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Effects of hamstring versus gastrocnemius streching on flexibility of physical therapy students

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Abstract
Background: Flexibility is characterized by the ability of a muscle to relax and give a stretch force and also by the range of motion available in a joint or group of joints and Stretching reduces muscle stiffness (by changing in passive visco-elastic properties), Hamstring and gastrocnemius muscle are muscles superficial posterior compartment of the leg and shortening of these muscles are evident.
Methodology: A comparative type of experimental study design, in which 150 participants was participated. Three group was designed; group a received hamstring stretching, group B received gastrocnemius stretching and group C received both gastrocnemius and hamstring stretching. Data was collected through sit to reach test via sit and reach box. Data was analyzed through SPSS. T-test was used for comparing the three intervention group scores.
Result: Result of the study showed no meaningful differences among hamstring and gastrocnemius flexibility.
Conclusion: Study concluded that there is a difference between flexibility of participants with reference of age and gender. The females are more flexible than males group that was younger had more flexibility than the older one. Study also highlighted that the flexibility is effected by stretching. It was seen that there was increase in the flexibility of hamstring and gastrocnemius muscle after stretching.

Keywords: Flexibility, stretching, hamstring, gastrocnemius and sit–to-reach test

Introduction
Chapter I
1. What is flexibility?
Ability of a muscle to stretch on its maximum level is said to be flexibility. Flexibility is characterized by the ability of a muscle to relax, stretch and provide available range of motion (ROM) at a joint or group of joints [1]. Flexibility permits the tissues to accommodate stress, reduce shock from impact and improve the value of movement, therefore it reduces and avoids injuries in addition to improve the joint range of motion (e.g. passive stretch) [1]. Flexibility is the ability of a single joint or many joints competency and ease to get pain free ROM [1]. Flexibility of a joint is followed by the elasticity of musculotendinous unit that permit a joint arthrokinematics i.e. the ability of the joint surfaces to glide or slide while the ability of periarticular connective tissues are concern with joint ROM and flexibility [1, 2]. The capability of a muscle to extend and ability of a joint to vary ROM [1, 3]. Previously rehabilitation field have encouraged the static hamstring muscle stretching which involved in a warm-up to enhance athletic performance and decreases chances of injury during heavy physical exercise [3]. Muscular flexibility is very important for regular specific function [1, 4]. Muscular tightness is early proposed with essential risk factor with the progression of muscle damage [4].

2. Types of flexibility
There are two types of flexibility

2.1 Static Flexibility
It relates to range of motion about joint with regards to no stress on speed, it is also known as passive flexibility, passive mobility or PROM [5]. The degree of joint motion through which joint can move passively within the available ROM depends upon the extensibility of adjacent muscles and connective tissues of the joints [5].

It is a specific stretching program that enhances flexibility [5]. Few researchers suggested that stretches of the 30 seconds, with the sets of 3–4 repetition with extreme augmentation of flexibility, they have also suggested that the stretching to be done 5 times or more than 5 times in a week [6]. Few researches have showed that proprioceptive neuromuscular facilitation (PNF) and contract-relax (CR) stretches are most effective [6]. Ballistic stretching is not more effective and may lead to injury while static or passive stretches have few benefits but not that much effective than PNF stretches [6].

Static flexibility is a key component of warm-ups, stretching methods related to static, ballistic and PNF which helps to increase flexibility and effective to improve ROM [5, 6]. Static stretching has been found to be effective for increasing the ROM at a particular joint, some researches indicated that it may decline the strength and power production of the stretched muscle group [7]. Increase in passivity and decrease in rigidity of the musculotendinous unit by the duration and strength of the stretching protocols, hence the active muscle leads to a rapid enhanced force next to the beginning of stretch, results successive muscle performance [8].

2.2 Dynamic Flexibility

The effect of dynamic stretching on muscular performance has not been clarified, few muscles are contracted actively and rhythmically to stretch the target muscle, dynamic stretching may differ muscular temperature and improve muscular performance therefore dynamic stretching during warm-up would be an effective technique for improve the muscular performance [9].

3. Flexibility technique

There are two important stretching techniques usually used for hamstrings flexibility includes static stretching, dynamic stretching and before contraction stretching i.e. PNF [10]. The most probable used method for hamstrings is static stretching, positioned in flexion of the hip joint and extension of the knee joint which stretches both the beginning and end part of target muscle [10].

Following are some of the major benefits of flexibility training: Reduces stress in the exercising muscles and releases tension developed during ADL and helps in balancing the tension placed across the joint by the muscles that cross it [11]. Proper posture minimizes stress and maximizes the strength of all joint movements though it decreases the risk of injury during exercise and daily activities because of their flexibility thus improve the exercise performance and sports activity [10, 11].

4. Hypertonia

4.1 Spasticity

It is a motor disorder characterized by a velocity dependent increased muscle tone with increased resistance to stretch, the larger and quicker the stretch, the stronger the spastic muscle resistance [12].

4.2 Rigidity

It is characterized by continuous resistance during range of motion that is self-regulating of the velocity movement [12].

4.3 Dystonia

It is a protracted involuntary movement disorder categorized by twisted or struggling repetitive movement with greater muscle tone [12].

4.4 Hypotonia

Hypotonia and flaccidity both are defined as the decreased or absent muscular tone resistance during passive movement and stretch reflexes are decreased or absent and limb become floppy [12].

5. Stretching protocols

For pre stretch measurements, subjects in both groups performed a total of 6 Active Knee Extensions (AKE) with a 60-second rest period between repetitions [13]. The first 5 AKEs act as warm-ups to decrease any effect that may occur with repeated measures performed from a cold start and the sixth AKE is recorded as the pre stretch measurement [13]. When the subject could not elongate his lower leg any farther without his thigh moving away from the cross-bar, he informs the investigator and held that position for approximately 2 to 3 seconds until a measurement is taken hence this is more appropriate method of assessing hamstring flexibility [13].

Stretching reduces muscle stiffness by altering the passive visco-elastic properties, speed of contraction may be enhanced relatively and decreased stiffness may reduce storage of recoil energy, which will require more energy [14]. Once performance is improved, the issue of increased risk of injury may be doubtful for some persons, though the immediate effects of stretching decline visco-elasticity and rise stretch capability in 3 to 4 weeks and seems to affect stretch tolerance, with no change in visco-elasticity [14].

6. Hamstring muscle

Hamstring is major muscle of posterior compartment of thigh muscle i.e. from medial to lateral semi-membranosus, semitendinosus and bicep femoris whereas bicep femoris long head originates from ischial tuberosity and short head from linea aspera, lateral supracondylar ridge of shaft of femur and inserts on head of fibula. Nerve supply to the long head is tibial portion of sciatic nerve and short head is supplied by common peroneal portion of sciatic nerve i.e. nerve root is L5,S1&2.Action of bicep femoris is to flex and laterally rotate the leg at knee joint whereas long head also extends thigh at hip joint [15]. Semitendinosus originates from ischial tuberosity and inserts to upper part of medial surface of shaft of tibia, nerve supply is tibial portion of sciatic nerve with nerve root of L5, S1, 2 and action is to flex and medially rotate leg at knee joint; extends thigh at hip joint [15, 16]. Semi-membranosus originates from ischial tuberosity and inserts at medial condyle of tibia, nerve supply is tibial portion of sciatic nerve, nerve root is same as others and action is to flex and medially rotate leg at knee joint, extends thigh at hip joint [15, 16].

6.1 Function of the Hamstring

The three muscles of the posterior compartment of thigh i.e. bicep femoris, semi-tendinous and semi-membranosus, are collectively called as Hamstrings and cross both hip and knee joints therefore it flex the leg at knee joint and extend the thigh at hip joint and are also known as the rotators of both joints [15, 16].

7. Gastrocnemius muscle

The gastrocnemius muscle is one of the calf muscles in the superficial posterior compartment of the leg which sits superficial to the larger soleus muscle [17]. It gives the calf its unique two-headed appearance and is a primary plantar flexor. Its origin is superior to articular surfaces of lateral and medial femoral epicondyle and insertion is at mid–posterior

calcaneus. Its action is to do plantar flexion at foot and flexion at knee [17]. It is innervated by tibial nerve having nerve root of S1 and S2 [17].

8. Sit and reach test

The sit and reach (SR) test is a field test used to measure hamstring and low back flexibility [18]. This test prevent the anticipation of acute and chronic musculoskeletal injuries and low back problems, postural deviation, gait limitations and risk of falling [18]. The SR test was used to access the subject's low back and hip joint flexibility [18]. Patient or participant is seated on the floor with knees fully extended and ankles in neutral dorsiflexion against the box, three post-test measurements are used to estimate differences between pretesting and post-testing [18, 19].

8.1 Equipment Required

Either a sit and reach box, alternatively a ruler can be used or a step or box [20]. This test perquisite along sitting position on the floor, with legs stretched out straight ahead with shoes off [20]. The soles of the feet are placed flat against the box with both knees locked and pressed flat to the floor while the examiner assist by holding them down, with the palms facing downwards and the hands on top of each other or side by side, whereas the subject reaches forward along the measuring line as far as possible [20]. Ensure that the hands remain at the same level, not one reaching forward than the other [20]. After some attempts, the subject reaches out and holds that position for one to two seconds while the distance is recorded [20]. Make sure there are no jerky movements [20]. The score is recorded to the nearest centimeter or half inch as the distance reached by the hand [20]. Some test versions use the level of the feet as the zero mark, while others have the zero mark 9 inches before the feet [20]. There is another modified sit and reach test which adjusts the zero mark depending on the arm and leg length of the subject [20]. This test only measures the flexibility of the lower back and hamstrings and it is reliable [20]. The reliability of this test depends on the amount of warm-up that is performed prior to test whether the same procedure is followed each time when the test is conducted [20]. Modified sit and reach test adjusts the zero mark depending on the arm and leg length of the subject [20].

9. What is stretching?

An agonist frequently becomes actively insufficient, before the antagonist becomes passively insufficient i.e. no more contraction by agonist, whereas no more stretch in antagonist [21]. Some activities require a great compact of flexibility that results in stretch and complete the elongation in all situations, from the resting length of a muscle [21]. Stretching is commonly practiced before athletic activities, though effects on subsequent performance and injury prevention are not well understood [21, 22]. There is an abundance of literature demonstrating that a single bout of stretching acutely impairs muscle strength, with a lesser effect on power, these effects are apparent when stretching is combined with warm-up, such as practice drills and low intensity dynamic exercises, is not known [22]. With respect to the effect of pre-participation stretching on injury prevention a limited number of studies of varying quality have shown mixed results [22].

9.1 Self-Stretching

Any exercise that is carried out independently by a patient and instructed by the therapist, it is stated as self-stretching [23]. The term elasticity and self-stretching are used inter changeably, as some therapist prefer to limit the definition of flexibility exercises to range of motion exercises that are part of overall training and fitness program [23]. Active stretching is occasionally used to represent self-stretching procedures, whereas inhibition or facilitation techniques into stretching exercises have also remain denoted as active stretching [23]. High-intensity and moderate-intensity stretching increases flexibility compared with low-intensity stretching, further more high-intensity stretching is superior to moderate-intensity stretching in terms of maintaining flexibility over time [24].

10. What is extensibility?

The extensibility is known as the capability of a muscle to lengthen with stretch at the endpoint [25].

We intend to determine the comparative effects of hamstring and gastrocnemius stretching on flexibility of physical therapy students. This study helps to understand that the gastrocnemius flexibility in university students and short-term stretching effect on the hamstring extensibility and to reduce backache and other muscular problems in addition to improve the flexibility of hamstring and gastrocnemius.

Chapter II
Material and Methods

1. Study design

A comparative experimental study conducted on 150 volunteered university students, aged between 19 to 25 years. The participants had no musculoskeletal limitations and low back pain that would hinder their performance in the test and were agreed with the informed consent.

2. Setting

This study was conducted under the supervision of physiotherapy and rehabilitation department of district Hyderabad on the students from different universities at Hyderabad.

3. Study duration

The duration of the study was 6 months.

4. Sampling technique

Non probability convenient sampling technique was performed at the university in physiotherapy and rehabilitation department.

5. Sample size

The study sample was 150 that includes 75 male and 75 female students, aged between 19 to 25 years were studied within three experimental group.

6. Sample criteria

6.1 Inclusion Criteria

- Age between 19 and 24years.
- Undergraduate students either male or female.

6.2 Exclusion Criteria

- `Participants with pain.
- Had previous back and limb surgery or spine/lower extremity injuries in the six months prior to data collection.
- Participants with illness such as neurological disease, rheumatic disease, muscular disease etc.
- Participants with musculoskeletal limitation.
- Participants with low back pain that limits their

performance in this test.
- Participants with knee problem.

7. Data collection instrument
A wooden box of 30.5cm x 30.5cm with a fixed 23 centimeter ruler on top and sit to reach test was used in the study to evaluate flexibility.

8. Data collection procedure
This study determines the exercise period of all students who were given a schedule for implementation of the plan along with a date for each session while the duration of each exercise session was also marked and the students were asked to make notes about duration of each session in the given form till the end. The average of three test trials was taken. All measures were performed on the same day.

For this study, 150 undergraduate students were recruited, i.e. 75 boys and 75 girls were divided equally into 3 groups (A, B and C) for practical reasoning and nature of the study. The intervention focuses on individuals studying at universities, signed informed consent prior to participate in this study.

The sit-and-reach (SR) test was used to estimate participants hamstring and gastrocnemius flexibility and extensibility. Briefly, at the beginning of the test the participants were standing in front of the box, and were asked to sit with their hip flex, knees extended and both hands on the top of the ruler, from this position the participants had to bend the trunk forward slowly and progressively with no swings in order to reach the furthest possible distance and remain still for at least 2 seconds (a score of 16 cm corresponded to the tangent of the feet, accuracy+- 0.5cm). The participants were allowed to perform the test twice with one minute interval and then the average score in cm will retain.

The stretching intervention program were performed by the all three groups along with sit to reach test at the beginning and at the end. Group A performed hamstring stretches using the static technique, each intervention session had 4 sets of stretching exercise with 2 repetitions of 30 seconds of stretch. Group B performed gastrocnemius stretches using static technique while Group C performed hamstring and gastrocnemius combine stretches. In all the stretching exercises the students were asked to sit with their hips flexed and knees extended. From this position the students flexed forward at the hip, tried to maintain the spine in a neutral position as much as possible until a gentle stretch was felt in the hamstrings. The stretch position was hold gently until the end point of range of motion was achieved i.e. stretch to the point of feeling the tightness without pain. Once the position was achieved, the participants hold it for 30 seconds during the first two sessions of the intervention, the physical education teacher explain in depth regarding the correct manner of the stretching exercises.

Fig 1: Shows sit to reach box (1), taking pre stretch measurements (2), participate performing active knee stretch (3) and post stretch measurement (4), respectively

9. Data analysis procedure
The Statistical t-test was applied for comparison of the pre and post intervention scores. Data was analyzed through Statistical Package for Social Sciences 21 (SPSS) descriptive statistics.

10. Ethical concern
The study was approved by the research Ethics Committee and all participants signed informed consent forms.

Chapter III
Results
This study was conducted for research purpose of finding out the flexibility of hamstring versus gastrocnemius in university students for which included age group was 19 to 24 with a sample size of 150. The results of this study are presented in graphs and tables which are given below.

Group A had pre stretching of Hamstring muscle, the lowest frequency was 29 (58.0%) and cumulative percentage was 58.0. Below average frequency was 8 (16.0%) and cumulative percentage was 74.0, average frequency was 5 (10.0%) and cumulative percentage was 84.0 and the greater than average frequency was 5 (10.0%) and cumulative percentage was 94.0, while the highest frequency was 3.0(6.0%) and cumulative percentage was 100 as shown in table no. 1.1.

Table 1.1: Tabular representation of group A pre stretch results

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	29	58.0	58.0	58.0
	<Average	8	16.0	16.0	74.0
	Average	5	10.0	10.0	84.0
	>Average	5	10.0	10.0	94.0
	High	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

Group A had post stretching lowest frequency is 25 (50.0%) and cumulative percentage is 50.0, average frequency was 11 (22.0%) and cumulative percentage was 82.0 whereas the high frequency was 3 (6.0%) and cumulative percentage was 100, as shown in table no. 1.2.

Table 1.2: Tabular representation of Group A post stretch result

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	25	50.0	50.0	50.0
	<Average	5	10.0	10.0	60.0
	Average	11	22.0	22.0	82.0
	>Average	6	12.0	12.0	94.0
	High	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

Group A had pre stretching of Hamstring muscle, the lowest frequency was 30 (60.0%) and cumulative percentage was 60.0. Below average frequency was 5 (10.0%) and cumulative percentage was 70.0, average frequency was 6 (12.0%) and cumulative percentage was 82.0 and the greater than average frequency was 7 (14.0%) and cumulative percentage was 96.0, while the highest frequency was 2(4.0%) and cumulative percentage was 100.0 as shown in table no. 2.1.

Table 2.1: Tabular representation Group B pre stretch result.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	30	60.0	60.0	60.0
	<Average	5	10.0	10.0	70.0
	Average	6	12.0	12.0	82.0
	>Average	7	14.0	14.0	96.0
	High	2	4.0	4.0	100.0
	Total	50	100.0	100.0	

Group B had post stretching lowest frequency of 23 (46.0%) and cumulative percentage is 46.0, average frequency was 7 (14.0%) and cumulative percentage was 78.0 whereas the high frequency was 2 (4.0%) and cumulative percentage was 100, as shown in table no. 2.2.

Table 2.2: Tabular representation Group B post stretch result.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	23	46.0	46.0	46.0
	<Average	9	18.0	18.0	64.0
	Average	7	14.0	14.0	78.0
	>Average	9	18.0	18.0	96.0
	High	2	4.0	4.0	100.0
	Total	50	100.0	100.0	

Group C had pre stretching of Hamstring muscle, the lowest frequency was 28 (56.0%) and cumulative percentage was 56.0. Below average frequency was 7 (14.0%) and cumulative percentage was 70.0, average frequency was 12 (24.0%) and cumulative percentage was 94.0 while the greater than average frequency was 3 (6.0%) and cumulative percentage was 100.0, as shown in table no. 3.1.

Table 3.1: Tabular representation Group C pre stretch result

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	28	56.0	56.0	56.0
	<Average	7	14.0	14.0	70.0
	Average	12	24.0	24.0	94.0
	>Average	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

Group C had post stretching lowest frequency is 23 (46.0%) and cumulative percentage is 46.0, below average frequency was 12 (24.0%) and cumulative percentage was 70.0, average frequency was 12 (24.0%) and cumulative percentage was 94.0 while the greater than average frequency was 3 (6.0%) and cumulative percentage was 100.0, as shown in table no. 3.2.

Table 3.2: Tabular representation Group C post stretch result

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	23	46.0	46.0	46.0
	<Average	12	24.0	24.0	70.0
	Average	12	24.0	24.0	94.0
	>Average	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

This result showed that the comparison of flexibility and extensibility among 3 groups the best outcome had found in Group C by a combined gastrocnemius and hamstring stretch with a significant value of less than 0.005 and improved flexibility in all 50 participants of this group.

Chapter IV
Discussion

Participants studied were undergraduate DPT students of Hyderabad, between the age range of 19 to 25 years, with no pain or any deformity. Sample of 150 participants were divided into three groups i.e. A, B and C, they were asked to perform hamstring stretch, gastrocnemius stretch and combined hamstring and gastrocnemius stretch, respectively. The flexibility of subjects were assessed and measured initially, followed by a segment of active stretching, it was again measured and result showed marked improvement with combine stretch of hamstring and gastrocnemius on group C.

Sit to reach test was used to measure the hamstring flexibility in current fitness test as it is commonly used in this field for its authenticity whereas this test have limitations for adults with low back pain or have difficulty in sitting on a level surface with leg extended [17, 34]. Study ensured that static stretching improved flexibility and extensibility and it is also evident in our research that static stretch with holding time of 30 seconds enhance the lower limb flexibility in adolescents and marked improvement is noted in other age groups such as in children, young adults and elderly adult [30, 32, 34, 47]. Female extensibility was showed more than male participants and it was noted in female students of university of Dammam [33].

The purpose of this study was to determine the relation between the hamstring and gastrocnemius flexibility among adolescents for which the test protocols for the measurments were taken from a study in which there reliability and validity were demonstrated [34]. However, the results were consistent

and showed marked improvement in extensibility and flexibility of lower limb with combine hamstring and gastrocnemius stretch rather than isolated hamstring or gastrocnemius stretch, in addition to this another research supports this combine stretch effectiveness [46].

The study shows positive results as it proved that there is a significant improvements in the flexibility of targeted muscles along with warm up and cool down stretch in both of the genders and accordingly this age group showed instant increase in the flexibility. The population was completely healthy and active while this physical education based on stretching development and maintenance program of hamstring and gastrocnemius also prevents injury rates [49].

Chapter V
Conclusion

This study was conducted to measure flexibility of hamstring verse gastrocnemius verses combined hamstring and gastrocnemius muscle stretch, in university students, with equal distribution of 75 males and 75 female's participants. In the comparison between three groups, we have found improved flexibility in group C participant with combined hamstring and gastrocnemius stretch.

References

1. Kim Jones, Karen Barker. Human movement explained. 1sted. Butterworth-Heinemann Ltd. 1996.
2. Stretching for Impaired Mobility. In: Kisner C, Colby L. Kisner C, Colby L Eds. Carolyn Kisner, and Lynn Allen Colby. eds. Therapeutic Exercise: Foundations and Techniques, 6e New York, NY: McGraw-Hill. 2017 Oct 08.
3. The efficacy of two modified proprioceptive neuromuscular facilitation stretching techniques in subjects with reduced hamstring muscle length James W, Youdas PT MS, 1 Kristin Haeflinger M, BS, 2 Melissa K Kreun, BA, 2 Andrew M Holloway, BA,2 Christine M Kramer, BS, 2 and John H Hollman, PT, PhD, 1. Physiotherapy Theory and Practice. 2010;26(4):240-250.
4. Nagarwal AK, Zutshi Ram CS, Zafar R, Jamia Hamdard. New Delhi, Improvement of Hamstring Flexibilitty: A Comparison between two PNF Stretching techniques, international journal of sports science and engineering. 2010, 04.
5. Thanda Aye, Tsugumi Kuramoto-Ahuja, Heonsoo Han, Hitoshi Maruyama. Published online 2017 Sep 15. DOI: 10.1589/ipts.29.1518. Comparison of immediate effects between two medical stretching techniques on Hamstrings flexibility.
6. Jo Fasen M, Annie o'connor M, Susan Schwartz L, John Watson O, Chris Plastaras T, Cynthia Garvan W, *et al*. A randomized controlled trial of hamstring stretching: comparison of four techniques, Journal of Strength and Conditioning Research 2009 National Strength and Conditioning Association.
7. Behroz Khodayaria, Yaghoob Dehghanib. The investigation of mid-term effect of different intensity of PNF stretching on improve hamstring flexibility, Social and Behavioral Sciences. 2012;46:5741-5744.
8. Young WB, Behm DG, Olyvia Donti, Charilaos Tsolakis, Gregory C. Bogdanis. Effects of Baseline Levels of Flexibility and Vertical Jump Ability on Performance Following Different Volumes of Static Stretching and Potentiating Exercises in Elite Gymnasts, ©Journal of Sports Science and Medicine. 2014;13:105-113.
9. Yamaguchi Taichi, Ishii Kojiro. Effects of static stretching for 30seconds and dynamic stretching on leg extension power, the journal of strength and conditioning research. 2005-08;19(3):677-683.
10. Susan B, O'Sullivan Glen DeP Ino M, MEd ATC, William Webright G, MEd, ATC, PT. Role of flexibility training in this exclusive excerpt from the book NSCA's Essentials of Personal Training, Second Edition, published by Human Kinetics.
11. Scott Spernoga G, Timothy Uhl L, Brent Arnold L, Bruce Gansneder M. Journal of Athletic Training. Duration of Maintained Hamstring Flexibility. After a One-Time, Modified Hold-Relax Stretching. 2001;36(1):44-48q.
12. Snell clinical anatomy by region 9th ed. 2012.
13. Ian Shrier MD PhD. Gray's Anatomy for students by Richard L. Drake, A, Wayne Vogl, Adam W.M. Mitchell 3rd ed.
14. Standring S (editor). Gray's Anatomy (39th edition). Churchill Livingstone. (2011) and Moore KL, Dalley AF. Anatomy. Lippincott Williams &Wilkins. 1999.
15. Baltaci G, Un N, Tunay V, Besler A, Gerceker S. Br J Sports Med. Comparison of three different sit and reach tests for measurement of hamstring flexibility in female university students. 2003;37:59-61.
16. Bandy BD, Sanders B. Therapeutic Exercise for Physical Therapist Assistants Techniques for Intervention, 2nd ed. Lippincott Williams & Williams: Philadelphia, PA. 2008.
17. Giorgos Paradisis P, Panagiotis Pappas T, Apostolos Theodorou S, Elias Zacharogiannis G, Emmanouil Skordilis K, Athanasia Smirniotou S. Effects of static and dynamic stretching on sprint and jump performance in boys and girls. Journal of Strength and Conditioning Research National Strength and Conditioning Association. 2013.
18. Clinical kinesiology text book.
19. Stretching for Impaired Mobility. In: Kisner C, Colby L. Kisner C, Colby L Eds. Carolyn Kisner, and Lynn Allen Colby. eds. Therapeutic Exercise: Foundations and Techniques, 6e New York, NY: McGraw-Hill. 2017 Oct 08.
20. McHugh MP, Cosgrave CH. To stretch or not to stretch: the role of stretching in injury prevention and performance. Scand J Med Sci Sports. 2010:20:169-181.
21. Stretching exercise guide.com copy right. 2007-2013
22. Lim, Wootaek, Easy method for measuring stretching intensities in real clinical settings and effects of different stretching intensities on flexibility, journal of back and musculoskeletal rehabilitation. 2018 Dec 11.
23. Cynthia Holzman Weppler S. Peter Magnusson, physical therapy. Increasing muscle extensibility: A matter of increasing length or modifying sensation. 2010 March, 90.
24. Autumn L, Davis Hammonds MS ATC, Kevin Laudner G PhD ATC, Steve McCaw PhD, Todd McLoda A PhD ATC. Journal of Athletic Training. Acute Lower Extremity Running Kinematics a Hamstring Stretch. 2012:47(1):5-14.
25. Kyoung-Il lIm PT, MSc·Hyung-CHunnam PT PhD, Kyoung-SIm Jung PT PhD. J Phys. Sci. Effects of Hamstring Extensibility, Muscle Activity, And Balance of different Stretching Techniques. 2014;26:209-213.
26. Yuichi Nishikawa PT MS, Junya Aizawa PT PhD, Na0hiko Kanemura PT PhD, Tetuya Takahashi MD PhD, Naohisa Hosomi MD PhD, Hirofumi Maruyama MD PhD, *et al*. J Phys. sci. Immediate effect of Passive and

active stretching on hamstring flexibility: a single –blinde randomized control trial. 2015;27:2167-3170.
27. Daniel Mayorga-Vega, Rafael Merino-Marban, Jesus Viciana. Journal of Sports science and Medicine. Criterion –Related Validity of sit – and – reach Tests for Estimating Hamstring and Lumber Extensibility: A Meta – Analysis. 2014;13:01-14.
28. Daniel Mayorga-Vega, Rafael Merno-Marban, Jorge Manzano-Lagunas, Humberto Blanco, Jesus Viciana. Journal of sports science and medicine. Effects of stretching development and maintenance program on hamstring extensibility in schoolchildren: A cluster-Randomized Controlled Trial. 2016;15:65-74.
29. Klaus Wiemann, Knut Hahn. International Journal of Sports Medicine. 1997 July;18(5):340-346.
30. Scott Davis D, Paul Ashby E, Kristi McCale L, Jerry Mcquain A, Jaime Wine M. Jouranl of Strength and Conditioning Research. q 2005 National strength and Conditioninig Association. The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. 2005;19(1):27:32.
31. DR. Hesham Ezzat. Impact factor T.625, TSSN: 2320-5083. The effect of increasing hamstring felxibility on hamstring muscles torque among applied science female stuents in university of dammam. 2014 Dec, 2(11).
32. Ayala F, Sainz de Baranda P, De SteCroix M, Santoja F. Physical Therap in Sport. Reproducibility and criterion – related validity af the sit and reach test and toe touch test for estimating hamstring flexibility in recreationally active young adults. 2012;13:219e226.
33. Jose Muyor M, Francisco Arrabal M. Campos, Journal of Human Kinetics. Effects of acute fatigue of the hip Flexor Muscles on Hamstring Muscle Extensibility. 2016;53:23-31.
34. Kevin Power, David Behm, Farrell Cahill, Michael Carroll, Warren young. An acute bout of static stretching: Effect on force and jumping performance. Med. Sci. sports Exerc. 2004;36(8):1389-1396.
35. Daniel Cipriani, Bobbie ABEL, Dayna Pirrwitz. A Comparison of Two Stretching Protocols on Hip Range of Motion: Implications for Total Daily Stretch Duration. Department of Physical Therapy, Journal of Strength and Conditioning Research. 2003;17(2):274-278.
36. Duration of Maintained Hamstring Flexibility After Cessation of an Acute Static Stretching Protocol Glen M. DePino, MEd, ATC; William G. Webright, MEd, ATC, PT; Brent L. Arnold, PhD, ATC Sports Medicine/Athletic Training Research Laboratory, University of Virginia, Charlottesville, VA. Journal of Athletic Training. © by the National Athletic Trainers' Association, Inc. 2000;35(1):56-59.
37. Unilateral static and dynamic hamstrings stretching increases contralateral hip flexion range of motion Anis Chaouachi1, Johnny Padulo1, Sofien Kasmi1, Aymen Ben Othmen1, Moktar Chatra1 and David G. Behm2 1Tunisian Research Laboratory ‘Sports Performance Optimization’, National Center of Medicine and Science in Sports (CNMSS), Tunis, Tunisia and 2School of Human Kinetics and Recreation, Memorial University of Newfoundland, St. John’s, NF, Canada. 2015 April 17. Received 15 January 2015; accepted.
38. Sam Morton K, James Whitehead R, Ronald Brinkert H, Dennis Caine J. Department of Physical Education, Exercise Science, and Wellness (PXW), University of North Dakota, Grand Forks, North Dakota. Resistance training vs. Static stretching: Effects on flexibility and strength. Journal of Strength and Conditioning Research National Strength and Conditioning Association. 2011.
39. Acute effect of a ballistic and a static stretching exercise bout on flexibility and maximal strength. Reury Frank Pereira Bacurau, Gizele De Assis Monteiro, Carlos Ugrinowitsch, Valmor Tricoli, Leonardo Ferreira Cabral, Marcelo Saldanha Aoki. School of Arts, Sciences and Humanities, University of Sa˜o Paulo, Sa˜o Paulo, Brazil; 2Exercise Physiology Laboratory, Physical Education School, UniFMU, Sa˜o Paulo, Brazil; 3School of Physical Education and Sport, University of Sao Paulo, Sa˜o Paulo, Brazil; and 4Exercise Physiology Laboratory, Esta ´cio de Sa ´ University, Rio de Janeiro, Brazil. Journal of Strength and Conditioning Research National Strength and Conditioning Association. 2009.
40. Acute effects of two hip flexor stretching techniques on knee joint position sense and balance, Hussain I YounisAslan, MA, MS, ACSM-RCEP,[1] Harsh H Buddhadev, PhD, PT,[2] David N Suprak, PhD, ATC,[2] and Jun G San Juan, PhD, ATC[2] Int J Sports Phys Ther. 2018 Aug;13(5):846-859.
41. Standing and Supine Hamstring Stretching Are Equally Effective Laura C Decoster,* Rebecca L Scanlon,* Kevin D Horn,* and Joshua Cleland This article has been cited by other articles in PMC.J Athl Train. 2004 Oct-Dec;39(4):330-334. PMCID: PMC535525.
42. A survey of flexibility training protocols and hamstring strains in professional football clubs in England. B Dadebo, J White, KP George. Br J Sports Med. 2004;38:388-394. DOI: 10.1135/bjsm.2002.000044.
43. A review of the acute effects of static and dynamic stretching on performance David G. Behm Anis Chaouachi. Eur J Appl Physiol DOI: 10.1007/s00421-011-1879-2. Received: 12 July 2010/Accepted: 16 February 2011 Springer-Verlag 2011.
44. Effects of Gastrocnemius, Hamstring, and Combined Stretching Programs on Knee Extensibility Pamela J Russell, PhD; Laura C. Decoster, ATC; and Darcie Enea, Med. Athletic Training & Sports Health Care. 2010, 2(2).
45. The Effect of Duration of Stretching of the Hamstring Muscle Group for Increasing Range of Motion in People Aged 65 Years or Older. J Brent Feland J William Myrer Shane S Schulthies Gill W Fellingham Gary W Measom. Physical Therapy. 2001 May 1;81(5):1110-1117. https://doi.org/10.1093/ptj/81.5.1110.
46. Bandy WD, Irion JM, Briggler M. The effect of time and frequency of static stretching on flexibility of the hamstring muscles. Phyr Thu. 1997;'77:1090-1096. Physical Therapy. 1997 Oct, 77(10).
47. Hamstring Muscle Injury: The Influence of Strength, Flexibility, warm-up, and Fatigue Teddy W. Worrell, EdD, PT, ATC1 David H. Perrin, PhD, ATC2. JOSPT. 1992 July, 16(1).
48. Effect of Hamstring Stretching on Hamstring Muscle Performance Teddy W. Worrell, Ed D, PT, SCS, ATC, FACSM1 Troy I. Smith, MS, PT, ATCZ lason Winegardner, MS, PT3. JOSPT. 1994 Sept, 20(3).
49. Effects of a Static Stretching Program on the Incidence of Lower Extremity Musculotendinous Strains Kevin M. Cross, MEd, ATC; Ted W. Worrell, EdD, PT, ATC Krannert School of Physical Therapy, University of Indianapolis, Indianapolis, IN. Journal of Athletic Training © by the National Athletic Trainers' Association, Inc. 1999;34(1):11-14.

50. A randomized trial of preexercise stretching for prevention of lower-limb injury rodney peter pope, robert dale herbert, john dennis kirwan, and bruce james graham. 0195-9131/00/3202-0271/0 medicine & science in sports & exercise® Copyright © 2000 by the American College of Sports Medicine Submitted for publication June 1998. Accepted for publication 1999 April.
51. Chronic Flexibility Improvement after 12 Week of Stretching Program Utilizing the ACSM Recommendations: Hamstring Flexibility Article in International Journal of Sports Medicine. 2010 March.
52. Anthony Kay D Ph.D. Sport, Exercise & Life Sciences, The University of Northampton, Boughton Green Road, NN2 7AL, United Kingdom; Submitted for publication April 2011. Accepted for publication. Effect of Acute Static Stretch on Maximal Muscle Performance: A Systematic Review. 2011 May.