

Improvement of Hamstring Flexibility: A Comparison between Two PNF Stretching Techniques

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Objective: To determine the effectiveness of two PNF stretching techniques for improving hamstring flexibility and to compare the effectiveness of two PNF stretching techniques (Hold Relax and Contract Relax- Antagonist Contract) for improving hamstring flexibility.

Subjects: 45 normal healthy male subjects.

Design: A randomised pre-test post-test control group design.

Method: The subjects were randomly assigned into three groups each consisting of 15 subjects. Hamstring flexibility for each group was measured using the active knee extension (AKE) test. Subjects of group A were treated with PNF hold relax stretching, whereas the subjects of group B were treated with PNF CRAC technique. The subjects of group C served as control group and were not subjected to any type of stretching. For each experimental group, stretch was performed three times a week for a total training period of three weeks.

Results: A repeated-measures analysis of variance (ANOVA) and a Post HOC analysis using Bonferroni comparisons was used to determine and compare the effectiveness of two PNF stretching techniques at the end of 3 weeks of training protocol. The results demonstrated significant improvement in hamstring flexibility for subjects of group B when compared with those of group A ($P = 0.03$) at the end of three weeks, with improvement ranging from 0.50 to 15.66 degrees of active knee extension ROM at 95 % confidence interval.

Conclusion: Both the techniques viz. PNF Hold Relax and PNF-CRAC are almost equal in their clinical effectiveness for improving hamstring flexibility and that either of the techniques may be used in clinical practice for improving hamstring flexibility.

Key words: Hamstring flexibility, PNF- Hold Relax, PNF-CRAC.

1. Introduction

Muscular flexibility is an important aspect of normal human function. Limited flexibility has been shown to predispose a person to several musculoskeletal overuse injuries and significantly affect a person's level of function^(1, 2, 3, 4, 5). Muscular tightness is frequently postulated as an intrinsic risk factor for the development of a muscle injury. Musculotendinous strains are among the most prevalent, as well as the most frustrating, groups of injuries for athletes and health care professionals⁶.

Hamstring strain injuries are common in sporting arena, and frequently occur in activities which involve running, sprinting, jumping or kicking (Best and Garrett, 1996; Clanton and Coup; 1998)^(7, 8, 9). As documented in several studies, incidence rates of hamstring strains range between 7.7% and 30% (Bennel et al, 1998)^(9, 10) with relatively high recurrence rates between 18% and 34%(Upton et al, 1996 and Heiser et al 1984)^(11, 12). Injury surveillances have found hamstring injuries to be the most common injury in athletics (especially in sprinters) (McLennan and McLennan, 1990; Bennell and Crossley, 1996)^(13, 14, 15), soccer (Woods et al., 2004)⁽¹⁶⁾, Australian Rules football (Orchard and Seward, 2002), cricket (Orchard et al., 2002a; Stretch, 2003)¹⁷, touch football (Neumann et al., 1998) and hurling (Watson,

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1996), whilst they are very common in rugby league (Gabbett, 2003)¹⁸ and rugby union (Targett, 1998). Using an injury definition as that preventing player participation in a match, as a percentage of total injuries occurring, prevalence has been measured between 11% (Stretch, 2003)¹⁹ and 15% (Orchard et al., 2002a) in cricket, 11% (Dadebo et al., 2004)²⁰ and 12% (Woods et al., 2004) in soccer and 16% in Australian Rules football (Orchard and Seward, 2003).

Lack of flexibility has been suggested as a predisposing factor to hamstring strains.^(21, 22) Worrell and Perrin (1992) proposed a theoretical model for hamstring strains, suggesting that they result from a complex interaction of four etiologic factors: warm-up, strength, fatigue, and flexibility. To prevent muscle injuries, stretching exercises before sports activities are usually recommended. Reasons for stretching relate to beliefs that stretching exercises will increase flexibility and decrease muscle stiffness^(3, 23, 24).

Maintaining normal muscle length requires regular stretching to prevent muscle stiffness and benefit from the decreased risk of musculoskeletal injuries and enhance physical performance^(1, 5). Previous studies concerning muscle stiffness suggests that, at a given muscle length, cyclic stretching will reduce the force that is placed upon the muscle and associated connective tissue^(6, 25). Theoretically, less tension will be applied within the musculotendinous tissue when it is subjected to the changes in joint motion that accompany sport or recreational activity. Thus, the potential for musculotendinous strain throughout the normal range of motion will be reduced by elongation of the musculotendinous unit.

Numerous stretching techniques have been developed, reported and applied by physical therapists, coaches and athletic trainers. Three methods of stretching have been emerged: 1) Ballistic stretching, 2) Static stretching and 3) PNF Stretching. All three methods have been shown to increase ROM immediately after stretching⁵.

Ballistic stretching (BS) uses momentum developed through bouncing movements to increase the tensile force on the muscle-tendon unit as it reaches full length.^(5, 26) This mode of stretching is considered the most likely to cause injury as it may exceed the extensibility limits of the muscle-tendon unit in an uncontrolled and destructive manner. The quick movements probably invoke a strong myotactic stretch reflex in the stretched muscle, the resulting sudden increase in the muscle tension reduces the extent to which the muscle can be lengthened and increases the chance of injury to the muscle or tendon²⁷. Also it has been argued that ballistic stretching does not allow for neurological adaptations to take place. As a result, the use of ballistic stretching has not been widely advocated.

Static stretching has been defined as a stationary stretch, held for a period of time, during which specified joints are locked in a position that places the muscles and connective tissues at their greatest possible length.¹⁵ The static stretch takes advantage of the inverse myotatic reflex, which promotes muscle relaxation and hence further stretch and ROM. The slow, controlled movement allows the stretch to be performed safely; with reduced risk of injury as compared o the other forms of stretching (Smith 1994)²⁸.

Proprioceptive Neuromuscular Facilitation (PNF) is a more advanced form of flexibility training that involves both the stretching and contraction of the muscle group being targeted. PNF stretching was originally developed as a form of rehabilitation. While there are several variations of PNF stretching, they all have one thing in common; they facilitate muscular inhibition. Various PNF stretching techniques based on Kabat's concept are: Hold Relax, Contract Relax, and Contract Relax Antagonist Contract (CRAC) etc. The Hold Relax (HR) technique involves an isometric contraction of the shortened muscle against maximum resistance followed by relaxation phase⁽²⁹⁾. The contract relax (CR) PNF technique includes the concentric contraction of the shortened muscle⁽²¹⁾ and then relaxation phase while in Contract Relax - Agonist Contract (CRAC) technique isometric contraction of the shortened muscle followed by relaxation and later concentric contraction of the opposing muscle or muscle group⁽³⁰⁾.

Considering the importance of hamstring flexibility in general and athletic population, maintaining the flexibility of hamstring muscle is of utmost importance for health care professionals and to achieve this goal one needs to know the most effective and efficient technique to gain hamstring flexibility. Numerous investigations establishes PNF techniques as more efficacious than traditional stretching exercises for range of motion or flexibility enhancement. Significant improvements have been noted in the hamstring flexibility when PNF stretching techniques are incorporated in comparison to slow stretch, ballistic stretch, static stretch^(29, 31, 32). Study done by Etnyre et al.³⁰ has compared the two PNF techniques viz. contract relax & contract relax antagonist contract PNF stretching techniques but interestingly review in the literature shows that no study has compared the effectiveness of hold relax and contract relax antagonist contract PNF techniques. So, the purpose of this experimental study is to compare the effectiveness of two PNF stretching

techniques viz. hold relax & contract relax antagonist contract techniques in improving the hamstring flexibility.

2. Method

The subjects selected for the study were 45 normal healthy male subjects on the basis of inclusion and exclusion criteria. The subjects were mostly students from Jamia Hamdard University along with some students from other universities. The recruitment of the subjects was based on the following inclusion criteria and exclusion criteria: age group- 20-30 years, presenting with hamstring tightness² as defined by limitation of 20 degree or more from full knee extension as determined by active knee extension test. Subjects with any history of musculoskeletal and neurological pathology of low back, pelvis, hip and knee or any injury or surgery of low back, hip, knee and hamstring muscle in last six months from time of study were excluded from the study.

The study was performed at the department of physiotherapy, Majeedia Hospital, New Delhi and at a local physiotherapy clinic. The duration of the study was 3 weeks. Instruments used for the study were standard full circle goniometer, cross bar made of PVC pipe to maintain 90 degree of hip flexion, straps for stabilization, stop watch and skin permanent marker. The time line to complete the study was one year.

Assigning Subjects: The subjects were randomly assigned into three groups with each group containing fifteen subjects: Group A - PNF- Hold Relax stretching group (15 subjects); Group B - PNF-Contract Relax-Antagonist Contract (15 subjects) and Group C - Control group (No stretching group) (15 subjects)

3. Procedure

The design of the study was an experimental "Pre-test post test control group design". Informed consent was obtained from the subjects meeting the inclusion and exclusion criteria and willing to participate in the study.

4. Protocol

Active Knee Extension Test (AKE)

Subjects were assessed for hamstring tightness using the AKE test^{1, 33} (figure 1). The subject was in supine position with hips in 90 degree flexed and knee flexed. A PVC cross bar was used to maintain the proper position of hip and thigh. The testing was done on the right lower extremity and subsequently the left lower extremity and the pelvis were strapped down the table to stable the pelvis and control any accessory movements. Landmarks used to measure hip and knee range of motion were greater trochanter, lateral condyle of femur and the lateral malleolus which were marked by a skin permanent marker. The fulcrum of the goniometer was centered over the lateral condyle of the femur with the proximal arm secured along the femur using greater trochanter as a reference. The distal arm was aligned with the lower leg using the lateral malleolus as a reference. The hip and knee of the extremity being tested was placed into 90 degree flexion with the anterior aspect thigh in contact with the horizontal bar of the PVC frame at all times to maintain hip in 90 degrees of flexion. The subject was then asked to extend the right lower extremity as far as possible until a mild stretch sensation was felt. A full circle goniometer was then used to measure the angle of knee flexion (figure 2). Three repetitions were performed and an average of the three was taken as the final reading for knee flexion range of motion (hamstring tightness).

Group A: After pre-treatment ROM measurement subjects of Group A received PNF- Hold Relax stretching (figure 3). The subjects were in supine position with their left lower extremity strapped down the table. Pre-determined time intervals for stretching, contracting and relaxing were used to standardize the method utilizing a stop watch. For each stretch, the investigator stretched the hamstring muscle by passively flexing the hip with knee fully extended, allowing no hip rotation. The lower leg was rested on the investigators right shoulder. The hamstring muscle was stretched until the subject first reported a mild stretch sensation; this position was held for 7 sec. Next, the subject then isometrically contracted the hamstring muscle for 3 sec by attempting to push his leg down towards the table against the resistance of the investigator. Following this, the subject was asked to relax for 5 sec. The investigator then passively stretched the muscle until a mild stretch sensation is reported. This stretch was held for 7sec. This sequence was repeated 5 times with each sequence separated from each by a 20 second interval⁹³. This was followed by post treatment measurement of ROM at the end of first, second and third week. The treatment was given 3 times per week for period of 3 weeks.

Group B: After pre-treatment ROM measurement subjects of Group B received PNF-Contract Relax-Antagonist Contract (CRAC) stretching (figure 4). The procedure followed was similar to the PNF-HR procedure except that instead of the post relaxation passive stretch the subjects were asked to concentrically contract the opposing muscle (quadriceps muscle), by attempting to further raise the leg, for 7 sec. This sequence was repeated 5 times with each sequence separated from each by a 20 second interval⁹³. This was followed by post treatment measurement of ROM at the end of first, second and third week. The treatment was given 3 times per week for period of 3 weeks.

Group C: The subjects of group C were assigned as control group (No Stretching Group). These subjects were asked to lay supine on the evaluation table for 5 min, the approximate time it took to stretch the experimental group. Post treatment measurement of ROM was assessed at the end of first, second and third week. This was repeated for 3 times per week for period of 3 weeks.

Protocol for Data Collection: The data was collected by the research student utilizing the data collection form (attached in the appendix section).

Data analysis: In this experimental study the dependent variable was active knee extension (AKE) ROM which was used as a measure of hamstring flexibility. A repeated-measures analysis of variance (ANOVA) measured the effectiveness of two PNF stretching exercises for improving hamstring flexibility. A Post HOC analysis using Bonferroni comparisons was used to compare the effectiveness of two PNF stretching techniques at the end of 3 weeks of treatment protocol by measuring the post test knee ROM. Ninety five percent confidence intervals were calculated for each pre test and post test scores. The significance level was set at a P value of less than /equal to 0.05.



Figure 1: Starting Position for AKE test.



Figure 2: Measurement of active knee extension ROM.



Figure 3: Application of PNF- Hold Relax Procedure.



Figure 4: Application of PNF- CRAC Procedure

5. Results

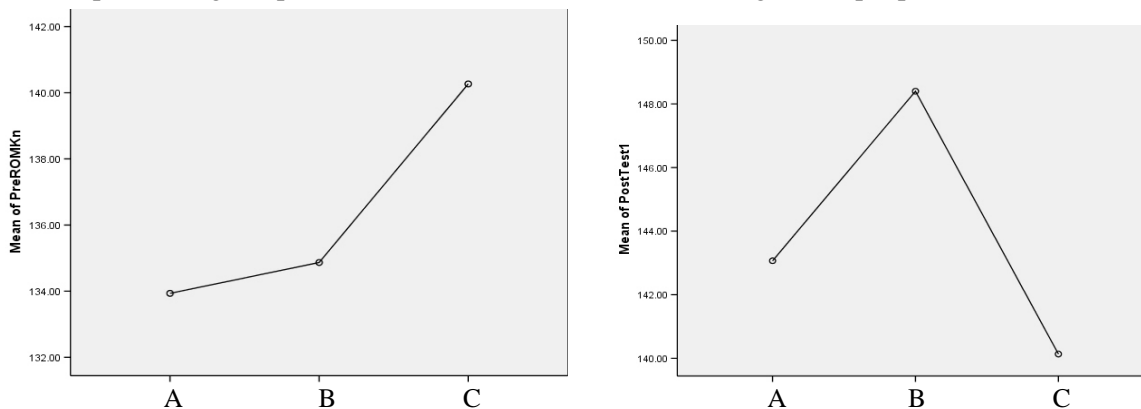
This study incorporated 45 healthy male subjects with a mean age of 23.88 ± 2.33 ranging from 20 to 30 years who met the inclusion and exclusion criteria. All the subjects participated in the study and there were

no drop outs. Repeated measure ANOVA was performed to compare the effectiveness of two PNF stretching techniques on hamstring muscle flexibility.

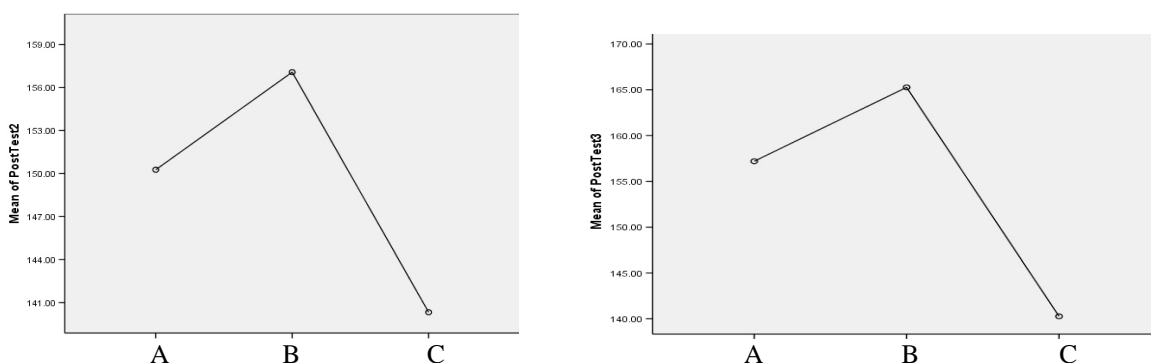
The data analysis revealed significant differences in the active knee ROM amongst the three groups at the end of three weeks. Table 1 shows the results of repeated measures ANOVA and between group comparisons using post HOC analysis. Post Test values of active knee ROM at the end of third week of the stretching intervention showed that there was significant improvement in the hamstring muscle flexibility for both groups with a P of less than 0.05 ($P = 0.00$). A Post HOC analysis using Bonferroni pair wise comparisons for between group analyses showed improvements in active knee extension ROM at the end of the third week for Group B to be significantly greater than Group A ($P = 0.03$) at 95 % confidence interval ranging from 0.50 to 15.66 degrees of active knee extension ROM.

6. Discussion

The purpose of this study was to compare two different PNF stretching techniques for improving hamstring muscle flexibility as evaluated by active knee extension range of motion. As per our knowledge this study was the first, which compared the effectiveness of two PNF stretching techniques viz. PNF- HR and PNF-CRAC for improving hamstring muscle flexibility in 45 healthy male subjects over a period of three weeks. The methodology employed in this study was based on sound research evidences. For example, holding an isometric contraction during the stretching manoeuvres for a duration of 3 seconds (Bonnar et al, 2004)³⁴; performing 5 repetitions (Scott et al, 2001)³³ of stretching technique per session with each stretch



Graph 1: Mean pre test baseline values of AKE ROM for the three groups. Graph 2: Mean post values of AKE ROM for the three groups at the end of first week.



Graph 3: Mean post values of AKE ROM for the three groups at the end of second week. Graph 4: Mean post test values of AKE ROM at the end of third week for the three groups

Separated by a 20 sec time interval³⁵; performed thrice weekly (Wallin et al, 1985)³⁶. Also the current research suggests keeping two PNF stretching sessions at least a 24 hour apart (Rowlands et al, 2003);³⁷ the possible explanation for this gap is to allow for the stretched muscles to relax before the application of another stretching session. As PNF stretching techniques involves intense stretching at a muscle's maximum length in a stretched position followed by an isometric contraction, this could possibly lead to excessive stresses on being placed on the stretched muscle(s) and result in overstretch injuries and the possible muscle

soreness. Therefore this time gap may allow for the muscle(s) to adjust to their new increased lengths via virtue of their viscoelastic property and thus possibly avoid possible complications.

The results of this investigation revealed that performance of PNF stretching techniques leads to improvement of hamstring flexibility in healthy male subjects chosen for the study. The results also demonstrated that PNF Contract Relax - Antagonist Contract (PNF-CRAC) stretching technique produced significantly greater gains in hamstring flexibility as measured by AKE test when compared with PNF Hold Relax (PNF-HR) stretching technique. The possible reason for this greater increase in hamstring flexibility for subjects who were subjected to PNF – CRAC stretching could be the theoretical basis of the technique i.e. two physiological mechanisms are engaged during the application of PNF – CRAC stretching which are autogenic inhibition via recruitment of the GTOs and reciprocal inhibition which causes inhibition of the target muscle following the contraction of the opposing muscle. Whereas during PNF- Hold Relax stretching only autogenic inhibition of the target muscle takes place.

Table 1: Repeated Measure ANOVA and Post HOC Pair wise comparison for between group analyses.

		Baseline Mean \pm SD N= 15	PTA1WK Mean \pm SD N= 15	PTA2WK Mean \pm SD N= 15	PTA3WK Mean \pm SD N= 15
Group A		113.9 \pm 9	143 \pm 8	150 \pm 7	157 \pm 7
Group B		134.86 \pm 11	148 \pm 10	157.06 \pm 9.8	165.26 \pm 8.9
Group C		140.26 \pm 8.8	140.13 \pm 8.7	140.33 \pm 8.9	140.26 \pm 8.8
ANOVA	F	1.74	3.19	13.37	35.09
	P	0.19	0.05	0.00	0.00
Post Hoc Pair wise Comparison	G A Vs G B	1.00	0.34	0.13	0.03
	G A Vs G C	0.27	1.00	0.02	0.00
	G B Vs G C	0.44	0.05	0.00	0.00

Key to table 1: S D: Standard Deviation; Baseline: Pre test Knee ROM.; PTA1WK: Post test Knee ROM after 1 week; PTA2WK: Post test Knee ROM after 2 week; PTA3WK: Post test Knee ROM after 3 week; G A Vs G B: Group A versus Group B; G A Vs G C: Group A versus Group C; G B Vs G C: Group B versus Group C

However some studies^(38, 39, 40) have questioned the role of autogenic inhibition and reciprocal inhibition during PNF stretching through EMG and H- reflex studies, but these studies differed from each other pertaining to their methodologies employed and were also limited by factors such as disparate muscle lengths, number of subjects, the year of the study etc. Whereas some studies^(27, 29, 31) attributes these mechanism to be linked with PNF stretching techniques. For example, Moore et al, 1991⁴¹ approved the theoretical basis of PNF stretching and proposed that the relax portion of the hold-relax manoeuvre should be applied quickly after the hold (muscle contraction) portion. Therefore the results of this study can be correlated with the popular belief that PNF stretching techniques lead to relaxation/inhibition of the stretched muscle (target muscle) via the two physiological mechanisms proposed by Sherrington (1940) namely reciprocal inhibition and autogenic inhibition.

Another possible explanation for the improved hamstring flexibility for the subjects in this study could be the viscoelastic nature of the muscle. As the total dose of the stretch for each stretching session was 70 seconds (7 sec of pre stretch + 7 second of post relaxation stretch x 5 repetitions). This aspect is in accordance with the findings of Bandy et al, 1994⁴² who showed that a 30 sec static stretch was sufficient for increasing the hamstring muscle flexibility.

One more explanation for this increased stretch could be the altered stretch perception again due to the stretch duration per se. Study done by Ulrike et al 2007³⁵ utilising a total dose of 40 sec stretch duration following a 6 sec isometric contraction duration of PNF-CR stretch for improving hamstring muscle flexibility, showed increased stretch tolerance for the subjects in that study. This finding may also be used to explain the reasons for increase in hamstring muscle flexibility considering the total dose of 70 sec stretch duration per session given thrice weekly for three weeks.

The results also demonstrated that the PNF stretching techniques employed in this group resulted in significant improvements in hamstring flexibility for both experimental groups after second week of the stretching protocol. These findings contradict the findings of Scott et al, 2005¹ which suggested that significant improvements in hamstring flexibility cannot be achieved with a 2 week stretching program. Also

significant improvement in PNF-CRAC group was seen even after the end of the first week. The possible explanation for this could be that Scott et al used a dose of 30 second duration performed 3 days per week, which is obviously less than the stretching dose used in our study.

7. Clinical Relevance

As the results of the study demonstrated that there was significant improvement in active knee extension range of motion (Hamstring flexibility) for subjects in both experimental groups when compared the control group, it can be assumed that the parameters used in our study were apt enough to produce positive results and that both techniques viz. PNF- Hold Relax and PNF-CRAC can produce gains in hamstring flexibility within two weeks utilizing the parameters in our study.

Although a post HOC comparison of the post test values at the end of the third week showed significant improvements in group B when compared with group A ($P = 0.03$) at 95 % confidence interval ranging from 0.50 to 15.66 degrees of active knee extension ROM, but a thorough consideration of the lower limit of the gain in active knee extension ROM suggests that after three weeks of stretching intervention any of the two PNF stretching techniques used in this study stretching may be used to improve hamstring muscle flexibility.

8. Limitations of the Study

The following were the limitation of our study: Study contains only male subjects, Subject blinding and researcher blinding were not implemented in this study, and research is done only among a particular age group, Small sample size.

9. Scope for Future Research

Further investigations in this area may overcome the limitations of this study by using a larger sample size, varying the age limit, comparing the effectiveness of the PNF stretching techniques used in our study amongst females only or comparing them for both males and females. Another scope could be to design a follow up study which could examine for how long did the gains in hamstring flexibility lasted after 3 weeks of stretching intervention or the training protocol can be increased to any desired level.

10. Conclusion

The study shows that the parameters utilized for the stretching manoeuvres were effective for improving hamstring muscle flexibility as measured by AKE test. Although the study supports the experimental hypothesis that PNF Contract Relax- Antagonist Contract stretching technique is more effective than PNF Hold Relax stretching technique for improving hamstring flexibility but both the techniques are almost equal in their clinical effectiveness for improving hamstring flexibility and that either of the techniques may be used in clinical practice for improving hamstring flexibility.

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