E-ISSN: 2706-8927
P-ISSN: 2706-8919
www.allstudyjournal.com
IJAAS 2025; 7(8): 107-111
Received: 25-06-2025
Accepted: 30-07-2025

Ravish Kumar
Master in Physiotherapy (MPT), Sports, Atal Bihari Vajpayee Medical University, Uttar Pradesh, India

Monika
Professor, Master in Physiotherapy (MPT), Sports, Atal Bihari Vajpayee Medical University, Uttar Pradesh, India

Corresponding Author:
Ravish Kumar
Master in Physiotherapy (MPT), Sports, Atal Bihari Vajpayee Medical University, Uttar Pradesh, India

Comparative effectiveness of eccentric training and Pnf stretching on hamstring flexibility in runners

Ravish Kumar and Monika

DOI: https://www.doi.org/10.33545/27068919.2025.v7.i8b.1623

Abstract
Hamstring tightness is widely recognized as a risk factor for injury, as reduced flexibility can hinder efficient movement and increase the likelihood of muscle strain. Improving flexibility helps muscle tissue better tolerate mechanical stress during physical activity. This study aimed to determine the more effective method for enhancing hamstring flexibility by comparing Eccentric Training and Proprioceptive Neuromuscular Facilitation (PNF) stretching. Sixty track athletes (27 males, 33 females) aged 18-26 years, all with bilateral hamstring tightness and specializing in sprint events (100m, 200m, 400m), participated in this experimental pre-post study. Participants were randomly divided into two groups of 30: one group received PNF Contract-Relax-Antagonist-Contract (CRAC) stretching, while the other performed Eccentric Training. Both interventions were conducted over a period of three weeks, with five sessions per week. Flexibility outcomes were measured using the Active Knee Extension, Passive Straight Leg Raise, and Sit and Reach tests. Analysis using paired and independent t-tests showed significant improvements in hamstring flexibility in both groups ($p<0.001$), with the PNF-CRAC group demonstrating significantly greater gains. The findings suggest that while both methods are effective, PNF stretching is superior for improving hamstring flexibility.

Keywords: PNF stretching, eccentric training, hamstring flexibility, runners

1. Introductions

Hamstring injuries are among the most frequently occurring injuries in sports, accounting for up to 50% of all muscle-related injuries and approximately 29% of total sports injuries [14]. These injuries are particularly common in activities that involve high-speed movements such as running, sprinting, kicking, or jumping [10]. Running, in particular, exerts significant strain on the musculoskeletal system, with the hamstring muscles being more actively engaged than other lower limb muscles. Muscle tightness in this region can influence the alignment of both proximal and distal joints, contributing to the high incidence of non-contact hamstring injuries. Tight hamstrings have been linked to altered running mechanics, decreased functional performance, and increased injury risk [7]. Clinically, hamstring tightness is identified when an individual is unable to extend the knee beyond 20 degrees of flexion while the hip is held at 90 degrees of flexion in a supine position [4].

Hamstring injuries commonly occur during high-speed eccentric contractions, particularly in the terminal swing phase of running. During this phase, the hamstring muscles experience peak lengthening followed by a rapid, forceful contraction. This makes them especially vulnerable to strain at high running speeds, such as in sprinting, where the mechanical load may exceed the muscle's capacity to resist [15]. Insufficient flexibility has been recognized as a key intrinsic risk factor contributing to hamstring strains [5]. Flexibility refers to a muscle's capacity to lengthen, allowing one or more joints to move through a full range of motion. Increasing the length of the musculotendinous unit is believed to reduce the risk of strain by minimizing resistance during movement [16].

Proprioceptive Neuromuscular Facilitation (PNF) is an advanced form of flexibility training that involves both stretching and contracting the target muscle group. While various PNF techniques exist, they all share the goal of inducing muscle relaxation through neuromuscular mechanisms [11]. The PNF-CRAC (Contract-Relax-Antagonist-Contract) technique works through two key physiological principles: autogenic inhibition, triggered by the Golgi tendon organs, and reciprocal inhibition, which relaxes the targeted muscle following contraction of its antagonist [9].

This dual mechanism reduces muscular resistance to stretching and facilitates greater range of motion improvements.

Given that hamstring injuries often result from eccentric loading, training the muscle eccentrically through its full range may reduce injury risk, enhance performance, and improve flexibility [8]. Although several studies have explored strategies to enhance flexibility, limited research has investigated the short-term effects of PNF stretching versus eccentric training on hamstring flexibility in runners. This highlights a gap in the literature and underscores the need for evidence-based protocols aimed at optimizing athletic performance and injury prevention. Therefore, the current study aims to evaluate and compare the effects of PNF-CRAC stretching and eccentric training on hamstring flexibility in runners. This research may help identify the more effective training approach for enhancing flexibility and reducing the risk of hamstring injuries.

2. Literature Review

Hamstring injuries are among the most prevalent muscle injuries in athletes, contributing to nearly 50% of all muscle strains and about 29% of sports-related injuries (Ekstrand *et al*., 2011; Woods *et al*., 2004). These injuries frequently occur in activities requiring running, sprinting, kicking, or jumping, where the hamstring muscles endure significant eccentric load, especially during the terminal swing phase of running (Schache *et al*., 2012; Heiderscheit *et al*., 2005). This phase involves rapid lengthening followed by forceful contraction, making the hamstrings particularly vulnerable to strain when subjected to high-intensity activities such as sprinting (Heiderscheit *et al*., 2005).

Muscle flexibility is a critical factor in injury prevention. Flexibility, defined as the ability of a muscle to lengthen and permit movement across a joint's full range of motion, reduces the risk of musculotendinous strain by allowing tissues to accommodate stress more effectively (Alter, 2004; Shrier, 2004). Tight hamstrings can negatively affect running mechanics and elevate injury risk by limiting joint mobility and increasing muscle tension (Bishop *et al*., 2018).

Proprioceptive Neuromuscular Facilitation (PNF) stretching, particularly the Contract-Relax Antagonist Contract (CRAC) technique, is widely used to improve muscle flexibility. PNF-CRAC involves both stretching and contracting the target muscle, facilitating increased range of motion through mechanisms like autogenic inhibition via Golgi tendon organs and reciprocal inhibition (Sharman *et al*., 2006; Hindle *et al*., 2012). Burgess *et al*. (2007) reported a significant 37% increase in active knee extension immediately after PNF-CRAC stretching without impairing sprinting or agility performance, indicating its effectiveness and safety for athletes.

Eccentric training is also recognized for its role in enhancing hamstring flexibility and reducing injury risk by promoting neuromuscular and structural adaptations. O'Sullivan *et al*. (2012) showed that eccentric exercise leads to increased fascicle length of the biceps femoris, improved muscle strength, and enhanced torque generation at longer muscle lengths, due to sarcomerogenesis. Nelson *et al*. (2005) found that eccentric training and static stretching produce similar flexibility improvements over six weeks, with eccentric training offering superior functional benefits through muscle remodeling. Similarly, Fard *et al*. (2014) demonstrated significant improvements in passive knee extension after eccentric training, attributing the benefits to enhanced cortical excitability and spinal inhibition that reduce muscle tightness.

While both PNF stretching and eccentric training have proven effective in improving hamstring flexibility, direct comparisons of their short-term effects among runners remain limited. Most research focuses on long-term outcomes or evaluates these methods in isolation (Fard *et al*., 2014; Nagarwal *et al*., 2020). This highlights the importance of studies comparing these interventions to determine the most effective approach for enhancing hamstring flexibility and preventing injuries in athletic populations.

In conclusion, the literature supports both PNF-CRAC stretching and eccentric training as valuable techniques for increasing hamstring flexibility. Understanding the differential impacts of these interventions can help optimize training protocols tailored to the needs of runners and other athletes.

3. Material and Methods

3.1 Participants and study design

This study employed an experimental pre- and post-test design. Participants were selected based on specific inclusion criteria. A total of 60 athletes, including both male and female sprinters specializing in 100, 200, and 400-meter events, aged between 18 and 26 years, were included. All participants exhibited bilateral hamstring tightness, defined as a limitation of 20 degrees or more from full knee extension. Prior to participation, written informed consent was voluntarily obtained from all subjects.

Individuals from non-athletic backgrounds or those with a history of acute or chronic low back pain, hamstring injuries within the past six months, visible swelling in the hamstring region, soft tissue injuries, fractures, or surgeries within the last six months were excluded from the study. Equipment utilized in the study included a standard full-circle goniometer, sit and reach box, TheraBand, stopwatch, weighing scale, and anthropometric measuring rod.

3.2 Procedure

All the subjects were undergone a pre-intervention examination to assess hamstring tightness using the AKE test, PSLR test and Sit and Reach test.

- **Active knee extension test:** The participant was placed in a supine position, with the non-testing leg and pelvis secured to the plinth to maintain stability. The test leg was positioned with both the hip and knee flexed at 90 degrees. A universal goniometer was used for measurement, with its fulcrum aligned over the lateral femoral condyle. The stationary arm was positioned along the shaft of the femur, while the movable arm was aligned parallel to the lateral malleolus of the ankle. The participant was then asked to actively extend the knee as far as possible until a gentle stretch was felt at the back of the knee. The average of the readings was recorded for analysis [2].
- **Passive straight leg raise test:** Participants were positioned lying supine for the Passive Straight Leg Raise (PSLR) test, which was conducted by two examiners. One examiner passively lifted the participant's leg with the knee kept extended and the ankle relaxed, continuing the movement until the

participant reached their maximum tolerable range of motion, indicated by a sense of resistance. The second examiner positioned the goniometer, placing the fulcrum over the greater trochanter of the femur. The stationary arm was aligned with the trunk, and the movable arm was aligned along the femur. The resulting angle of motion, in degrees, was recorded for analysis [17].

- **Sit and Reach Test:** A sit-and-reach box, measuring 30.5 cm in height, was used to assess the flexibility of participants. The top of the box featured a ruler calibrated so that the 35 cm mark aligned with the participant's fingertip-to-toe distance. Participants sat with their legs extended, knees straight, and feet flat against the front edge of the box. With arms extended forward, palms facing down, and hands aligned, they reached as far as possible along the measuring scale without bending their knees. Three attempts were recorded, measured in centimeters to the nearest 0.5 cm, using the left-side scale of the measurement indicator [1].

Following baseline assessments, participants were randomly divided into two intervention groups of 30 each using a convenient random allocation method: Group A received PNF-CRAC stretching (30 participants), and Group B underwent eccentric training (30 participants).

In Group A, participants lay in a supine position with the left leg stabilized on the table. The duration of stretching, contraction, and relaxation phases was controlled using a stopwatch. The examiner passively raised the participant's leg, keeping the knee extended to induce a mild stretch, held for 10-15 seconds. The participant then performed a 5-second isometric contraction of the hamstring against resistance, followed by a 10-second concentric contraction of the quadriceps (the antagonist) by actively lifting the leg. This cycle was repeated five times, with 20-second rest intervals between each repetition. A post-intervention assessment was conducted after three weeks [11].

In Group B, participants were also positioned supine with the left leg extended and a rigid TheraB and looped around the heel. Holding both ends of the band, they pulled it to flex the right hip while maintaining full knee extension. A gentle stretch was achieved at full hip flexion, during which participants engaged in eccentric contraction of the hamstring to control the motion. This position was held for 10 seconds and repeated five times consecutively, without rest. Post-intervention measurements were taken after three weeks [4].

3.3 Statistical Analysis

Data analysis was done using SPSS Version 20. Paired t-test and an independent sample t-test was used to find the significant difference within and between both groups respectively.

4. Results

4.1 Demographic data of the study population

Descriptive statistics were applied to determine the mean and standard deviation for the runners' age, weight, height, and BMI. Results from the paired t-test indicated no significant differences between groups for these variables (*p*>0.05), confirming that the groups were homogeneous in terms of their baseline characteristics (Table 1).

Table 1: Demographic data of the study population

	Males			Females		
	Group-A	Group-B		Group-A	Group-B	
Parameters	Mean ±S.D	Mean ±S.D	T-value	Mean ±S.D	Mean ±S.D	T-Value
Age (years)	21.8±2.85	22.28±3.09	-.382	21.17±2.78	22.12±2.52	-1.02
Weight (kgs)	56.92±9.42	60.64±10.84	-.948	52.88±2.78	51.06±4.90	1.321
Height (cms)	170.40±7.84	166.95±8.97	1.063	163.39±7.75	160.51±4.87	1.270
BMI (kg/m²)	19.54±2.38	21.58±2.10	-2.368	19.71±2.37	20.31±2.54	-.705

p>0.05, Data are presented as mean ± SD

Abbreviation: BMI = body mass index.

4.2 Within-group comparison of mean scores of Active Knee Extension Test, Passive Straight Leg Raise Test and Sit and Reach Test of Group A and Group B

Data analysis showed significant improvements in the Active Knee Extension Test, Passive Straight Leg Raise Test, and Sit and Reach Test for both groups after three weeks. Table 2 presents the within-group comparisons performed using a paired t-test. The resulting t-values indicate a highly significant increase in hamstring flexibility in both groups, with a P-value ≤ 0.001.

Table 2: Within-group comparison of mean scores of Active Knee Extension Test, Passive Straight Leg Raise Test and Sit and Reach Test of Group A and Group B

Groups	Group A (PNF-Stretching)			Group B (Eccentric Training)		
	Mean ±S.D		T-Value	Mean ±S.D		T-Value
	Pre-test	Post-test		Pre-test	Post-test	
AKE (Right)	142.5±4.89	163.7±6.99	-40.63***	142.46±4.57	157.26±4.60	-39.39***
AKE (Left)	146.6±4.84	168.9±5.86	-59.97***	145.9 ±4.22	157.26 ±4.6	-41.25***
PSLR (Right)	69.2 ±5.15	88.63 ±6.69	-45.12***	68.4 ±4.75	84 ±5.08	-43.24***
PSLR (Left)	72.13 ±5.42	92.4 ±6.21	-57.03***	72 ±5.11	88.26 ±5.13	-44.19***
SRT	33.7 ±4.77	40.73 ±5.23	-36.13***	31.13 ±5.1	36.66 ±5.31	-35.22***

***P≤0.001

Abbreviation: Active Knee Extension Test (AKE), Passive Straight Leg Raise Test (PSLR), Sit and Reach Test (SRT)

4.3 Between-group comparison of mean difference scores (improvement score) of active knee extension test, passive straight leg raise test and sit and reach test of both groups

Table 3 clearly indicates that the between-group comparison of the mean and standard deviation of improvement scores (post-intervention) demonstrated a statistically significant enhancement in all three outcome measures of hamstring flexibility on both the right and left sides ($p \leq 0.001$). Furthermore, when comparing the mean improvement scores across all three tests, Group A showed greater gains than Group B.

Table 3: Between-group comparison of mean difference scores (improvement score) of active knee extension test, passive straight leg raise test and sit and reach test of both groups.

Parameters	Group-A (PNF-Stretching)	Group-B (Eccentric Training)	
	Mean ± S.D	Mean ± S.D	T-Value
AKE (Right)	21.2±2.85	14.8±2.05	9.95***
AKE (Left)	22.3±2.03	15.83±2.10	12.1***
PSLR (Right)	19.43±2.35	15.6±1.97	6.82***
PSLR (Left)	20.26±1.94	16.26±2.01	7.81***
SRT	7.03±1.06	5.4 ±0.72	6.94**

***P≤0.001, **P≤0.01

5. Discussion

This study aimed to compare the effects of PNF-CRAC (Contract Relax Antagonist Contract) stretching and eccentric training on hamstring flexibility in runners. The demographic characteristics of participants were similar across both groups. The results demonstrated significant improvements in hamstring flexibility for both interventions, with the PNF-CRAC stretching method showing notably greater effectiveness than eccentric training. The isometric contraction involved in PNF-CRAC promotes post-isometric relaxation, which reduces muscle tension and enhances stretch tolerance, pain threshold, as well as reciprocal and autogenic inhibition, leading to increased knee range of motion and hamstring length +. These findings align with Nagarwal *et al.*, [11] who reported that PNF-CRAC facilitates similar physiological mechanisms for improving hamstring flexibility compared to PNF Hold Relax (PNF-HR), which mainly relies on autogenic inhibition.

Burgess *et al.* [3] observed a significant increase up to 37% in active knee extension range of motion immediately following three sets of PNF-CRAC stretching, although this did not affect agility or sprint performance, indicating no detrimental impact on athletic ability. Group B, which received eccentric training, also showed significant gains in hamstring flexibility as measured by the Active Knee Extension (AKE), Passive Straight Leg Raise (PSLR), and Sit and Reach Test (SRT) ($p \leq 0.001$). According to O'Sullivan *et al.*, [13] eccentric training induces neuromuscular adaptations such as increased fascicle length of the biceps femoris long head, greater hamstring muscle strength and volume, and enhanced torque production at extended muscle lengths. These changes result from sarcomerogenesis, where muscles adapt to eccentric loading by optimizing torque generation at longer joint angles, reducing injury risk and improving flexibility.

Nelson *et al.* [12] found that eccentric hamstring training and static stretching produce similar flexibility improvements after six weeks, but eccentric training offers superior functional benefits due to structural muscle adaptations. Fard *et al.* [6] also reported significant enhancements in passive knee extension test scores following six weeks of eccentric training ($p < 0.05$). This type of training increases cortical excitability and spinal inhibition, lowering motor activity during eccentric contractions and thus reducing muscle tightness.

Unlike some earlier studies, the present findings indicate that both PNF stretching and eccentric training positively influence hamstring flexibility. However, when comparing the two, the PNF stretching group demonstrated superior improvements in flexibility among runners. Since flexibility is crucial in sports injury prevention, PNF stretching presents an effective method for athletes to enhance hamstring flexibility efficiently. Its potential to deliver significant gains within fewer sessions makes it particularly beneficial for athletes with limited training time preparing for competition [2].

6. Conclusion

In conclusion, both PNF stretching and eccentric training effectively enhance hamstring flexibility in runners. However, PNF-CRAC stretching produced greater improvements in hamstring flexibility compared to eccentric training in runners experiencing hamstring tightness.

7. Acknowledgments

The authors wish to express their sincere gratitude to everyone who provided support and encouragement throughout the completion of this study.

8. Funding: This research, authorship, and publication were carried out without any financial assistance.

9. References

1. Alter MJ. Science of flexibility. Champaign (IL): Human Kinetics; 2004.
2. Ayala F, de Baranda PS, Croix MS, Santonja F. Criterion-related validity of four clinical tests used to measure hamstring flexibility in professional futsal players. Phys Ther Sport. 2011;12(4):175-81.
3. Bishop C, Jones E, Woods K. Recovery following marathon running: A systematic review. Sports Med. 2018;48(2):337-358.
4. Biswas S, Alagingi NK. Compare the effectiveness of static stretching and muscle energy technique on hamstring tightness among student population. Compare. 2018;3(2).
5. Burgess KE, Connick MJ, Graham-Smith P. Effect of contract-relax proprioceptive neuromuscular facilitation

stretching on hamstring muscle flexibility. J Strength Cond Res. 2007;21(3):788-792.
6. Burgess T, Vadachalam T, Buchholtz K, Jelsma J. The effect of the contract-relax-agonist-contract (CRAC) stretch of hamstrings on range of motion, sprint and agility performance in moderately active males: A randomised control trial. S Afr J Sports Med. 2019;31(1):1-5.
7. Dasappan S, Kumar RR, Sharad KS. Effects of eccentric training and static stretching to improve hamstring flexibility among physiotherapy students; 2021.
8. DePino GM, Webright WG, Arnold BL. Duration of maintained hamstring flexibility after cessation of an acute static stretching protocol. J Athl Train. 2000;35(1):56-59.
9. Ekstrand J, Hagglund M, Walden M. Injury incidence and injury patterns in professional football: The UEFA injury study. Br J Sports Med. 2011;45(7):553-558.
10. Fard Mehregan A, Hadadnezhad M, Letafatkar A. Effect of eccentric training on knee strength and hamstring flexibility in active females with hamstring tightness: A clinical trial study. J Gorgan Univ Med Sci. 2020;22(3):19-27.
11. Fard M, Alizadeh M, Khalil S. The effect of eccentric training on passive knee extension angle and hamstring muscle flexibility in athletes. J Sports Med Phys Fitness. 2014;54(2):133-140.
12. Fereydounnia S, Shadmehr A, Salemi P, Amiri S. Comparison of ROM, perceived tightness, and kinetic variables during balance, walking, and running tasks in athletes with and without hamstring tightness using sensor insoles. Sport Sci Health; 2022, p. 1-7.
13. Heiderscheit BC, Silder A, Sherry MA, Chumanov ES, Thelen DG. Hamstring strain injuries: recommendations for diagnosis, rehabilitation, and injury prevention. J Orthop Sports Phys Ther. 2005;35(5):289-299.
14. Hibbert O, Cheong K, Grant A, Beers A, Moizumi T. A systematic review of the effectiveness of eccentric strength training in the prevention of hamstring muscle strains in otherwise healthy individuals. N Am J Sports Phys Ther. 2008;3(2):67-81.
15. Hindle KB, Whitcomb TJ, Briggs WO, Hong J. Proprioceptive neuromuscular facilitation (PNF): its mechanisms and effects on range of motion and muscular function. J Hum Kinet. 2012;31:105-13.
16. Kotteeswaran K, Snigdha J, Alagesan J. Effect of proprioceptive neuromuscular facilitation stretching and dynamic soft tissue mobilization on hamstring flexibility in subjects with low back ache: A single blinded randomized controlled study. Int J Pharm Bio Sci. 2014;5:228-33.
17. Msp G, Garud P. To compare the immediate effects of eccentric training versus hold relax proprioceptive facilitation on hamstring flexibility in male football players aged 15-21 years. Age. 2019;15(21):1.
18. Nagarwal AK, Zutshi K, Ram CS, Zafar R, Hamdard J. Improvement of hamstring flexibility: A comparison between two PNF stretching techniques. Int J Sports Sci Eng. 2010;4(1):25-33.
19. Nagarwal A, Giri R, Raghuwanshi M. Effect of PNF contract-relax-antagonist-contract and PNF hold-relax techniques on hamstring flexibility. Int J Physiother. 2020;7(2):174-179.
20. Nelson RT, Bandy WD, Thelen MD. Comparison of eccentric training and static stretching for improving hamstring flexibility. J Athl Train. 2005;40(3):199-204.
21. Nelson RT, Bandy WD. Eccentric training and static stretching improve hamstring flexibility of high school males. J Athl Train. 2004;39(3):254-258.
22. O'Sullivan K, McAuliffe S, De Burca N. Alterations in hamstring muscle architecture in response to eccentric training. J Sports Sci. 2012;30(12):1342-1348.
23. O'Sullivan K, McAuliffe S, De Burca N. The effects of eccentric training on lower limb flexibility: A systematic review. Br J Sports Med. 2012;46(12):838-845.
24. Rudisill SS, *et al*. Evidence-based hamstring injury prevention and risk factor management: A systematic review and meta-analysis of randomized controlled trials. Am J Sports Med. 2022;50(5):1-15.
25. Schache AG, Dorn TW, Blanch PD, Brown NA, Pandy MG. Mechanics of the human hamstring muscles during sprinting. Med Sci Sports Exerc. 2012;44(4):647-658.
26. Schache AG, Dorn TW, Blanch PD, Brown NA, Pandy MG. Mechanics of the human hamstring muscles during sprinting. Med Sci Sports Exerc. 2012;44(4):647-658.
27. Sharman MJ, Cresswell AG, Riek S. Proprioceptive neuromuscular facilitation stretching: mechanisms and clinical implications. Sports Med. 2006;36(11):929-939.
28. Shrier I. Does stretching improve performance? A systematic and critical review of the literature. Clin J Sport Med. 2004;14(5):267-273.
29. Singh AK, Nagaraj S, Palikhe RM, Neupane B. Neurodynamic sliding versus PNF stretching on hamstring flexibility in collegiate students: A comparative study. Int J Phys Educ Sports Health. 2017;1(1):29-33.
30. Wadhwa G, Garg C. Comparison of sit and reach test, back saver sit and reach test and chair sit and reach test for measurement of hamstring flexibility in female graduate and undergraduate physiotherapy students. Natl Editorial Advis Board. 2014;8(4):4230.
31. Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. The football association medical research programme: An audit of injuries in professional football-analysis of hamstring injuries. Br J Sports Med. 2004;38(1):36-41.