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Original Research Article

PNF stretching and its immediate impact on hamstring flexibility and agility

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ABSTRACT

Background: Hamstring muscle is the most common muscle that goes into tightness due to changes in the active lifestyle. Hamstring tightness in college students can result from a combination of factors, including prolonged periods of sitting during lectures and study sessions, insufficient physical activity, poor posture. Hamstring tautness is often an indicator of muscle weakness, which may affect the performance. The aim of the study was to assess the immediate effects of proprioceptive neuromuscular facilitation (PNF) stretching on hamstring flexibility and agility in lower extremity.

Methods: This study was conducted at Tejasvini Physiotherapy College. The participants recruited were students from the college aged between 18-25 years both male (n=30) and females (n=30). The hamstring flexibility was checked using active knee extension test in pre and post-test and the performance was assessed by using agility test (t-test and Illinois test). In post-test PNF contract relax agonist contract (CRAC) stretch was given to all the participants and their performance was rechecked. Data were analysed by SPSS 16.0 and the effect of pre and post PNF contract relax agonist contract was estimated by using paired t-test.

Results: Using paired t-test, the PNF CRAC stretch made an average of hamstring flexibility of 8.3 and 8.0 in right and left of males, 8.0 and 9.0 in right and left of females. Following the intervention, the agility t-test and Illinois test shows a 0.4 and 0.5 in males and 0.5 and 0.6 in females.

Conclusions: The current study showed a statistically significant improvement in hamstring flexibility scores of agility test following PNF CRAC stretch.

Keywords: Active knee extension test, Hamstring flexibility, Illinois test, PNF contract relax agonist contract stretch, T-test

INTRODUCTION

Hamstring muscles play a crucial role in the performance of many daily activities, such as walking, running, jumping and controlling movement of the trunk.[1] Flexibility in the hamstring muscles is essential for maintaining optimal biomechanics, influencing agility, posture, and functional performance.[2] Hamstring flexibility can decline due to postural imbalances, scar tissue, spasms, or sustained muscle contraction. Prolonged sitting keeps the hamstrings in a shortened state, making it a primary cause of reduced flexibility.[3]

Agility, defined as the ability to rapidly change direction in response to a stimulus externally. while maintaining balance and speed, is influenced by multiple factors including neuromuscular coordination, dynamic balance, muscle power, and flexibility.[4] Hamstring flexibility enables longer strides, greater range of motion, and quicker neuromuscular response, boosting agility. Tight hamstrings restrict hip flexion and knee extension, limiting efficiency and rapid directional changes.[5] Therefore, the relationship between hamstring flexibility and agility has become an area of growing interest, particularly in sports and physiotherapy research.

Studies have shown that extended sitting contributes to hamstring shortening and reduced flexibility, which can impair lower extremity function and increase injury risk.[6-8] Various therapeutic interventions have been explored to address hamstring tightness, including static stretching, eccentric training, dynamic mobilization, and neurodynamic techniques.[9] Among these, proprioceptive neuromuscular facilitation (PNF) stretching has gained prominence due to its potential to produce immediate and significant improvements in muscle flexibility. PNF stretching combines passive stretching with isometric contractions, enhancing neuromuscular coordination and increasing range of motion.[10,11]

Although PNF stretching is known to improve flexibility, little evidence exists on its immediate effects on hamstring flexibility and how these acute changes influence agility in the lower extremity. Most studies emphasize long-term outcomes or athletic populations, leaving short-term impacts and broader applicability underexplored. Therefore, the study aims to investigate the immediate effects of proprioceptive neuromuscular facilitation (PNF) stretching on hamstring flexibility and its association with agility in the lower extremity.

METHODS

Study design and setting

This single group pre-post interventional study was carried out in Mangalore, Karnataka, over an eight-month period from March to November 2023.

Study participants and sampling

The study comprised 60 student participants (30 boys and 30 girls), aged between 18 and 25 years, who were selected based on predefined eligibility criteria. Inclusion criteria required participants to be within the specified age range, provide written informed consent, and have no history of surgical procedures or musculoskeletal deformities. Exclusion criteria included any lower limb injury, recent surgical history, physical deformity, limb length discrepancy, or sports-related injury.

Data collection tool and technique

Participants recruited for the study were college students aged 18-25 years, comprising 30 males and 30 females. Prior to data collection, informed consent was obtained from all participants. Selection was based on predefined inclusion and exclusion criteria. Hamstring flexibility was assessed using the active knee extension (AKE) test during both pre-test and post-test phases. Agility performance was evaluated using the agility t-test and the Illinois agility test. During the post-test, participants underwent proprioceptive neuromuscular facilitation (PNF) stretching using the contract-relax agonist-contract (CRAC) technique, involving 10 seconds of contraction followed by 5 seconds of rest, repeated for seven cycles. Following the intervention, hamstring flexibility was reassessed and agility tests were repeated to observe any changes in performance resulting from the PNF stretching.

Outcome measures

Active knee extension test (AKET) was used to evaluate hamstring muscle length and detect potential hamstring contracture by measuring the range of active knee extension in a hip-flexed position. During the test, the participant lies supine on an examination table with the non-testing limb stabilized on the surface. The testing limb is positioned with both the hip and knee flexed at 90 degrees. A lag of up to 20 degrees from full extension is considered normal; any limitation beyond this indicates hamstring tightness. The range of motion is measured using a universal goniometer, with the fulcrum placed at the lateral epicondyle of the femur, the stationary arm aligned parallel to the thigh pointing toward the greater trochanter, and the movable arm aligned parallel to the leg pointing toward the lateral malleolus. The examiner passively extends the leg and records the angle of extension.[12]

The agility t-test was employed to assess participants' performance in multidirectional movement. The setup involved four cones arranged at points A, B, C, and D, with 10 yards between A and B, and between C and D. Essential equipment included a stopwatch, a flat surface, and a timekeeper. Participants started at cone A, sprinted 10 meters forward to cone B, and touched the top of the cone with their right hand. They then shuffled 5 meters left to cone C, touching it with their left hand, followed by a 10-meter shuffle to the right to cone D, touching it with their right hand. Afterward, they shuffled 5 meters back to cone B, touched it with their left hand, and backpedalled to cone A. Timing began as they crossed the start gate and ended upon their return. The test was deemed invalid if participants crossed one foot over the other while shuffling, failed to touch the cones correctly, or did not maintain a forward-facing posture throughout.[13]

The Illinois agility test (IAT) was used to assess agility and overall performance. The test course was set up using cones, with four center cones spaced 3.3 meters apart and four corner cones placed 2.5 meters from the center cones. Participants began the test lying prone behind the starting line, with arms at their sides and head turned either to the side or facing forward. On the "go" command, they quickly rose to their feet and sprinted to the first tape mark, which they were required to touch or cross with their foot. They then turned back and proceeded to the first centre cone, weaving up and back through the four centre cones. After completing the weave, they sprinted to the second tape mark on the far end, again touching or crossing it with their foot. Finally, they turned and ran as quickly as possible across the finish line. The time taken to complete each trial was recorded in seconds.[14]

PNF stretching was used as an outcome measure to assess improvements in range of motion (ROM) and hamstring flexibility. Specifically, the contract-relax agonist-contract (CRAC) technique was applied, which involves activating the antagonist muscle group to enhance flexibility more effectively than traditional stretching or the hold-relax method. Participants were positioned in a side-lying posture while the therapist stood behind in a walk-stand position. The hip was slightly extended, and the knee maintained in full flexion. The therapist stabilized the hip as the participant performed a maximal voluntary isometric contraction of the rectus femoris muscle for 10 seconds, followed by a 5-second relaxation phase. The knee was then moved into a new range of flexion, held for 10 seconds, and the sequence was repeated for five repetitions. The technique aimed to increase ROM without inducing pain, and improvements in flexibility were recorded post-intervention.[15,16]

Statistical analysis

Statistical analysis of the data was performed using SPSS version 16.0. The normality of the dataset was assessed using the Kolmogorov-Smirnov test, confirming that the data were normally distributed. Descriptive statistics for age, height, weight, and BMI were calculated using mean and standard deviation. A paired t-test was applied to compare hamstring flexibility and agility performance, with statistical significance determined at a 95% confidence interval ($p<0.05$).

RESULTS

The descriptive statistics revealed that male participants were older (24.0±1.47 versus 20.2±1.68 years), taller (183.6±5.13 versus 157.8±5.87 cm), heavier (62.3±7.27 versus 49.0±9.73 kg), and had higher BMI (20.7±2.66 versus 19.6±3.68) than females. Standard deviations indicated moderate homogeneity in age and height, while females showed slightly greater variability in weight and BMI. Overall, the sample displayed expected gender differences yet remained sufficiently homogeneous to support valid comparisons (Table 1).

Table 2 shows the mean and standard deviation values for hamstring flexibility, Illinois agility test, and t-test performance among males and females before and after intervention. Both genders demonstrated reductions in hamstring flexibility scores (indicating improved flexibility) and decreases in agility test times (indicating enhanced performance). These descriptive results suggest consistent improvements across all measured variables following the training program.

Table 1: Demographic data of the study participants.

Gender	Variables	Mean±SD			
		Pre		Post	
		Right	Left	Right	Left
Males	Hamstrings flexibility	39.3±9.3	37.1±9.8	31±8.6	29.1±9.1
	Illinois test	19.09±1.1		18.5±1.2	
	T-test	12.6±0.8		12.2±0.9	
Females	Hamstrings flexibility	39.8±10.4	38.3±10.1	31.8±9.1	29.3±8.8
	Illinois test	22.7±1.5		22.1±1.4	
	T-test	16.6±1.8		16.1±1.7	

Table 2: Pre and post intervention mean scores for hamstring flexibility and agility performance in male and female participants.

Variables	Males	Females
	Mean±SD	Mean±SD
Age in years	24.00±1.47	20.16±1.68
Height	183.60±5.13	157.83±5.87
Weight	62.30±7.27	49.00±9.73
BMI	20.70±2.66	19.61±3.68

Table 3 presents the inferential statistics from paired t-tests comparing pre- and post-intervention scores. Both males and females exhibited statistically significant improvements in hamstring flexibility ($p<0.01$ for both right and left sides) and agility performance (Illinois and t-test, $p<0.01$). The confidence intervals confirm that the improvements were consistent and reliable, with all t values indicating strong statistical evidence of change.

Table 3: Pre-post intervention differences in hamstring flexibility and agility performance following PNF stretching among male and female participants.

Gender	Variables	Mean±SD	Std error	95% confidence interval		t value	P value
				Lower	Upper		
Males	Right Pre-Post	8.3±4.4	0.8	6.6	9.9	10.32	<0.01*
	Left Pre-Post	8.0±3.6	0.6	6.6	9.3	12.1	<0.01*
	T-Test Pre-Post	0.4±0.3	0.06	0.2	0.5	6.4	<0.01*
	Illinois Pre-Post	0.5±0.4	0.07	0.3	0.9	7.32	<0.01*
Females	Right Pre-Post	8.0±5.1	0.9	6.06	9.9	8.4	<0.01*
	Left Pre-Post	9.0±4.4	0.8	7.3	10.6	11.1	<0.01*
	T-Test Pre-Post	0.5±0.5	0.1	0.3	0.7	5.08	<0.01*
	Illinois Pre-Post	0.6±0.8	0.1	0.3	0.9	4.1	<0.01*

*Statistically Significant (test performed was paired t test).

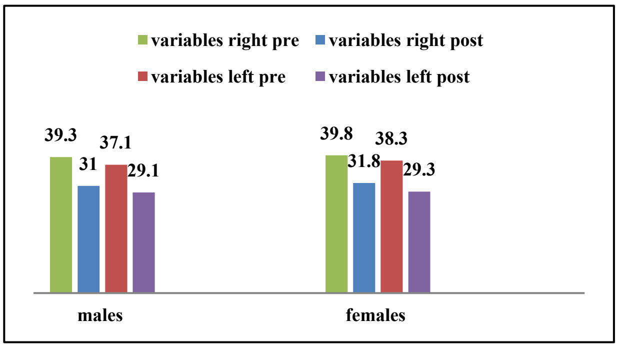

Figure1: Pre and post changes happened in hamstring flexibility after giving PNF CRAC stretch.

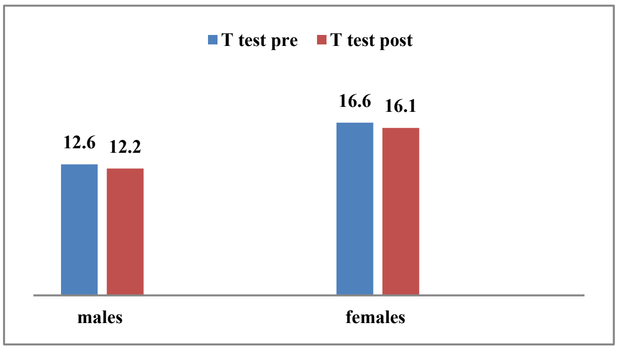

Figure 2: Pre and post changes in the agility t-test.

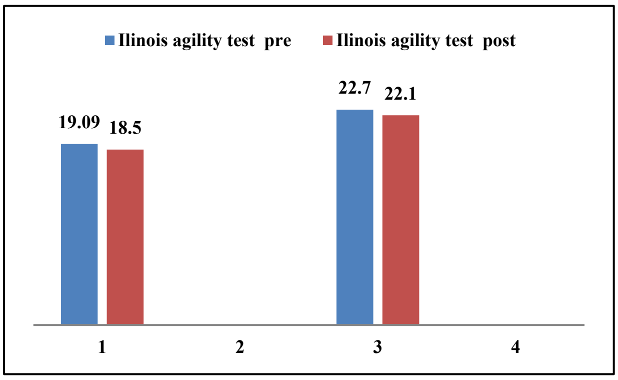

Figure 3: Pre and post changes in agility Illinois test.

DISCUSSION

The present study examined the immediate effects of PNF stretching, specifically the contract-relax- antagonist-contract (CRAC) technique, on hamstring flexibility and agility in the lower extremity. The findings revealed significant improvements in both flexibility and agility among, male and female participants, supporting the efficacy of PNF stretching as a rapid intervention strategy.

The observed increase in hamstring flexibility aligns with previous literature that has consistently demonstrated the superiority of PNF stretching over static and dynamic techniques. Remya et al reported that PNF stretching produced greater immediate gains in hamstring flexibility compared to static stretching and neurodynamic sliding.[3] Similarly, Deb and Sharma highlighted in their review that PNF stretching is particularly effective due to its neurophysiological basis, which combines autogenic and reciprocal inhibition mechanisms to enhance muscle length.[17] These findings collectively reinforce as a rapid intervention to address hamstring tightness.

In addition to flexibility, agility performance improved significantly following PNF stretching. This is consistent with Burgess et al., who found that CRAC stretching of the hamstrings enhanced sprint and agility performance in moderately active males.[18] The improvement in agility may be attributed to increased range of motion and reduced muscular stiffness, which facilitate more efficient lower extremity movement patterns. Martinez et al emphasized that hamstring tightness and fatigue negatively affect dynamic stability and agility, suggesting that interventions targeting flexibility can directly enhance agility.[19] Furthermore, Thieschafer and Busch noted in their scoping review that agility is a trainable quality influenced by neuromuscular and biomechanical factors, supporting the notion that flexibility interventions can contribute to agility development.[13]

This study has certain limitations that should be considered. The relatively small sample size reduces the generalizability of the findings, and the absence of longitudinal assessment limits understanding of whether the observed improvements are maintained over time. The agility test was conducted barefoot and recorded only once, which may affect the reliability of the results. Moreover, the investigation focused solely on the immediate effects in healthy young adults, restricting applicability to other groups such as injured athletes, older adults, or clinical populations.

Further research should explore the broader benefits of PNF stretching across diverse populations, including different age groups, fitness levels, and activity backgrounds. Larger sample sizes and longitudinal designs are needed to determine whether improvements in flexibility and agility are maintained over time and contribute to enhanced performance or injury prevention. Such studies will help establish PNF stretching as a valuable tool in sports, rehabilitation, and general physical well-being.

CONCLUSION

The current study demonstrated a statistically significant improvement in hamstring flexibility and agility scores following PNF CRAC stretching. Overall, applying the CRAC technique to the hamstring muscles of active males and females effectively increased active knee extension range of motion and produced measurable performance changes. These results indicate that CRAC stretching is a safe and efficient method for enhancing hamstring length and can be recommended by physiotherapists as part of exercise regimens.

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