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Comparing the immediate effects of different neural mobilization exercises on hamstring flexibility in recreational soccer players

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Background: Hamstring strain injuries remain a challenge for both athletes and clinicians given the high incidence rate, slow healing, and persistent symptoms. Increased tension in the neural structures is a known causative factor for hamstring tightness for which neural mobilization has emerged as a significant adjunct to routine stretching techniques.
Objective: To compare the short-term effects of neural sliding and neural tensioning on hamstring length in male recreational soccer players with hamstring tightness.
Methods: Sixty-two participants between ages 18 and 30 years were randomly assigned to one of the two groups viz. neural sliding or neural tensioning. Participants in either group performed the given stretching protocol in three sets. The Active Knee Extension Test (AKET) and Sit and Reach Test (SRT) were recorded before intervention, immediately after intervention, and after 60 min. between- and within group-analysis was done using analysis of variance.
Results: Between-group analysis showed that neural tensioning was more effective than neural sliding in improving hamstring length on both measures, however this difference was negligible. Within-group analysis demonstrated that the mean post-test scores on the AKET test and SRT were significantly greater than the pre-test scores in both groups ($p < 0.05$). A reduction in the post-test scores was observed after 60 min, irrespective of the type of stretching ($p < 0.05$).

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Conclusion: There was no difference in short-term effects of neural sliding or neural tensioning on hamstring flexibility in male recreational soccer players. Both groups showed improved flexibility immediately after the intervention with reduction in the effect after 60 min.

Keywords: Exercise therapy; hamstring muscles; nerve stretching; range-of-motion; rehabilitation.

Introduction

The hamstring muscle is most susceptible to injury and represents a significant portion of lower extremity musculotendinous injuries in athletic competitions.[1,2] Hamstring muscle injury is a complex problem for athletes, physicians, physical therapists, and athletic trainers as these injuries tend to recur and limit participation in athletic competitions.[2,3] Football players are especially prone to this injury given the sprinting demands of the sport and due to the extreme stretch incurred by the hamstring muscles.[4–7] They occur primarily during high-speed or high-intensity exercises and have a high rate of recurrence.[8,9]

Flexibility is a vital component of a physical conditioning programme that allows the tissue to accommodate easily to stress, to dissipate shock impact, and to improve efficiency of movement, thus minimizing or preventing injury.[10] Several methods have been tried to increase the hamstring flexibility in previous studies.[11,12] Majority of studies have compared different stretching types in terms of increasing the flexibility of the hamstring. Among these, Proprioceptive Neuromuscular Facilitation (PNF) techniques, static stretching, and active dynamic stretching are the most preferred.[13] Moreover, the different intensities and frequencies of the use of these methods were also compared.[14] Although the necessity of a warm-up might be obvious, specific elements that should be included in the warm-up may be less clear.

Apart from musculoskeletal causes, hamstring has also been shown to tighten due to increased tension in the neural structures. Non-contractile tissues can come under tension during passive or active movements of hip flexion or knee extension.[15] Mobilization exercises applied to neural tissues are used as a supportive method in the treatment of musculoskeletal injuries. Neural mobilization exercises may reduce neural sensitivity to the movement and may be useful as an addition to rehabilitation programs to increase hamstring flexibility.[16,17]

Neurodynamic functions and physiological properties of neural tissue can be reduced owing to reduced muscle flexibility, furthermore causing tonus problems in the hamstring muscle making it sensitive to stretch and pain.[18] Thus, this mechanical sensitivity in neural tissues creates a ground for injuries by adversely affecting the functioning of protective mechanisms against muscle injury.[17,19] Studies are available concerning neural sliding and neural tensioning exercises enhancing hamstring flexibility.[20,22] Neural sliding is a neural mobilizing technique applied to the neural stem to slide the neural body in which one end of a neural stem is extended while the other end is relaxed.[22] Neural tensioning is a neural mobilizing technique applied to the neural stem to stretch the neural body in which both ends of a neural stem are extended.[23]

Although the effects of neural sliding and neural tensioning exercises on hamstring flexibility have been investigated in those affected with hamstring injuries and low back pain, the effect of neural mobilization exercises on flexibility and its effect in athletes, especially football players remains uncertain. Recreational athletes, as compared to trained athletes do not undergo regular training or sufficient pre-event warm-up, which may be important before any sporting activity in order to prevent injuries such as those of muscle sprains.[24] Furthermore, despite use of dynamic stretching by some sports participants, scant research exists on the effects of this mode of stretching on physical performance parameters closely related to the actual demands of sport.[25] Hence, the aim of this study was to compare the effects of neural sliding and neural tensioning in recreational soccer players. We hypothesized that the two types of neural exercises will not be equally effective in improving hamstring flexibility.

Materials and Methods

Participants and Screening: This experimental study adopted a pre-test–post-test design in which a total of 64 male recreational soccer players were recruited. Undergraduate and post-graduate students studying at a Medical College University in South India were selected using convenience sampling. Ethical clearance was obtained from the Institutional Ethical Committee.

Recreational males soccer players between ages 18 and 30 years and body mass index (BMI) of 18.5–23 kg/m^2, competing in college and inter-college competitions, who did not indulge in regular soccer-specific training for the last two years were included in the study. Only those with hamstring tightness defined as deficit of 30° from full active knee extension with the hip at 90° were included. Elite athletes, those with history of low back pain, lower extremity injuries that required treatment or that might have inhibited performance in last twelve months, those who have undergone lumbar spine or any lower extremity surgery in the last six months and those who did not give consent were excluded from the study.

Out of 92 males who enrolled for the study, 28 with no hamstring tightness and/or history of injuries were excluded and hence only 64 participants were included in the study. An informed consent was obtained from all participants once they had been screened for eligibility and any relevant questions were answered on the procedure and data collection process. The participants were randomly assigned to two groups (32 in each group) by using computer generated sequence of random numbers. Group I received Neural Sliding

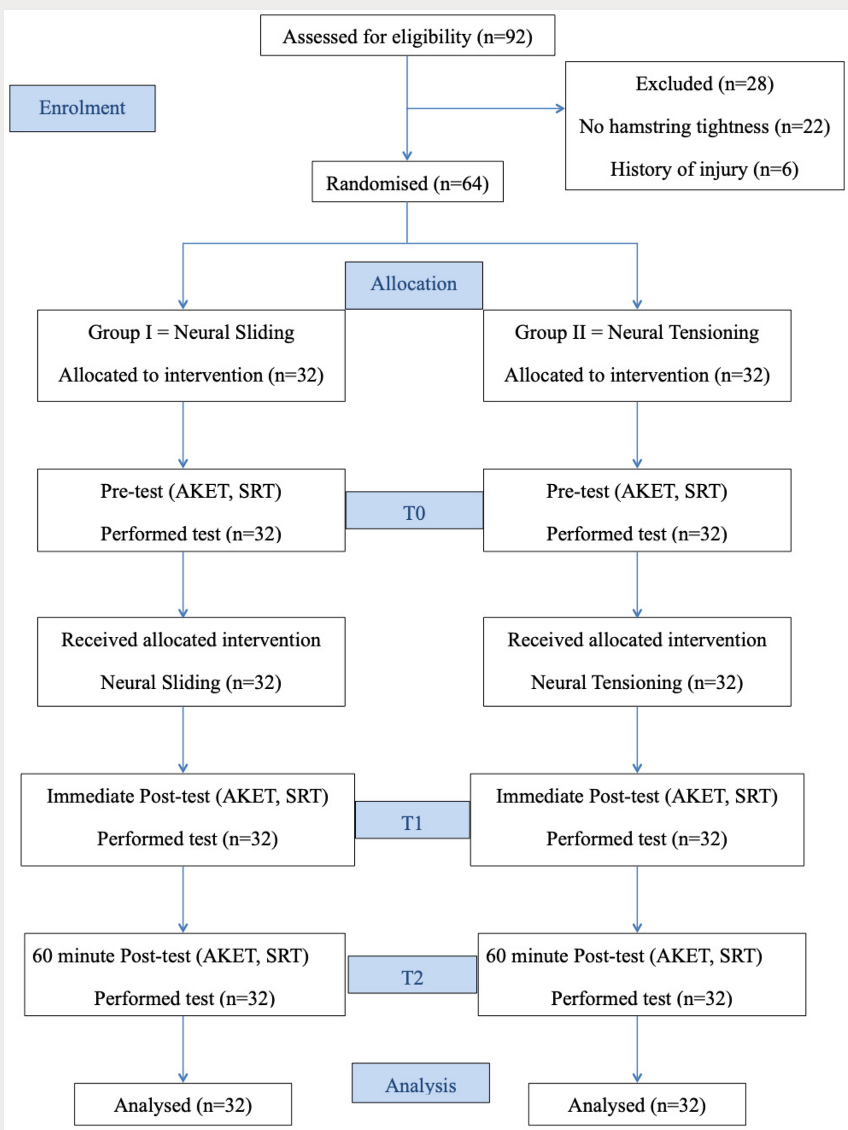

Fig. 1. Study flow chart.

and Group II received Neural Tensioning (Fig. 1). The therapist who administered the outcome measures and performed the data analysis was blinded to the group the participants belonged to.

Intervention

Neural Sliding: The participant was placed high on a plinth in order not to touch his feet to the ground, with his hands held on his back. Exercise was performed in two stages. In the first stage, the participant was asked to extend the cervical region and extend the knee along with ankle dorsiflexion at the same time. In the second stage, the participant was asked to flex the cervical region and flex the knee with ankle plantar flexion at the same time. One set consisted of 30 repetitions. One repetition was completed in 2 s and a total of 30 repetitive exercises were performed approximately in 60 s. Similarly, three sets were performed alternatively for each extremity. A rest period of 30 s was given between the sets.

Neural Tensioning: This was also performed in the same position as the neural sliding technique and in two stages. In the first stage, the participant was asked to flex the cervical region and at the same time extend the knee to extension and dorsiflex the ankle. In the second stage, the participant was asked to restore ankle dorsiflexion, maintain cervical flexion, and take the knee into flexion at the same time. One set consisted of 30 repetitions. One repetition was completed in 2 s and a total of 30 repetitive exercises were performed approximately in 60 s. Similarly, three sets were performed alternatively for each extremity. A rest period of 30 s was given between the sets.

Outcome measures

Active Knee Extension Test (AKET): The AKET was used to assess hamstring muscle length and the range of active knee extension in the position of hip flexion. It is known to have excellent interrater and intrarater reliability for assessing hamstring flexibility in healthy adults.[26,27] The participant was positioned in the 90/90 position on a plinth, with knee and hip flexed to 90°. The opposite leg was placed flat on the couch with the knee fully extended and maintained in this position throughout the end of the test. The participant was then instructed to actively extend the knee being tested through the full available range-of-motion until firm muscular resistance was felt, while the hip was maintained at 90° flexion. The stationary arm of the goniometer was aligned along the femur with reference point at the greater trochanter of femur, fulcrum at the lateral femoral condyle of knee joint and the moving arm was aligned with the lateral malleolus. Angles were measured in degrees, in both limbs, representing the active range-of-motion. An average of the right and left extremities was used for statistical analysis.

Sit and Reach Test (SRT): The SRT is the most widely used flexibility test for hamstrings, hip and lower back and was used to assess functional flexibility of the hamstring.[28] A measuring tape was placed on the floor with a right angle (made with tape) at the 15 in mark. The participant was seated with the measuring tape between the legs. Heels of the feet touched the edge of the right angle taped line (at the 15 in mark) and about 10–12 in apart. The participant then slowly reached forward as far as possible with both hands, holding the position for approximately 2 s and was asked to refrain from jerky movements, keep the fingers overlapped and touch the measuring tape. The most distant point (in inches) reached with the fingertips was recorded. The knees remained extended throughout the test.

Each participant in either group was assessed on two consecutive days. They performed the AKET test and SRT a day prior to performing the exercises (T0). Exercises were performed on Day 2 after which the readings of AKET test and SRT were taken immediately after the intervention (T1) and 60 min after the intervention (T2).

Sample size estimation: Based on the study done by Balci *et al.*,[29] to expect an improvement in the AKET test, i.e., a mean difference of 3.22°, with 95% confidence interval, 80% power and allowable error of 5%, the sample size for the study was estimated to be a minimum of 64 participants.

Data analysis: Statistical package SPSS (IBM SPSS Statistics for macOS, ver 29.0.1.0 (171). Arming, NY: IBM Corp.) was used to analyze the data. The Levene's Test was used to assess the equality of variances. The demographic characteristics and the baseline (pre-intervention) criterion measures were compared between the two groups using the Independent *t*-test. A 3×2 Analysis of Variance was used to find out the group effect (Neural sliding and Neural tensioning), time effect (pre-intervention, post (immediate)-intervention, and post (60 min) intervention), and group $\times$ time

Table 1. Demographic characteristics and outcome variables for neural sliding and neural tensioning groups.

Variable	Neural sliding group ($N = 32$) Mean ± SD)	Neural tensioning group ($N = 32$) Mean ± SD)	Independent *t*-test *p*-value
Age (years)	22.5 ± 1.3	21.2 ± 1.1	0.68
BMI (kg/m^2)	21.9 ± 2.0	21.5 ± 2.1	0.73
AKET (°) [T0]	13.5 ± 0.7	12.6 ± 0.8	0.95
SRT (cms) [T0]	41.8 ± 1.7	41.2 ± 1.8	0.91

Notes: AKET: Active Knee Extension Test; BMI: Body Mass Index; *N*: Sample Size; SD: Standard Deviation; SRT: Sit and Reach Test.

interaction effect. If the group effect, time effect, or interaction effect was found to be significant, then the *post hoc* pairwise comparison was analyzed using the Bonferroni correction test. The effect size was calculated using the Partial Eta Squared statistic (p^2) to compare the results of within group and between group. p^2 was interpreted as large (> 0.14), medium (> 0.06) or small (> 0.01). Statistical significance was inferred at *p*-value less than 0.05.

Results

Both groups were similar at the baseline for all outcome measures and demographic variables ($p > 0.05$). Demographic characteristics such as age and BMI were found to be non-significant between the groups. AKET and SRT scores were found to be statistically non-significant between the two groups at baseline (Table 1).

The AKET showed a statistically significant time effect ($F = 32.707$; $p = 0.030$), and group × time interaction ($F = 10.095$; $p < 0.001$), whereas no significant difference was found in the group effect ($F = 0.032$; $p = 0.875$) (Table 2). A *post hoc* pairwise comparison indicated that there was a statistically significant difference in the AKET scores when comparing pre-intervention and post-immediate intervention ($p < 0.001$) results, as well as pre-intervention and post 60 min intervention results ($p < 0.001$) (Table 3). No significant difference in the AKET was found between post-immediate intervention and 60 min post intervention ($p > 0.05$) (Table 3).

The SRT showed a statistically significant time effect ($F = 19.367$; $p = 0.049$), whereas no significant difference was found in the group effect ($F = 14.628$; $p < 0.62$) and group × time interaction ($F = 1.723$; $p < 0.181$) (Table 2). A *post hoc* pairwise comparison indicated that there was a statistically significant difference in the AKET scores when comparing pre-intervention and post-immediate intervention ($p < 0.001$) results, as well as pre-intervention and post 60 min intervention

Table 2. Outcome measures at baseline, immediately after intervention and after 60 min of intervention for neural sliding and neural tensioning groups.

Variables	Neural sliding group ($N = 32$) Mean ± SD)	Neural tensioning group ($N = 32$) Mean ± SD)	Time (T) effect η_p^2 ($p-$value)	Group (G) effect η_p^2 ($p-$value)	$G \times T$ interaction η_p^2 ($p-$value)
AKET (°)					
T0	13.5 ± 0.7	12.6 ± 0.8	0.83 (0.030)*	0.61 (0.0875)	0.87 (< 0.001)*
T1	9.4 ± 0.8	9.7 ± 1.0			
T2	9.2 ± 0.8	9.5 ± 1.0			
SRT (cms)					
T0	41.8 ± 1.7	41.2 ± 1.8	0.92 (0.049)*	0.68 (0.062)	0.93 (0.181)
T1	44.8 ± 1.7	43.1 ± 1.8			
T2	44. 5 ± 1.7	42.8 ± 1.9			

Note: * Significant difference ($p < 0.05$). AKET: Active Knee Extension Test; *N*: Sample Size; SD: Standard Deviation; SRT: Sit and Reach Test; T0: Before intervention; T1: Immediately post-intervention; T2: 60 min post-intervention.

Table 3. *Post hoc* pairwise comparison using the Bonferroni correction between pre- and post (immediate)-intervention and pre- and post (60 min)-intervention for both groups combined.

Variables	(*I*) Time	(*J*) Time	Mean difference ($I - J$)	*p*-value
AKET	Before intervention	Immediately post-intervention	3.5	0.000*
		60 min post-intervention	3.6	0.000*
	Immediately post-intervention	60 min post-intervention	0.1	0.836
SRT	Before intervention	Immediately post-intervention	−2.4	0.000*
		60 min post-intervention	−2.1	0.000*
	Immediately post-intervention	60 min post-intervention	0.2	1.000

Note: *Significant difference ($p < 0.05$). AKET: Active Knee Extension Test; SRT: Sit and Reach Test.

results ($p < 0.001$) (Table 3). No significant difference in the SRT was found between post-immediate intervention and 60 min post intervention ($p > 0.05$) (Table 3).

Talking about the short-term effects, the between-group analysis demonstrated that neural tensioning was more effective than neural sliding in improving hamstring length measured by AKET ($p < 0.05$; □ $p^2 = 0.024$) and SRT ($p < 0.05$; □ $p^2 = 0.032$), however, the difference in the effect of the two regimens was negligible (Figs. 2 and 3). Similarly, the between-group analysis saw a negligible difference in maintaining the effect of the two regimens measured by AKET ($p < 0.05$; □ $p^2 = 0.021$) and SRT ($p < 0.05$; □ $p^2 = 0.030$) after 60 min (Figs. 2 and 3).

Discussion

Rehabilitation practitioners incorporate exercises designed specifically to improve the flexibility of musculo-tendinous structures to reduce the incidence of injury and enhance muscle performance.[2,30,31] Worrel *et al.* stated that a lack of hamstring flexibility was the single most important characteristic of hamstring injuries in athletes.[31] Non-ballistic active range-of-motion exercises have been advocated to be more effective than static stretching for increasing range-of-motion.[32]

The results of this study revealed that both neural sliding and neural tensioning exercises increase hamstring flexibility. Participants in the neural tensioning group showed greater improvement in hamstring flexibility as compared to the neural sliding group, however, this difference was negligible and could have occurred due to measurement errors. A previous study that compared the effect of different mobilization exercises of the sciatic nerve, identified that neural tensioning and sliding mobilization techniques are clinically known to release movement in the nerve bed.[23] This may be one of the reasons for both exercises to yield the same result.

Balci *et al.* found that neural sliding and neural tensioning exercises of the sciatic nerve yielded similar results in male and female wrestlers in improving hamstring flexibility and functional flexibility.[29] Similarly, few other authors also concluded that neural tensioning and neural sliding exercises in addition to static stretching of the hamstrings

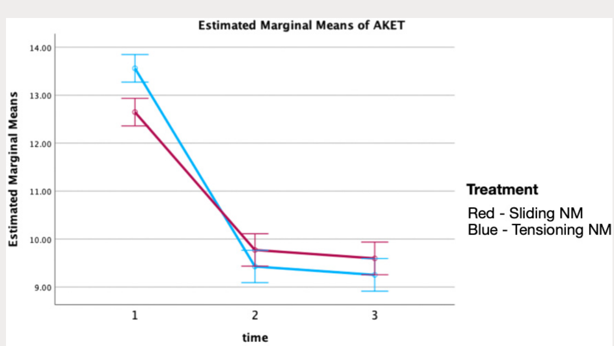

Fig. 2. Changes in AKET over time (NM: Neural Mobilization).

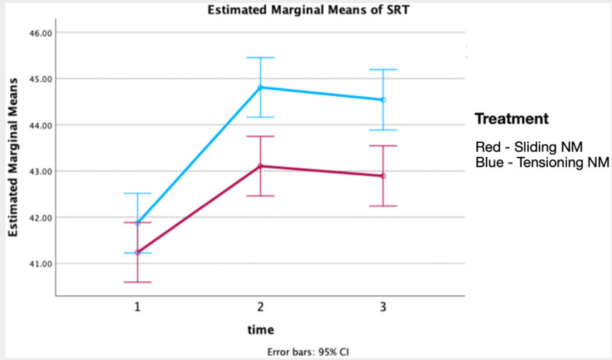

Fig. 3. Changes in SRT over time (NM: Neural Mobilization).

were equally effective at increasing hamstring flexibility.[33,34]

This study demonstrated that there was an increase in hamstring flexibility after neural mobilization exercises. As noted by Ellis *et al.*, the authors consider that this increased flexibility was achieved as the exercises provided displacement of the sciatic nerve in the posterior thigh region.[23] It is also suggested that the increase in the mobility of neural tissue and decreasing sensitivity can be an additive effect for the particular finding.[35] It has been also emphasized that there is little neural activity in individuals with short hamstring length.[36] However, whether this diminishing mobility is due to intra-neural factors (injury to the post-stretch neural tissue) or extra-neural factors (reduced neural motility resulting from muscle injury and adhesions) remains unclear.[35,37] Although there is not enough evidence, we assume that an increase in the mobility of neural tissues simultaneously occurs with the increase in the hamstring length.

In addition to the above findings, it was also noted that while there was an increase in the hamstring length immediately after stretching, this effect slightly reduced when hamstring flexibility was measured again after 60 min. This finding was seen in both groups, irrespective of the intervention. Only few studies have measured duration of static stretching effects on range-of-motion in lower extremities at various time intervals.[38,39] The results of Moller's group showed that increase in hamstring length remained for up to 90 min after stretching while Weijer noted a decrease in stretching effects after 15 min.[38,39] Direct comparisons of their results with the findings of this study are difficult because of variation in sample population and the outcome measures used. For the muscle to remain in a lengthened position for long, it is reasonable to suspect that tensioning or stretching may adjust the positional sensitivity of the Golgi tendon organs by affecting the muscle's elasticity. This adjustment may begin early after stretching and involve a recoil of the stretched elastic components of the tendon to a new state of equilibrium.[39]

Further research is warranted to evaluate the influence of stretching on the risk of exercise related injury and also to determine if tangible gains can be made in strength, injury reduction, and performance enhancement through the use of dynamic training in the form of neural mobilization. Besides a small sample size, the study only included recreational soccer players. The study did not have a treatment group to control for the effect of repeated test application. Also, the findings only apply to the techniques used in this study. Given that we did not have a third group that underwent only measurements, we do not know whether the improvements seen in both groups are simply due to familiarity with the tests over time. Further, the results could not prove how long the immediate effect of the exercise would last. Hence, the results of this study can be further confirmed in larger and more diverse populations including women and professional athletes.

Conclusion

Overall, the results of this study indicate that there was no clinically relevant difference in change in hamstring flexibility when comparing the short-term effects of neural sliding and neural tensioning exercises applied to sciatic nerve in male recreational soccer players. There were improvements in flexibility with both forms of intervention although whether this is due to the intervention or repeated testing requires further investigation. Based on the results, physical therapists, coaches and other strength and conditioning professionals can consider including either form of active stretching with the hope of improving overall performance by reducing hamstring tightness. However, these results only apply to the protocol used in this study. Further research can be done in larger populations including professional athletes and other forms of sport. Moreover, future studies that investigate whether the given regime could reduce the risk of injuries or injury recurrence are warranted.

Conflict of Interest

The authors declare no of interest with respect to the authorship and/or publication of this paper.

Author Contributions

CJ. D'souza: Conceptualization, Design, Data curation, Writing — original draft and editing, Resources, Methodology, Formal analysis, Supervision, and Data collection and sampling.

S Rajasekhar: Conceptualization, Resources, Writing–editing, Formal analysis, and Supervision.

RL Shetty: Conceptualization, Design, Writing–editing, Data curation, Resources, and Data collection and sampling.

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