ijlpr 2020; doi 10.22376/ijpbs/lpr.2021.11.3.L43-49

International Journal of Life science and Pharma Research

ISSN 2250-0480

Research Article

Physiotherapy

A Comparative Study on Efficacy of Ballistic Stretching Versus Modified Hold Relax Technique in Increasing Hamstring Flexibility

Dr. Abhijit Dutta

Associate Professor, Associate Dean, Faculty of Paramedical Sciences, and Assam down town University, Assam, India

Abstract: In the literature, the terms "flexibility" and "muscle length" are often used synonymously when referring to the ability of muscles to be lengthened to their end range. The flexibility of the hamstring muscle is important in the prevention of injury, muscular and postural imbalance and maintenance of a full range of joint movement optimal musculoskeletal function and enhanced performance in day-to-day activities. To evaluate the comparative effectiveness of modified hold-relax technique and ballistic stretching for increasing hamstring flexibility in football players. To evaluate the comparative effectiveness of modified hold-relax technique and ballistic stretching for increasing hamstring flexibility in football players. This study includes (N=50) subjects with hamstring tightness within the age group of 18-28 years. They were randomly assigned into 2 groups (Group A and B). Group A had 25 (N=25) subjects who are treated with Modified hold- relax stretching, Group B had 25 (N=25) who are treated with ballistic stretching. The subjects were given intervention 3 sessions per week for 4 weeks. ANOVA one way classification was used to compare between and within the groups. Test within the subject of effect is highly significant for both the groups. Each group has p=0.000. Test between the subjects were used to compare between the groups, it showed highly significant p=0.000. But clinically modified hold- relax is superior to ballistic stretching. The findings suggest that modified hold- relax and ballistic stretching both was statistically significant in improving hamstring flexibility. But modified hold- relax technique showed better results compared to ballistic stretching.

Keywords: Hamstring, Modified hold- relax, Ballistic stretching, Flexibility.

***Corresponding Author**

Dr. Abhijit Dutta , Associate Professor, Associate Dean, Faculty of Paramedical Sciences, and Assam down town University

Recieved On 06 March 2021
Revised On 06 May 2021
Accepted On 11 May 2021
Published On 19 May 2021

Funding This Research did not receive any specific grant from any funding agencies in the public, commercial or not for profit sectors.

Citation Dr. Abhijit Dutta , A Comparative Study on Efficacy of Ballistic Stretching Versus Modified Hold Relax Technique in Increasing Hamstring Flexibility.(2021).Int. J. Life Sci. Pharma Res.11(3), 43-49 http://dx.doi.org/10.22376/ijpbs/lpr.2021.11.3.L43-49

1. INTRODUCTION

In this study the term Flexibility and Muscle length are often used and both these terms have the meaning i.e it is the capacity of muscles to be lengthened to their end rang.[1] The flexibility of the hamstring muscle is important in the prevention of injury, muscular and postural imbalance and maintenance of full range of joint movement optimal musculoskeletal function and enhanced performance in day-to-day activities.[2]The hamstring strain is a condition well recognised by medical personnel, coaches, and athletes.[3,4,5] Such injuries are a major cause of time lost from sport.[6] Hamstring strains are among the most common injuries in sport and are most often observed in sports that involve sprinting and jumping.[7]Hamstring muscles are the muscles at the back of the thigh comprising the long head of the bicep femoris, the semitendinosus and the semimembranosus muscles.[8] Hamstring muscles arises from ischial tuberosity act across both hip and knee joints and are innervated by the tibial nerve.[9] Hamstring muscle injuries are one of the most common musculotendinous injuries in lower extremity.[10] Decreased hamstring flexibility is a risk factor for development of patella tendinopathy and patella-femoral pain, hamstring strain injury.[11] Recurrent hamstring injuries develop in more than 30% of athletes, with most occurring during the ensuing sporting season.[12] The initial Football Association Audit of Injuries study found that 12% of all injuries reported over two seasons were hamstring strains, this being the most prevalent injury.[13] Players were 2.5 times more likely to sustain a hamstring strain than a quadriceps strain during a game.[14]The causes of a hamstring strain are complicated and multifactorial, involving muscle strength imbalance, inadequate warm-up, lack of flexibility, muscle fatigue, and previous strain/inadequate rehabilitation.[15] The hamstrings are an example of the muscle groups that has a tendency to shorten . Lack of hamstring flexibility was the single most important characteristic of hamstring injuries in athletes.[16] Increasing hamstring flexibility can play an important role in preventing lower extremity overuse injuries. [17] Inadequate muscular flexibility has been cited as one possible cause of hamstring injury. Other contributing factors for hamstring injury include lack of hamstring strength, inadequate warm-up, and muscle fatigue.[15,17,18] Athletes with a history of hamstring injury have significantly less hamstring flexibility than their uninjured counterparts and are prone to recurrence of hamstring injuries.[19] Therefore, the identification of simple therapeutic regimens capable of increasing hamstring flexibility may reduce the chance for injury of athletes with low levels of hamstring flexibility or a history of a hamstring injury.[20] Flexibility is an intrinsic property of the body tissues that determines the range of motion achievable without injury at a joint or group of joints.[21]Flexibility can be enhanced by simple, non-surgical procedures like stretching the shortened muscles.[22] It has been suggested that stretching may acutely improve flexibility by reducing musculotendinous stiffness. Flexibility exercises are designed to increase tissue elasticity, thereby increasing the range of motion (ROM) of specific joints.[15,19] Increased ROM is believed to both enhance athletic performance and decrease the severity and frequency of injuries[23] To evaluate the comparative effectiveness of modified hold-relax technique and ballistic stretching for increasing hamstring flexibility in football players. Modified Hold Relax technique is hold relax is a technique of facilitating normal muscle sensation and muscle awareness. It is often applied when there is muscle tightness. It is a relaxation technique to obtain a lengthening reaction of muscle whose action is an antagonist to movement limited in range, it means an increasing range of movement in joints, it is effective, simple and pain-free.[8] ballistic stretching is characterized by the use of vigorous and rhythmic movement of a body segment throughout this range of motion in order to lengthen a muscle or muscle group.[9] Movements produced to perform the ballistic stretching can lead to a warming up of the body musculature. The increase of muscle temperature during strain can produce a decrease in viscosity of tissues and rectify the undulations of collagen.[24] Various studies have been done using a modified hold-relax stretching techniques for increasing hamstring flexibility and have concluded modified hold-relax as an effective stretching technique for increasing hamstring flexibility. Studies have also been done using a ballistic stretching technique for increasing hamstring flexibility in football players and have shown significant improvement with ballistic stretching. So far, there are limited studies done on comparison between both techniques. So, this comparative study is needed to see which technique give better results with greater sample size, with male subjects and increased stretching time for improving hamstring flexibility in football players.

2. METHODOLOGY

2.1 Subject

- Sample size: 50 subjects were included in this study.
- Source of sample: a subject with hamstring tightness from college football players of Assam Downtown University.
- Study population: cases of hamstring tightness.
- Sampling design: convenient sampling

2.2 Study Area

Department of physiotherapy, ADTU, Panikhaiti, Guwahati-26, Assam, India.

2.3 Study Design

Comparative study design with pre-and post- treatment.

2.4 Inclusion Criteria

1. Age group 18-28 years.
2. Gender-male.
3. Subject with hamstring tightness (20-40 degrees active knee extension loss with hip in 90-degree flexion).[25,26]
4. Subjects who stop hamstring stretching for two months.
5. Irregular players.
6. Subjects who are able to comprehend comments and willing to participate in the study.

2.5 Exclusion Criteria

Subjects involving in any other physical fitness program in the last six months.[27]

1. Neuromuscular disorders.
2. Cardiovascular disorders.

2.6 Regular players

2.6.1 Study Variables

Independent variables:

Modified hold relax stretching
Ballistic stretching

Dependent variables:

Sit and reach test
Active knee extension test

2.7 Materials Used

- Sheets of paper
- Towels
- Pen
- Stopwatch
- Universal goniometer
- Sit and reach box
- Strapper
- Mat
- Plinth/couch

2.8 Outcome Measures

- Active knee extension test (AKET)
- Sit and reach test (SRT)

2.9 Protocol

50 subjects were assigned into two groups 25 in each group and subjects were selected by convenient sampling method on the basis of inclusion criteria. Group A- Subjects received modified hold- relax technique. Group B- Subjects received ballistic stretching. The post-intervention measurement for the same was taken after the completion of 4 weeks of treatment, that is, at the end of the study.

2.10 Conventional Therapy

Slow jogging as warm-up for both the groups for 3 minutes. Each subject was measured for flexibility by using sit and reach test using sit and reach the box and active extension test by using a universal goniometer. Day 0 - i.e before the exercise started. Day 28 – that is, at the end of the treatment.

2.11 Duration of The Treatment

10 minutes ideal for the stretch without injuring and making the muscle fatigue

2.12 Modified Hold - Relax Technique

5 cycles of 20 repetitions of modified hold- relax stretching was given: 3 times a week for 4 weeks.

2.13 Ballistic Stretching

5 cycles of 20 repetitions of ballistic stretching was given: 3 times a week for 4 weeks.

2.14 Procedure

2.14.1 Modified Hold Relax Techniques

Position of the subject- Supine lying position Therapist position- Stand by the side of the subject With hip and knee, 90 degrees flexion and a therapist then stretch the hamstring passively until the subjects felt and reported a mild stretch sensation in that position the subject was then asked to contract for 20 seconds and then relax for 10 seconds. After 1 set the subject was given rest for 30 seconds. 5 sets of 20 repetitions were performed.

2.14.2 Ballistic Stretching

Subject position- Supine lying position Therapist position - Stand by the side of the subject Flexion extension movements of the hip with knee kept in full extension, the movements were performed by the therapist with the fastest speed as possible, respecting the limit of each volunteer.5 cycles of 20 repetitions with 30 seconds interval between them.

2.14.3 Conventional Therapy

3 minutes of slow jogging for both the group as warm-up exercise.

3. STATISTICAL ANALYSIS

Statistical analysis was done using statistical software namely, SPSS 22.00 version, Microsoft Word and Excel have been used to generate graphs tables, etc. A total no. of 50 (n=50) subjects were taken for the study. Improvements in the hamstring flexibility using Active Knee Extension test (Goniometer) and Sit and Reach Test (sit and reach box) from baseline to the last follow-up were measured by computing change scores for each group and taking the group mean, as well as by computing change in each outcome variable between groups. Repeated Measures of ANOVA with one-way classification using multivariate tests were used to assess the statistical significance of the change score. A .05% of probability was adopted as the level for the statistical significance. Degrees of Freedom Df = n

4. RESULTS

Table-1. Age Wise Distribution Among The Group

Group	N	Mean	Std. Deviation	Minimum	Maximum
Group-1	25	22.76	1.94	22.61	22.91
Group-2	25	22.68	2.43	22.49	22.88

According to the data analysis, the mean age in group 1 was 22.76 years with a standard deviation of 1.94 and in group 2 mean ages were 22.68 years with a standard deviation of 2.43.

Table - 2intragroup comparison of pre treatment and post treatment for AKET for group-1					
Group	**N value**	**Mean**	**Standard error mean**	**Standard deviation**	**P value**
PRE- TESTRIGHT LEG	25	19.44	0.26475556	6.62	
POST- TEST RIGHT LEG	25	53.99	0.16123369	4.03	<0.001
PRE- TEST LEFT LEG	25	19.69	0.29501828	7.37	
POST- TEST LEFT LEG	25	54.14	0.167696467	4.19	<0.001

The result proves that there is highly significant improvement in hamstring flexibility from the pre- treatment to the post treatment value for AKET when patients were treated with modified hold-relax technique

Table – 3 intragroup comparison of pre and post treatment for AKET for group-2					
Groups	N value	Mean	Standard error mean	Std. Deviation	P value
PRE- RT LEG	25	23.89	0.280158	7.0039	<0.001
POST –RT LEG	25	34.702	0.153841	3.846	
PRE- LT LEG	25	23.9296	0.287804	7.1950	<0.001
POST- LT LEG	25	34.7032	0.152362	3.809	

The result proves that there is highly significant improvement in hamstring flexibility from the pre- treatment to the post treatment value for AKET when patients were treated with ballistic stretching technique

Table- 4.intragroup comparison of pre treatment and post treatment for SRT for group-1					
Groups	N value	Mean	Standard error mean	Std. Deviation	P value
PRE- RT LEG	25	18.596	0.156458514	3.91146	
POST- RT LEG	25	41.0624	0.088288639	2.2072	<0.001
PRE- LT LEG	25	18.596	0.156458514	3.91146	
POST- LT LEG	25	41.0624	0.088288639	2.20721	<0.001

The result proves that there is highly significant improvement in hamstring flexibility from the pre- treatment to the post treatment value for SRT when patients were treated with modified hold- relax technique.

Table - 5intragroup comparison of pre treatment and post treatment for SRT for group- 2					
Groups	**N value**	**Mean**	**Standard error mean**	**Standard deviation**	**P value**
PRE- RT LEG	25	20.7692	0.154807	3.87017	
POST- RT LEG	25	27.0804	0.102039	2.5509	<0.001
PRE- LT LEG	25	20.7692	0.154807	3.8701	
POST- LT LEG	25	27.0884	0.102039	2.5509	<0.001

The result proves that there is highly significant improvement in hamstring flexibility from the pre- treatment to the post treatment value for SRT when patients were treated with modified hold- relax technique.

Table- 6 inter-group comparison of post treatment values for AKET between group-1 and group- 2						
Groups		**N value**	**Mean**	**Standard error mean**	**Standard deviation**	**P value**
GROUP-1	POST- RT LEG	25	53.9832	0.161234	4.030842261	
	POST- LT LEG	25	54.1436	0.167696	4.192411677	<0.001
GROUP-2	POST- RT LEG	25	34.702	0.153841	3.846035838	
	POST- LT LEG	25	34.7032	0.152362	3.809055789	<0.001

The result proves that in both the groups there is a significant improvement in hamstring flexibility from the post-treatment value in-between group 1 and group 2 when measured by AKET but when compared between the post mean values and standard deviation values Group 1 shows more highly significant as compared to Group 2. That is a group who received modified hold- relax stretching shows highly significant as compared to Group-2 who received ballistic stretching.

Table – 7 Inter-Group Comparison of Post Treatment For SRT Between Group-1 And Group- 2						
Groups		**N value**	**Mean**	**Standard mean error**	**Standard deviation**	**P value**
GROUP-1	POST- RT LEG	25	41.0624	0.088289	2.207215969	
	POST- LT LEG	25	41.0624	0.088289	2.207215969	<0.001
GROUP-2	POST- RT LEG	25	27.0884	0.102039	2.550969881	
	POST- LT LEG	25	27.0884	0.102039	2.550969881	<0.001

The result proves that in both the groups there is significant improvement in hamstring flexibility from the post treatment value in between group 1 and group 2 when measured by AKET but when compared between the post mean values and standard deviation values Group 1 shows more highly significant as compared to Group 2.

5. DISCUSSION

Comparing the mean values and the standard deviation values for both the groups, group A which is modified hold-relax grouphad initial mean and standard deviation values for AKET was 19.436 ± 6.618889 for the right leg and 19.6892 ± 7.375457 for left leg and has improved to 53.9832 ± 4.030842 for right leg and to 54.1436 ± 4.192412 for left leg, and for SRT initial values was 18.596 ± 3.911462855 for both right and left leg and has improved to 41.0624 ± 2.207215969 after 4 weeks of treatment. The result for group B, which is ballistic stretching, initial mean values for AKET are 23.89 ± 7.003941152 for left leg and 23.9296 ± 7.195088881 for the right leg and has improved to 34.702 ± 3.846035838 for left leg and 34.7032 ± 3.809055789 for right leg after 4 weeks of stretching, the initial values for SRT was 20.7692 ± 3.870173252 for both right and left leg and has improved to 27.0884 ±2.550969881 after 4 weeks of stretching. These findings go along with the previous results of Davis, Ashby, McCale, McQuain, and Wine which concluded that there is a significant increase in hamstring flexibility after 4 weeks of modified hold relax but not with static stretching intervention.[28] Gauri Shankaret al, in their comparative study, found that modified hold relaxation is more effective because the isometric muscle action completed immediately before the passive stretch which help to achieve autogenic inhibition - a reflex relaxation that occurs in muscle where the Golgi tendon organ is stimulated. Modified hold-relax stretching improves flexibility through relaxation of the contractile component of the muscles. Scott Spernoga et al, found that the sequence of 5 modified hold relaxes stretching produced significant increase in hamstring flexibility.[29] In this study, modified hold relax protocol has been used for Group 1 subjects and shows that modified hold relax increases in hamstring flexibility in football players[11], this is consistent with Sharman Malanie who found that proprioceptive neuromuscular facilitation produces superior ROM.[30] The immediate flexibility gain can be explained by the viscoelastic properties of the muscle. This property is a response of the muscle-tendon unit to stretching with a fixed length, which generates a decrease in stress over time.[24,30] This reduced length of the muscle-tendon unit is known as stress relaxation and allows a deformed muscle-tendon unit more easily in the next repetition, thus providing greater flexibility.[24] Another explanation found is based on the increased tolerance of the muscle-tendon unit to elongation, although this mechanism is still unknown.[24] Previous studies have compared various forms of PNF to interventions to increased hamstring flexibility using stretching interventions performed over multiple weeks. Prentice j. et alshowed significant increases in hip flexibility for 10 weeks of slow-reversal-hold PNF techniques over an SS intervention.[16] House RW et aldid a comparative study of ART versus modified hold relax PNF to find out the difference in hamstrings flexibility in 34 healthy subjects treated two times per week for 2 weeks.[28] They concluded that modified hold relax PNF demonstrated greater improvement in hamstring flexibility than ART at 10 days follow-up.[16,28] In this study the other subjects in Group 2, ballistic stretching was given for increasing hamstring flexibility and from the data analysis, the result showed that ballistic stretching produced a significant increase in hamstring flexibility. This may offer some support to the findings of Mary Hellen Morcelliet al, who found that after applying ballistic and contract-relax stretching techniques there was an increased in the flexibility of the hamstring muscles. The data corroborate the findings of other studies on the implementation of stretching protocols to increase the flexibility of the hamstring muscles.[24] Nelson and Kokkonen have reported a 9% improvement in the sit-and-reach test after passive ballistic stretching.[17] SRT also shows good reliability to assess the flexibility of hamstring muscles.[20] Concerning to gains of flexibility that were observed after the application of ballistic stretching, the literature reports that movements produced to perform the ballistic stretching can lead to a warming up of the body musculature.[24,31] The increase of muscle temperature during strain can produce a decrease in viscosity of tissues and rectify the undulations of collagen.[24] Very few studies have been done on ballistic stretching for hamstring muscles. This type of stretching may be beneficial for athletes, it carries a risk of injury.[31] Ballistic stretching is generally not recommended for normal people who are not active in sports.[31] Florida-based physician assistant Stephanie Mazal explains that this is because there is a risk of straining or pulling a muscle.[31]According to Chaoj, stretching movements that are too forceful can damage the soft tissues around the joints, such as ligaments.[35] This can develop into tendonitis, Over time, even small muscle tears can lead to reduced flexibility and movement.[31,32] However, ballistic stretching may be helpful to some people as long as it's done correctly.[24,31,32] A study in the British Journal of sports medicine found that ballistic stretching was better than static stretching at improving hamstring flexibility in people with tight hamstrings.[31] In this study, slow jogging was advised to the subjects before the stretching technique was given as warm-up exercised. Warm-up before stretching for athletic activity often includes both stretching and warm-up, making it difficult to assess their independent effects on injuryprevention.[33,34] Sharma et al. reported stretching along with warming up is an effective way to improve hamstring flexibility.[11]A summary of 22 clinical studies in the 1950s and 1960s found that flexibility and performance(especially strength and speed) in a number of sporting activities improved after warm-up, especially when stretching was vigorous, sustained, and related to the activity to be undertaken, and subsequent studies found similar results.[33,34]

6. CONCLUSION

On the basis of the results, it can be concluded that the present study provided evidence to support the use of a physical therapy regimen for hamstring tightness in the form of stretching for improvement of hamstring flexibility in terms of AKET (Goniometer), SRT (sit and reach box) for measuring of hamstring flexibility respectively. In addition, results support that both modified hold- relax stretching and ballistic stretching showed improvement statistically after 4 weeks of stretching. But, when compared with each other, modified hold- relax stretching showed more improvement in hamstring flexibility as compared to ballistic stretching. Hence, both modified hold- relax technique and ballistic stretching can be used effectively for increasing hamstring flexibility.

6.1 LIMITATIONS OF THE STUDY

The study did not include follow up. Thus results can't tell us about the effectiveness of both the intervention in long term. Small sample size.

7. CONFLICT OF INTEREST

Conflict of interest declared none

8. REFERENCES

1. Abdulrahim Zakaria, Rao Melam Ganeswara, Syamala Buragadda. Efficacy of PNF stretching techniques on hamstring tightness in young male adult population. World J Med Sci. 2012;7(1):23-6. doi: 10.5829/idosi.wjms.2012.7.1.61290.
2. Odunaiya N, Hamzat T, Ajayi O. The effects of static stretch duration on the flexibility of hamstring muscles. Afr J Biomed Res;8(2). doi: 10.4314/ajbr.v8i2.35765.
3. Woolstenhulme Mandy Mandy T, Griffiths Christine Christine M, Woolstenhulme Emily Emily M, Parcell Allen Allen C. Ballistic stretching increases flexibility and acute vertical jump height when combined with basketball activity. J Strength Cond Res. 2006;20(4)(4):799-803. doi: 10.1519/R-18835.1, PMID 17194248.
4. Bradley Paul S, Olsen Peter D, Portas Matthew D. The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. J Strength Cond Res. 2007 Feb;21(1):223-6. doi: 10.1519/00124278-200702000-00040, PMID 17313299.
5. Morcelli MH, Oliveira JMCA, Navega MT. Comparação do alongamento estático, balístico e contrair-relaxar nos músculos isquiotibiais. Fisioter Pesqui. 2013;20(3):244-9. doi: 10.1590/S1809-29502013000300008.
6. Young W, Clothier P, Otago L, Bruce L, Liddell D. Acute effects of static stretching on hip flexor and quadriceps flexibility, range of motion and foot speed in kicking a football. J Sci Med Sport. 2004 Mar;7(1):23-31. doi: 10.1016/s1440-2440(04)80040-9, PMID 15139161.
7. Todd Lane William. Effects of dynamic, static stretch, and proprioceptive neuromuscular facilitation or running velocity, step length, and step rate- jack N. Averitt College of Graduate Studies (COGS)-fall 2006. Available from: https://digitalcommons.georgiasouthern.edu/cgi/viewcontent.cgi?article=1634&context=etd.
8. Feland JB, Myrer JW, Merrill RM. Acute changes in hamstring flexibility: PNF versus static stretch in senior athletes. Phys Ther Sport. 2001;2(4):186-93. doi: 10.1054/ptsp.2001.0076.
9. Marek Sarah M, Cramer Joel T, Fincher ALouise, Massey Laurie L, Dangelmaier Suzanne M, Purkayastha Sushmita, Fitz Kristi A, Culbertson Julie Y. Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. J Athl Train. Apr–Jun 2005;40(2):94-103. PMCID PMC1150232, PMID 15970955.
10. Bernhart Cassandra. A review of stretching techniques and their effects on exercise, A. Available from: https://digitalcommons.liberty.edu/cgi/viewcontent.cgi?article=1397&context=honors [senior thesis] submitted in partial fulfilment of the requirements for graduation in the Honors Program:; 2013.
11. Spernoga Scott G, Uhl Timothy L, Arnold Brent L, Gansneder Bruce M. Duration of maintained hamstring flexibility after a One-Time, modified hold-relax stretching protocol. J Athl Train Athl Train. 2001. Jan–Mar 2001;36(1):44-8. PMID 12937514, PMCID PMC155401.
12. Andreas Konrad, Markus Tilp. Effects of ballistic stretching training on the properties of human muscle and tendon structures. J Appl. Physiol. 1985 Volume 117Issue 1July. 2014:29-35. doi: 10.1152/JAPPLPHYSIOL.00195.2014, PMID 24812641.
13. Morcelli MH, Oliveira JMCA, Navega MT. Comparação do alongamento estático, balístico e contrair-relaxar nos músculos isquiotibiais. Fisioter Pesqui. 2013;20(3):244-9. doi: 10.1590/S1809-29502013000300008.
14. Mohammad Nasiri, Mansour Balavar, Akbar Asghari. The effect of four different muscle stretches on the flexibility of hamstring muscles in university boys of 18 to 28 years old of Mahabad Payame Noor University. Middle East J Sci Res. 2011;8(2):416-23.
15. Mahieu Nele Nathalie, McNair Peter, De Muynck Martine, Stevens Veerle, Blanckaert Ian, Smits Nele, Witvrouw Erik. Effect of static and ballistic stretching on the muscle-tendon tissue properties. Med Sci Sports Exerc. 2007;39(3):494-501. doi: 10.1249/01.mss.0000247004.40212.f7, PMID 17473776.
16. Puentedura Emilio J, Huijbregts Peter A, Celeste Shelley, Edwards Dale, In Alastair, Landers Merrill R, Fernandez-de-Las-Penas Cesar. Immediate effects of quantified hamstring stretching: hold-relax proprioceptive neuromuscular facilitation versus static stretching. Phys Ther Sport. Aug 2011;12(3):122-6. doi: 10.1016/j.ptsp.2011.02.006, PMID 21802038.
17. Mistry Gopi S, Vyas Neeta J, Sheth Megha S. Comparison of the effect of Active Release Technique versus Proprioceptive neuromuscular Facilitation Stretching (Modified Hold-Relax) On Hamstring Flexibility In Patients Having Chronic Low Back Pain. Vol. 6(5); 2015. NJIRM. Available from: http://nicpd.ac.in/ojs-/index.php/njirm/article/view/969.
18. Gribble PA, Guskiewicz KM, Prentice WE, Shields EW. Effects of static and hold-relax stretching on hamstring range of motion using the Flexibility LE1000. J Sport Rehabil. 1999 Aug;8(3):195-208. doi: 10.1123/jsr.8.3.195.
19. Wells KF, Dillon EK. The sit and reach—A test of Back and leg flexibility. Res Q Am Assoc Health Phys Educ Recreat. 1952;23(1):115-8. doi: 10.1080/10671188.1952.10761965.
20. Baltaci G, Un N, Tunay V, Besler A, Gerçeker S. Comparison of three different sit and reach tests for measurement of hamstring flexibility in female

university students. Br J Sports Med. Feb 2003;37(1):59-61. doi: 10.1136/bjsm.37.1.59, PMID 12547745.

21. Hamid Mohamad Shariff A, Ali Mohamed Razif Mohamed, Yusof Ashril. Interrater and intrarater reliability of the active knee extension (AKE) test among healthy adults. J Phys Ther Sci. Aug 2013;25(8):957-61. doi: 10.1589/jpts.25.957, PMID 24259893.
22. Cameron DM, Bohannon RW. Relationship between active knee extension and active straight leg raise test measurements. J Orthop Sports Phys Ther. May 1993;17(5):257-60. doi: 10.2519/jospt.1993.17.5.257, PMID 8343784.
23. Spernoga Scott G, Uhl Timothy L, Arnold Brent L, Gansneder Bruce M. Duration of maintained hamstring flexibility after a One-Time, modified hold-relax stretching protocol. J Athl Train. Jan–Mar 2001;36(1):44-8. PMID 12937514. PMCID PMC155401.
24. Norris CM, Matthews M. Inter-tester reliability of a self-monitored active knee extension test. J Bodyw Mov Ther. 2005;9(4):256-9. doi: 10.1016/j.jbmt.2005.06.002.
25. 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):56-9. PMID 16558609. PMCID PMC1323439.
26. Davis DScott, Ashby Paul E, McCale Kristi L, McQuain Jerry A, Wine Jaime M. The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. J Strength Cond Res. 2005. Feb 19;19(1):27-32. doi: 10.1519/14273.1, PMID 15705041.
27. Ahmed Hashim, Iqbal Amir, Anwer Shahnawaz, Alghadir Ahmad. Effect of modified hold-relax stretching and static stretching on hamstring muscle flexibility. J Phys Ther Sci. Feb 2015;27(2):535-8. doi: 10.1589/jpts.27.535, PMID 25729210. PMCID PMC4339180his.
28. Davis DScott, Ashby Paul E, McCale Kristi L, McQuain Jerry A, Wine Jaime M. The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. J Strength Cond Res. 2005 Feb 19;19(1):27-32. doi: 10.1519/14273.1, PMID 15705041.
29. Spernoga Scott G, Uhl Timothy L, Arnold Brent L, Gansneder Bruce M. Duration of Maintained Hamstring Flexibility After a One-Time, Modified Hold-Relax Stretching Protocol. J Athl Train. 2001 Jan–Mar;36(1):44-8. PMCID PMC155401. PMID 12937514.
30. Sharman Melanie J, Cresswell Andrew G, Riek Stephan [1]. Andrew G Cresswell, Stephan Riek Proprioceptive neuromuscular facilitation stretching Mechanism and clinical implication. J Sports Med. 2006;36(11):929-39. doi: 10.2165/00007256-200636110-00002, PMID 17052131.
31. Goldman Rena et al. Ballistic Stretching in athletes. J Strength Cond Res. 2014;21(1):223-6.
32. Covert Christopher A [1], Melanie P Alexander, John J Petronis, D Scott Davis. Comparison of ballistic and static stretching on hamstring muscle length using an equal stretching dose. Journal of Strength and Conditioning Research / National Strength & Conditioning Association. 2010, 24(11):3008-14. PMID: 20375742
DOI: 10.1519/JSC.0b013e3181bf3bb0.
33. Thacker Stephen B [1], Julie Gilchrist, Donna F Stroup, C Dexter Kimsey Jr . The Impact of Stretching on Sports Injury Risk: A Systematic Review of the Literature. American College of Sports Medicine. 2004 Mar;36(3):371-8 PMID: 15076777 DOI: 10.1249/01.mss.0000117134.83018.f7.
34. O'Sullivan Kieran, Murray Elaine, Sainsbury David. The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. BMC Musculoskelet Disord. 2009;10:37. doi: 10.1186/1471-2474-10-37, PMID 19371432:37. Trial Registration ACTRN12608000638336.