Original Article

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Effectiveness of Vibration Foam Roller Stretching and Ballistic Stretching on Hamstring Flexibility among Amateur Male Athletes – A Randomized Control Trial

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Abstract:

Objective: The primary objective of this study was to compare the effectiveness of vibration foam-roller stretching and ballistic stretching in improving hamstring flexibility, assessed using the active knee extension test and the sit-and-reach test.

Material and Methods: A total of 80 participants (aged 18 to 25 years) were randomly allocated into two equal groups using a concealed envelope method. Sealed, opaque envelopes containing group assignments (Group A: vibration foam roller stretching; Group B: ballistic stretching) were prepared by an independent researcher not involved in recruitment or assessment. After baseline evaluation, participants were assigned sequentially by opening the next envelope, ensuring allocation concealment. Group A (n=40) received vibration foam roller stretching, and Group B (n=40) received ballistic stretching to improve hamstring flexibility. Both groups completed three training sessions per week over four weeks. The primary outcome was hamstring flexibility, measured using the active knee extension (AKE) test in degrees (°). The secondary outcome was the sit-and-reach test (SRT) in centimeters (cm). Assessments were conducted at baseline and immediately post-intervention to evaluate within- and between-group differences.

Results: The ballistic stretching group showed significantly greater post-intervention improvements across all outcome measures. In the AKE test, right-side mean±S.D. values were 149°±12.27 versus 129.8°±1.03, and left-side values were 149.5°±12.21 versus 130.2°±0.74, both showing enhanced outcomes in the ballistic group (p-value<0.001). Similarly, in the SRT, the ballistic group achieved a mean±S.D. of 28.9±1.39 cm compared to 21.2±1.73 cm in the vibration foam roller group (p-value<0.001).

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Conclusion: Ballistic stretching was more effective than vibration foam roller stretching in improving hamstring flexibility among amateur male athletes. Clinically, these findings suggest that ballistic stretching can be safely integrated into physiotherapy and sports training programs to prevent hamstring tightness and reduce the risk of flexibility-related injuries.

Keywords: athletic performance, bouncing movement, hamstring muscles, muscle stretching exercises, range of motion

Introduction

Flexibility is the ability of a joint to move spontaneously with a full range of motion (ROM). The posterior thigh muscles—semimembranosus (SM), semitendinosus (ST), biceps femoris (long and short heads)—are collectively known as the hamstrings. Due to their length, multiarticular nature, and high strain risk, they are prone to repeated injuries. Reduced muscle flexibility leads to tightness, limiting joint range of motion. This tightness often results from inactivity or poor recovery after injury[1]. A key component of motor skill is "flexibility," as human movement depends on the range of motion provided by synovial joints, which are crucial for musculoskeletal injury prevention and recovery. This can be described by the range of motion in a specific joint or by the extensibility of a muscle group, with the surrounding soft tissue being naturally extensible. The ROM defines joint flexibility and the joint's full capacity for movement, yet because ROM is intrinsically influenced by muscle health and joint structure, any imbalance in these components can result in decreased flexibility. Muscle length and flexibility are frequently used interchangeably to describe a muscle's capacity to extend across a joint to its maximum length. Reduced hamstring flexibility is considered a contributing factor to lower back pain, as research indicates that participants with lower back pain frequently have tight hamstrings[2]. A study by Sheetal Mahadik shows that the prevalence of hamstring tightness in youngsters is 82% when assessed using an active knee extension test[3]. Muscle strains, shin splints, stress fractures, and patellofemoral pain syndrome are examples of musculoskeletal overuse injuries caused by decreased flexibility in the lower extremities, which leads to a decrease in strength, stability, endurance, and more, affecting the psychosocial aspect of the athlete[4]. Hamstring muscles are known to be the most frequently injured multi-joint muscle group, as they have a wider functional range and typically a higher percentage of fast-twitch muscle fibers[5–8]. ROM is also influenced by muscle health and joint structure, resulting in any imbalance decreasing flexibility. Hamstrings, also known as mobilizers in the hip and knee areas, are among the most frequently shortened muscles, and tightness can cause postural and biomechanical abnormalities. An athlete's lower back and lower limb injuries are frequently associated with limited hamstring flexibility[9]. Many factors, including fascial restrictions, can limit flexibility, as different body structures are connected by fascia, a connective tissue that envelops blood vessels, muscles, and nerves. Injury, illness, inactivity, or inflammation can cause restrictions, which may result in severe physical pain, as well as decreased flexibility, strength, endurance, and motor coordination[10].

Fascia encases the body's organs and muscle groups, providing a supportive and cushioning structure that, when stuck, causes limited mobility[11]. Type Ia and type II muscle spindle receptors are activated by ballistic stretching, which increases the excitability of homonymous alpha motor neurons and triggers the stretch reflex, resulting in the contraction of the stretched muscle, increasing the risk of muscle fiber damage, and therefore is frequently regarded as less beneficial for extending the range of motion[12]. Studies show that static stretching lowers strength capacity and can occasionally impact vertical jump performance. This force reduction could be the result of altered neural activation or changes in the musculotendon unit's mechanical properties[13]. According to neurological research, ballistic stretching exhibits more autogenic inhibition, such as H- reflex suppression, and causes peak tensions and energy absorptions within the musculotendinous unit, more than in static stretching. With recent studies suggesting the nonlocal effects that could alter the mechanical sensitivity of the muscles, it has gained popularity due to its ability to increase the range of motion and provide massage-like effects on muscles and fascia[14]. Foam rolling is a common massage technique in both athletic and rehabilitation settings due to its portability and ease of use. A growing body of research showcases the use of self-administered foam rolling (SAFR) as a warm-up before exercise and/or a recovery method after exercise as an adjunct to conventional soft tissue therapies. Vibration stimulation primarily contributes to muscle activity, strength, and neural mechanisms[15–18]. Athlete trainers and physical therapists opt for foam rollers for efficiency in warm-ups and recovery in order to increase ROM, improve muscle function, and reduce pain and tightness in the muscles as a part of the Self-Myofascial Release (SMR) technique [19,20]. This rehabilitation technique offers physiological benefits similar to massage, improving arterial function, supporting the vascular endothelium's health, lowering parasympathetic nervous system activity, and easing muscle soreness, which aids in the recovery process from exhaustion[20]. Professional and amateur athletes use foam rolling as a self-massage and self-myofascial release, as it provides the ease of regulating pressure over muscles, improving blood circulation, and reducing inflammation[11,16,21]. Roller massage bars come in a range of sizes, shapes, and materials, with exteriors made of dense foam and a solid plastic cylinder for the use of upper extremities[22]. The impact of foam rolling on neuromuscular function up to 72 hours following the onset of DOMS (delayed onset muscle soreness) and additional studies showcase that a single foam rolling session improves range of motion without compromising neuromuscular (isometric) function, thereby helping with DOMS recovery while maintaining physical function[23] .

Stretching is a crucial part of individualized rehabilitation programs, improving soft tissue extensibility and muscle flexibility by addressing adaptation-induced hypomobile structures. Most athletes and strength training coaches incorporate this in their pre-event warm-ups, which increases joint range of motion and flexibility, improving their performance, general fitness, and reducing the risk of injury[5,14,24–26]. According to recent studies, stretching may not significantly reduce injuries sustained during practice or competition; therefore, considering it the most effective type to prevent performance issues has become a topic of increasing discussion. Further studies show that static stretching lowers the muscle group's strength and power output, impairing muscular performance, making it less desirable, according to some experts [27]. Ballistic stretching is a high-speed and high-intensity technique characterized by rapid bouncing movements that target and stretch the shortened structures through momentum, moving the body segment through its range of motion. An alternative to static stretching requires careful control of intensity within safe limits, as failure to do so may cause injury[28]. Both static and ballistic stretching are effective in enhancing hamstring flexibility, which in turn improves the range of motion in knee extension[9].

These age-related physiological differences may influence how individuals respond to stretching modalities; for example, static stretching reduces muscle stiffness less effectively in older adults than in younger adults[29] . Although foam rolling and ballistic stretching have been individually studied for improving hamstring flexibility, there is limited evidence directly comparing their effectiveness among amateur male athletes. Addressing this gap is important as hamstring tightness is prevalent in this population and can increase the risk of musculoskeletal injuries.

While ballistic stretching and vibration foam rolling have been studied individually for hamstring flexibility, their comparative effects remain unexplored. Additionally, prior research has not simultaneously assessed bilateral flexibility using the sit-and-reach test alongside single-leg measures with the active knee extension test. This study addresses these gaps, providing evidence on the efficacy of both interventions in amateur male athletes.

This study aimed to provide clinical and practical insights for physiotherapists, athletic trainers, and athletes on selecting appropriate interventions to enhance flexibility, performance, and injury prevention. Therefore, we hypothesized that ballistic stretching would produce greater improvements in hamstring flexibility assessed using the active knee extension (AKE) test and the sit-and-reach test (SRT) than vibration foam-roller stretching following a four-week intervention period.

Material and Methods

Participants

This study was conducted at Saveetha College, Chennai, India, from January 2024 (3rd Week) to February 2024 (2nd Week). A total of 80 participants from Saveetha College, Chennai District, were selected based on the inclusion and exclusion criteria using a concealed envelope randomization technique. Sealed, opaque envelopes containing group assignments (Group A: vibration foam roller stretching; Group B: ballistic stretching) were prepared in advance by an independent researcher not involved in participant recruitment or outcome assessment. Following baseline evaluation, each participant was assigned sequentially by opening the next envelope, ensuring allocation concealment. Participants were recruited based on the inclusion and exclusion criteria: Male athletes between the ages of 18 and 25 who had either unilateral or bilateral hamstring tightness met the inclusion requirements. In order to be eligible, participants had to have no history of significant hamstring injuries and demonstrate less than 125° in the active knee extension test and less than 20 cm in the sit and reach test[30,31]. Participants with spinal disc herniation, lower limb fractures, and hamstring muscle/tendon injuries or those who had had lower limb surgery within the previous three months were excluded. Exclusion criteria also included lumbar or lower limb neurological involvement in patients who had been experiencing low back pain for the previous two months, and participants who were unwilling or uncooperative.

Ethical clearance

This research related to human use has complied with all the relevant national regulations and institutional policies and has followed the tenets of the Declaration of Helsinki, and has been approved by the ISRB Committee of Private institution and Hospital in Chennai, India (Approval No:17/032/2024/ISRB/SR/SCPT). This study was registered in the Thai Clinical Trials Registry (TCTR) under reg no. TCTR20250609003.

Study guidelines

The research followed the CONSORT 2010 statement: extension to randomized controlled trial. The study was conducted over 4 weeks. (Figure 1). Sample size was determined using G*Power Software Version 3.1.9.7 for the Wilcoxon–Mann–Whitney test. Prior power analysis was conducted using a two-tailed test, assuming a large effect size (Cohen's d=0.84), an alpha level of 0.05, and a power of 0.95 (1-β=0.95). The analysis indicated that a minimum of 80 participants (40 in each group) would be required to detect a statistically significant difference. This ensured sufficient power to avoid Type II error in the study.

Group allocation

After obtaining informed consent from all participants, they were split into two groups of 40 participants each

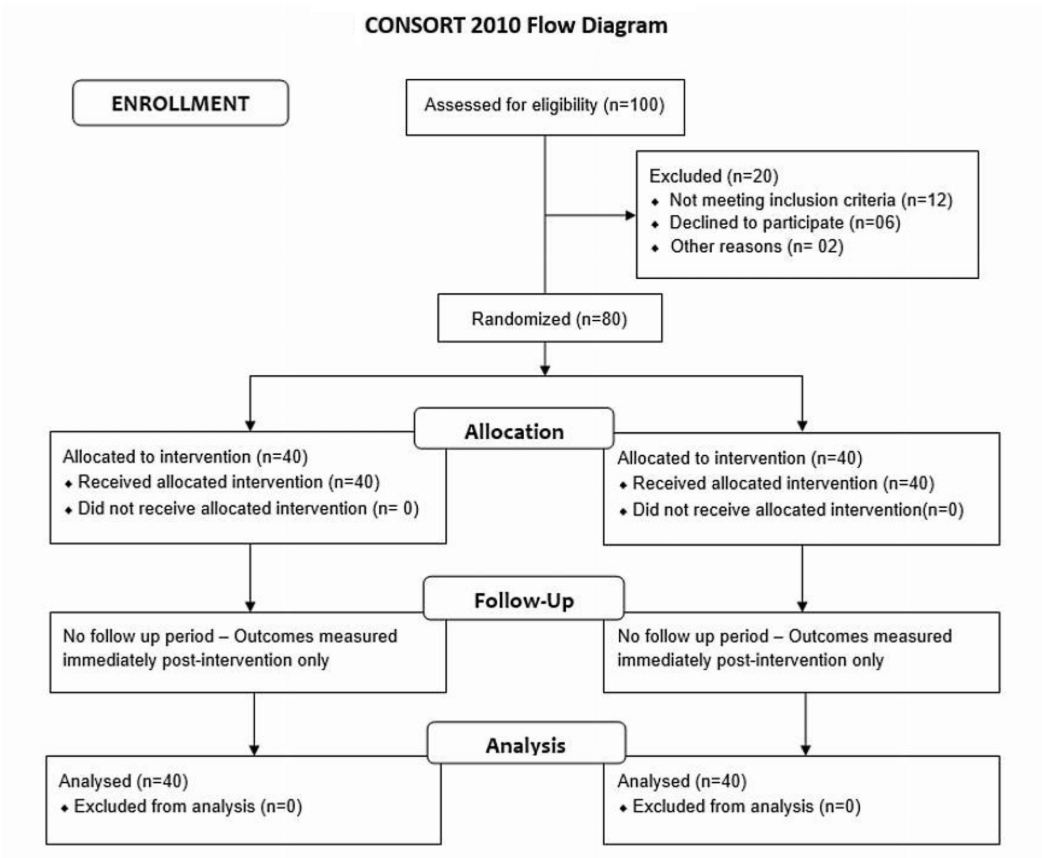


Figure 1 CONSORT flow diagram

at random using a concealed envelope randomization sampling technique. Group A received the vibration foam roller stretching exercise, and Group B received the ballistic stretching exercise. Demographic data were collected from each participant before treatment (Table 1).

Intervention

This study was conducted on 80 healthy amateur male athletes aged 18 to 25 years who consented to participate. The sample was selected according to the specified inclusion and exclusion criteria. The intervention was explained to participants, and institutionally approved written consent was obtained. Participants were divided into two groups by concealed-envelope randomization sampling. Group A Vibration Foam Roller Stretching=40, Group B Ballistic Stretching=40. Pre-intervention and post-intervention evaluation immediately following the stretch was taken with the sit-and-reach test and active knee extension test to measure hamstring muscle flexibility. Both tests were performed three times, and the average of the three measurements was used for data analysis.

Vibration foam roller stretching[32,33]

Forty participants received vibration foam roller stretching continuously for 4 weeks. The FR group supported the tester's weight while rolling back and forth, while positioning the hamstring of one leg on a vibration foam roller. A commercially available vibrating foam roller

Table 1 baseline demographic characteristics of participants in group A (vibration foam roller) and group B (ballistic Stretching)

Variable	Category	Group A (n=40) (%)	Group B (n=40) (%)	Total (n)	p-value
Gender	Male	40 (50)	40 (50)	80 (100)	-
Age (years)	18–20	12 (15)	20 (25)	32 (40)	>0.05
	21–23	18 (22.5)	11 (13.8)	29 (36.25)	
	23–25	10 (12.5)	09 (11.2)	19 (23.75)	
Body mass index (BMI, kg/m^2)	16.5–18.5 (Under weight)	9 (11.25)	11(13.75)	20 (25)	>0.05
	19.5–24.9 (Normal weight)	24 (30)	28 (35)	52 (65)	
	25–29.9 (Over weight)	03 (3.75)	05 (6.25)	08 (10)	

n=number of samples

was used and set to 30 Hz. Each session consisted of 5 sets of 10 repetitions, with each repetition involving 30 seconds of rolling over the hamstring followed by a 10-second rest interval, resulting in a total rolling time of 25 minutes per leg per session. Participants applied bodyweight pressure to the roller until a moderate tolerable pressure was achieved; therapists provided initial familiarization and monitored technique. The device setting and bout duration were kept constant across all participants. Over the course of the four-week intervention, participants attended three training sessions every week.

Group ballistic stretching

Participants sat with their dominant leg fully extended on the edge of a plinth with the foot flat on the floor and the non-dominant leg positioned off the plinth edge. The dominant leg was kept fully extended with the ankle plantarflexed to reduce neural tension, and participants bent forward at the hips to achieve a manageable stretch. The stretching protocol consisted of 3 sets of 5 repetitions per leg, with each repetition involving 30 seconds of small bouncing motions (3–5°) at the end of the range of motion, guided by a metronome set to one beat per second to maintain a consistent rhythm. A 10-second rest interval was provided between sets. The researcher provided verbal instructions during the first session and offered reminders in subsequent sessions to ensure proper posture, intensity, and pace. Sessions were conducted three times per week for four weeks. Total active stretching time per session was approximately 15 minutes (7 min and 30s per leg), totalling 45 minutes per week and 180 minutes over the four-week intervention period. Both legs were trained equally, and this technique was standardized across all participants.

Outcome measurements

The primary outcome was hamstring flexibility, measured using the AKE test in degrees (°). The secondary outcome was the SR test in centimeters (cm). The assessors in this study were blinded to the participants' group allocation.

SRT (in cm)

The participants sit with their hips at a 90° angle, their knees fully extended, and their feet pressed against a sit-and-reach box to perform the sit-and-reach test, which assessed the flexibility of the posterior muscle chain. With one hand placed over the other, the participants flexed their hips forward, reaching as far as they could without bending their knees. Regarding reliability, the sit-and-reach test demonstrated excellent reliability, with ICC values ranging from 0.988 to 0.998, SEM between 2.31 and 7.44, and an estimated MDC of approximately 1–2 cm[34].

AKE (in degrees):

After marking the fibular head and lateral malleolus, a line was drawn (in centimetres) from the greater trochanter to the lateral femoral epicondyle using a tape measure. With the lateral femoral epicondyle acting as the fulcrum of the goniometer, the stationary arm was aligned with the line connecting the greater trochanter and lateral femoral epicondyle, while the moving arm was aligned with the line connecting the lateral malleolus and the fibular head. Active knee extension measurements were performed while the participants were in a supine position. The test hip and knee were both flexed to 90 degrees, as determined by a goniometer, while the other leg remained flat on the treatment table. In this study, tension refers to the passive resistance or stretch felt in the posterior thigh during the AKE test. Before pelvic compensation, it is the endpoint of motion and displays the maximum hamstring extensibility. The hamstrings' tightness and flexibility are demonstrated by the measurement. The AKE test demonstrated high reliability, with ICC values of 0.87–0.94, SEM of 2.6°–2.9°, and an MDC of 7–8°. These values support the reliability of the outcome measures used in the present study[35].

Statistical analysis

All data were analyzed using Statistical Package for the Social Sciences (SPSS) version 27. The Wilcoxon test was applied within Groups A and B, while the Mann–Whitney U test was used to compare the two groups. The age and sex distribution of the participants are presented in Table 1. Table 2 illustrates the differences in the AKE test within Groups A and B, whereas Table 3 presents the between-group comparison for the AKE test. Table 4 shows the differences in the sit-and-reach test between the two groups.

Results

The study noted that among the 40 participants in Group A: Vibration Foam Roller Stretching, 12 (30 %) were aged 18-20 years, 18 (45 %) were aged 21-23 years, and 10 (25 %) were aged 23-25 years. In contrast, in Group B: Ballistic Stretching, out of 40 participants, 20 (50%) were aged 18-20 years, 11 (27.5 %) were aged 21-23 years, and only 09 (22.5 %) were aged 23-25 years. No statistically significant difference was observed between Group A (Vibration Foam Roller) and Group B (Ballistic Stretching) in terms of gender, age, or BMI distribution (p-value>0.05), indicating comparable baseline characteristics (Table 1).

The Wilcoxon signed-rank test for the active knee AKE test demonstrated that the 4-week intervention resulted in statistically significant improvements in hamstring tightness. In Group A (Vibration Foam Roller Stretching), significant improvements were observed on both the left (Z=–5.515, p-value<0.001) and right sides (Z=–5.566, p-value<0.001), with a mean increase of approximately 10°

Table 2 Comparison of pre- and post-test scores for AKE and SRT

Group	Side/Test	Pre-test (N=40) (Mean±S.D.)	Post-test (N=40) (Mean±S.D.)	Z-value	p-value
A	AKE left	120±0.73	130.2±0.74	-5.515	<0.001
	AKE right	119±0.99	129.8±1.03	-5.566	<0.001
	SRT	17.5±1.46	21.2±1.73	-5.394	<0.001
B	AKE left	108.8±6.22	149.5±12.21	-5.513	<0.001
	AKE right	112.1±6.86	149±12.27	-5.526	<0.001
	SRT	16.7±1.61	28.9±1.39	-5.519	<0.001

*p-value<0.05, AKE=active knee extension test in degrees (°), SRT=sit-and-reach test in centimeters (cm).

in knee extension. Similarly, Group B (Ballistic Stretching) demonstrated statistically significant improvements on the left (Z=–5.513, p-value<0.001) and right sides (Z=–5.526, p-value<0.001), with a mean increase of approximately 37°, indicating substantial gains in hamstring flexibility. In addition, the SRT revealed significant within-group improvements for both groups, with Group A showing a mean increase of approximately 3.7 cm (Z=–5.394, p-value<0.001) and Group B demonstrating a mean increase of approximately 12.2 cm (Z=–5.519, p-value<0.001), as presented in Table 2. These within-group improvements following the intervention period are also illustrated in Figure 2.

The Mann-Whitney U test demonstrated no statistically significant differences in pre-test scores between Group A and Group B; however, statistically significant differences were observed in the post-test scores for hamstring tightness. For the AKE test, significant intergroup differences were identified on both the right and left sides (U=142.5, p-value<0.001; U=135, p-value<0.001), as shown in Table 3. Similarly, the SRT test showed a statistically significant difference in post-test scores between Group A and Group B (U=1.50, p-value<0.001), as presented in Table 4. Since all p-values were less than 0.05, the null hypothesis was rejected, indicating that the treatment interventions had a significant effect on hamstring tightness. These intergroup differences in post-test outcomes are further illustrated in Figures 3 and 4.

Effect sizes with 95% confidence intervals (CI) were calculated for all outcomes, revealing large effects: AKE-right (d=1.45; 95% CI, 1.14), AKE-left (d=1.38; 95% CI, 1.08), and sit-and- reach test (d=1.57; 95% CI, 1.24), indicating substantial post-intervention improvements in hamstring flexibility.

Both groups demonstrated statistically significant improvements in AKE following the intervention (p-value<0.001). Group A showed a mean gain of approximately 10°, which exceeds the minimal detectable change (MDC) of about 2°, indicating a clinically meaningful improvement in hamstring flexibility. Group B demonstrated a markedly larger improvement of approximately 20° compared to Group A.

Table 3 Post-test (AKE) for vibration foam roller stretching and post-test (AKE) for ballistic stretching

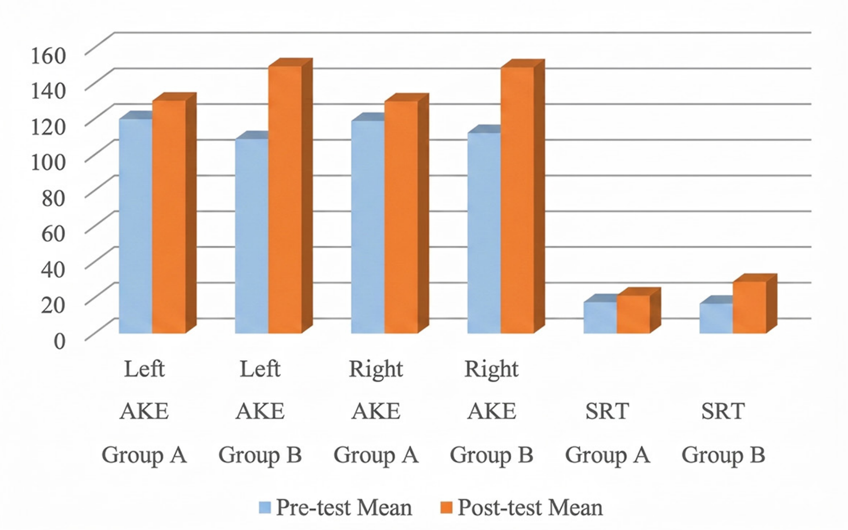
Group	Side	Post-test (AKE) (Mean±S.D.)	W	U	Z- value	p-value
A	Left	130.2±0.74	962.5	142.5		<0.001
	Right	129.8 ±1.03			-6.371	<0.001
B	Left	149.5±12.21	955	135		<0.001
	Right	149±12.27				<0.001

*p-value<0.05, AKE=active knee extension test in degrees (°), S.D.=standard deviation

Table 4 Post-test (SRT) for vibration foam roller stretching and post-test (SRT) for ballistic stretching

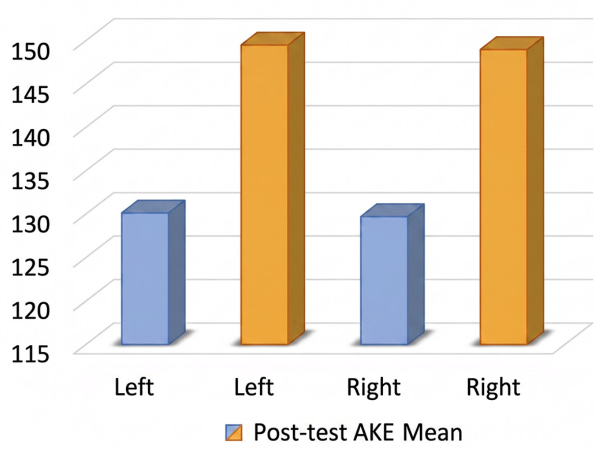
Group	Post-test (SRT) (Mean±S.D.)	W	U	Z value	p-value
A	21.2±1.73	821	1.50	-7.321	<0.001
B	28.9±1.39				<0.001

*p-value<0.05, SRT=sit-and-reach test in centimeters (cm), S.D.=standard deviation



AKE=active knee extension, SRT=sit-and-reach test

Figure 2 Pre and post test hamstring flexibility in group A and B



AKE=active knee extension

Figure 3 Post-test AKE comparison

Discussion

The study compared the effects of vibration foam roller stretching and ballistic stretching on hamstring tightness among amateur male athletes. The results showed that while both approaches improved hamstring flexibility, ballistic stretching produced more substantial benefits than vibration foam roller stretching. Hamstring flexibility is a critical factor influencing athletic performance, injury prevention, and overall physical function. This is supported by improvements in the AKE test and the SRT, both of which showed statistically significant increases in range of motion among participants who performed ballistic stretching compared to those who undertook vibration foam roller stretching.

A meta-analysis and systematic review by Jan Wilke et al. (2019) examined how foam rolling affects the range of motion in healthy adults. The study found that, compared with no exercise, foam rolling can produce immediate increases in joint range of motion. However, foam rolling was not found to be more effective than stretching. Based on the current evidence, foam rolling (FR) is a suitable technique that is not inferior to stretching for acutely inducing significant improvements in joint range of motion.

Several studies also support that ballistic stretching improves hamstring flexibility by increasing the ROM. C. K. Kishore Kumar et al. (2010) concluded that both static and

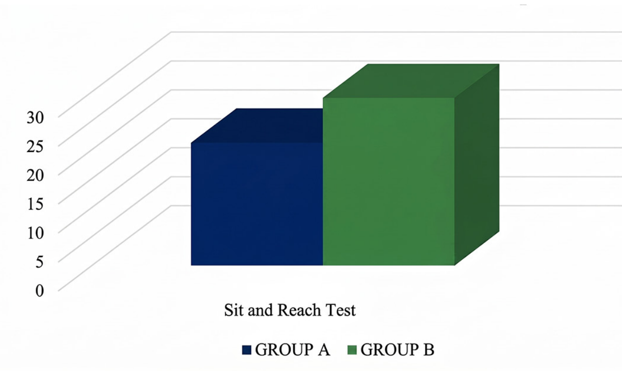


Figure 4 Post-test sit-and-reach test scores group A vs. B

ballistic stretching differ significantly in their effects. After six weeks of stretching, a paired *t*-test with a p-value≤0.05 demonstrated that ballistic stretching improves hamstring flexibility more effectively than static stretching. Although these results cannot be generalized to the entire population, the study found that ballistic stretching enhances hamstring flexibility in individuals with tight hamstrings more efficiently than static stretching.

Konrad and Markus Tilp et al. (2014) concluded that six weeks of ballistic stretching effectively increased dorsiflexion ROM through a lower-leg muscle program, without affecting muscle or tendon structure. The increase in ROM is likely due to improved stretch tolerance rather than mechanical changes. They suggested that further research, including factors like muscle hardness, could provide more insight. David G. Behm and Potential Effects of Dynamic Stretching on Injury Incidence of Athletes: A Narrative Review of Risk Factors (2023) stated that ballistic stretching, involving rapid bouncing movements, can improve flexibility but does not significantly enhance strength or vertical jump performance. It may also lead to less controlled muscle activation, increasing the risk of strain or injury. When used appropriately, it can support activities requiring dynamic flexibility, depending on the stretch difficulty and the individual's experience.

Although ballistic stretching has been associated with an increased risk of muscle strain in some studies, in the present study, it was performed with controlled, small-amplitude motions under close supervision, and no adverse events were observed. These findings are consistent with Behm et al. (2023), who reported that dynamic and ballistic stretching when applied appropriately can safely enhance flexibility without increasing injury risk. Thus, when applied appropriately, ballistic stretching can be a safe and effective method to enhance hamstring flexibility in amateur athletes[36]. The observed improvements in hamstring flexibility following vibration foam-roller stretching are likely multifactorial. Mechanical pressure applied through the roller may facilitate myofascial release, reducing fascial adhesions, and improving tissue extensibility. Additionally, increased local perfusion and muscle temperature could enhance compliance and reduce stiffness. Repeated stretching may also increase stretch tolerance, allowing participants to achieve a greater range of motion. Furthermore, the vibratory stimulus may contribute to neuromodulation, decreasing reflex excitability and promoting relaxation of the muscle–tendon unit. Although the present study did not directly measure these mechanisms, the flexibility gains are likely the result of the combined effects of mechanical, vascular, and neuromuscular factors.

Consistent with previous studies, ballistic stretching produced substantial improvements in hamstring flexibility (Kishore Kumar et al., 2010; Konrad & Tilp et al., 2014), whereas vibration foam-roller stretching yielded smaller immediate gains (Lim & Park, 2019). Unlike these prior studies, which examined each intervention separately, the present study directly compared the two approaches, providing novel insight into their relative efficacy. Variations in effect size may be attributed to differences in intervention protocols, participant characteristics, and measurement methods.

Age-related differences in flexibility showed that older participants exhibited smaller reductions in muscle stiffness than younger individuals. This finding supports the results of Hirata et al. (2019), who reported reduced responsiveness to stretching in older adults, likely due to altered neuromuscular function, decreased elasticity, and increased collagen cross-linking. These outcomes suggest that stretching programs should be age-adjusted with longer duration, lower intensity, or gradual progression to enhance flexibility while minimizing strain risk. Although the intensity of ballistic and foam-roller stretching should be moderated in older adults, these methods may still provide complementary neural and myofascial benefits. However, variations in baseline flexibility or activity levels and the modest, moderately aged sample limit the generalizability of these findings.

The present study assessed immediate post-intervention hamstring flexibility, and therefore, the observed improvements represent short-term gains. These effects may be partially transient and could diminish over time if the interventions are not performed consistently. Sustained enhancements in flexibility are likely to require regular and repeated application of the stretching protocols over an extended period.

Clear guidelines are provided by this randomized controlled trial for physiotherapists who treat male amateur athletes. When it comes to rapidly and efficiently increasing hamstring flexibility, ballistic stretching is the best option. However, foam rolling is a great substitute for mild hamstring tightness. Foam rolling has been found to be beneficial for warm-ups and blood flow enhancement, which lowers the chance of injury. Combining the two methods can sometimes produce even better outcomes by targeting both the neural and muscular components. The long-term impacts of these techniques on postural health, athletic performance, and injury prevention should be investigated in future research. The synergistic benefits of foam rolling and ballistic stretching may also be better understood with more research into their combined application.

Limitation

This study has several limitations that should be considered when interpreting the findings. The one-month intervention period restricted the ability to determine long-term effects, and no follow-up assessments were conducted after the intervention. The duration of pain experienced by participants was not measured, which may have limited the clinical interpretation of the flexibility gains. Additionally, the study included only amateur male athletes, reducing the generalizability of the results to females, other age groups, or professional athletic populations. Flexibility was evaluated solely through conventional measures, the sit-and-reach test and the active knee extension test, without the incorporation of advanced biomechanical, neuromuscular, or morphological assessments, such as electromyography or ultrasound imaging. Moreover, participants' prior stretching habits, training load, and potential diurnal variations in flexibility were not controlled, which may have acted as confounding factors influencing the outcomes.

Practical implications

These findings suggest that from a clinical and athletic perspective, ballistic stretching is particularly helpful when the goal is to achieve rapid and practical flexibility gains, particularly before performance activities. For mild tightness recovery and injury prevention, foam-roller stretching is a helpful alternative. A coordinated approach could optimize the advantages of both the brain and the muscles, enhancing flexibility and performance.

Clinical and athletic applications

The findings suggest that regulated, supervised ballistic stretching can enhance hamstring flexibility and functional readiness during warm-ups, particularly for athletes engaged in activities involving rapid, forceful lower-limb movements such as running, jumping, and kicking. For individuals with mild hamstring tightness or in recovery, vibration foam-roller stretching may be preferable due to its myofascial release, circulation, and muscle relaxation benefits. Combining ballistic and vibration foam-roller stretching may yield synergistic effects, optimizing performance and reducing injury risk through neural and myofascial mechanisms.

Future directions

Future research should control for potential confounding factors by documenting participants' stretching habits, monitoring training regimens, and standardizing assessment times. Incorporating advanced measures, such as EMG, muscle thickness, fascicle length, and long-term follow-ups, would further elucidate the neuromuscular and structural mechanisms underlying flexibility adaptations.

Conclusion

Both vibration foam roller stretching and ballistic stretching contribute to increased hamstring flexibility; however, the benefits of ballistic stretching are notably greater. It is a more comprehensive method, as it can help alleviate muscle restrictions, particularly in individuals with musculoskeletal disorders or pronounced tightness. These findings highlight the importance of specialized, evidence-based interventions to reduce hamstring strain and enhance overall physical performance in male amateur athletes.

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Conflict of interest

There are no conflicts of interest, according to the authors.

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