Research Paper

Acute Effect of Massage, Static Stretching, and Foam Rolling on Hamstring Muscle Flexibility

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Citation Darvish B, Piri H, Rahimi M, Shadi E. Acute Effect of Massage, Static Stretching, and Foam Rolling on Hamstring Muscle Flexibility. Physical Treatments. 2026; 16(3):273-282. http://dx.doi.org/10.32598/ptj.16.3.626.1

http://dx.doi.org/10.32598/ptj.16.3.626.1

Article info:
Received: 11 Jun 2025
Revised: 23 Jan 2026
Accepted: 10 Feb 2026

Keywords:
Hamstring tightness, Foam rolling (FR), Static stretching (SS), Massage

ABSTRACT

Purpose: Optimized flexibility, a critical component of physical fitness, substantially influences sports performance and injury prevention. This study aimed to evaluate the immediate effects of static stretching (SS), massage, and foam rolling (FR) on the flexibility of hamstring muscles.

Methods: This study employed a quasi-experimental, pre-test-post-test design. The statistical population consisted of football players with hamstring tightness. Thirty participants, aged between 17 and 25 years, were selected as research participants based on the inclusion and exclusion criteria and entered the study with full consent and awareness. The participants were divided into three groups: SS, massage, and FR. The straight leg raise test assessed hamstring flexibility. A one-way analysis of covariance (ANCOVA) was conducted to compare the three groups, with a significance level of $P \leq 0.05$.

Results: A ANCOVA revealed a significant difference in the immediate effects of three interventions ($F_{2, 27}=5.274$, $P<0.05$). The Bonferroni post hoc pairwise comparison revealed that the SS group showed a significantly greater improvement in flexibility than the FR group ($P=0.004$). Additionally, compared to the massage group, SS performed better ($P=0.04$). However, the Bonferroni post hoc test did not find a significant difference between the massage and FR groups ($P=0.289$).

Conclusion: Compared to massage and FR, SS seems to be a suitable option for increasing immediate flexibility in football players with hamstring tightness.

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Highlights

- In people with short hamstrings, SS is superior to massage in increasing hip flexion ROM in the acute setting.
- In individuals with shortened hamstrings, in terms of acute effect, SS is better than FR to increase hip flexion ROM.
- Massage and FR have no acute effect on hip ROM.

Plain Language Summary

This study was conducted to assess the immediate effect of static stretching (SS), massage, and foam rolling (FR) on the flexibility of football players' hamstring muscles. The study involved 30 football players aged 17-25 with tight hamstrings. These players were assigned to one of three groups: SS, massage, or FR. The straight leg raise test assessed hamstring flexibility. The results showed that SS significantly improved hamstring flexibility compared to massage and FR. In simple terms, if you are a football player with tight hamstrings, doing static stretches is likely the best way to acutely increase your flexibility compared to getting a massage or using a foam roller. In conclusion, for football players with tight hamstrings, SS is an effective method to immediately enhance hip flexion range of motion (ROM). This finding is helpful for athletes and coaches seeking to improve performance and prevent sports injuries by optimizing flexibility and ROM.

Introduction

Flexibility refers to the capacity to move a specific joint through its full range of motion (ROM), which is influenced by the joint's structure, the condition of the ligaments and fascia, and the elasticity of the surrounding muscles [1]. It is a key factor that significantly affects physical fitness and sports performance [2, 3]. The type of joint, periarticular tissues, gender, and age all influence flexibility [2, 4]. Abnormal muscle stiffness, which impairs the elastic properties of these tissues, makes it difficult to lengthen the muscles during physical activities when internal and external forces are applied. This restriction ultimately reduces the ROM [5]. Adequate flexibility and muscle stiffness can improve performance, reduce muscular pain, and lower the risk of sports injuries. In contrast, a lack of optimal flexibility results in restricted ROM and muscle imbalances, which not only negatively affect athletic performance but also increase the likelihood of injury [6, 7]. Hamstring strains are among the most common sports injuries in football players, and due to the high risk of recurrence in affected individuals, scientific research into these injuries is essential [8]. Studies have shown that insufficient strength or poor flexibility is usually the cause of most hamstring injuries [8, 9].

Stretching exercises can lead to long-term increases in joint ROM [10]. Various stretching exercises exist; however, static stretching (SS) and proprioceptive neuromuscular facilitation (PNF) are the most common strategies. Muscles and surrounding connective tissues are stretched to mild discomfort or stretch perception during SS [11]. SS can be used to enhance flexibility and reduce the risk of injury when incorporated into warm-up routines [12]. In this context, previous studies have affirmed the effectiveness of these exercises in enhancing ROM [11, 13]. Changes in flexibility after SS interventions are attributed to alterations in stiffness of the tendon-muscle unit [14, 15] and stretch tolerance [16]. The impact of SS on the two factors mentioned is influenced by the duration of stretching [17, 18]. It has been reported that ROM increases immediately following SS [17, 18]. However, some studies have shown that, for instance, the myotendinous unit of the hamstring muscles is significantly affected after 180 seconds of SS [19, 20].

Self-myofascial release (SMR) has recently become a common technique in both sports and clinical environments. This self-administered approach involves applying compressive forces to soft tissues. It simulates the impacts of manual techniques and is intended to address soft-tissue dysfunctions [21, 22]. A foam roller is a widely utilized SMR tool in sports and physiotherapy practices [23]. Two benefits of SMR with a foam roller are that it does not negatively affect muscle strength [24] or vertical jump performance [25]. Additionally, foam rolling (FR) can improve maximal running speed [26], reduce muscle soreness [27], and enhance neuromuscular efficiency [28]. Several studies have primarily investigated the effects of FR on ROM, pain, and the mechani-

cal characteristics of the lower limbs [29]. While some investigations have demonstrated that FR can enhance ROM, the underlying mechanisms of this enhancement remain insufficiently understood [25]. The effectiveness of SMR is attributed to the direct application of pressure to soft tissues, which may result in fascia warming, the breakdown of fibrous adhesions, and the restoration of soft-tissues' elastic properties [30].

Massage is the purposeful manipulation of soft tissues using fingers, hands, forearms, elbows, knees, or feet, with or without the application of lubricants, coverings, heat, cold, handheld tools, or other external devices, for therapeutic or enhancement purposes [31]. Swedish massage applied to the hamstrings appears to enhance hamstring flexibility in female athletes, with the effect remaining even after a 5-day cessation of the massage [32]. In a previous study, Crossman et al. (1984) investigated the impact of massage on hamstring flexibility in women, and their results showed that this intervention significantly enhanced hamstring excursion [33]. Since then, several studies have investigated the effect of massage on flexibility; however, the results remain inconclusive. Some studies have reported that massage enhances hamstring flexibility and range of motion [34–37], whereas others have found no significant improvements [38, 39]. Some studies have indicated that massage can enhance flexibility [34-36], while others have reported contradictory findings [38, 39]. In this regard, Hopper et al. (2005) found that soft tissue mobilization can increase hamstring flexibility [37].

There is limited experimental evidence supporting SMR, with the existing literature primarily reporting chronic rather than acute effects of myofascial release on muscle function. Several methods are employed to enhance muscle flexibility, and numerous studies have been conducted in this area. This research compares the effects of SS, massage, and FR on hamstring flexibility in football players with hamstring tightness.

Materials and Methods

This study employed a quasi-experimental, pre-test-post-test design. The study's statistical population included male football players aged 17-25 with hamstring tightness. The sample consisted of 30 individuals from the population who were purposefully selected and randomly allocated to three research groups. The inclusion criteria for the current research were being a football player, being male aged 17-25 years, and having hamstring tightness. Participants with a history of hamstring muscle injury, lower limb injury in the past year, or back pain [38]. Participation in exercise programs and corrective exercises affecting the test result was excluded.

Before starting the test process, all stages were fully explained to the participants; they were instructed to complete and sign the consent form and the personal information questionnaire if they agreed to participate in the study. The researcher used the massage technique and flexibility measurement, but SS and FR were used independently after teaching the subjects these techniques. The test was conducted in three separate sessions (day 1: massage; day 2: SS; day 3: FR). In the test session, the participant's height, weight, and hamstring muscle flexibility were initially measured and recorded. After the interventions, hamstring muscle flexibility was measured again and recorded on a specific form. The classic massage technique, which includes stroking and circular movements with the palm (effleurage) from the distal to the proximal part, similar to kneading dough towards the front, applying pressure with the hand, lifting and shaking from the proximal to the distal, was applied to the back of the thigh. These steps were repeated five times in order. The entire massage process lasted for 8 minutes (Figure 1, part B).

For the SS, the participant was supine with their trunk upright and the non-tested leg resting flat on the ground. The tested leg was gradually lifted off the ground while maintaining a straight knee. The participant maintained this position for 30 seconds, completing four repetitions of 30 seconds each [39] (Figure 1, part D).

To perform FR, the participant was instructed to position the foam roller near the hamstring origin and sit on it. Then, they moved it towards the knee, with the knees straight and the ankle relaxed. Next, the participant was instructed to bear their weight with extended arms, with the palms on the floor, and lift the torso upward to increase pressure between the foam roller and the hamstring muscles (three 1-minute repetitions with a 30-second rest interval) [38]. In this study, dynamic thermoplastic rubber (DTR) foam rollers with a circumference of 10 centimeters and a thickness of 3 centimeters were used [39]. DTR foam rollers have semi-flexible, asymmetrical nodes on their surface, which increase pressure on the tissues (Figure A1 and 1C).

The passive straight-leg raise (PSLR) and the sit-and-reach tests are commonly employed in clinical and research settings to assess hamstring flexibility [40]. In this study, the PSLR test was utilized. The Shapiro-Wilk test was conducted to evaluate the normality of the data distribution, and one-way ANCOVA was used to com-

pare the immediate effects of the interventions. The Bonferroni post hoc test was conducted for pairwise comparisons. A significance level of 95% and an alpha level of 0.05 or lower were considered in the analysis.

Results

In this study, 30 participants completed each research stage. The participants were homogeneous regarding demographic factors, such as body mass index (BMI), weight, height, and age, with no significant differences noted. The normality of the data distribution was assessed using the Shapiro-Wilk test. A significance level greater than 0.05 indicated a normal distribution of the data (Table 1).

Another assumption of a one-way analysis of covariance (ANCOVA) test is the homogeneity of variances. Levene's test was conducted to assess the homogeneity of variances.

Considering the results of Shapiro-Wilk and Levene's tests, we used ANCOVA to compare flexibility among the three groups (SS, massage, FR). The output of the ANCOVA analysis (Table 2) showed that, after controlling for pre-test effects (covariate), there is a significant difference in hamstring muscle flexibility among the three groups.

The results of the ANCOVA indicated significant differences among the groups. Therefore, we employed the Bonferroni post hoc to detect which specific pairs of groups showed significant differences. Since we had three groups, the significance level, set at 0.05, was divided by the number of groups, resulting in a significance level of 0.017 for each comparison. The results revealed significant differences between the SS and massage groups and between the SS and FR groups. However, no significant difference was found between the massage and FR groups (Table 3).

Discussion

This study aimed to compare the effectiveness of three stretching interventions—SS, FR, and massage—on hamstring flexibility in football players with hamstring tightness. The results showed that all three interventions positively impacted hamstring flexibility, as measured by the PSLR test. However, SS led to a significant improvement in hip ROM in football players with hamstring tightness. These findings align with the studies conducted by Siebert et al. (2022), Škarabot et al. (2015), Couture et al. (2015), and Evans (2014) [41-44]. Siebert et al. (2022) compared the effects of dynamic stretching (DS), FR, and SS on hip joint ROM. Their study suggested that SS and DS are effective methods for increasing actual ROM, whereas the benefits of FR seem more related to pain threshold adjustments rather than a direct

Table 1. Participants' demographic characteristics

Group / Variables	Mean±SD			Sig.
	SS	Massage	FR	
Age (y)	19.3±1.63	19±1.82	19.4±1.5	0.85
Height (cm)	177.8±7.02	180.5±5.06	177.3±5.03	0.42
Weight (kg)	69.6±7.84	71.4±9.21	67.4±5.01	0.50
BMI	22.02±2.15	21.87±2.29	21.46±1.68	0.82

BMI: Body mass index.

PHYSICAL TREATMENTS

Table 2. Results of ANCOVA

Variables	Sum of Squares	df	Mean Square	F ratio	P	Effect Size
Pre-test	441.975	1	441.975	171.449	0.001	0.868
Group	174.648	2	87.324	33.874	0.001*	0.723
Error	67.025	26	2.578			
Sum	148830	30				

*Significant difference.

PHYSICAL TREATMENTS

Table 3. Results of the Bonferroni post-hoc test

Group	Group	Mean Difference	Standard Error of the Mean (SEM)	P
SS	Massage	4.014	-0.718	0.001
	FR	5.77	0.719	0.001
Massage	Foam rolling	1.756	0.719	0.065

PHYSICAL TREATMENTS

improvement in ROM [43]. Škarabot et al. (2015) investigated the effects of FR and SS on ankle ROM in adolescent athletes. Participants in the mentioned study were randomly assigned to three groups: FR, SS, and a combination of both. The results revealed that SS increased ROM by 6.2%, while the combination of FR and SS increased ROM by 9.1%. However, FR alone had no significant effect on ROM, which aligns with the current study's findings [44]. Couture et al. (2015) compared the impacts of long-term (4×30-second) and short-term (2×10-second) myofascial release interventions on knee ROM in healthy individuals. The findings of that study indicated that neither myofascial release protocol led to a significant improvement in knee ROM [41]. Evans (2014) also demonstrated that SMR does not affect flexibility or hamstring strength during movements. This researcher recommended avoiding reliance on SMR to increase flexibility during warm-up, as its effectiveness is inconsistent with previous findings, suggesting the need for further research in this area [42].

The SS technique is recognized as an efficient approach for increasing muscle flexibility and ROM in the sports world. This method improves the extensibility of muscles and connective tissue by inducing neural and muscular adaptations that can enhance ROM. From a neurocognitive perspective, this method can also help increase an individual's tolerance to stretching by reducing the excitability of motor neurons and stretch reflex sensitivity, thereby increasing ROM [45]. Additionally, SS reduces the sensitivity of muscle spindles and increases their adaptation to stretching. This method can minimize the signals of primary and secondary afferent receptors embedded in muscle spindles. Also, by exerting forces on tendons, autogenic inhibition reflexes and muscle relaxation are mediated by Ib nerve fibers. This combination of neurophysiological effects can enable muscles to elongate further and increase their flexibility [46].

Another reason for the superior effect of SS on hip flexion ROM compared to FR may be the nature of the applied forces. SS primarily applies longitudinal forces to tendon and muscle tissue, substantially increasing the ROM. However, FR primarily induces transverse forces on muscle tissue, indicating that the reported improvements in ROM in previous studies may be due to a change in pain threshold rather than actual tissue adaptation [47].

The results of the current study do not align with the results of Reiner et al. (2022), Killen et al. (2019), and Su et al. (2016) [39, 48, 49]. Reiner et al. (2022) conducted a study comparing the effects of SS and vibration FR on hip ROM. The results indicated that vibration FR led to a larger improvement in hip flexion ROM than SS exercises [49]. Killen et al. (2019) also demonstrated that all interventions (FR, SS, and DS) were effective in improving hamstring and quadriceps muscle flexibility, with FR significantly more efficient at enhancing flexibility than SS and DS [48]. Su et al. (2016) also found similar results [39]. Another potential reason for the lack of change in the hip ROM with SMR in the current study may be inadequate pressure applied to the tissue of interest. Several participants in Evans et al.'s (2014) study reported feeling minimal or no pressure during the SMR protocol. Suboptimal positioning during rolling causes more body weight to be applied to the hands rather than to the roller and the tissue of interest. Subsequent studies could improve the effectiveness of SMR by using yoga blocks under the hands and applying more pressure on the thighs. Notably, unlike participants in previous studies with normal hip joint ROM, the samples in the current study exhibited hamstring tightness.

The current study's findings indicated that 8 minutes of massage had no significant effect on hip ROM. Similarly, Barlow et al. (2004) found that one massage on the posterior thigh muscles had a significant effect on SLR performance [50]. Wiktorsson-Moeller et al. found that [51] massage, whether performed alone or with a warm-up, did not significantly increase hip ROM. It has been stated that massage does not alter the mechanical characteristics of myotendinous units or increase ankle ROM [52].

Figure 1. Experimental intervention protocols for hamstring flexibility
(A) and (C) Foam rolling protocol. (B) Massage protocol. (D) Static stretching protocol.

PHYSICAL TREATMENTS

The limitations of the current study include a small sample size and limited familiarity with the participants' SMR. This study investigated the immediate effects of SS, massage, and FR on hip flexion ROM in football players with hamstring tightness. Future research should explore the long-term impact and sustainability of these methods in athletes with hamstring tightness.

Conclusion

This study compared hamstring muscle flexibility among SS, massage, and FR groups. The results of the ANCOVA revealed that, after adjusting for pre-test effects as a covariate, hamstring flexibility was substantially different among the three groups. Overall, the findings suggest that SS is a more effective option to increase flexibility immediately in football players with short hamstrings than massage and FR. These findings can be beneficial for athletes and coaches in selecting the optimal method to enhance flexibility and prevent physical injuries.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Research Ethics Committee of Sciences and Research Branch, Islamic Azad University, Tehran, Iran (Code: IR.IAU.SRB.REC.1400.005).

Funding

The article was extracted from the master's thesis of Bahar Darvish, approved by the Sciences and Research Branch, Islamic Azad University, Tehran, Iran.

Authors' contributions

Study design and data collection: Hashem Piri and Bahar Darvish; Writing: Elahe Shadi and Mohammad Rahimi; Final approval: All authors.

Conflict of interest

The authors declared no conflicts of interest.

Acknowledgments

The authors are grateful to all those who helped them in conducting this research.

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