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# Effectiveness of proprioceptive neuromuscular facilitation (PNF) vs foam Roller exercise on hamstring muscle flexibility in college going students- A comparative study

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**Abstract**

**Background:** Flexibility is a key component of the physical fitness that enables an individual in order to move smoothly and safely. Studies have shown that shortening of hamstring group of muscles predisposes altered mobility of the spine & pelvis, also altering the gait of the individual. Individual studies have proven the positive effect of PNF on lower limb flexibility and the benefit of Foam Roller Exercise. The aim of the present study was to compare the effect of PNF Hold-Relax stretching technique and Foam Roller Exercise on hamstring muscle flexibility in college going healthy individuals.

**Method:** Thirty healthy individuals with mild to moderate hamstring tightness in the age group of 18- 25 years participated in this study. Group A received PNF Hold-Relax stretching technique in sitting position with hip flexed till barrier with knee extended followed by strong isometric contraction to the hamstrings for 8 minutes with 10 seconds rest after every three repetitions. Group B received Foam Roller Exercise. Pre and post measurements were taken using AKE test and standard sit and reach test.

Result: Significant results were found between both the groups indicating more effectiveness of PNF Hold-Relax stretching technique to improve hamstring flexibility.

**Conclusion:** Our study supported the alternate hypothesis that is PNF Hold-Relax stretching technique has greater effects on improving hamstring flexibility.

**Clinical Implication:** According to the therapist either of the techniques can be applied but greater improvements were seen by PNF Hold-Relax stretching technique than by Foam Roller Exercise.

**Keywords:** stretching, PNF, flexibility, foam roller

## Introduction

Physical fitness has an important role to maintain optimum health of an individual [1] Flexibility is one among various components included in physical fitness. It is the ability of a muscle for lengthening and allowing joint movement in a particular range of motion which should be unrestricted and pain free which is important in the rehabilitation of musculoskeletal injuries and its prevention [1, 2].

Limited flexibility refers to the tightness of a muscle which is a slow, non-pathologic response of a muscle and its connective tissue to the range of motion being utilized in the related joints as adaptive shortening of the muscle which can cause musculoskeletal symptoms which may lead to decrease in strength, stability and endurance [3, 4]. Lack of flexibility is a predisposing factor to hamstring strains [5].

Hamstring muscles stabilize the knee joint, and decelerates extension of the knee contracting eccentrically, allowing knee flexion and hip extension [6] Tightness of hamstring muscle is due to lack of its ability to change its length from its state of full contraction to full stretch [6]. Lack of ability of the hamstring to fully stretch could possibly due to mechanical or neural reasons, or even due myofascial adhesions which restricts the muscle from gliding freely in its full range of motion [7, 8].

Due to shortening the connective elements of muscles be in continuous shortened state and the muscle shows increased reactivity to central as well as peripheral stimuli. Tightness of hip musculature is common which may result from adaptive changes in the muscles which are not routinely stretched. In an ambulatory individual, extreme tightness of hip musculature can create significant problems in gait [1, 9].

Two joint muscles have an impact on two joint systems performing multiple functions and thus they are more susceptible to various injuries. Hamstring is a two-joint muscle and hence tightness is common in the muscle in both active and sedentary individuals which is a predisposing factor to hamstring strains [9, 10]. Maintaining hamstring flexibility can prevent acute as well as chronic musculoskeletal injuries and low back problems,

postural deviations, gait limitations, and fall risk [5, 2]. Tight hamstrings can also lead to reduced stride length and cadence, which can cause dynamic balance problems to arise [1, 2]. Baghyashree Koli, et.al. conducted a study on the prevalence and severity of hamstring tightness among college student and concluded that prevalence of hamstring tightness is found to be very high in college going students of age group 18-25 years.

Dipesh Thakur *et. al.* conducted a study in order to find out correlation between the right and left hamstring length in both gender for determining the prevalence of hamstring tightness among college students.

Olga Delgado Valdivia *et. al.* conducted a study on changes in flexibility according to gender and educational stage and concluded that greater mean flexibility is seen in women than in men across most of the age ranges.

Hamstring muscle tightness is defined as Knee Flexion Angle (KFA) greater than 20 degrees where KFA is the degree of knee flexion measured from terminal knee extension in 90 degrees hip flexion [7, 12].

Studies have shown that hamstring tightness is seen more in those who sit for longer hours which causes adaptive changes and may shorten the hip muscles [13]. Prolonged sitting causes pelvic tilt which causes the hamstring to go into shortened position and put load on the muscle with large amount of force and thereby increases the risk of injury [9, 10].

Nishchal Ratna Shakya et.al. conducted a study on prevalence of hamstring muscle tightness among undergraduate physiotherapy students of Nepal using Passive Knee Extension Test. The study showed medium prevalence of hamstring muscle tightness among physiotherapy students of KUSMS. The prevalence of hamstring muscle tightness is found to be greater in male compared to female students.

High rate of muscle tightness is among the people who are having prolonged sitting hours and a sedentary lifestyle. Being sedentary or not participating in sufficient physical activities leads to shortening and tightening of muscles. Muscles becomes sore when tension occurs in under used muscles which results in muscle shortening [13]. Hamstring flexibility can be increased by using various techniques like soft tissue manipulation, massage, muscle energy techniques, stretching, PNF, Myofascial Release technique, self-induced myofascial release using a foam roller [2, 3].

PNF stretching or proprioceptive neuromuscular facilitation stretching, are stretching techniques commonly used in clinical environments to enhance both active and passive joint range of motion with the ultimate goal being to optimize motor performance and complete rehabilitation. [14, 15] PNF technique help improving the overall functional ability of patients by developing muscular strength and endurance, joint stability, mobility, neuromuscular control and co-ordination [3, 16].

Proprioceptive neuromuscular facilitation (PNF) technique involves cyclic contraction and stretching of the targeted muscle which results in autogenic inhibition as well as increased compliance of the muscle.[15] Autogenic inhibition, stress relaxation and gate control theory focus on the Golgi tendon organ. If isometric contraction and concentric contraction is used immediately before stretch, autogenic inhibition gets facilitated. When the Golgi tendon organ is stimulated, autogenic inhibition takes place in the same muscle. By improving its motor performance and rehabilitation, the muscle is relaxed and strengthened. Thereby active and passive movements are improved. It occurs in the contracted/stretched muscle where a decrease in motor excitability is seen because of inhibitory signals sent from the stretched or the contracted muscles [8, 14].

Self-Myofascial release technique using a foam roller is used to relieving soft tissue from abnormal tight facia [3, 17]. It involves the Golgi tendon organ. The source of pressure while using foam roller is the individual's weight. The pressure causes the Golgi tendon organ to sense a change of tension occurring in the muscle and responds to its high and prolonged tension by inducing relaxation of the muscle spindles [2, 8].

The use of foam roller is thought to heat up the muscle and fascia due to the friction created by the rolling action, with simultaneous tissue stretch which results from the pressure exerted by the person's body weight [8, 18].

It has been theorized as foam rolling breaks fibrous adhesions in the fascia which allows the muscle for more free gliding and therefore improving its range [8].

Another explanation is the thixotropic property seen in the muscle and fascia, thixotropic is a physical property of the muscle and tissue [18]. It is been proposed that by the application of force, the transformation of connective tissue fascia from a thickened state to a liquid state can be possible. The application of pressure with Foam Rolling along the direction of the muscle generates the force within the soft tissue.

Thus, the thixotropic property shows reduction of stiffness as well as change in property in muscles and fascia by decreasing tissue resistance [8, 18].

**Need for study**

Previous studies have shown the positive effect of PNF Hold-Relax stretching technique on hamstring flexibility in healthy individuals and athletes.

Studies have proven the benefit of Foam Rolling to improve hamstring flexibility in healthy individuals.

There are a very few literatures comparing the effectiveness of PNF Hold-Relax stretching technique and Foam Roller Exercise on hamstring muscle flexibility.

Thus, the need of study to compare the effectiveness of PNF Hold-Relax stretching technique and Foam Roller Exercise on hamstring muscle flexibility in college going students.

**Aim**

To compare the effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) stretching technique and Foam Roller Exercise on hamstring flexibility in college going students.

**Objectives**

To investigate the effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) stretching technique on hamstring flexibility in college going students.

To investigate the effectiveness of Foam Roller Exercise on hamstring flexibility in college going students.

To compare the effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) stretching technique and Foam Roller Exercise on hamstring flexibility in college going students.

**Hypothesis Null hypothesis**

There will be no significant effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) on hamstring flexibility in college going students.

There will be no significant effectiveness of Foam Roller Exercise on hamstring flexibility in college going students.

There will be no significant difference between effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) and foam roller exercise on hamstring muscle in college going students.

**Alternate hypothesis**

There will be significant effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) stretching technique on hamstring flexibility in college going students.

There will be significant effectiveness of Foam Roller Exercise on hamstring flexibility in college going students.

There will be significant difference between the effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) stretching technique and Foam Roller Exercise on hamstring flexibility in college going students.

**Methodology**

Type of study – Experimental study Study design – Randomized clinical trial Sample size – 30
Age group – 18-25 years Study duration – 6 months
Sampling technique –Simple Random Sampling Study setting – UG colleges in Miraj

**Materials**

Universal goniometer Foam roller
Yoga mat Stool
Low plinth Stop watch Wooden Box Scale

**Inclusion criteria**

- Age group – 18 – 25 years
- Gender - male
- Hamstring tightness > 20 degrees (AKE test)
- UG college going students
- Participants willing to participate

**Exclusion criteria**

- Regular sports player
- Post fracture of lower limb
- Post-surgery of lower limb or lumbar spine
- Subjects using lower limb prosthesis or orthotics

**Procedure**

After informed consent a total of 30 subjects were recruited in the study according to the inclusion and exclusion criteria. They were divided in two groups with 15 in each group by simple random sampling technique. Pre-treatment tests- active knee extension test and standard sit and reach test was done after explaining the whole procedure to the participants. Active knee extension test was done placing the participants in supine position, then they were instructed to flex their hip till 90 degrees which was fixed in place. They were asked to extend their knees in this position till the point of discomfort. Knee flexion angle was measured in this position. 20 degrees was kept as the minimum range for inclusion. Standard sit and reach test was performed with the participants in long sitting with feet in neutral position with the box placed at the end. The participants were asked to lean forward with their arms straight and the distance was being measured. Range <24 cms was considered as hamstring tightness.

Group A was given PNF Hold-Relax stretching technique. Position of participants was in sitting position. Participants in sitting position placed their leg on a plinth in front which was shorter than the height of their chair. The knee was kept extended and foot was pointed toward the ceiling to avoid hip rotation. Participants flexed their trunk down toward the table (trunk + hip flexion) until their hamstrings were stretched to the point of discomfort. They sustained the stretching position for 5 seconds. They were then instructed to push their heel

into the table (to contract the hamstrings) for 5 seconds using maximum effort. Then leaning their trunk further toward the table and holding the new position for 5 seconds. A 10-second break was permitted between every three repetitions. The procedure was carried out for 8 minutes.

**Fig 1**

Group B was given Foam Roller Exercise. Position of participants – sitting position. The participants were instructed to perform rolling of the foam roller along the hamstrings from the ischial tuberosity to the posterior knee. During rolling the participants were instructed to maintain terminal knee extension and use arms for support. There was a rest of 10 seconds after every minute. The procedure was carried out for 8 minutes per session.

**Fig 2**

The intervention was carried out for 3 weeks. AKE test and standard sit and reach test was measured after the termination of the treatment.

**Statistical analysis**

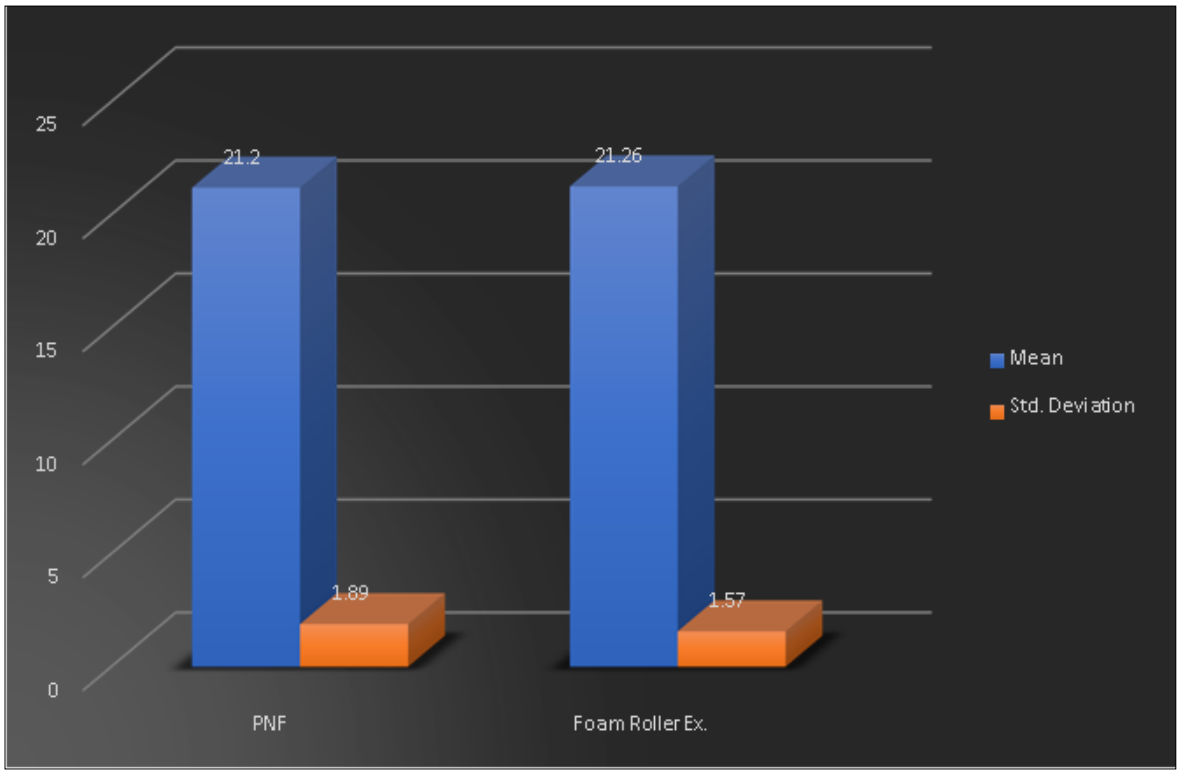
Data analysis was performed using the level of significance of AKE test and standard sit and reach test for hamstring flexibility was measured using paired t-test and unpaired t-test.

**Group A:** Paired t-test was done to compare values within the group, pre-treatment and post- treatment values.

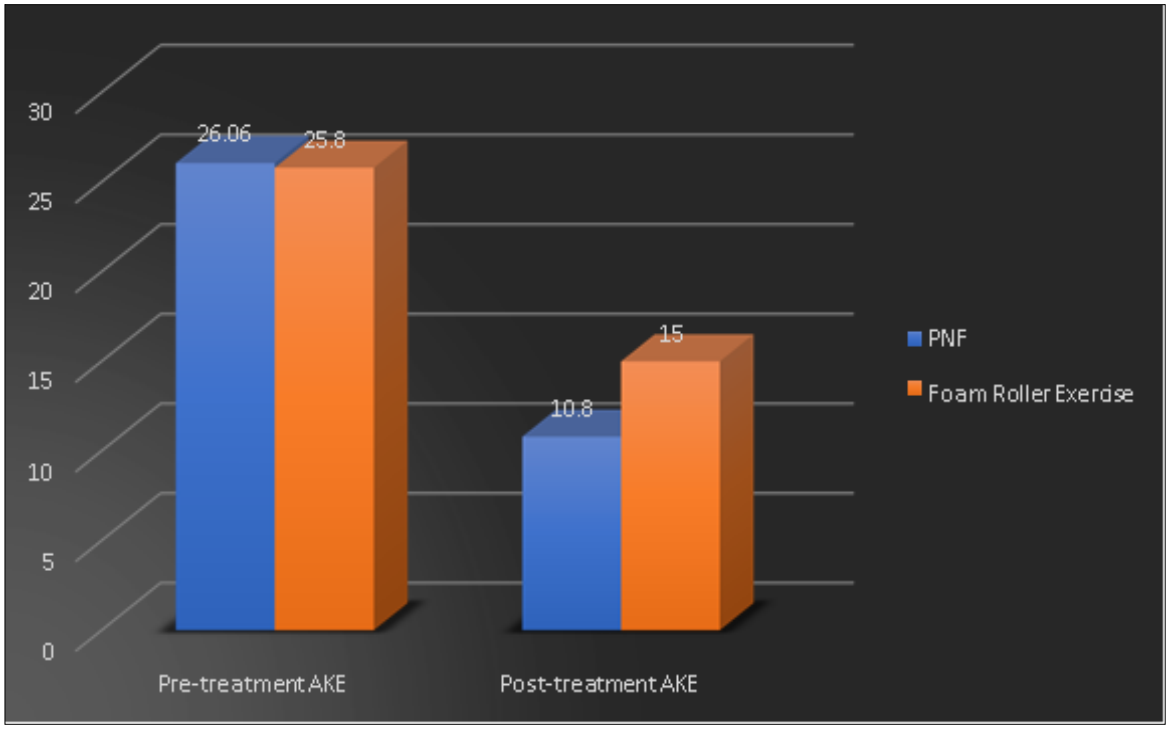
**Group B:** Paired t-test was done to compare values within the group, pre-treatment and post- treatment values.

**Group A & B:** Unpaired t-test was done to compare values between the groups, pre- treatment and post-treatment values of both groups with each other.

**Results**

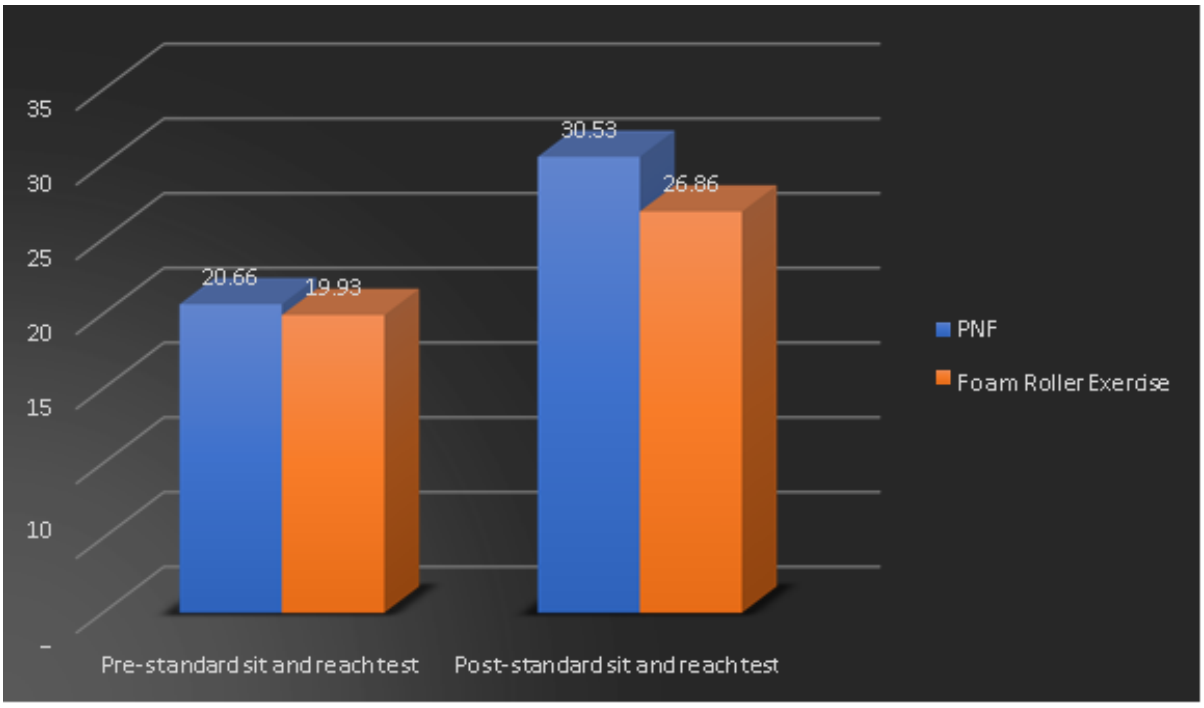



**Graph 1:** Bar diagram representing average age of participants




**Inference:** This graph shows pre-treatment and post-treatment AKE test values comparing both the groups.

**Graph 2:** Bar diagram representing comparison of mean values of AKE score in pre and post treatment




**Inference:** This graph shows pre-treatment and post-treatment standard sit and reaach test values comparing both the groups.

**Graph 3:** Bar diagram representing comparison of mean values of standard sit and reach test score in pre and post treatment

**Table 1:** Descriptive statistics of participants receiving PNF and Foam Roller Exercise on hamstring flexibility via knee flexion angle measured by AKE test and standard sit and reach test and its comparison using paired t test

| Group | Outcome measure | N | Mean | Std. Deviation | t value | P value |
|---|---|---|---|---|---|---|
| PNF | Pre AKE score | 15 | 26.06 | 1.38 | 21.97 | <0.0001 |
| | Post AKE score | 15 | 10.08 | 2.30 | | |
| | Pre- Standard sit and reach score | 15 | 20.66 | 1.71 | 11.55 | <0.0001 |
| | Post- Standard sit and reach score | 15 | 30.53 | 2.82 | | |
| Foam Roller Exercise | Pre AKE score | 15 | 25.8 | 1.47 | 17.67 | <0.0001 |
| | Post AKE score | 15 | 15 | 1.85 | | |
| | Pre- Standard sit and reach score | 15 | 19.93 | 1.94 | 10.91 | <0.0001 |
| | Post- Standard sit and reach score | 15 | 26.86 | 1.50 | | |

**Inference:** This table shows pre-treatment and post-treatment values within both the groups depicting that both the treatment techniques were effective.

**Table 2:** Descriptive statistics of subjects receiving PNF Hold-Relax stretching technique on hamstring flexibility via AKE score and standard sit and reach score and its comparison using unpaired t test.

| Outcome measure | Group | N | Mean | Std. Deviation | t value | P value |
|---|---|---|---|---|---|---|
| Pre AKE | PNF | 15 | 26.06 | 1.38 | 0.49 | 0.62 |
| | Foam Roller Exercise | 15 | 25.8 | 1.47 | | |
| Post AKE | PNF | 15 | 10.8 | 2.30 | 5.51 | <0.0001 |
| | Foam Roller Exercise | 15 | 15 | 1.85 | | |
| Pre – Standard Sit and Reach test | PNF | 15 | 20.66 | 1.71 | 1.09 | 0.28 |
| | Foam Roller Exercise | 15 | 19.93 | 1.94 | | |
| Post – Standard Sit and reach | PNF | 15 | 30.53 | 2.82 | 4.45 | 0.0001 |
| | Foam Roller Exercise | 15 | 26.86 | 1.50 | | |

**Inference:** This table shows pre-treatment and post-treatment values within both the groups depicting that PNF group showed better results than Foam Roller group.

**Discussion**

The purpose of this study was to compare the effectiveness of proprioceptive neuromuscular facilitation hold-relax stretching technique and foam roller exercise on hamstring muscle flexibility in college going students. In this study, the values of pre- treatment and post treatment Proprioceptive Neuromuscular Facilitation (PNF)

Hold-Relax stretching technique and Foam Roller Exercise were analysed, it was statistically proven that there is significant improvement in both Proprioceptive Neuromuscular Facilitation Hold-Relax stretching technique and Foam Roller Exercise. When comparison was done between the groups, from both the techniques Proprioceptive Neuromuscular Facilitation Hold-Relax stretching technique was proved more significant.

After informed consent a total of 30 subjects were recruited in the study according to the inclusion and exclusion criteria. They were divided in two groups with 15 in each group by simple random sampling technique. Pre-treatment tests were done which were active knee extension test and standard sit and reach test was done after explaining the whole procedure to the participants. Active knee extension test was done placing the participants in supine position, then they were instructed to flex their hip till 90 degrees which was fixed in place. They were asked to extend their knees in this position till the point of discomfort. Knee flexion angle was measured in this position. 20 degrees was kept as the minimum range for inclusion. Standard sit and reach test was performed with the participants in long sitting with feet in neutral position with the box placed at the end. The participants were asked to lean forward in this position with their arms straight and the distance was being measured. Range <24 cms was considered as hamstring tightness.

The intervention was carried out for 3 weeks. AKE test and standard sit and reach test was measured after the termination of the treatment. The mean of the pre and post values were compared using a Paired T test for intra-group results and an Unpaired T test for inter-group result. The results were found to be extremely significant within the groups (<0.0001 and <0.0001) respectively and significant in between the PNF and Foam Roller groups (<0.0001 and 0.0001) respectively, suggesting both the techniques have treatment effects and PNF group showed better results than Foam Roller group. The study was done over a period of 3 weeks consisting 12 sessions in all.

PNF stretching techniques act on the Golgi tendon organ which relaxes the muscles after a sustained contraction is applied to it. Autogenic inhibition is facilitated by the hold phase (isometric contraction) and contract phase (concentric contraction) used immediately before the relax phase (stretch). The PNF Hold-Relax stretching technique increases the joint range of motion by performing voluntary muscle contraction and promoting muscle relaxation and then stretching to decrease the reflexive components which cause muscle contraction.

Soni S, *et. al.* 2020 Jan 22;8(12). conducted a study on Effectiveness of PNF Stretching Versus Static Stretching In Healthy Individuals With Hip Adductor Tightness and concluded that PNF stretching proved better than static stretching.

Junker DH, *et. al.* 2015 Dec 1;29(12):3480-5 conducted this study to compare the effectiveness of the foam roll myofascial release with a conventional contract-relax proprioceptive neuromuscular facilitation (PNF) stretching method and a control group. The study concluded that the foam roll can be seen as an effective tool to increase hamstring flexibility within 4 weeks. The effects could be compared with the scientifically proven contract-relax PNF stretching method.

A study performed by McDonald, *et al*. to evaluate the effect of an acute bout of self- myofascial release on quadriceps using foam roller on ROM, resulted significantly. The proposed theory behind increase in range of motion was that there will be significant changes in the thixotropic property after application of heat or mechanical stress. Foam rolling provides with enough mechanical stress to fascia encasing the muscle.

Roylance, *et al*. who performed a study to compare the effectiveness of static stretching and postural alignment exercises when given with and without foam roller, the group which received foam roller in conjunction with static stretching and postural alignment exercises had shown improvements in the joint range of motion also explained this mechanism The fascia which remains thick and more viscous when kept undisturbed, softens and becomes more gel like following the application of a foam roller.

Foam rolling is thought to release myofascial adhesions that restricts the muscle from lengthening and allowing full range as it mechanically breaks down the cross-links and changes its state from a more thickened (viscous) state to a more liquid (gel like) state as well as increase the soft tissue compliance.

Myofascial release acts by facilitating stretch into the restricted fascia. It removes tightness and restrictions that impede full range of motion. The improvement seen is due to a shearing of cross-links and a change in the viscosity of the ground substance. The change in viscosity leads to increase in the production of hyaluronic acid and thereby, increases the glide of the fascial tissue.

Stovern O, *et. al.* conducted this study in order to evaluate the effect of training of foam rolling on ankle and knee range of motion, hamstring flexibility, agility, and vertical jump height. The study concluded as six weeks of foam rolling had a positive effect on hamstring flexibility and did not negatively affect agility or vertical jump height.

Jung J, *et. al.* 2017 Mar 30;6(1):45-51 conducted this study with the aim to identify the area with greatest effect by self-myofascial release technique (self-MFR) in the hamstring, suboccipital, and plantar regions. The study concluded that indirect application based on the anatomy trains could be effective for those who need to improve muscle flexibility.

Moreover, self-MFR easily removes myofascial pain while maintaining flexibility, and can be performed at any time and place.

Laura Deguzman *et. al.* conducted a study, The Immediate Effects of Self-administered Dynamic Warm-up, Proprioceptive Neuromuscular Facilitation, and Foam Rolling on Hamstring Tightness to compare the immediate effects of three stretching techniques on hamstring tightness, as measured by passive knee extension angle. The study resulted in PNF intervention eliciting a greater improvement in knee extension angle compared to the foam

rolling intervention, but not when compared to the dynamic warm-up intervention. And also explained as PNF is thought to effectively increase the knee extension angle via two underlying mechanisms: mechanical and neural. In the hold-relax technique, hamstring relaxation is elicited by autogenic inhibition by actively extending the knee against resistance. Later, the hamstrings are stretched. The increases in joint range of motion due to dynamic warm-up exercises are thought to be achieved by creating an exercise-induced increase in blood flow and local tissue temperature, which results in greater muscle and tendon extensibility. Similar to PNF, dynamic warm-ups also include a neural aspect because some of the exercises may incorporate reciprocal inhibition mechanism. As explained regarding foam roller exercises, foam rolling is thought to release myofascial adhesions that may restrict the muscle from lengthening and allowing full joint motion. Thus, immediate improvements in range of motion following foam rolling may be attributed to a release of myofascial restrictions. Myofascial restrictions cannot be evaluated via musculoskeletal evaluation process, patients with myofascial adhesions should theoretically show an increase in range of motion after foam rolling, whereas those without myofascial adhesions will not. According to previous studies, it was concluded that PNF Stretching was much more effective than Foam Roller Exercise as well as it remained less effective due to ceiling effect after carrying out exercise for 8 min daily. According to the present study, PNF is more effective than foam roller, as the protocol of the study was for 3 weeks, and for foam roller duration was kept 8 min similar to the previous studies. So, due to ceiling effect and less study duration, Foam Roller Exercise didn't show any significant difference in regard with PNF stretch in pre-test and post-test result, whereas PNF due to its neural and mechanical mechanisms working at receptor level that is Golgi tendon worked effectively in increasing muscle flexibility and hence showed significant difference in regard with foam roller in pre- test and post-test result, hence this study concludes PNF Hold-Relax stretching technique is more effective than Foam Roller Exercise.

**Conclusion**

This study supported the alternate hypothesis i.e., PNF Hold- Relax stretching technique was more effective than Foam Roller exercise on improving hamstring flexibility in college going students. Foam Roller exercises also showed significant improvement in hamstring flexibility.

**Clinical Implication**

According to the therapist proprioceptive neuromuscular facilitation (PNF) hold-relax stretching technique and foam roller exercise both of the techniques have shown treatment effects over hamstring flexibility. PNF Hold-Relax stretching technique has shown to have more effects compared to Foam Roller Exercise. Hence both the techniques can be clinically be applicable to the patients.

**Limitation and Suggestion**

- Limitation of this study was a small sample size.
- There was small duration of treatment per session
- Further study may include a larger sample, longer duration of treatment per session and include both the gender as well.

**References**

1. Thakur D, Rose S. A Study To Find Out The Correlation Between The Right And Left Hamstring Length In Both Genders To Determine The Prevalence Of Hamstring Tightness Among College Students. Journal of Health and Allied Sciences NU,2016:6(04):46-52.
2. Junker DH, Stöggl TL. The foam roll as a tool to improve hamstring flexibility. The Journal of Strength & Conditioning Research,2015:29(12):3480-5.
3. Nagarwal AK, Zutshi K, Ram CS, Zafar R, Hamdard J. Improvement of hamstring flexibility: A comparison between two PNF stretching techniques. International journal of sports science and engineering,2010:4(1):25-33.
4. Koli BK, Anap DB. Prevalence and severity of hamstring tightness among college student: a cross sectional study. Int J Clin Biomed Res,2018:4(2):65-8.
5. Khan S, Kanpariya H, Nanda D. Comparison of Immidiate Effect of Hold-Relax Proprioceptive Neuromuscular Facilitation and Foam Roller Exercise on Tight Hamstring Muscle in School Going Children"-An Experimental Study. Indian Journal of Physiotherapy & Occupational Therapy, 2020, 13(1).
6. Agre S, Agrawal R *et al*. conducted this study to compare the effect of foam roller with static stretching and static stretching only on hamstring muscle length in football players, 2016.
7. Shakya NR, Manandhar S. Prevalence of hamstring muscle tightness among undergraduate physiotherapy students of Nepal using passive knee extension angle test. Int J Sci Res Pub,2018:8(1):182-7.
8. Deguzman L, Flanagan SP, Stecyk S, Montgomery MM. The immediate effects of self- administered dynamic warm-up, proprioceptive neuromuscular facilitation, and foam rolling on hamstring tightness. Athletic Training and Sports Health Care,2018:10(3):108-16.
9. Pradip B, Sudhir B, Nidhi B. Prevalence of tightness in hip muscles in middle aged Indian men engaging in prolonged desk jobs: A descriptive study,2018:5(2):15-21.
10. Mondal M, Sarkar B, Alam S, Das S, Malik K, Kumar P. Prevalence of piriformis tightness in healthy sedentary individuals: a cross-sectional study. IJHSR,2017:7(7):134-42.

11. Valdivia OD, Ortega FZ, Rodríguez JJ, Sánchez MF. Changes in flexibility according to gender and educational stage. Apunts: Medicina de l'esport, 2009, 10-7.
12. Davis DS, Quinn RO, Whiteman CT, Williams JD, Young CR. Concurrent validity of four clinical tests used to measure hamstring flexibility. The Journal of Strength & Conditioning Research,2008:22(2):583-8.
13. Mane A, Yadav T. Prevalence of Iliotibial Band Tightness in Prolonged Sitting Subjects. Indian Journal of Public Health Research & Development,2020:11(5):44-8.
14. Victoria GD, Carmen EV, Alexandru S, Antoanela O, Florin C, Daniel D. the PNF (Proprioceptive Neuromuscular Facilitation) Stretching Technique-A Brief Review. Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health,2013:2:13.
15. Soni S, Patel P, Barot P. Effectiveness of PNF Stretching Versus Static Stretching In Healthy Individuals with Hip Adductor Tightness: A Randomized Clinical Trial. International Journal of Scientific Research,2020:8(12):21.
16. Kandalkar N, Warude T, Pawar A, Godse A, Savsaviya K. Effect of PNF Stretching and Foam rolling Exercises in Patellofemoral Pain Syndrome. Indian Journal of Public Health Research & Development,2019:10(5):59-63.
17. Jung J, Choi W, *et. al.* Immediate effect of self-myofascial release on hamstring flexibility. Physical Therapy Rehabilitation Science,2017:6(1):45-51.
18. Stovern O, Henning C, Porcari JP, Doberstein S, Emineth K, Arney BE, Foster C. The Effect of Training with a Foam Roller on Ankle and Knee Range of Motion, Hamstring Flexibility, Agility, and Vertical Jump Height.
19. Baltaci G, Un N, Tunay V, *et. al.* Comparison of three different sit and reach tests for measurement of hamstring flexibility in female university students. Br J Sports Med,2003:37:59-61.
20. The active knee extension test and Slump test in subjects with perceived hamstring tightness Kate Elissa Kuilart*, Melanie Woollam, Elizabeth Barling, Nicholas Lucas School of Exercise and Health Sciences, University of Western Sydney, 2005