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Effectiveness of Contract-relax Vs Post-Isometric Relaxation in Hamstring Tightness in Healthy Young Adults

Purva P Dalvi[1], Bibi Maryam Mutahira[2]

[1]Intern, Rashtrasant Janardhan Swami college of Physiotherapy, Kopargaon
[2]Assisstant Professor, Rashtrasant Janardhan Swami college of Physiotherapy, Kopargaon

Abstract

Objective: The objective of the study was to compare the effectiveness of Post-isometric Relaxation Technique VS Contract-Relax Technique to improve hamstring flexibility in healthy young adults.

Method: Total 30, male and female participants,15 in each group, i.e. Group A & Group B between the age group 18 to 24 years were selected from RJS Group of Institutes, Kopargaon using random sampling method according to the inclusion and exclusion criteria. Pre-assessment of active knee extension range of motion (ROM) was done using Active Knee Extension (AKE) test with the universal full- circle goniometer and Reading 1 was noted for each subject. The subjects in Group A were given Post-isometric relaxation, 8 seconds for 12 days and Group B were given Contract-Relax Technique, 17 seconds for 12 days. Reading 2 & Reading 3 were noted on the 6^{th} and 12^{th} day of the treatment session respectively.

Results: The results indicate a statistically significant difference between Group A and Group B. The t-value of 5.908 and p-value of less than 0.01 provides significant support for the alternative hypothesis of Hypothesis 1. The Mean values of Group B [4.44] is significantly higher than that for Group A [2.36] which suggests that Contract-Relax technique showed more significant increase in the Active knee extension range of motion than the Post-isometric relaxation after 12 days of treatment protocol.

Conclusion: The statistical data results concluded that Contract-relax technique is more effective than Post-isometric relaxation technique in improving the hamstring flexibility in healthy young adults.

Keywords: Hamstring Flexibility, Contract-Relax, Post-Isometric Relaxation

Introduction

Hamstring muscle is a two joint muscle. Hamstrings are the major knee flexors and also aid in hip extension. Physiologically full stretch occurs in this muscle only if the knee is fully extended and hip fully flexed. Complete contraction occurs when the knee is fully flexed and hip is fully extended. Complete contraction and stretching rarely occurs in normal daily activity and hamstrings are therefore rarely put through their full physiological amplitude. Therefore, chance of it going into tightness are more in individuals not participating in any daily stretching routine.

Hamstring muscle tightness is a common condition even among young healthy individuals and recreational athletes. Hamstrings strain remains a primary concern for rehabilitation professionals as they result in a debilitating injury characterized by acute loss of functional performance, prolonged periods of recovery, and resultant increased incidence of recurrence. [1,2,3]

Flexibility refers to the ability of muscles, joints, and soft tissues to move through an unrestricted, pain-free range of motion. It involves the capacity of these structures to stretch, lengthen, and contract without limitations, allowing for smooth and efficient movement.

Muscle Energy Technique (MET) is a technique that was developed in 1948 by Fred Mitchell, Sr, D.O. [4] It is a form of manual therapy, widely used in Osteopathy, that uses a muscle's own energy in the form of gentle isometric contractions to relax the muscles via autogenic or reciprocal inhibition and lengthen the muscle. As compared to static stretching which is a passive technique in which the therapist does all the work, MET is an active technique in which the patient is also an active participant. MET is based on the concepts of Autogenic Inhibition and Reciprocal Inhibition. If a sub-maximal contraction of the muscle is followed by stretching of the same muscle it is known as Autogenic Inhibition MET, and if a submaximal contraction of a muscle is followed by stretching of the opposite muscle, then this is known as Reciprocal Inhibition MET. [5]

Autogenic and Reciprocal Inhibition both occur when certain muscles are inhibited from contracting due to the activation of the Golgi tendon organ (GTO) and the muscle spindles. These two musculotendinous proprioceptors located in and around the joints and muscles respond to changes in muscle tension and length, which helps manage muscular control and coordination.

The GTO response plays an important role in flexibility. It is located between the muscle belly and its tendon, senses increased tension when the muscle contracts or stretches. When the muscle contracts, the GTO is activated and responds by inhibiting this contraction (reflex inhibition) and contracting the opposing (antagonist) muscle group. This process is known as autogenic inhibition.

The muscle spindle is located within the muscle belly and stretches along with the muscle itself. When this occurs, the muscle spindle is activated and causes a reflexive contraction in the agonist muscle (known as the stretch reflex) and relaxation in the antagonist muscle. This process is known as reciprocal inhibition.[6]

Autogenic Inhibition MET is further divided into two techniques – Post facilitation stretch (PFS) and post-isometric relaxation (PIR).

Post isometric relaxation technique (PIR) was developed by Karel Lewitt.[6] To decrease the hyper tonicity and tightness of a shortened muscle, post isometric relaxation technique is used by a therapist. In Post Isometric Relaxation (PIR), submaximal isometric contraction of the muscle for a brief period of time is used to decrease the tone of the shortened muscle. Postural muscles are mostly treated by this muscle energy technique. The muscles like hamstring frequently become stiff and tight and can lead to muscular imbalance thus causing restriction in movement of joints and muscles.

Proprioceptive neuromuscular facilitation (PNF) is an approach to therapeutic exercise that combines functionally based diagonal patterns of movement with techniques of neuromuscular facilitation to evoke motor responses and improve neuromuscular control and function. This widely used approach to exercise was developed during the 1940s and 1950s by the pioneering work of Kabat, Knott, and Voss. [7]

PNF techniques can be used to develop muscular strength and endurance; facilitate stability, mobility, neuro-muscular control, and coordinated movements; and lay a foundation for the restoration of function. PNF techniques are useful throughout the continuum of rehabilitation from the early phase of tissue healing when isometric techniques are appropriate to the final phase of rehabilitation when high-speed, diagonal movements can be performed against maximum resistance.

Proprioceptive neuromuscular facilitation techniques used for stretching (PNF stretching), [8,9,10,11,12] also referred to as active stretching [13] or facilitative stretching, [14] integrate active muscle contractions into

stretching manoeuvres purportedly to facilitate or inhibit muscle activation and to increase the likelihood that the muscle to be lengthened remains as relaxed as possible as it is stretched.

PNF uses the concept of muscle relaxation being fundamental to elongation of muscle tissue. In theory it is performed in a way that it uses proprioceptive abilities of Golgi Tendon Organ and muscle spindle to relax and inhibit the muscle in order to gain more effective stretch.

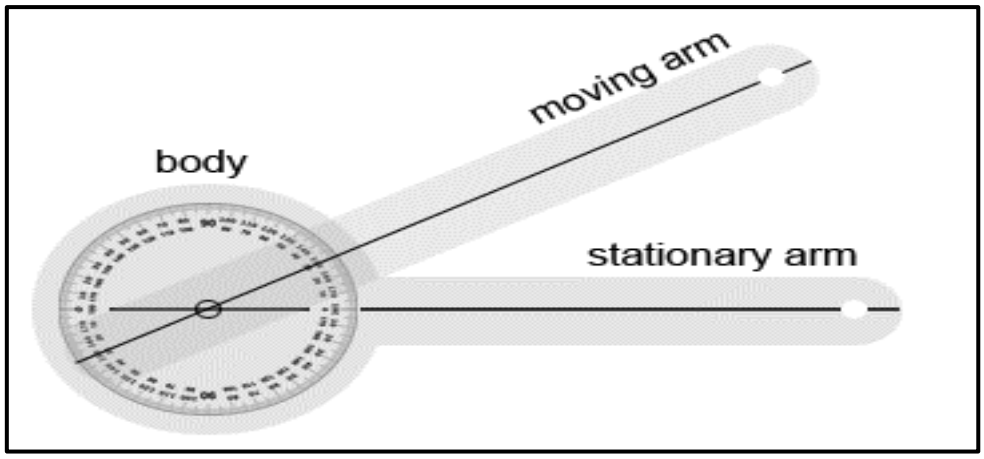
There are several variations of PNF stretching, they all have one thing in common; they facilitate muscular inhibition. Various PNF stretching techniques based on Kabat's concept are: Hold Relax, Contract Relax, and Contract Relax Antagonist Contract (CRAC) etc.

The Hold Relax (HR) technique involves an isometric contraction of the shortened muscle against maximum resistance followed by relaxation phase.[15] The contract relax (CR) PNF technique includes the concentric contraction of the shortened muscle [16] 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. [17]

Goniometry is the art and science of measuring the joint ranges in each plane of the joint.[18] The term 'goniometry' is derived from the Greek words 'gonia' meaning angle and 'metron' meaning measure, therefore goniometry refers to the measurement of angles, which in rehabilitation settings refers to the measurement of angles in each plane at the joints of the body. Goniometry is an important part of a comprehensive examination of joints and surrounding soft tissue.

Parts of Universal Goniometer – Body, Arms, Fulcrum

Figure 1 Parts of Goniometer



The body of a universal goniometer resembles a protractor and may form a half circle or a full circle. The scales on a half-circle goniometer read from 0 to 180 degrees and from 180 to 0 degrees. The scales on a full-circle instrument may read either from 0 to 180 degrees and from 180 to 0 degrees, or from 0 to 360 degrees and from 360 to 0 degrees. Sometimes full-circle instruments have both 180-degree and 360-degree scales. Increments on the scales may vary from 1 to 10 degrees, but 1 to 5 degree of increments are the most common.

The arms of a universal goniometer are designated as moving or stationary according to how they are attached to the body of the goniometer. The stationary arm is a structural part of the body of the goniometer and cannot be moved independently from the body. The moving arm is attached to the centre of the body of most plastic goniometers by an arivet that permits the arms to move freely on the body.

The fulcrum of the goniometer may be placed over the approximate location of the axis of motion of the joint being measured.

Materials and methodology

Materials:

1. Universal Full circle Goniometer
2. Stopwatch
3. Body marker

Methodology:

1. **Study design -** Experimental Comparative study
2. **Place of study** - Rashtrasant Janardhan Swami College of Physiotherapy, Kopargaon
3. **Sample size** - 30 participants
4. **Sampling method** - Random sampling method
5. **Study duration** - 5 months
6. **Treatment duration** – 6 sessions per week for 2 weeks

INCLUSION CRITERIA

1. Age 18 to 24 years
2. Both Male and Female
3. Willing to participate
4. Active knee extension ROM > 45°
5. Asymptomatic healthy individuals
6. Right side (dominant) leg.

EXCLUSION CRITERIA

1. Age less than 18 or more than 24 years
2. Uncooperative individuals
3. Recent hamstring injury or trauma (<=1month)
4. Hamstring repair surgery
5. Musculoskeletal deformity or injury of lower limb.
6. Athletes or daily exercising individuals
7. Recent Hip or Knee surgery
8. Individuals experiencing pain along with tightness

Outcome measures

Active Knee Extension Test (AKE):

The interrater reliability intraclass correlation coefficients (ICC2,1) were 0.87 for the dominant knee.[20]

Procedure

Total 30 subjects, male and female both were selected based on the inclusion and exclusion criteria, and written consents were taken. The subjects were randomly assigned using chit method, into Group A and Group B with 15 subjects in each group. The subjects with active knee extension angle more than 45 degree were included in the study and subjects who were athletes or the daily exercising subjects were

excluded from the study. The dominant leg (knee) was determined based on the subject's preferred leg when kicking a ball or while performing a single leg jump.[21] Subjects which had left leg dominance were excluded from the study. The subjects selected in the study were instructed to abstain from any form of sport or physical exercises. After the whole procedure was explained to the subjects, the pre-test (Active knee extension test) was performed to assess the initial range of motion of active knee extension using a standard full-circle goniometer and Reading 1 was noted for each subject**.**

Active knee extension (AKE) test:

Subjects were assessed for hamstring tightness using the AKE test. The subject was in supine position with hip and knee in 90-degree flexion. The testing was done on the right lower extremities (dominant knee) for all the subjects. The left leg which was not being measured was stabilized at the one third lower thigh, manually by the other therapist.

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 hip was taken into flexion and maintained at 90- degree. 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. When hip and knee were maintained at 90 degree each, the subject was then asked to extend the knee of the lower extremity being tested as far as possible until a mild stretch sensation was felt. A full circle goniometer was then used to measure the angle of knee extension [22,23] Baseline 90 degree of knee flexion was considered as 0 degree while assessing the active knee extension angle. The selected subjects were then assigned to either Group A or Group B (15 in each group), including males and females, using Random sampling method. Subjects in Group A were given Post-isometric relaxation (MET) to Hamstring muscle 8 seconds, and subjects in Group B were given Contract-Relax technique (PNF) for 17 seconds. Both the techniques were given for 6 consecutive days for 2 weeks.

Post- isometric Relaxation:

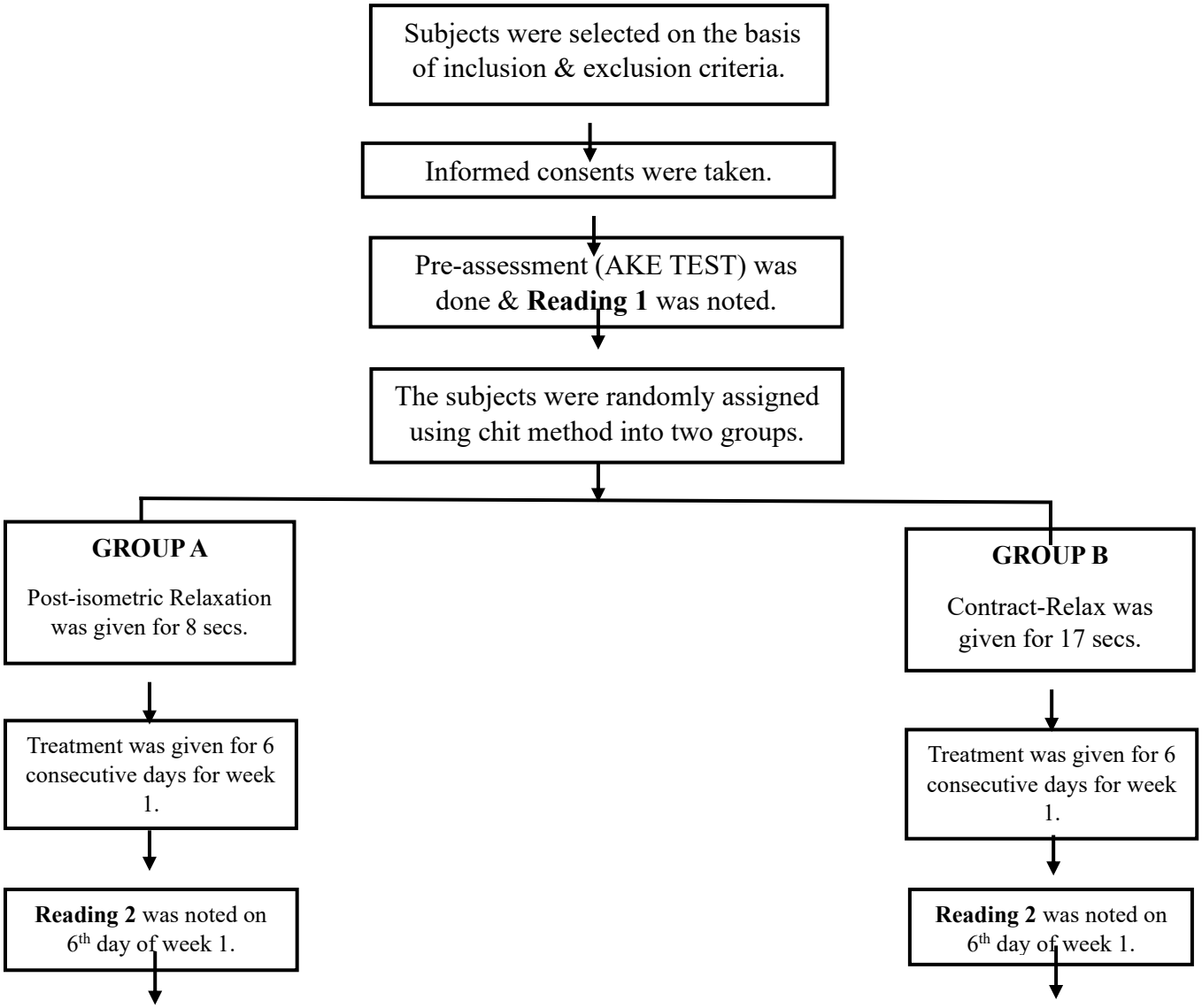
Subjects were asked to lie on their back (supine lying) with hip flexed at 90 degree and the knee was extended until the point where resistance started taking out the slack and then the patient was asked to push away from that point against the matched resistance of approximately 10% of maximum effort to create isometric contraction. The subject was asked to breathe in and hold for 8 seconds and then release both breath and effort so that slack was taken up and tissue was eased to new barrier point and process was repeated five times for 6 consecutive days per week for a period of 2 weeks.[24] After the treatment, Reading 2 and Reading 3 were noted on the 6th day and the 12th day of the treatment respectively to check for the improvement in Active knee Extension angle (hamstring tightness).

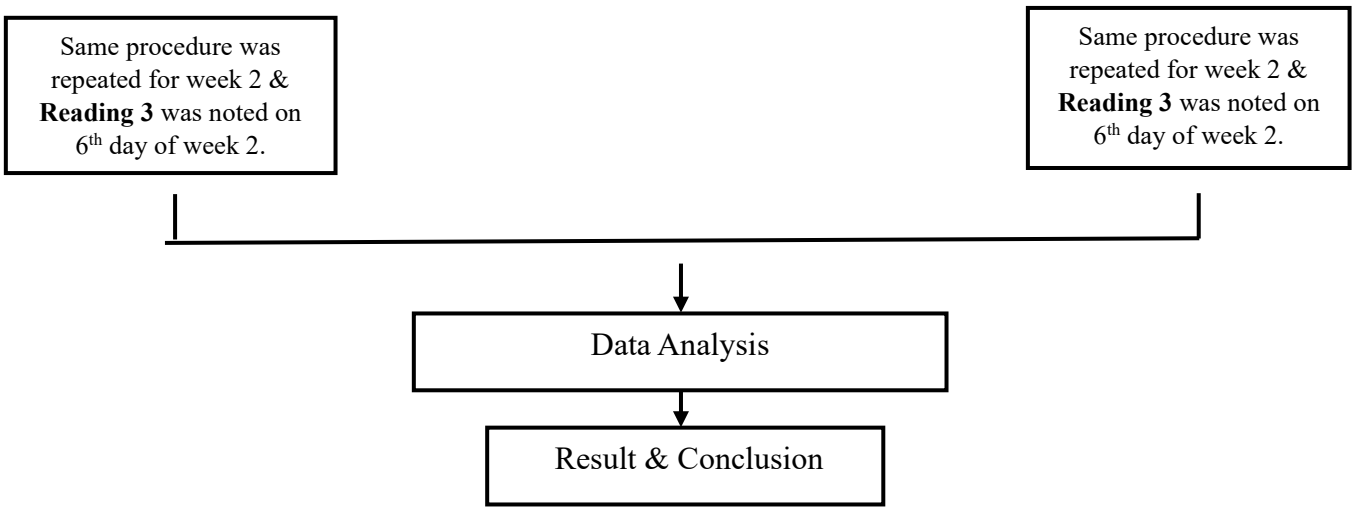
Figure 2 Post Isometric Relaxation Technique

Contract-Relax Technique:

The subjects were in supine position with their right lower extremity stabilised pre-determined time intervals for stretching; contracting and relaxing were used to standardize the method utilizing a stop watch. For each stretch, the therapist stretched the hamstring muscle by passively flexing the hip with knee fully extended, allowing no hip rotation. The lower leg was rested on the therapist's 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 the leg down towards the table against the resistance of the therapist. Following this, the subject was asked to relax for 5 sec. 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 interval [23]. The treatment was given 6 days consecutively per week for period of 2 weeks. [23,24] Post-treatment measurement of ROM was done & Reading 2 and Reading 3 were noted on the 6th day and the 12th day of the treatment respectively to check for the improvement in Active knee Extension angle (hamstring tightness).

PROTOCOL





Statistical analysis

The primary objective of this analysis is to compare and analyse the data collected with the help of outcome measure, Active knee Extension test in order to identify the patterns, significant relationship and trends among the key variables. The dataset includes active knee range of motion measurements of 30 subjects divided into two groups- Group A & Group B with 15 subjects in each. The statistical Analysis was performed using Independent 2 sample 't' Test and 1-tailed 't' test, including descriptive analysis. The analysis focuses on age distribution, gender differences, comparison between the 3 readings for each subject to make comparison between both the study groups to draw the conclusion regarding which treatment method is more effective in improving the hamstring flexibility in healthy young adults.

Table 1 Age Distribution in the Study Groups

Age distribution in the study groups				
	GROUP A		GROUP B	
Age intervals	**Observations**	**Percentage**	**Observations**	**Percentage**
18 - 20	3	25.0	3	25.0
21 - 24	12	75.0	12	75.0

The age distribution between Group A and Group B shows similar patterns across both groups. For the age interval of 18 to 20 years, both Group A and Group B have an equal representation, with 25.0% of participants falling within this range. In contrast, the age interval of 21 to 24 years accounts for a larger proportion, with 75.0% of participants in both groups falling within this category. This indicates that both groups are predominantly composed of individuals in the early stages of adulthood, particularly within the 21 to 24-year age range, suggesting similar demographic characteristics between the two groups.

Figure 3 Age Distribution in Group A

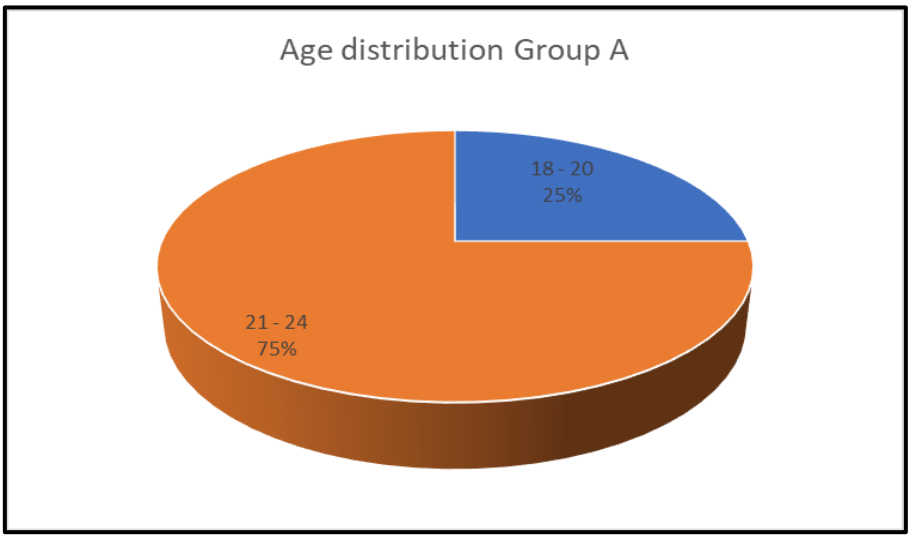


Figure 2 Age Distribution in Group B

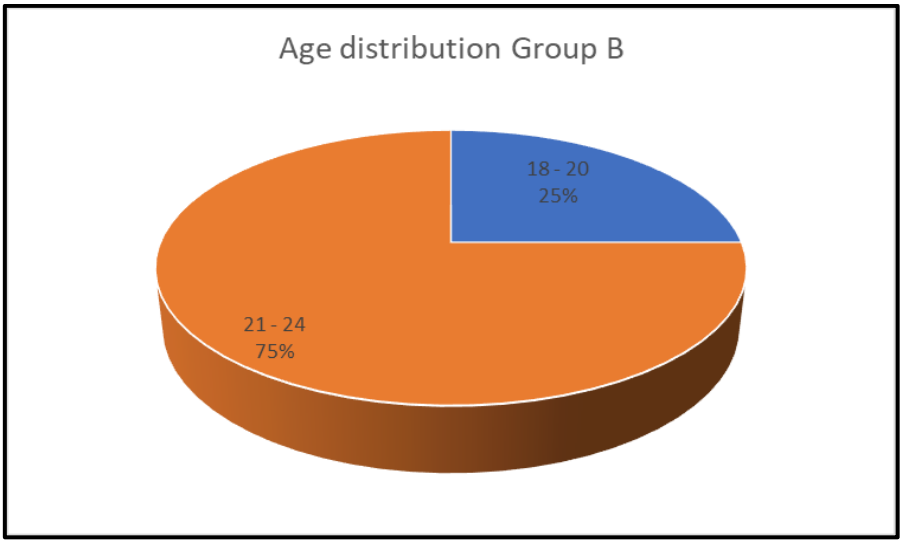
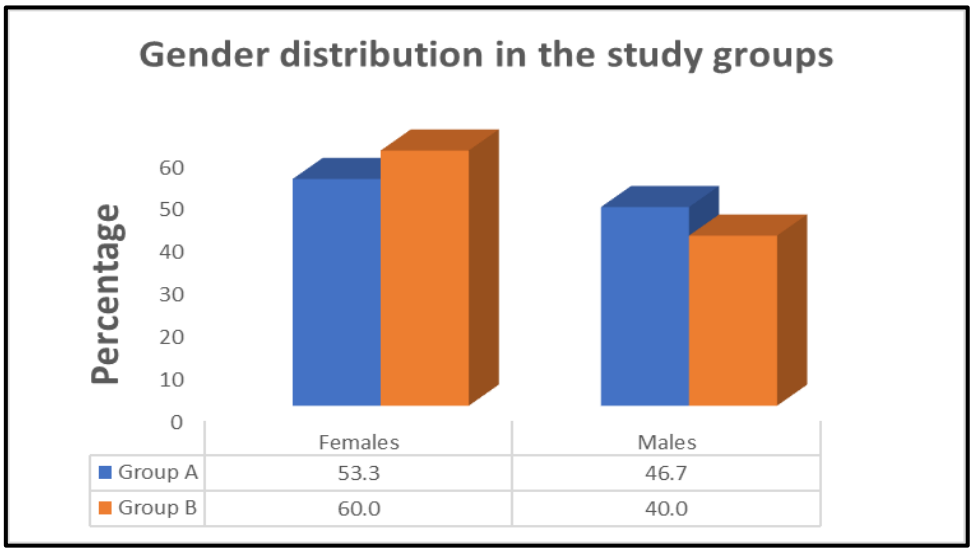


Table 2 Gender Distribution in Study Groups

Gender distribution in the study groups				
	GROUP A		**GROUP B**	
Gender	**Observations**	**Percentage**	**Observations**	**Percentage**
Females	8	53.3	9	60.0
Males	7	46.7	6	40.0

Figure 3 Gender Distribution Graph



Among 15 participants in Group A, 8 were females (53.3%) and 7 were males (46.7%). Group B had 9 females (60.0%) and 6 male participants (40.0%).

Statistical analysis result

For improving the hamstring flexibility we used Post-Isometric Relaxation for group A and Contract-Relax technique for group B. We used StatistiXL software 2.0. Independent 2 sample 't' test was used for comparing mean differences in readings between groups A & B.

The analysis yielded the following results:

Table 3 Descriptive Analysis for Group A and B

Descriptive Analysis						
Variable	**Mean**	**Std Dev.**	**Std Error**	**Lower 95% CL**	**Upper 95% CL**	**N**
Mean reading group A	2.36	0.61	0.16	2.018	2.694	15
Mean reading group B	4.44	1.32	0.32	3.766	5.123	15

Table 4 Showing Pre and Post Result Comparison between Group A and Group B

1-tailed t-Test (Mean reading group B > Mean reading group A)					
Ho. Diff	**Mean Diff.**	**SE Diff.**	**'t' value**	**DF**	**'p' value**
0.000	2.089	0.354	5.908	28	0.000
			Significant		**'p' < 0.01**

The results indicate a statistically significant difference between Group A and Group B. The t-value of 5.908 and p-value of less than 0.01 provides significant support for the alternative hypothesis of Hypothesis 1. The Mean values of Group B [4.44] is significantly higher than that for Group A [2.36] which suggests that Contract-Relax technique showed more significant increase in the Active knee extension range of motion than the Post-isometric relaxation after 12 days of treatment protocol.

Inference:

't' value 5.908 is significant ['p' < 0.01].

This shows that mean reading of group A and group B are significally different.

Mean differences in readings of group B [4.44] is greater than that of group A [2.36]

Hence, it can be concluded that CONTRACT-RELAX TECHNIQUE is better compared to POST-ISOMETRIC RELAXATION.

Figure 4 Comparison of Mean Values of Group A and Group B

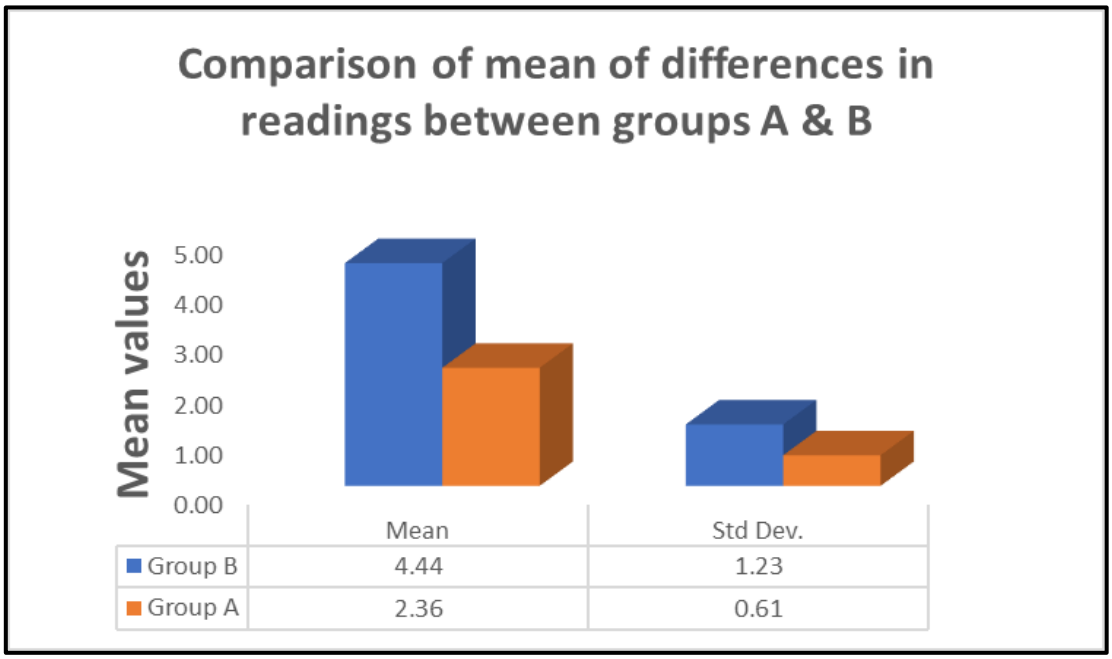


Figure 5 Pie Chart of Mean Values of Both Study Groups

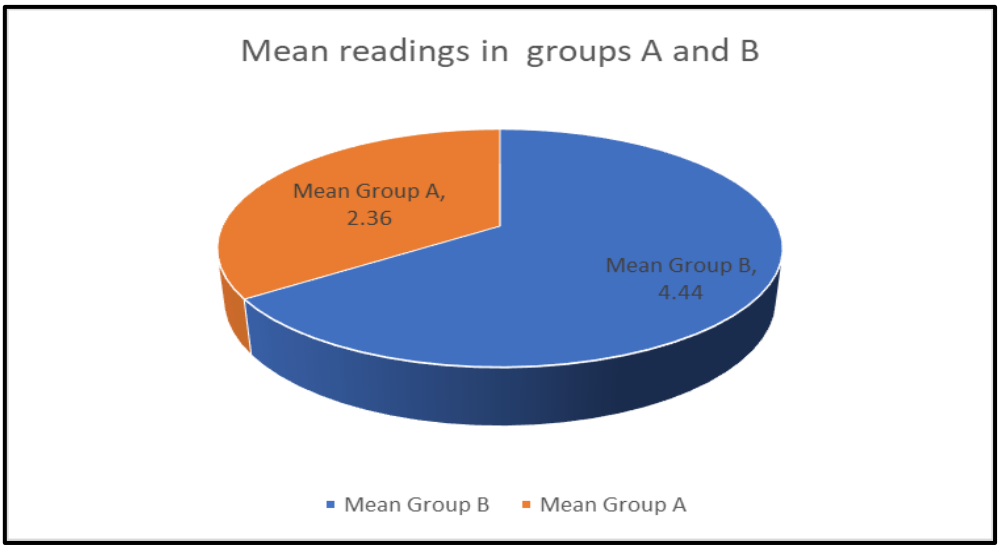
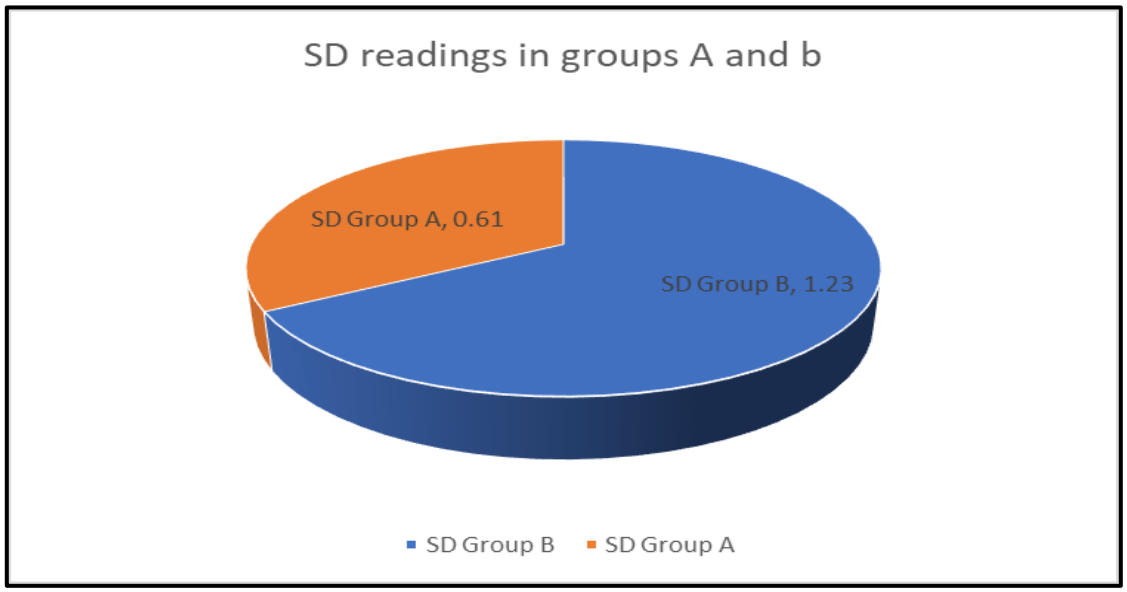


Figure 6 Pie Chart of Standard Deviation of Both Study Groups



Discussion

Hamstring tightness is one of the most common musculoskeletal condition seen across various populations but noticeably seen in older adults, sedentary individuals as well as active population. For healthy young adults sitting or standing in the same position for a prolonged period of time is very common which contributes to the reduced hamstring flexibility along with poor posture habits and sedentary lifestyle ways such as lack of exercise etc.

Despite its commonality, hamstring tightness is often underdiagnosed or considered a minor issue. But reduced hamstring flexibility in healthy young adults can have a range of physical, functional long-term consequences. One of the most significant concern is the increases risk of hamstring injury which may occur due to the tightness of the muscle.

Various treatment approaches were found to be effective in improving the hamstring flexibility in heathy young adults such as Active & Passive stretching, Proprioceptive Neuromuscular Facilitation technique, Muscle Energy techniques etc.

The conducted study aims to compare the effectiveness of Contract-Relax Technique VS Post-isometric relaxation in improving the hamstring flexibility in healthy young adults. The study population selected were college going both male & female students, with inactive lifestyle, within the age group of 18 to 24 years. Total 30 subjects were selected bases on the inclusion and exclusion criteria and randomly assigned into two groups- Group A & Group B with 15 participants in each group. Active Knee extension (AKE) test was used to take the pre-assessment of active knee range of motion and Reading 1 was noted. Group A was given Post-isometric relaxation for 8 seconds and Group B was given Contract-Relax technique for 17 seconds. Both the treatment protocols were given for 6 consecutive days for 2 weeks. Post-treatment AKE test was performed on the 6^{th} day and 12^{th} day of the treatment protocol and Reading 2 & 3 were noted respectively.

The results indicate a statistically significant difference between Group A and Group B. The t-value of 5.908 and p-value of less than 0.01 provides significant support for the alternative hypothesis of Hypothesis 1. The Mean values of Group B [4.44] is significantly higher than that for Group A [2.36]

which suggests that Contract-Relax technique showed more significant increase in the Active knee extension range of motion than the Post-isometric relaxation after 12 days of treatment protocol.

A similar study conducted by **Nagarwal A.K et al** (**2009**) conducted a study on Improvement of Hamstring Flexibility: A comparison between PNF stretching techniques on 45 healthy male subjects of 20 to 30 years which concluded that PNF Contract-Relax Agonist Contract is better than Hold-Relax stretching technique in improving hamstring flexibility.

A comparative study by **Dr. Sumer Shaha et al. (2020)** conducted a study on Comparing the effect of static, ballistic and contract-relax stretching on hamstring muscles flexibility in young individuals with 90 young healthy individuals, both male & female within the age group of 18 to 24 years which concluded that all three static, ballistic and contract-relax technique is beneficial in improving flexibility of hamstring muscles but contract relax stretching is more effective than the static stretching and ballistic stretching ($p<0.05$).

Similarly, a comparative study by **Myoung-Hee Lee et al. (2008)** Effect of Contract-Relax Technique of Proprioceptive Neuromuscular Facilitation on Hamstring Flexibility conducted a study on 52 college students. The results of this study suggest that PNF is more effective method on hamstring flexibility than passive stretching or active stretching.

Another study, by **Amit Kumar Singh et al. (2016)** Neurodynamic sliding versus PNF stretching on hamstring flexibility in collegiate students: A comparative study was a pre-post experimental study, 60 participants, both male & female with age ranging from 20 to 30 years which concluded that PNF stretching is more effective than Neurodynamic sliding in increasing hamstring flexibility in collegiate students.

Also, **Abdulrahim Zakaria et al. (2012)** conducted a study on Efficacy of PNF stretching tightness in male adult population which concluded that Both stretching regimes, i.e. PNF self-stretch and therapist applied PNF stretch which incorporated the facilitator components of PNF-techniques, achieved a significant increase in hip flexion range.

The possible mechanism behind the improvement of hamstring flexibility reflected by the results of all of the above studies involves Proprioceptive neuromuscular facilitation techniques used for stretching (PNF stretching), [8,9,10,11,12] integrate active muscle contractions into stretching manoeuvres purportedly to facilitate or inhibit muscle activation and to increase the likelihood that the muscle to be lengthened remains as relaxed as possible as it is stretched. PNF uses the concept of muscle relaxation being fundamental to elongation of muscle tissue. In theory it is performed in a way that it uses proprioceptive abilities of Golgi Tendon Organ and muscle spindle to relax and inhibit the muscle in order to gain more effective stretch. The contract relax (CR) PNF technique includes the concentric contraction of the shortened muscle [16] and then relaxation phase.

Hamstring tightness is the most common condition seen in young adults, college going students as they maintain sitting or standing postures for prolonged period of time which causes reduction in the hamstring flexibility. Proper posture education, ergonomic advice and effects of Contract-relax technique & Post-isometric relaxation not only improves the hamstring flexibility but also improves the quality of life.

Conclusion

Hereby, the study concludes that Contract-Relax technique and Post-isometric relaxation are both effective in reducing the hamstring tightness. But, on statistical analysis, mean value of Group B [4.44] was found to be greater than the mean value of Group A [2.36], which concludes that Contract-Relax technique is

more effective than Post-isometric relaxation in improvement of hamstring flexibility in healthy young adults.

References

1. Smith AD, Stround MC, Queen C. Flexibility and anterior knee pain in adolescent delite figure skates. Journal of Pediatric orthopaedic; 1991; 11: 77-82.
2. Gajdosik R, Lusin G, hamstring muscle tightness reliability of an active knee extension test (author's response). Physical therapy;1983; 63:1086-1090.
3. Russell TN, William DB. Eccentric training and Static stretching improves hamstring flexibility of high school males, Journal of athletic training; 2004; 39:254-258.
4. Waxenbaum JA, Scafidi JM, Lu M. Physiology, Muscle Energy. StatPearls [Internet]. 2020 Jul 6.
5. Chaitow L, Crenshaw K. Muscle energy techniques, Elsevier Health Sciences; 2006.
6. Lewit K, Simons DG. Myofascial pain: relief by post-isometric relaxation. Archives of Physical medicine and rehabilitation; 1984 Aug;65(8):452-6.
7. Knott, M, Voss, DE: Proprioceptive Neuromuscular Facilitation, Patterns and Techniques, ed 2. Harper & Row, Philadelphia, 1968
8. Brody, LT: Impaired joint mobility and range of motion. In Hall CM, Brody, LT (eds): Therapeutic Exercise–Moving Toward Function, ed 2. Lippincott Williams & Wilkins, Philadelphia, 2005; Pp 113–148.
9. Cornelius, WL, Jensen, RL, Odell, ME: Effects of PNF stretching Phases on acute arterial blood pressure. J Appl Physio; l 20:222–229,1995.
10. Hertling, D: Soft tissue manipulations. In Hertling, D. Kessler, RM(eds): Management of Common Musculoskeletal Disorders, ed 4. Lippincott Williams & Wilkins, Philadelphia, 2006, pp 179–259.
11. Ostering LR, Robertson, R, Troxel, R, Hansen, R: Differential Response to proprioceptive neuromuscular facilitation (PNF) stretch Technique. Med Sci Sports Exercise; 22:106–111, 1990.
12. Zachazewski, JE: Flexibility in sports. In Sanders, B (ed): Sports physical therapy; Appleton & Lange, Norwalk, CT, 1990, pp 201–22.
13. Winters, MV, Blake, CG, Trost, JS, et al: Passive versus active stretching of hip flexor muscles in subjects with limited hip extension; a randomized clinical trial. Phys Ther 84(9):800–807, 2004.
14. O'Sullivan, SB: Strategies to improve motor control and motor learning, In O'Sullivan, SB, Schmitz, TJ (eds): Physical Rehabilitation: Assessment and Treatment, ed 4; FA Davis, Philadelphia, 2001, pp 363–411.
15. Tanigawa M C. Comparison of the hold-relax procedure and passive mobilization on increasing muscle length; Physical Therapy. 1972; 52(7): 725-735.
16. DePino G M, Webright W G. Duration of Maintained Hamstring Flexibility After Cessation of an Acute Static Stretching Protocol; Journal of Athletic Training, 2000, 35(1): 56-59.
17. Etnyre BR, et al. Chronic and Acute Flexibility of Men and Women Using Three Different Stretching Techniques, Research Quarterly for Exercise and Sport. 1988, 59(3): 222-228.
18. Viraj N. Gandbhir, Bruno Cunha,In: StatPearls, Treasure Island (FL): StatPearls Publishing; 2020 Jan.2020 Jun12.Pubmed.gov. National Library of Medicine.National Centre for Biotechnology Information.
19. Cynthia C. Norkins, Joyce D. White, Measurement of Joint Motion; A Guide to Goniometry (4th ed.); pp (24-26).

20. Mohamad Shariff A Hamid; Interrater and Intrarater Reliability of the Active Knee Extension (AKE) Test among Healthy Adults J. Phys. Ther. Sci.; 25: 957–961, 2013.
21. Scott D, Ashby P E., The effects of 3 stretching techniques on hamstring flexibility using consistent stretching Parameters, Journal of Strength and conditioning research. 2005, 19(1): 27-32.
22. Scott G. Spernoga, Timothy L. Duration of maintained hamstring flexibility after onetime modified hold relax Stretching protocol. Journal of Athletic Training. 2001, 36(1): 44-48.
23. Megha Seth, Comparison of Muscle Energy Technique and Post Isometric Relaxation on Hamstring Flexibility in Healthy Young Individuals with Hamstring Tightness, International Journal of Health and Rehabilitation Sciences; 2014, 10.5455/ijhrs.000000054.