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Comparative Analysis of Muscular Flexibility among Recreational Racquet Players using Dynamic Oscillatory Stretching and Contract-Relax (PNF) Technique - A Rehabilitative Report

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Abstract

Background: Forward lunge is approximately 15% of all movement in racquet games especially badminton. One of the important muscles involved in forward lunge is biceps femoris. It acts as an agonist muscle during the forward lunging for the knee flexion. Increased hamstring tension causes pelvic alternation, which is another important factor in keeping an upright posture. Primitive Objective of this research is to identify the instant effect of rehabilitative Dynamic oscillatory stretching technique and Contract-Relax (PNF) technique on hamstring flexibility in recreational badminton players, and to perform a comparative analysis the acute effect of rehabilitative Dynamic oscillatory stretching and Contract-Relax (PNF) technique on hamstring flexibility in recreational badminton players.

Methods: Quantitative method, quasi-experimental study with a pre-test and post-test design used to estimate the causal influence of the physiotherapeutic intervention. 45 potential participants were volunteered to be involved in this study. Participants were recruited by using the convenience sampling method. Informed consent was acquired from all partakers, and any relevant criteria were mentioned beforehand earlier to the data collection phase.

Results: This study results shown, a significant difference of p-value is 0.18 ($p>0.05$). Hence, the null hypothesis is accepted as there is no statistically significant difference in effectiveness of DOS group and CR PNF group.

Conclusion: A few studies been conducted targeting particularly recreational badminton players. Hence, this research carried out to develop a framework of different stretching techniques to help us for making a good training program or warm up regime for recreational badminton players to improve their hamstrings elasticity and minimising the risk of injury. The investigation results showed, both techniques would help in improving hamstring flexibility.

Keywords: Rehabilitation, PNF Technique, Hamstring pliability, Recreational Badminton Player, Sports Physiotherapy.

1. Introduction

The badminton is a non-contact racquet ball/shuttle game demanding bounces, deep-lunges, instant swift in direction and rapid overhead arm movements from a maintaining good stance and balance throughout the game. Comparatively Badminton has been a very safe sport[1] with no or minimal contact force. Preceding researches majority conducted in Europe, revealed the threat of injuries in badminton is estimated to be 1.6–2.9 injuries per player per 1,000 hours of play[2].

The physical needs of racquet games such as badminton are associated with acute injuries to the limbs may frequently[3].Nevertheless, overuse injuries may also affect the back, shoulder, lower leg, and knee[4,5]. The lower limbs are very prone to sustain a high level of stress in the challenging movements of badminton, which may result in discomfort and injury[6].

Research outcomes reveal changes in the occurrence of injury in accordance with the muscles besides most frequent in the knee and the shoulder among the amateur badminton players[7]. It's well known that hamstring muscles are accountable for hip and knee movements in walking, squatting and angling the pelvis. The hamstring muscles are important postural muscles and help to some extent in the control of the standing torso along with other movements such as walking, running and jumping[8].

The thigh posterior muscle injury is one of the most common injuries in athletes[9,10,11] Muscle injuries range from acute muscle strains and tears to chronic proximal hamstring tendinopathy. Immense muscle contraction will lead to strains, which are the most common muscle injury, which have high rates of recurrence and can lead to prolonged absence from sports[9,11]

Recent studies have shown that increased hamstring strength reduces injury risk and improves deceleration capacity.[12,14] During sports activities hamstring muscle contraction is vital, which help the torso to maintain orientation and mediating control of the body's center of mass[13].

Hamstring injuries often occur during the high velocity running due to how rapidly they must decelerate the lower leg as it swings through prior to taking the next step. "Failure in extending the knees totally while the hip is flexedwith discomfort or pain along the posterior thighand/or knee is generally attributed to hamstring muscle stiffness"[14].

Hamstring muscle length is not measured directly. Hamstring muscle length is measured using the angular measurements of unilateral hip flexion with the kneeextended position[15]. Hamstring muscle stiffness is identified using the Knee Extension Angle (KEA). In case the Knee Extension Angle (KEA) greater than 20 degrees, where KEA is the degree of knee flexion from terminal knee extension consider to be tight or less flexiable.[16,17].

The competent players can suffer from injuries during activities, to avoid such damages and improve the soft tissue tractability, stretching program is suggested as a warming-up activity. Around numerous forms of stretching, that includes static, ballistic, and proprioceptive neuromuscular facilitation (PNF) stretching, besides wide-ranging investigation data associating these starching techniques exists. It is difficult to determine that a specific stretching technique is superior over others, as results vary across investigations based on the study conditions. Nevertheless, PNF is recognized to be more effective than other stretching methods as it increases together passive and active flexibility and improves range of motion in the limited time[18,19] and there by helps the athletes for faster recovery and enhanced game performance. Numerous studies have been conducted on hamstring muscle stretching techniques and flexibility.[20-23]

Dynamic Oscillatory Stretching (DOS) is an innovative technique that is a hybrid of Proprioceptive Neuromuscular Facilitation (PNF), Oscillating Passive Physiological Mobilization, and Agonist Contract Relaxation (ACR) in Static Stretching. In this technique, the agonist muscle group creates a stretch in response to the contraction of the antagonist muscle group[24]. The component of oscillatory movement added in DOS has resemblance to the oscillatory physiological mobilization as described by Maitland[25].

The Proprioceptive Neuromuscular Facilitation (PNF) stretching technique is been practiced to improve the muscle elasticity and has been shown to have a positive effect on active and passive range of motions.

Current research suggests that, that PNF techniques do increase joint ROM and literatures also suggests that, more frequently with combined methods such as the contract-relax (CR) and contract-relax-antagonist-contract (CRAC) methods of PNF works more effectively and commonly used. The CR method aimed to stretch a muscle (TM) and hold it in such a posture, and participants contracted the TM isometrically and maximally for a period.[25,26,27]

In the present study, we intend to examine the Acute Effect of Dynamic oscillatory stretching (DOS) and contract-relax (PNF) technique on hamstring flexibility among recreational badminton players. Recent studies on stretching technique and effects on exercise states that contract relax technique allows antagonist have contraction similar to hold relax technique while the oppositegroup of musclehave to contract eccentricallyaligned with autogenic and reciprocal inhibition. Flexibility can be improved by stimulating the

proprioception and neuromuscular system[28]. Furthermore, hamstring is the target group of muscle which consists of semimembranosus, semitendinosus, long head and short head of the biceps femoris. It is a two joint muscle, which acts as a primary hip extensor and knee flexor[29]. Tight hamstring leads to difficulty of energy absorption while muscle lengthening and difficulty in producing force while the muscle is shortening[30].

Badminton was played in Malaysia as early as 1809, since then badminton is one of the elite core sports in Malaysia[31]. Worldwide, the pervasiveness of injury among the exclusive shuttlecock players ranges between 170 and 253 injuries per year[32,33]and the frequency proportion is 1.6 to 2.9 per 1,000 player hours[8,9].

Collective factors related to injury such as age[32], gender[33], previous injuries[34], badminton rules[35] and playing field may still be relevant under the current scoring system. Injury research, particularly knee and shoulder injury incidence and injury types, may change. It also transitions from chronic to acute with increasing game aggression[36].

Furthermore, Electromyography (EMG) was used to identify the electrical activities of the muscles. They mentioned that semitendinosus in hamstring is one of the vital muscles in vertical jump activity. Vertical jumps, lunges and immediate change of direction are the actions needed in a badminton game[37].

Badminton consists of roughly 15% of forward lunges as an important step which require bicep femoris to work which is one of the hamstring muscles. Forward lunge is approximately 15% of all movement in badminton. One of the importance muscles involved in forward lunge is biceps femoris. It acts as agonist muscle during the extension of knee in the forward lunging. This is being one of the affirmative reasons to carry out the study. This study particularly focuses on the hamstring muscle among badminton players. Jumper's knee (42.7%), succeeded by the hamstring and quadriceps muscle strain(11.8%), are most common injuries prevalent among badminton players[38].

2. Materials & Methods

Participants: A total of 45 potential participants were volunteered to be involved in this investigation as shown in figure-I. Samples were recruited by using convenient sampling method, knowledgeable consent was obtained from all applicants, and any relevant criteria were mentioned beforehand prior to the data collection phase through online Google form document. Ethical Approval was applied from Faculty Research Review Committee of MAHSA University**.** The data collection procedure was undertaken abiding COVID-19 national regulations (Malaysia), guidelines and protocols were taken into consideration particular regulations related to lockdown levels, data were safely collected[39].

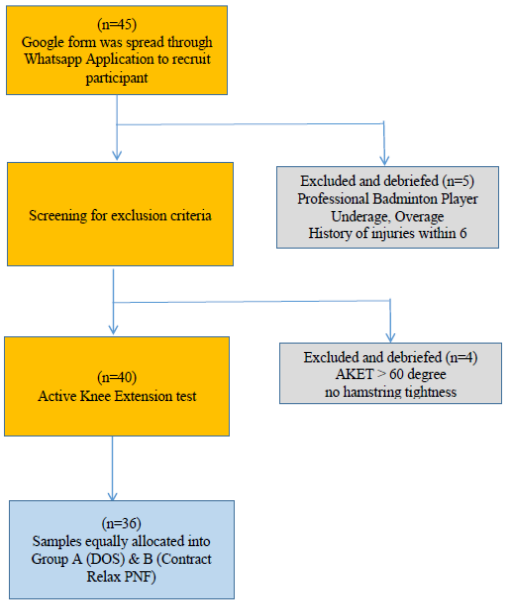

Fig-I: Flowchart demonstrating the Research process

Outcomes measures: That fulfilled all the criteria to proceed with the AKET as shown in the figure-II. For the present study subjects with Hamstring flexibility <60-degree knee extension during AKET, males & female ranging from 18-25 years old Recreational badminton player, play more than two times a week.

Interventions: A total of 36 recreational badminton players, whoever accomplished the inclusion criteria were allocated into two different assemblies randomly. The first group, Group A consist of 18 samples were given dynamic oscillatory stretching as an intervention. In contrast, Group B has 18 samples and were administrated by PNF contract relax stretching.

The dynamic oscillatory stretching for hamstring was conducted on sample in supine lying on the mat, and researcher lift up affected leg passively until restriction felt. Sample can assist the researcher at the beginning while raising the limb by tightening hip flexor muscles and sustaining the knee at extended position. Furthermore, the participants are instructed to contract the hip flexor by moving towards the direction of researcher's resisting hand and hold the contraction for ten seconds. 101,102, until 110 were used to standardized ten seconds hold duration. Mild slow stretch was administrated passively by the researcher at end range. The steps above were repeated for ten repetitions and three sets required to complete the intervention. The total stretching time allocated was five minutes also equivalent to three hundred seconds of dynamic oscillatory stretching.

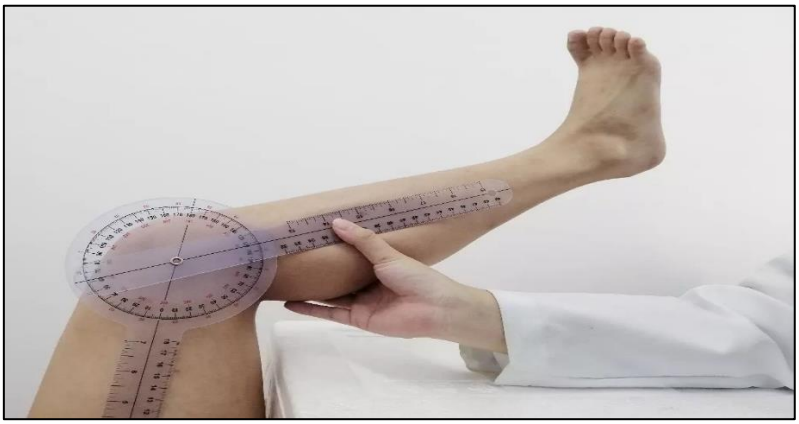

Fig-II: AKET for measurement Method-Placement of Goniometer on Active Knee Extension

Dosage: DOS: 5 minutes: 10 sec x 10 repetitions x 3 sets. Thirty seconds rest given in between sets. Meanwhile for Contract relax stretching technique (PNF) group, samples were instructed to push onto the researcher's shoulder. 101,102, until 110 counting were used to standardized ten seconds hold duration. Besides, researcher proceed to bring the leg to new range with stretching movement, instruct patient to take normal breathing and relax for another ten seconds by maintaining position at the new range. Then steps above are repeated for ten times. Thirty seconds rest given in between sets and a total of three sets required to complete this intervention.

Dosage: CR: 5 minutes: 10 sec x 10 repetitions x 3 sets.After the intervention, a five minutes rest was given to all samples before proceeding to do post-test assessment by measuring the new active knee extension degree by using goniometer.

Statistical analysis: Data analysis performed using Statistical Package of Social Sciences (SPSS) version 23. Kolmogorov Smirnov test was used to check for the variables of pre and post intervention. Data were cleaned and checked for the missing values later feuded to the Microsoft Excel Sheet and charted for the numerical analysis. Several statistical measures such as mean, standard deviation and test of significance were analysed

3. Results

The Statistical Package of Social Sciences (SPSS) was used to analyze all the tabulated data. All descriptive data collected were analyzed with descriptive statistic.Thirty-six samples which divided into Group A (n=18) for dynamic oscillatory stretching and Group B (n=18) for contract relax stretching technique (PNF)

Table-I: Data distribution of frequency and percentage of gender

Variable		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	25	69.4	69.4	69.4
	Male	11	30.6	30.6	30.6
	Total	36	100.0	100.0	100.0

Interpretation: 36 subjects participated in this experimental investigation. There are 25 females and 11 males, which is 69.4% and 30.6% respectively of the total participants.

Table-II: Data distribution of Mean and standard deviation of age

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Age	36	18.00	25.00	22.0556	1.62031

Interpretation: According to the information obtained, the mean age of all subjects is 22.06 with a 1.62 as standard deviation.

After the intervention given, there was a post-test to measure is there any improvement of the ROM. Hence AKET with goniometer is used again to assess the ROM of hamstring muscle in the samples. Relationship of each intervention and the hamstring flexibility were measured and recorded. The average readings of AKET after both interventions are recorded. The data collected will be recorded in a data collection form.

Table-III: Independent sample T-test values among the groups

Test Value	Intervention (DOS*)		Intervention(CR**)	
	Pre –test value	Post-test value	Pre –test value	Post-test value
Mean	134.2778	141.7778	137.2222	144.5000
Std. Deviation	5.27821	4.58329	7.59687	6.98949
t-value	-1.350		-1.382	
p-value	0.186		0.176	
DOS- Dynamic oscillatory stretching		***CR-contract relax stretching***		

Interpretation: The mean range of motion measurement of Active Knee Extension (AKE) test after both interventions given were recorded. The Intervention A (DOS), results show significant differences of p-value 0.186 ($p>0.05$) and intervention B (CR PNF) shows significant differences of p-value 0.176 ($p>0.05$). The pre-test mean value of ROM before the DOS was 134 and the post-test mean value is 141.7. Similarly, the pre-test mean value of ROM before the CR was 137 and the post-test mean value is 144.5. The results indicate that both the intervention are statically significant and that is suggestive of both the intervention can be used in terms of improving the hamstring flexibility.

Fig-III: Graphical representation of the t-test values

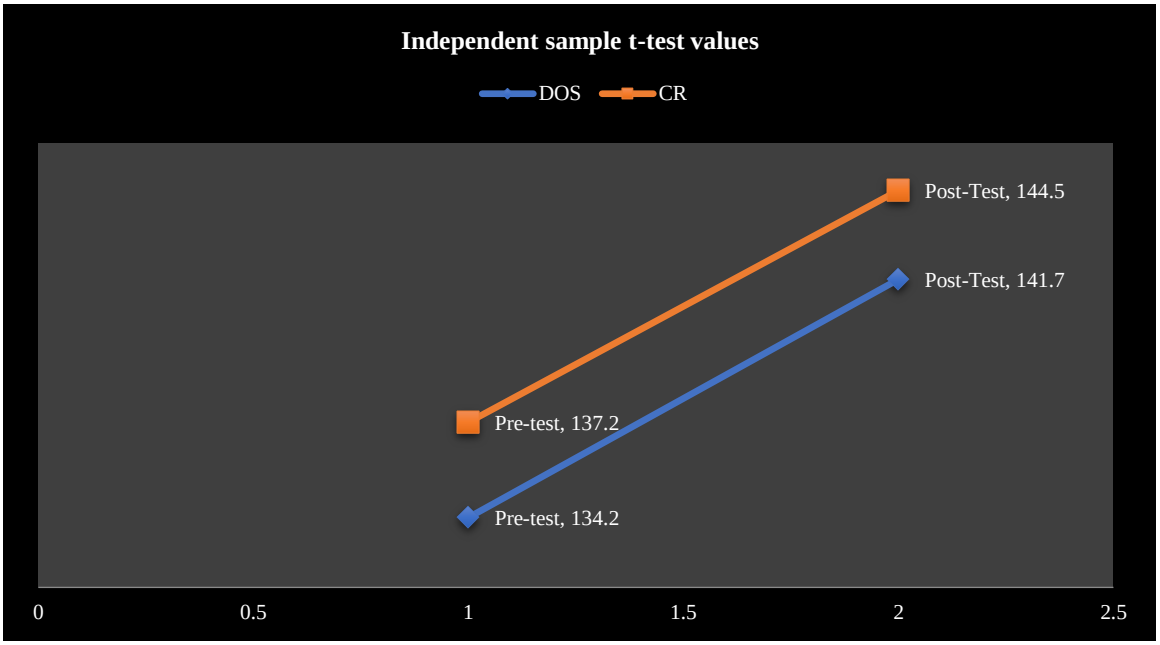

Table-IV: Independent sample T-test values between the groups

Intervention Group	Mean	Std. Deviation	p-value
DOS	141.7778	4.27821	**0.8557**
CR	144.5000	3.56319	
***DOS- Dynamic oscillatory stretching**		****CR-contract relax stretching**	

Interpretation: The mean of range of motion measurement of active knee extension test when compared between two interventions given were recorded. The mean differences of ROM between Intervention A (DOS) 141.77 and intervention B (CR PNF) 144.5 were compared using Independent Sample t test. The results shown no significant differences of p-value is 0.855 ($p>0.05$), between these 2 variables. Hence, null hypothesis is accepted as of no substantial difference found in the effectiveness of DOS and CR group according to the results recorded.

4. Discussion

Stretching is one of the famous physiotherapeutic intervention performed during the sports rehabilitation program, recommended to rise the muscle extensibility and ROM, also to line up the collagen fibers during the muscle healing process. Stretching technique also provide a new dimension for pre & post sports induced muscular recovery.

In numerous researches, investigators examined various stretching techniques on subjects with taut hamstrings, few authors report that both static and pre-contraction stretching are capable of increasing acute hamstring flexibility[40,41,42], while others suggest static stretching[43,44,45] or PNF stretching[46,47] is more functional. PNF is a stretching technique that can produce effective outcomes such as range of motion gain and improve physical performance[48].

A study conducted on dynamic oscillatory stretching efficiency on hamstring extensibility and stretch tolerance, the result finding revealed that both static stretching and dynamic oscillatory stretching protocols can improve

hamstring muscle extensibility. Though, the increased extensibility achieved within the dynamic oscillatory stretching group was greater than for the static stretching group, both immediately and one hour following the application of the intervention[49].

To further explanation, about the improved hamstring extensibility and perceived tolerance to the stretch demonstrated by the DOS group. This can be derived from theories of muscle property changes and reflex muscle relaxation, but is most likely explained by the improved stretch tolerance theory[50,51,52].

The finding of the current investigation indicates insignificant statistical difference between the DOS and CR PNF groups. The mean differences of ROM between Intervention A (DOS) 141.77 and intervention B (CR PNF) 144.5 were statically compared using Independent Sample t Test. The study results shown no significant differences of p-value i.e., 0.855 ($p>0.05$), between these 2 variables. This can be further justified as no statistically significant difference appeared as small sample sizes were recruited. But however, if the pre-test and post-test values on each stretching techniques is compared, it shows a valid statistical difference, which is indicative that both physiotherapeutic stretching procedures are effective in improving the hamstring flexibility among badminton players.

Similarly, result finding of this present research is in line with a published article, which suggests that DOS is a combination of contract relax PNF technique, sustain stretching and mobilization physiologically with oscillation. Hamstring muscle considered as an agonist in hip flexion can be lengthening due to the contraction of antagonist muscle located on the opposite. When antagonist was contracted, the agonist able to relax better in a lengthen stage. Hamstring muscles can relax and improve the range of motion with oscillation applied at the end range helps in improving the mobility of the joint[53].

Besides that, recent research indicates DOS was useful in improving hamstring flexibility with an immediate effect of increase in stretch tolerance and muscle extensibility. Range of motion increased due to the contraction of quadriceps which allow the hamstring to relax and lengthen hence the stretch tolerance can be elevated. Pain sensation were reduced in all the samples due to the focus on quadriceps contraction and the oscillation at the end of DOS procedure that helps in breaking the adhesion between soft tissue[54].

The benefits of stretching techniques seem to be effective in increasing extensibility of tight muscle and reducing muscular pain. For improving the joint Range of Motion, any type of physiotherapeutic stretching is effectual, while PNF-based stretching stands to be more effective to achieve immediate gains. In order to preserve the muscle strength & enhance performance athletes are recommended to engage static stretching before competition or activity, whereas dynamic stretching is recommended for warm-up.[55]

To prevent the decrease in strength and performance that may occur in athletes due to static stretching before competition or activity, dynamic stretching is recommended for warm-up[55].

5. Conclusions

Good hamstring flexibility is important in preventing injury and improves physical performance.[56]

This research intended to develop a rehabilitative framework by comparing the efficacy of two physiotherapeutic popular stretching techniques - dynamic oscillatory stretching and PNF contract relax. The research finding of this study indicates both dynamic oscillatory stretching and PNF contract relax would help in improving hamstring flexibility. Studies also suggest that conventional physical therapy treatment alone will have minimal effect, rather provided in a combination, the recovery is faster[57]. Thus, both physiotherapeutic procedures can be incorporated in sports rehabilitation to prevent on-site injury thereby improving the athlete's recovery time & game performance. It is also suggestive that, active/self-stretching can be practiced in young adult's badminton players to enhance game performance & minimize injuries.

Conflict of interest: The authors have no conflicts of interest.

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References

1. Backx FJ, Erich WB, Kemper AB, Verbeek AL. Sports injuries in school-aged children. An epidemiologic study. Am J Sports Med 1989; 17:234-40.
2. Jørgensen U, Winge S. Epidemiology of badminton injuries. Int J Sports Med 1987; 8:379-82
3. Yung PSH, Chan RHK, Wong FCY, et al. Epidemiology of injuries in Hong Kong elite badminton athletes. Res Sport Med 2007;15:133–46.
4. Fahlström M, Lorentzon R, Alfredson H. Painful conditions in the Achilles tendon region in elite badminton players. Am J Sports Med 2002;30:51–4.
5. Fahlström M, Yeap JS, Alfredson H, et al. Shoulder pain - A common problem in world-class badminton players. Scand J Med Sci Sport 2006;16:168–73.
6. Park SK, Lam WK, Yoon S, et al. Effects of forefoot bending stiffness of badminton shoes on agility, comfort perception and lower leg kinematics during typical badminton movements. Sport Biomech 2017;16:374–86.
7. Marchena-Rodriguez, A., Gijon-Nogueron, G., Cabello-Manrique, D., & Ortega-Avila, A. B. (2020). Incidence of injuries among amateur badminton players: A cross-sectional study. Medicine, 99(18), e19785. https://doi.org/10.1097/MD.0000000000019785
8. Portnoy H, Morin F. Electromayographic study of postural muscles in various positions and movements. Am J Physiol-Legacy Content. 1956;186(1):122-6
9. Askling CM, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings. The American journal of sports medicine. 2007;35(2):197–206.
10. Kujala UM, Orava S, Jarvinen M. Hamstring injuries. Current trends in treatment and prevention. *Sports medicine.* 1997;23(6):397–404.
11. Orchard J, Best TM, Verrall GM. Return to play following muscle strains. *Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine.* 2005;15(6):436–441.
12. Al Attar, W.S.A., Soomro, N., Sinclair, P.J., Pappas, E., Sanders, R.H. (2018) Effect of injury prevention programs that include the Nordic hamstring exercise on hamstring injury rates in soccer players: A systematic-review and meta-analysis. Sports Medicine, 47(5), pp. 907–916
13. Ogaya, S., Okita, Y., Fuchioka, S. (2016) Muscle contributions to center of mass excursion in ankle and hip strategies during forward body tilting. Journal of Biomechanics, 49(14), pp. 3381-3386.
14. Akinpelu, A.O., U. Bakare, and B.A. Adegoke, Influence of age on hamstring tightness in apparently healthy Nigerians. Journal of Nigeria Society of Physiotherapy, 2009. 15(2): p. 35-41. 2.
15. Bhavana, S., Mhatre, B.S., Singh, Y.L., Tembhekar, J.Y., Mehta, A, Which is the better method to improve "perceived hamstrings tightness" – Exercises targeting neural tissue mobility or exercises targeting hamstrings muscle extensibility? Int J Osteopathic Med, 2013. 3.
16. Gajdosik, R.L., et al., Comparison of four clinical tests for assessing hamstring muscle length. Journal of Orthopaedic & Sports Physical Therapy, 1993. 18(5): p. 614-618
17. Siddle, J., Greig, M., Weaver, K., Page, R.M., Harper, D., Brogden, C.M. (2018) Acute adaptations and subsequent preservation of strength and speed measures following a Nordic hamstring curl intervention: a randomised controlled trial. Journal of Sports Sciences, DOI: 10.1080/02640414.2018.1535786
18. Feland JB, Marin HN: Effect of submaximal contraction intensity in contract-relax proprioceptive neuromuscular facilitation stretching. Br J Sports Med, 2004, 38: E18.
19. Feland JB, Myrer JW, Merrill RM: Acute changes in hamstring flexibility: PNF versus static stretch in senior athletes. PhysTher Sport, 2001, 2: 186–193.

20. Cini A., DeVasconcelos G.S. & Lima C.S, 2017, 'Acute effect of different time periods of passive static stretching on the hamstring flexibility', Journal of Back and Musculoskeletal Rehabilitation 30, 241–246. 10.3233/BMR-160740
21. Freitas S.R., Vilarinho D., Rocha Vaz J., Bruno P.M., Costa P.B. & Mil-Homens P, 2015, 'Responses to static stretching are dependent on stretch intensity and duration', Clinical Physiology and Functional Imaging 35, 478–484. 10.1111/cpf.12186
22. Cipriani D.J., Terry M.E., Haines M.A., Tabibnia A.P. &Lyssanova O, 2012, 'Effect of stretch frequency and sex on the rate of gain and rate of loss in muscle flexibility during a hamstring-stretching program: A randomized single-blind longitudinal study', Journal of Strength and Conditioning Research 26, 2119–2129. 10.1519/JSC.0b013e31823b862a
23. Freitas S.R., Vilarinho D., Rocha Vaz J., Bruno P.M., Costa P.B. & Mil-Homens P, 2015, 'Responses to static stretching are dependent on stretch intensity and duration', Clinical Physiology and Functional Imaging 35, 478–484. 10.1111/cpf.12186
24. Michaeli A, Tee JC, Stewart A. Dynamic oscillatory stretching efficacy on hamstring extensibility and stretch tolerance: a randomized controlled trial. Int J Sports Physical Ther. 2017Jun;12(3):305.
25. Funk DC, Swank AM, Mikla BM, Fagen TA, Farr BK. Impact of Prior Exercise on Hamstring Flexibility: A Comparison of Proprioceptive Neuromuscular Facilitation and Static Stretching. Natl Str Cond Assoc J. 2003;17(3):489–492.
26. Lucas RC, Koslow R. Comparative study of static, dynamic, and proprioceptive neuromuscular facilitation stretching techniques on flexibility. *Percept Motor Skill.* 1984;58(2):615–618.
27. Wallin D, Ekblom B, Grahn R, Nordenborg T. Improvement of muscle flexibility: a comparison between two techniques. *Am J Sport Med.* 1985;13(4):263–268
28. Bernhart, Cassandra M., "A Review of Stretching Techniques and Their Effects on Exercise" (2013). Senior Honors Theses. 383.
29. Sato, K., Nimura, A., Yamaguchi, K., Akita, K., 2012. *Anatomical study of the proximal origin of hamstring muscles*.
30. Autumn, L., Hammonds, D., Kevin, G., Laudner., McCaw, S., Todd, A., McLoda., 2012. Acute Lower Extremity Running Kinematics After a Hamstring Stretch.
31. Shariff, AH., George, J., Ramlan, A., 2009. Musculoskeletal injuries among Malaysian badminton players.
32. Shariff AH, George J, Ramlan AA. Musculoskeletal injuries among Malaysian badminton players. Singapore Med J. 2009;50:1095–1097
33. Yung PS-H, Chan RH-K, Wong FC-Y, et al. Epidemiology of injuries in Hong Kong elite badminton athletes. Res Sports Med. 2007;15:133–146.
34. Nadler SF, Wu KD, Galski T, et al. Low back pain in college athletes: a prospective study correlating lower extremity overuse or acquired ligamentous laxity with low back pain. Spine (Phila Pa 1976). 1998;23:828–833.
35. Emery CA, Pasanen K. Current trends in sport injury prevention. Best Pract Res ClinRheumatol. 2019;33:3–15.
36. Olsen OE, Myklebust G, Engebretsen L, et al. Relationship between floor type and risk of ACL injury in team handball. Scand J Med Sci Sports. 2003;13:299–304.
37. Charoenpanich, Nongnapas&Boonsinsukh, Rumpa&Sirisup, Sirod&Saengsirisuwan, Vitoon. (2013). Principal component analysis identifies major muscles recruited during elite vertical jump. ScienceAsia. 39. 257. 10.2306/scienceasia1513-1874.2013.39.257.
38. Yusof, B., WoonShih, N., TingKai, C., Chengli, J., Wasli, F., 2018.
39. https://www.who.int/blueprint/priority-diseases/key-action/liverecovery-save-of-ethical-standards-for-research-during-public-health-emergencies.pdf
40. YoudasJWHaeflingerKMKreunMKHollowayAMKramerCMHollman JH. The efficacy of two modified proprioceptive neuromuscular facilitation stretching techniques in subjects with reduced hamstring muscle length. Physiother Theory Pract. May 2010;26(4):240–250.

41. de WeijerVCGorniakGCShamus E. The effect of static stretch and warm-up exercise on hamstring length over the course of 24 hours. J Orthop Sports PhysTher. Dec 2003;33(12):727–733.
42. WebrightWGRandolphBJPerrin DH. Comparison of nonballistic active knee extension in neural slump position and static stretch techniques on hamstring flexibility. J Orthop Sports PhysTher. Jul 1997;26(1): 7–13.
43. DepinoGMWebrightWGArnold BL. Duration of maintained hamstring flexibility after cessation of an acute static stretching protocol. J Athl Train. Jan 2000;35(1):56–59.
44. Bandy WDIrionJMBriggler M. The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. J Orthop Sports PhysTher. Apr 1998;27(4):295–300.
45. Ferreira GNTeixeira-SalmelaLFGuimaraes CQ. Gains in flexibility related to measures of muscular performance: impact of flexibility on muscular performance. Clin J Sport Med. Jul 2007;17(4): 276–281.
46. HalbertsmaJPGoeken LN. Stretching exercises: effect on passive extensibility and stiffness in short hamstrings of healthy subjects. *Arch Phys Med Rehabil*. Sep 1994;75(9):976–981.
47. Tanigawa MC. Comparison of the hold-relax procedure and passive mobilization on increasing muscle length. PhysTher. Jul 1972;52(7):725–735.
48. David, G., Anthony, J., Anthony, D., Malachy, M. 2015. Acute Effects of Muscle Stretching on Physical Performance, Range of motion, and Injury Incidence in Healthy Active Individuals: A Systematic Review.
49. Michaeli, A., Tee, J. C., & Stewart, A. (2017). Dynamic oscillatory stretching efficacy on hamstring extensibility and stretch tolerance: a randomized controlled trial. International journal of sports physical therapy, 12(3), 305–313
50. Fryer G. MET: efficacy and research in: Chaitow L. Muscle Energy Techniques. 2nd ed. Churchill Livingstone: Elsevier; 2013; 95-132.
51. McHugh MP Johnson CD Morrison RH. The role of neural tension in hamstring flexibility. Scand J Med Sci Sports. 2012;22:164-169.
52. Ben M Harvey LA. Regular stretch does not increase muscle flexibility: a randomized controlled trial. Scand J Med Sci Sports. 2010;20:136-144.
53. Ganesh, B., Veedika, V., Vidhi, S., 2019. Immediate effect of dynamic oscillatory stretching vs. neurodynamic sliding technique on stretch tolerance, popliteal angle range and hamstring flexibility in apparently healthy individuals with hamstring tightness.
54. Arie, M., Jason, C., Aimee, S., 2017. *Dynamic Oscillatory Stretching Efficacy on Hamstring Extensibility and Stretch Tolerance: A Randomized Control Trial*.
55. Page P. (2012). Current concepts in muscle stretching for exercise and rehabilitation. International journal of sports physical therapy, 7(1), 109–119.
56. Sivagnanam, R., Senthilkumar, N., Sudhakar, S., 2018. Comparative Effect of PNF Stretching Technique On Hamstring.
57. Kutty, R.K., Gebrekidan, H.G., Lerebo, W.T., &Gebretsadik, M.A. (2014). Neural mobilization a therapeutic efficacy in a piriformis syndrome model: an experimental study.