM) compared to Vibration Massage or Light Hand Massage on hamstrings' flexibility and knee proprioception.
Methods: 16 healthy non-injured male participants (mean age 23.7 years, height 1.80 cms and body mass 77.7 kg) were randomly assigned to the following interventions: (a) 5min IASTM, (b) 5min Vibration Massage and (c) 8min Light Hand-Massage, sequentially delivered to all participants with an in-between 1-week time interval. A single application of each intervention was given over the hamstrings of their dominant leg (repeated measures under 3 different experimental conditions). An active knee angle reproduction proprioception test and the back-saver sit and reach flexibility test were performed before and immediately after each intervention. Reliability of outcomes was also assessed.
Results: Reliability for flexibility ($ICC_{3,1}$ = 0.97–0.99/SEM = 0.83–1.52 cm) and proprioception ($ICC_{3,1}$ = 0.83–0.88/SEM = 1.63–2.02°) was very good. For flexibility, statistically significant immediate improvement ($p < 0.001$) was noted in all 3 groups (1.61–3.23 cm), with no between-group differences. For proprioception, improvement in the IASTM (2.12°), Vibration Massage (0.32°) and Light Hand-Massage (1.17°) conditions was not statistically significant; no between-group differences were also evident.
Conclusions: Our findings indicate that muscle flexibility was positively influenced immediately after a single intervention of IASTM, Vibration Massage or Light Hand Massage. Proprioception changes were not statistically significant either within or between groups. Further evaluation of those interventions in a larger population with hamstrings pathology is required.

1. Introduction

Hamstring injuries are amongst the most common sports injuries, accounting for 12–16% of all athletic injuries in football, especially when acceleration is required (Petersen and Holmich, 2005). They can be challenging to manage and usually have a high recurrence rate, of about one third within the first two weeks (Erickson and Sherry, 2017). Many risk factors leading to hamstring strains have been proposed, such as decreased flexibility (de la Motte et al., 2019; Gabbe et al., 2005; McHugh and Cosgrave, 2010), eccentric hamstrings strength deficits (Goossens et al., 2015; Petersen et al., 2011) or eccentric hamstrings strength asymmetries (Fousekis et al., 2011), poor core stability involving the gluteal and trunk muscles (Schuermans et al., 2017) and previous hamstring injury (Engebretsen et al., 2010).

These risk factors do not seem to independently exert an effect

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but have been proposed to interact in a complex manner (Buckthorpe et al., 2019). For instance, 'previous hamstring injury' is likely to reflect documented hamstrings strength and flexibility deficits (Maniar et al., 2016), associated with one or more previous injuries in these muscles. As far as flexibility is concerned, negative correlations have been reported between hamstrings' flexibility and peak hamstring muscle strain (length deformation in relation to optimal length) in all 3 hamstring muscles during the late swing phase of sprinting (Wan et al., 2017). Therefore, during strenuous activities like sprinting, participants with less flexible hamstrings tend to present with more relative elongation in all 3 hamstrings, translating to higher internal forces development. Physiotherapy interventions targeting flexibility may be important in controlling the amount of peak elongation reached during participation in high-intensity sports activities. In addition, normalization of hamstring eccentric strength deficits at hamstring lengthened states may act preventively against hamstring strain injuries (Schmitt et al., 2012), either due to the changes in eccentric strength in isolation or in conjunction with associated changes in fascicle length of the hamstrings (Timmins et al., 2016), acting protectively against subsequent hamstrings strains (Buckthorpe et al., 2019).

Hamstrings lack of flexibility is typically managed using static and dynamic stretching (Behm et al., 2016) but also using Instrument-Assisted Soft Tissue Mobilization (IASTM) (Seffrin et al., 2019) or therapeutic hand or Vibration Massage (Poppendieck et al., 2016). Massage is a physical therapy intervention with purported biomechanical (flexibility increase, tissue adhesion prevention), physiological (increased skin and muscle temperature, increased blood flow and parasympathetic activity), neurological (decrease muscle tension and pain perception) and psychological advantages (Zhong et al., 2019). Vibration Massage, on the other hand, consists of vibration input to muscles, utilized to promote relaxation and flexibility gains, usually with the aid of an electromechanical device (Osawa and Oguma, 2013). With Vibration Massage parameters such as the vibration frequency, duration, and amplitude can be better controlled in relation to difficulties in applying constant pressure, technique and duration with manual massage (Edge et al., 2009).

Hamstrings flexibility and neuromuscular activation patterns may be important predictors not only for hamstrings muscle strains (de la Motte et al., 2019) but also for knee joint injury (Opar and Serpell, 2014). Previous hamstring strain injuries have also been proposed as potential risk factors for anterior cruciate ligament (ACL) injury (Opar and Serpell, 2014), especially when the significant contribution of the hamstrings in generating posterior shear forces that are protective for the ACL during cutting maneuvres is considered (Maniar et al., 2018). Indeed, strength, timing of activation as well as flexibility enhancement of the hamstrings are amongst the main components of ACL injury prevention programs (Padua et al., 2018).

Specialized mechanoreceptors are contained in muscles, tendons, fascia and skin, converting mechanical stimuli to action potentials transmitted to the central nervous system for optimal movement control (Clark et al., 2015). Exercise-induced quadriceps (Torres et al., 2010) or hamstrings (Paschalis et al., 2008) muscle damage has been shown to impair knee proprioception acuity. Also, a reflex arc between the ACL and the hamstrings has been previously demonstrated (Krogsgaard et al., 2002; Tsuda et al., 2001, 2003), denoting a protective signalling effect of the ACL to the knee flexors. Therefore the influence of interventions to muscles surrounding the knee (Proske, 2015) and their overlying fascia (Stecco et al., 2016) in knee joint proprioception acuity requires further study.

The present study aimed to act as a pilot study, to assess the relative effect of IASTM, Vibration Massage and Light Hand Massage applied to the posterior thigh surface on hamstrings flexibility and knee proprioception.

2. Methods

2.1. Participants

Sixteen young healthy male individuals were included in this study, thirteen of which were amateur footballers and the other three regularly involved in other sports (basketball and volleyball) without any previous major injuries in the lower limbs and without any injury at least 12 months before and throughout the duration of the experiment. All subjects were recruited either via e-mails sent to School of Health students via group mailing lists or notifications posted on School notice boards describing the aims and purposes of the study. All participants were instructed to wear athletic outfit during testing. Lastly, all tests were performed with the dominant limb only, determined by asking participants which leg they would use to kick a ball. All subjects signed a written informed consent, presenting the exclusion criteria and the aims and purposes of the study prior to their participation. The study protocol was approved by the Ethics Committee of Metropolitan College. All rights of participants were protected at all times, according to the declaration of Helsinki.

2.2. Study design

A randomized repeated measures study design was followed. All participants were assigned to receive all three interventions in random order. A time interval of 1-week separated each subsequent measurement from its previous one. The IASTM intervention was delivered for 5 min and the Vibration Massage for 5 min also. In those two groups 3 min of light pressure hand massage (gliding methods or effleurage in the classical massage form) preceded the main intervention, to warm-up the posterior dominant thigh area, as well as to counterbalance the treatment time to that of the third intervention, in which light pressure hand massage was delivered for 8 min.

All subjects completed a questionnaire about their general health status including any previous injuries to the lower limbs, as well as their demographic details before randomization. Each participant was asked to sequentially open 3 closed envelopes, to determine the order of their participation in the interventions. Every intervention was preceded by 3 repetitions of an active angle reproduction proprioception test and 3 repetitions of a single-leg Sit and Reach flexibility test. Immediately post-intervention, 3 repetitions of the two outcomes (proprioception and flexibility) followed.

2.3. Interventions

The IASTM techniques were provided by 3 certified therapists (ArthroTools, Greece) of minimum 1 year experience in the application of the techniques. The IASTM arthro-bar tool was utilized with the necessary amount of friction balm applied on the skin over the area of treatment. Its concave bevelled contact surface was diagonally placed (30–60° angles) during the sweeping movements applied with moderate pressure in all directions on the skin overlying the hamstring muscle group of participants' dominant lower limb (Fig. 1).

Local muscle vibration was administered over the posterior thigh of the dominant leg in a distal to proximal direction by another 2 members of the research team. Two commercially available electrical tapping massage units (Beurer MG70, Beurer GmbH, Ulm, Germany) delivering vibratory waves at 47 Hz to the

Fig. 1. The IASTM arthro-bar tool, applied over the hamstrings with its concave contact surface.

deep muscle and tendon tissues were utilized (Fig. 2).

Light Hand Massage was administered over the posterior thigh of the dominant leg by another 3 members of the research team. 8 min of light pressure effleurage massage, applied by hand in a distal to proximal sequence, was selected as an intervention for light warm-up of the posterior dominant thigh area, of less intensity that the other two, considered to be of less therapeutic benefit in relation to more intense pressure levels (Field, 2014; Field et al., 2010).

Fig. 2. The Vibration Massage device, applied over the hamstrings.

2.4. Outcome measures

All measurements took place in the main Lab of the School of Physiotherapy. For hamstring flexibility, a single-leg variation of the Sit and Reach test (Wells and Dillon, 1952) was utilized, testing the dominant leg only, to evaluate flexibility before and after each of the 3 interventions used. The non-dominant leg was kept in a relaxed flexed position, with the hip in external rotation and the sole of its foot touching the inner thigh of the dominant leg. A standard sit and reach box was constructed, according to instructions in the original publication (Wells and Dillon, 1952). The test possesses high reliability and validity for hamstrings flexibility testing in its original version and its variations (Baltaci et al., 2003; Hui and Yuen, 2000; Mayorga-Vega et al., 2014; Wells and Dillon, 1952). Measurements were repeated three times before and three after the intervention, with a 10 s interval in between each set of measurements. Reliability of the sets of trials before and after the intervention was separately examined, and the most reliable set of measurements was used for the main comparisons.

The joint position sense (JPS) proprioception test measures the accuracy of position reproduction and can be executed actively or passively in both open and closed kinetic chain positions (Angoules et al., 2011). For the purposes of this study, knee JPS was evaluated with a knee flexion active angle reproduction test from prone lying, before and after each of the 3 interventions. The prone position has previously been utilized for knee proprioception measurement (Furlanetto et al., 2016; Safran et al., 1999) and was selected for concurrent concentric activation of the hamstrings during JPS measurement. The 'iHandy Level' smartphone application was used for angle measurements, as smartphones are increasingly utilized for joint angle and proprioception measurements, with verified reliability and validity (Milanese et al., 2014; Mourcou et al., 2015). Participants were placed in prone lying, without any visual contact with their lower limbs or testing equipment. The examiner first placed participants' knee passively to 45° of knee flexion, as measured by a mobile phone placed with its upper vertical side on the posterior surface of the lower end of the tibia on the skin overlying the Achilles tendon, and maintained the participants' knee angle position in order to fix an adjustable plastic arm onto the posterior surface of the participants' heel, to serve as an indicator for the reproduction of the 45° angle. Participants then performed a few (4–5) active knee flexion repetitions (Fig. 3a), with 10s intervals in between, in order to memorize the target angle. Immediately afterwards, the plastic arm indicator was removed and participants performed, without looking, 3 sequential knee flexion repetitions actively, attempting to reproduce the target angle. Once the target position was reached, according to participants, the examiner recorded the angle of each repetition with the smartphone's application (Fig. 3b). Measurements were repeated three times before and three after the intervention, with a 10 s interval separating repetitions within each set of measurements. Reliability of the sets of trials before and after the intervention was separately examined, and the most reliable set of measurements was used for the main comparisons.

2.5. Data analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 20. Descriptive data including the mean (standard deviations) of the 6 individual Sit and Reach (flexibility) and the 6 Proprioception (knee flexion active angle reproduction) measurements before and after the application of the 3 interventions were presented in Table 1. For the proprioception data in particular, measurement of target accuracy was recorded in relation to the set target angle at 45° of knee flexion

Fig. 3. Set up for the proprioception experiment, with subjects lying prone on an examination couch: (a) the plastic arm used as an indicator for memorizing the target angle through active knee flexion concentric repetitions, and (b) angle recording with the 'iHandy level' smartphone application, once the target angle (as perceived by participants) was reached.

Table 1
Sit and Reach Test flexibility (cms) repeated measurements before and after the 3 interventions (n = 16/treatment intervention).

	1st Measurement	2nd Measurement	3rd Measurement
IASTM-Pre	30.54 (10.34)	31.36 (9.19)	32.38 (10.42)
IASTM-Post	31.62 (9.33)	33.06 (8.77)	33.91 (9.04)
Vibration Massage-Pre	26.69 (6.29)	28.00 (7.03)	29.44 (7.04)
Vibration Massage-Post	29.91 (6.72)	31.25 (6.97)	32.66 (7.26)
Light Hand Massage-Pre	32.69 (9.63)	32.72 (8.98)	34.37 (8.06)
Light Hand Massage-Post	33.62 (9.16)	35.12 (8.80)	35.53 (8.48)

and the absolute error (AE) index of target estimation was then calculated (Table 2). AE is the average absolute deviation, without regard to direction, between the subjects' responses and the target. It is regarded as a measure of overall accuracy in performance (Schmidt, 2019).

Reliability. For within-day test-retest reliability of both the flexibility and proprioception data, four separate repeated measures analyses of variance (ANOVA) were performed between the 3 and also between the last 2 measurements of flexibility and proprioception before and after the therapeutic interventions for the whole sample of 48 measurements (16 participants x 3 interventions), to ensure the stability of our measurement procedures (Portney and Watkins, 2014). The scores of 3 valid attempts (and the last 2) for flexibility (sit and reach) and for proprioception (active 45° knee flexion angle reproduction) were used for the reliability analysis. Reliability was determined by the ICC Model 3,1 (two-way mixed model-consistency type), with values above 0.75 classified as good and values exceeding 0.90 considered to be ensuring reasonable validity. The precision of the measurement was additionally described using the standard error of the measurement ($SEM = SD\sqrt{1 - ICC}$), which is the standard deviation of measurement errors, estimated in the same units as those of the original measurements. The significance level for all comparisons was set at 0.05 (Portney and Watkins, 2014).

Table 2
Active knee angle reproduction proprioception absolute error (°) repeated measurements in relation to a set target angle of 45° before and after the 3 interventions (n = 16/treatment intervention).

	1st Measurement	2nd Measurement	3rd Measurement
IASTM-Pre	6.44 (5.02)	6.77 (5.52)	8.19 (5.93)
IASTM-Post	4.92 (3.95)	5.62 (3.94)	5.11 (3.83)
Vibration Massage-Pre	5.29 (4.00)	6.50 (4.70)	6.00 (3,80)
Vibration Massage-Post	5.35 (4.16)	5.84 (5.28)	6.34 (5.93)
Light Hand Massage-Pre	4.95 (3.10)	7.04 (6.64)	7.15 (6.57)
Light Hand Massage-Post	6.43 (5.45)	5.86 (5.68)	5.99 (5.47)

Between treatment interventions comparisons. Two separate repeated measures two-way ANOVA were performed to test the main effects of the repeated measures (pre-post application) between the 3 treatment interventions (IASTM, Vibration Massage and Light Hand Massage) on flexibility and proprioception data, as well as their interaction. Both dependent variables were measured at the continuous level. Sphericity was explored with the Mauchly's Sphericity test.

Achieved Power & Sample size calculation. For the between-interventions differences, the power achieved was calculated. If not sufficient, the sample size required to achieve an 80% power was also calculated based on the minimum expected differences for the interaction effect of "time*intervention". The GLIMMPSE online program for computing power and sample size for repeated measures and longitudinal designs was utilized to perform all relevant calculations (Guo et al., 2013).

Clinical trial registration was exempt for this study.

2.6. Results

The demographic mean (SD) data for the sample of male participants used was 23.7 (3.8) years, 1.80 (0.05) cms height and 77.7 (6.7) kg body mass. Flexibility (Table 1) and proprioception (Table 2) data were tested with the Shapiro-Wilk test, and was verified they were all normally distributed ($p > 0.05$). Individual measurements of the dependent variables (flexibility and proprioception) were analytically presented before and after the application of each of the treatment interventions (Tables 1–2).

Reliability of dependent variables. The same-day test-retest reliability values for the flexibility and proprioception data was high in general, however if the first measurement was discarded, reliability indices (ICC for proprioception pre data and all the SEMs) improved (Table 3). SEMs were expressed in cms for the flexibility test and in degrees (°) for the proprioception test. Between-measurement systematic differences ($p = 0.031 < 0.05$) were only detected for the Proprioception 1–3 Pre data.

Between treatment interventions comparisons. Sphericity was ascertained for flexibility (Mauchly's W = 0.971, p = 0.81) and proprioception (Mauchly's W = 0.944, p = 0.67) data. Also, variances in measurements before and after each intervention were similar between interventions for flexibility (Levene's F = 0.27–0.63, p = 0.53–0.76) and for proprioception (Levene's F = 1.47–2.11, p = 0.13–0.24). For flexibility, statistically significant

Table 3
Flexibility and Proprioception reliability indices ($ICC_{3,1}$ and SEM) for all and the last 2 repeated measurements for the data before and after the 3 interventions (n = 48).

	ICC (95% CI)	SEM
Sit and Reach 1–3 Pre	0.96 (0.94–0.98)	1.75 cm
Sit and Reach 2–3 Pre	0.97 (0.95–0.98)	1.52 cm
Sit and Reach 1–3 Post	0.97 (0.96–0.98)	1.43 cm
Sit and Reach 2–3 Post	0.99 (0.98–0.99)	0.83 cm
Proprioception 1–3 Pre	0.66* (0.51–0.77)	2.97°
Proprioception 2–3 Pre	0.83 (0.71–0.90)	2.02°
Proprioception 1–3 Post	0.81 (0.72–0.88)	2.03°
Proprioception 2–3 Post	0.88 (0.80–0.93)	1.63°

*p < 0.05.

immediate improvement was observed within all 3 groups [$F(1,15) = 47.85$, $p < 0.001$], with no between-group differences [$F(2,14) = 0.94$, $p = 0.41$]. Therefore the improvements noted for the 3 interventions over time (IASTM: 1.61 cm – Vibration Massage: 3.23 cm – Light Hand Massage: 1.78 cm) were of similar extent (Fig. 4). For proprioception, however, the immediate changes recorded in AE (Fig. 5) were not statistically significant either within-group [$F(1,15) = 0.99$, $p = 0.33$] or between-group [$F(2,14) = 0.37$, $p = 0.70$].

Achieved Power – Sample size calculation. The power achieved for the interaction effect based on the flexibility outcome was 0.065 and for the proprioception outcome was 0.095. To achieve adequate power of 0.80, based on the observed mean values per treatment group and for a common standard deviation of 8.4 cm for flexibility and 4.9° for proprioception and significance level $p = 0.05$, a sample of 755 participants/group or 258 participants/group would be respectively required.

3. Discussion

Soft-tissue therapeutic interventions targeting flexibility of certain muscle groups such as the hamstrings may be important in preventing muscle strains in various sports (de la Motte et al., 2019; Gabbe et al., 2005). These interventions may in parallel affect proprioception acuity of anatomically and neurophysiologically related joints (Shin and Sung, 2015; Tsuda et al., 2001). In the present study all participants were sequentially assigned to a single session of 3 soft-tissue interventions (IASTM-Vibration Massage-Light Hand Massage) applied in random order on the posterior thigh area of the dominant leg, to evaluate their relative effectiveness in hamstrings flexibility as well as knee proprioception.

The results of this study indicate that all 3 interventions demonstrated signs of improving flexibility. Common mechanisms may be involved in the immediate increase of flexibility, with all 3 interventions applied, as their effect on flexibility was similar. As it is surmised in a recent systematic review examining the effects of foam rolling on the immediate increases in range of motion (Hendricks et al., 2019), these may occur as a result of improved blood flow, transference of interstitial fluid into the circulation via arterial dilatation and thrixotropic tissue changes, which in turn cause a neural inhibitory effect to the central nervous system. The dosage to achieve flexibility benefits with foam rolling were determined to be between 90 and 120 s (Hendricks et al., 2019), therefore the duration of all 3 interventions used in the current experiment all exceeded this dosage. However, only the immediate effect of those interventions on flexibility was examined in the current and most similar studies.

Indeed, similar results for muscle flexibility were reported in studies examining the effect of a single IASTM application in

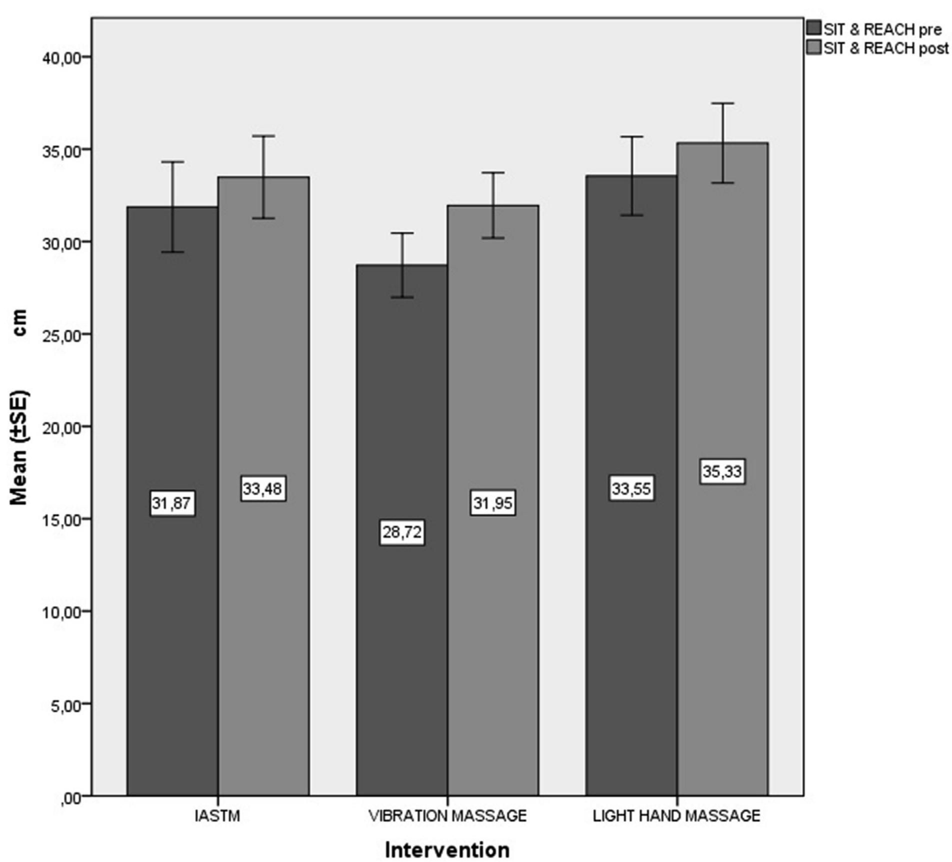

Fig. 4. Pre and post interventions mean (±1 Standard Error) flexibility data measured with the Sit and Reach test (in cms).

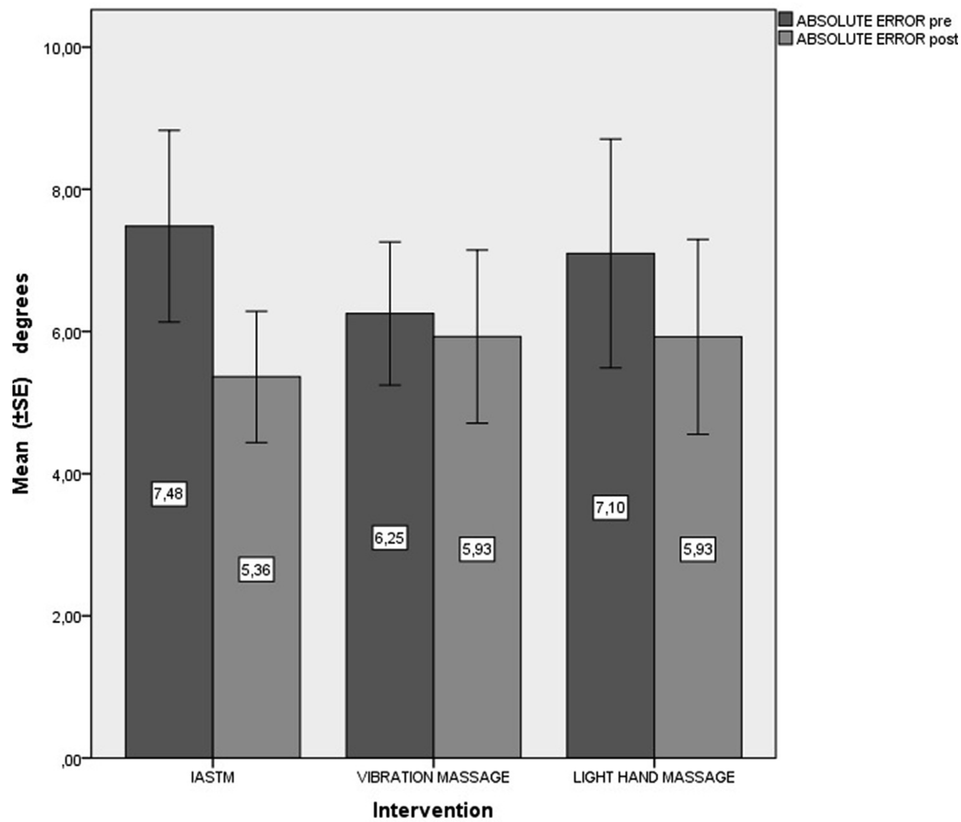

Fig. 5. Pre and post interventions mean (±1 Standard Error) active angle reproduction proprioception data (in degrees).

healthy volunteers of similar age and athletic participation to those included in our study. Specifically, IASTM applications for 1 and 2 min respectively in the posterior thigh area was of similar effectiveness to self-myofascial release in 2 studies (Kim et al., 2014; Markovic, 2015). Additionally, IASTM techniques applied in the hamstrings for 1–2 min were of superior effectiveness to hold-relax and strain-counterstrain PNF techniques (Kim et al., 2018) or compared to passive stretching only (Gunn et al., 2019). Also, a 10 min application of IASTM either in the trunk or the hamstrings along the superficial back line (Plantar fascia, Achilles tendon/gastrocnemius, all Hamstrings, Sacrotuberous ligament, and Lumbar fascia/erector spinae), was more effective in increasing hamstrings flexibility in relation to a control condition (Eid et al., 2017). Adding IASTM along the performance of several active movements of the lower limbs to a control warm up/cool down program (5 times per week, for 12 weeks), had clearly increased the flexibility of non-injured male soccer players on a more long-term basis (Kim and Yim, 2018). Therefore, IASTM seems effective in increasing flexibility in the short-term, even with short duration of application.

An additional mechanism promoting flexibility with Vibration Massage is considered to be via muscle spindle stimulation, increasing the stretch-reflex latency (Pope and DeFreitas, 2015) and decreasing motor unit firing frequency (Barrera-Curiel et al., 2019) of vibrated muscles. It has been previously demonstrated that vibration-enhanced static stretching increases hamstring flexibility compared to static stretching only using vibration frequencies of 44 Hz for 2–7 min (Issurin et al., 1994), 35 Hz for 45 s (Jemni et al., 2014) or 30 Hz for 4 min (Kinser et al., 2008; Sands et al., 2006).

Although manual massage is usually considered to increase extensibility of soft tissues via muscle relaxation mechanisms mediated via tactile, pressure and proprioceptive receptors, increased blood flow and increased muscle temperature mechanisms (Zhong et al., 2019), not all studies could verify a positive outcome. Significant hip ROM increase was reported with a 30 s massage session compared to a 10 s session focusing on the hamstrings' distal musculotendinous junction or no massage (Huang et al., 2010). Also, deep stripping massage only or in combination with eccentric exercise improved significantly hamstrings flexibility (Forman et al., 2014). However, other studies failed to demonstrate flexibility improvements with classic massage techniques such as gliding and kneading (Barlow et al., 2004; Jourkesh, 2007). Studies that have examined muscle stiffness reduction after massage applications have reported this effect to be short-lived (Crawford et al., 2014; Eriksson Crommert et al., 2015). A meta-analysis on the effects of massage on performance recovery reported small effects in general and a tendency for shorter massage sessions lasting between 5 and 12 min to have larger effects than sessions lasting more than 12 min (Poppendieck et al., 2016). Differences in manual massage techniques applied between studies or between the pressures applied between therapists may have been responsible for the disparity in the results reported between studies. Also, treatment times in previous studies differed significantly between them, ranging from 10 s to 15 min.

On the other hand, joint proprioception seems to rely on muscle spindle input of surrounding muscles also. It has been shown that athletes participating in high neuromuscular intensity postural challenge exercises (including cutting and pivoting) demonstrated increased knee proprioception acuity in relation to athletes performing less-intense training (Courtney et al., 2013). The effect of increased physical activity on knee proprioception acuity enhancement has been subsequently confirmed in a wider age-range population (Relph and Herrington, 2016). These parallel improvements were attributed to the increased activation of muscle spindles associated with regular exercise.

Regarding the contribution of fascia in knee proprioception there are no studies to date examining the effect of IASTM on joint proprioception (Seffrin et al., 2019). Some evidence can be drawn from studies that have tested the effect of foam rolling myofascial release technique on proprioception. A single hamstrings foam rolling session (2 min duration) resulted in significant proprioception improvement of around 1.5° knee joint position matching error (pre-post differences) maintained at the 20 min follow up (David et al., 2019), however this study did not include a control group. Also, another study that compared foam rolling with or without vibration (28 Hz vibration frequency) applied to the quadriceps and hamstrings for 1.5 min per muscle group once, demonstrated a significant small worsening effect for non-vibration rolling of 0.95° in relation to no change with vibration rolling; hamstrings flexibility equally improved between groups (Lee et al., 2018). A third study demonstrated no difference in proprioception acuity between a group of athletes that combined jogging with foam-rolling applied for in the hamstrings, quadriceps and the calf muscles (45 s per muscle) in comparison to a control group that performed only jogging (Romero-Franco et al., 2019).

Also, stimulating manual massage techniques applied for 10 min to muscles of the thigh were found to significantly increase knee joint position sense by 1.75° in relation to a control (rest) condition (Henriksen et al., 2004). Another study has demonstrated positive effects of 15 min manual massage in relation to a control condition post exercise-induced muscle damage (Shin and Sung, 2015). However, the results of our study do not confirm these findings. Finally, another study has demonstrated that a 10-min gliding massage to the whole lower limb did not affect knee proprioception acuity in a group of athletes with delayed onset muscle soreness (Agostini et al., 2018). Muscle vibration at higher frequencies (over 30 Hz) has been reported to benefit proprioception sense (Aman et al., 2015), however no significant change in joint repositioning error post Vibration Massage application in this study.

In the current study, although joint repositioning error post IASTM application was less compared to the other 2 interventions, the changes noted were not statistically significant either within or between-interventions, even though the magnitude of these changes were comparable to similar previous studies (David et al., 2019; Henriksen et al., 2004). The trend of decrease in joint repositioning error with IASTM can probably be attributed to stimulation of fascia mechanoreceptors and fascia-related proprioceptive mechanisms enhancement (Stecco et al., 2016). Especially retinacula are the most highly innervated fascial tissues, with many free nerve endings, Ruffini and Pacini corpuscles, Golgi-Mazzoni and rare spherical clubs and are considered an organ with proprioceptive properties. Superficial fascia is a more elastic tissue and therapeutic approaches using small amount of pressure could be effective for its treatment. On the contrary, the deep fasciae and the epymisium are deeper layers and therefore require more pressure with therapeutic modalities, like using smaller surface IASTM tools or manual deep friction (Stecco et al., 2016).

There are some limitations in relation to this study. Our results can be extrapolated only to a young healthy male population similar to the one examined herein. Participants were healthy male volunteers, with no fascial restrictions or severe hamstrings inflexibility. Although subjects were randomly allocated to the sequential application of the 3 interventions, there was no blinding of therapists, assessors and participants to the interventions administered. Also, the sample size was relatively small; therefore, this is a pilot study designed to compare the differences in outcome between the 3 therapeutic interventions used. Since there were no differences identified between the 3 therapeutic interventions, a control or a carefully selected placebo condition can be included in a future study. In addition, only one session of each intervention was applied and only the immediate effects of the interventions delivered were considered. Further research encompassing larger samples, including participants of both genders and of various athletic involvement are required to elucidate the role of each intervention delivered in a block of sessions rather than a single application on a more long-term basis. Additional outcomes could be included in future studies, like injury prevention or injury recurrence, to either examine their preventive role against hamstring strains and knee injuries or if those interventions are to be applied as part of a muscle strain or knee injury rehabilitation program. The cumulative long-term relative or synergistic effect of those techniques in performance enhancement and injury prevention in the lower extremity requires further examination.

4. Conclusions

In a group of healthy non-injured male volunteers, muscle flexibility after a single intervention of IASTM, Vibration Massage or Light Hand Massage on the hamstrings of the dominant leg was similarly positively affected. Although not reaching statistical significance, similar trends were recorded with an active angle reproduction proprioception test. Further research is required to verify the results obtained and to extend measurements in injured populations.

5. Clinical relevance

- This study shows signs that IASTM techniques, Vibration or Light Hand Massage applied on the hamstrings may lead to flexibility improvement, as measured with the sit-and-reach test
- Proprioception also seems to be affected, although the improvements noted with all 3 therapeutic interventions did not reach statistical significance either within or between interventions

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Authors' contributions

G.A.K. had executive role in supervising this project, performed the statistical analysis and helped to design the manuscript. All authors contributed to data collection, designed and drafted the manuscript, have read and approved the final version of the manuscript and agreed with the order of presentation of the authors.

Declaration of competing interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

CRediT authorship contribution statement

George A. Koumantakis: Conceptualization, Formal analysis, Investigation, Visualization, Methodology, Supervision, Validation, Writing - review & editing, Data curation, Project administration, Resources, Software, Writing - original draft. **Eleonora Roussou:**

Data curation, Project administration, Resources, Software, Writing - original draft. **Georgios A. Angoules:** Data curation, Project administration, Resources, Software, Writing - original draft. **Nikolaos A. Angoules:** Data curation, Project administration, Resources, Software, Writing - original draft. **Theodoros Alexandropoulos:** Data curation, Project administration, Resources, Software, Writing - original draft. **Georgia Mavrokosta:** Data curation, Project administration, Resources, Software, Writing - original draft. **Prokopios Nikolaou:** Data curation, Project administration, Resources, Software, Writing - original draft. **Filippi Karathanassi:** Data curation, Project administration, Resources, Software, Writing - original draft. **Maria Papadopoulou:** Data curation, Project administration, Resources, Software, Writing - original draft.

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