

ORIGINAL RESEARCH

IJPHY

PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION STRETCHING VERSUS STATIC STRETCHING ON SPRINTING PERFORMANCE AMONG COLLEGIATE SPRINTERS

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ABSTRACT

Background: A warm-up is important part of preparation for sprinting. There is popularity of doing stretching as part of warm up before athletic activity. The static stretching and PNF stretching is performed by athletes but their effectiveness on sprinting performance is in state of debate. The objective is to determine the effect of static stretching and PNF stretching on sprinting performance in college sprinters and to compare the effects of PNF stretching over static stretching on sprinting performance in college sprinters.

Method: A total of 100 subjects were taken for the study that fulfill the inclusion criteria and all were divided into group- A (static stretching) and group- B (PNF stretching) by simple random sampling method. Both the groups received 5 minutes of warm-up exercises. Pre-Post design was used, which consisted of running a 40-yard sprint immediately following 2 stretching conditions aimed at the lower limb muscles

Results: In static stretching group sprint time changed from 6.55 with standard deviation of 0.93 to 6.12 with standard deviation of 1.02 ($P < .001$) and in PNF stretching group sprint time changed from 6.73 with standard deviation of 1.22 to 6.23 with standard deviation of 1.10 ($P < .001$). However when comparing between group- A (6.12 ± 1.02) and group- B (6.23 ± 1.10) there was no significant difference ($P > .605$).

Conclusion: Hence both static stretching and PNF stretching can be performed before sprinting activity to improve the sprinting performance.

Keywords: Static stretching, PNF stretching, Warm-up, sprinting performance, 40- yard sprint test

Received 22nd June 2015, revised 28th July 2015, accepted 31st July 2015



www.ijphy.org

DOI: 10.15621/ijphy/2015/v2i4/67741

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INTRODUCTION

Sprinting is a burst of speed or activity, or to run at top speed for brief time.¹ A sprinting performance is mainly determined by the force and speed with which muscle can contract and relax, and because of the cyclic motion, the correct timing of the change from contraction to relaxation.²

Sprinting abilities vary widely among individuals but all runners have a maximum sprinting speed that they can exceed. It has been suggested that the force-velocity relationship of skeletal muscle plays a critical limiting role in the maximum speed at which human can sprint. Greater stride frequency requires the legs to move through the stride cycle at faster rates, and the muscles to shorten and lengthen more rapidly.³

Athlete body composition and mental capabilities determines their sport performance. The bigger the athlete, the better the performance in certain sports (football, basketball volleyball) and is not always same, smaller and lighter are considered to be better for performance (gymnastics, diving, figure skating). The decrease in performance is found due to poor warm-up techniques and time period, poor modification of shoes, increase duration of activity, faulty practice of stretching.^{4, 5}

Warm-up prepares the body for exercise. The type of exercise to be performed determines the type of warm-up (general or specific). The benefits of warm up are numerous including increasing the temperature of the muscles and connective tissues, increasing the range of movement, reducing the incidence of injury, decreasing the severity of injury, delaying the onset of muscular fatigue, preventing and alleviating muscle soreness, increasing the level of skill and muscular efficiency, and prolongation of sporting life.⁶

Stretching is traditionally used as part of a warm up to increase flexibility or range of motion before intense physical work in an attempt to improve better performance^{7, 8} and reduce the risk of injury.^{9, 10, 11, 12} Recent high quality randomized trial, have shown that structured warm-up programs designed to prevent injuries can reduce injury risk by 50% or more. The sport specific warm-up found more effective than general warm-up in sprinting performance. The effect of warm-up lasts approximately 30 minutes, so it is important not to warm-up too early.¹³

The proper warm-up with static stretching (SS) and proprioceptive neuromuscular facilitation stretching (PNFS) techniques, if performed prior to activity is effective in improving the sprinting performance.^{14, 15} Static stretching is commonly

used and well accepted as an effective form of stretching to increase flexibility and range of motion during short-duration (5–30 sec) stretches and has been considered a safest form of stretching.^{13, 16, 17, 18}

During static stretching, it is thought that Golgi Tendon Organ, which monitor tension created by stretch of a muscle tendon unit may contribute to muscle elongation by overriding any facilitative impulses from the primary afferent of the muscle spindle (1_a afferent fibers) and may contribute to muscle relaxation by inhibiting tension in the contractile unit of the muscle being stretched through mechanisms of autogenic inhibition. The combined neurophysiological effects results in improved muscle elongation. Additional benefit of static stretching using low intensity includes less ganger of soft tissue tearing, less post exercise muscle soreness and decrease energy requirement.¹⁶

Proprioceptive neuromuscular facilitation (PNF) is an approach to therapeutic exercise performed by alternating contraction and relaxation of both agonist and antagonist muscles. It is based on the observation that muscle relaxation is increased both after agonist and antagonist muscle contraction.¹³ Facilitated stretching refers to the use of neuromuscular technique to relax (inhibit) and elongate muscle when used in conjunction with stretching. Most of the literature has shown that Contract-Relax method and the Contract-Relax-Antagonist-Contract method of PNF are more effective in increasing ROM and muscular performance. Four theoretical physiological mechanisms for increasing ROM and muscle performance after PNF stretching were identified: autogenic inhibition, reciprocal inhibition, stress relaxation, and the gate control theory.^{19, 20} The recent research has proven that PNF techniques do increase muscle elasticity, passive and active range of motion, and muscular performance when performed in regard to exercise.¹⁹

Effect can last 90 minutes or more after the stretching has been completed.²¹ The duration of these effects can vary because of various things, such as change in the percentage of maximum voluntary isometric contraction asked for and the duration of the contraction of the target muscle during PNF stretching. The contraction has been proven to produce better effects when held a total of 3-10 seconds.²²

PNF showed a decrease in strength, power output, and muscle activation.²³ Similar decrease in ground reaction time and jump height, in drop jumps following PNF stretching.^{24, 25} However PNF has

been shown to be beneficial to increase stride length, frequency, and ROM.²⁶ Nelson found PNF is more beneficial than strength training in increasing strength and athletic performance in untrained individual.²⁷

Sayers did a study to determine which phase of a 30 meters sprint (acceleration or maximal velocity) was affected by pre performance static stretching on elite female soccer players and found that static stretching before sprinting results in slower time in acceleration and overall sprint time.²⁸

The factors that can affect the effects of static and PNF stretch include, the age and gender of the person stretching being performed on, the specific muscles being stretched, the technique employed, duration of stretch and the percentage of the maximal voluntary isometric contraction.¹⁹

A warm up is important part of preparation for a sprinting. Stretching is typically part of warm up however, debate exist as to the most appropriate type of stretching to perform. The effects of the static and PNF stretching have been studied when it comes to ROM, muscle strength, power output and vertical jump height. However the acute effect of static and PNF stretching on sprinting is less clear and hasn't been compared. So there is state of controversial in its acceptance by the athletic and fitness communities. Various studies in the past had shown improvement on ROM, flexibility, endurance, vertical jumping after stretching techniques. The conflicting evidence on effectiveness between static stretching and PNF stretching on performance of sprinting, concluding that further research needs to be done in order to understand which stretching technique is best for sprinters among collegiate. The popularity of doing stretching before athletic performance is a compelling reasons to perform this study. The objectives of this study are to determine and compare the effects of PNF stretching and static stretching on sprinting performance in collegiate sprinters.

METHODOLOGY

Procedure:

100 subjects were taken for the study from Padmashree Group of Institute that fulfilled the inclusion criteria and all were divided into 2 groups by simple random sampling method. Informed consent was taken from all the subjects. Baseline characteristics like Age, Gender, and Body Mass Index (BMI) were taken before the procedure. Group A received static stretching and group B received PNF stretching. Both the group received 5 minutes of warm-up exercises.

Pre-stretching:

A measurement for the 40-yards was made using a standard field tape measure. All the subjects underwent 5-mins warm-up exercises, which includes forward/backward arms swings, side-to-side trunk rotations with arms extended outward, walking lunges, forward/backward leg swings, side-to-side leg swings, hopping in place with locked knees, jogging in place with high knees, jogging in place with butt kicks and walking forward. Following 5 minutes warm-up exercises a maximal effort 40 yard sprint test was performed with command "GO". The time taken to complete the test was recorded by stop watch, which was recorded as pre-test value.

Post-stretching:

The stretching protocols used were static stretch and proprioceptive neuromuscular facilitation stretching. Muscle groups of the lower limb contributing sprinting in terms of its major biomechanical components (hip and knee extension, hip and knee flexion, ankle plantarflexion), quadriceps, hamstrings, gastrocnemius, gluteus maximus and iliopsoas were used for stretch.⁵⁰ Two hours of rest was given after taking pre- test value. Then all the subjects performed 5 minutes of warm-up exercises followed by designated stretching protocol. Within 60 seconds following the designated stretching post-stretch maximal effort 40-yard sprint test was performed with command "GO" and starts the stopwatch. Time taken to complete the test was recorded. The test is conducted 3 times. The fastest recorded time was used as post-stretch value to assess the subject performance. The pre- and post-stretch 40-yard sprint time were compared to determine the effects of stretching in performance of college sprinters.

Group-A

Students (n=50) in this group received warm-up exercises and Static stretching. During the static stretching the muscles of lower extremity were passively stretched to the point before discomfort for each subject for 15 seconds. The stretches were repeated 2 times in both legs in an alternative manner with 3 seconds of rest after each stretching.²⁹

Group- B

Students (n=50) in this group received warm-up exercises and PNF stretching. PNF involved stretching the lower extremity muscles using the contract-relax method and contract-relax-antagonist-contraction method. The stretches were repeated 2 times in both legs in an alternative

manner with 3 seconds of rest after each stretching.

1. Contract-relax method:

During the contract-relax method, the agonist muscle was passively stretched to its maximum tolerance ROM for 10 seconds then subject performed 15 second maximal voluntary isometric contraction of agonist muscle followed by passive stretch of the same muscle for 10 seconds.

2. Contract-relax-antagonist-contract method:

During contract-relax-antagonist-contract method, the agonist muscle was passively stretched to its maximum tolerance ROM for 10 seconds then subject performed 15 second maximal voluntary isometric contraction of agonist muscle followed by active contraction of antagonistic muscle for 10 seconds.³⁰

DATA ANALYSIS

Descriptive statistics was performed to find out mean, range, standard deviation for demographic variables and outcome variables. Chi-square test was used to find out gender difference among both groups. Unpaired t-test was used to find out the significant difference among demographic variables such as age. Paired t-test and Unpaired t-test was used to find out the significant difference within and between groups respectively for 40 yard sprint time.

RESULTS

Hundred subjects were studied. Table- 1 shows the demographic data of 100 subjects included in the study. Data are mean plus minus standard deviation.

Table 1: Baseline data for demographic variables

| Variable | Group A | Group B | p-value |
|--------------|---------------|---------------|---------|
| Age | 21.74 ± 1.85 | 21.84 ± 1.99 | > .795 |
| Gender (M/F) | 30/20 | 25/25 | > .315 |
| Weight | 58.00 ± 9.35 | 56.62 ± 6.77 | > .400 |
| Height | 164.22 ± 7.34 | 164.96 ± 5.92 | > .580 |
| BMI | 21.32 ± 2.67 | 20.76 ± 1.99 | > .236 |

Table 2: Baseline data for outcome variable

| Variable | Pre | Post | p-value |
|----------------------|-------------|-------------|---------|
| 40- yard sprint test | 6.55 ± 0.93 | 6.73 ± 1.22 | > .425 |

In group- A the mean 40-yard sprint test was 6.55 with standard deviation of 0.93 and in group- B the mean 40- yard sprint test was 6.73 with standard deviation of 1.22 which was statistically not significant (p-vale is greater than 0.425). These data

shows that the outcome variable was homogeneous between groups.

Table 3: Pre- Post comparison within groups

| Variable | Pre | Post | p-value |
|----------|-------------|-------------|---------|
| Group A | 6.55 ± 0.93 | 6.12 ± 1.02 | < .001 |
| Group B | 6.73 ± 1.22 | 6.23 ± 1.10 | < .001 |

Table- 3 shows within comparison for group-A and group-B. In group-A the pre score of 40-yard sprint test was improved form 6.55 with standard deviation of 0.93 to post score of 6.12 with standard deviation of 1.02 which was statistically significant (P-value is less than 0.001). In group- B the pre score of 40-yard sprint test was improved form 6.73 with standard deviation of 1.22 to post score of 6.23 with standard deviation of 1.10 which was statistically significant (P-value is less than 0.001).

Table 4: Difference between groups

| Variable | Group A | Group B | p-value |
|---------------------|-------------|-------------|---------|
| 40-yard sprint test | 6.12 ± 1.02 | 6.23 ± 1.10 | > .605 |

Table- 4 shows the mean improvement between group- A and group- B. when comparing between groups the mean gain in improvement for 40-yard sprint score in group- A was 6.12 with standard deviation of 1.02 and group- B was 6.23 with standard deviation of 1.10 which was statistically not significant (p-vale greater than 0.605).

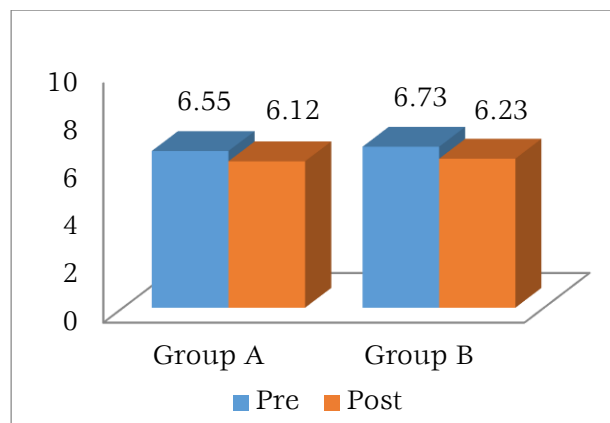


Fig-1: Pre- Post comparison of 40-yard sprint score within groups

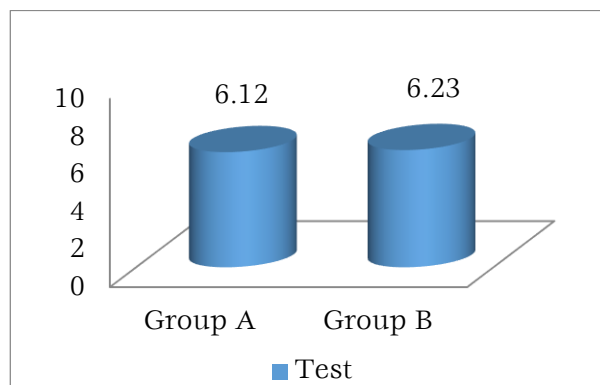


Fig-2: Comparison between groups

DISCUSSION

The result of this study provides the evidence to answer for 3 main questions: Is static stretching useful in improving sprinting time among collegiate sprinters? Is PNF stretching useful in improving sprinting time among collegiate sprinters? Is there any difference between static stretching and PNF stretching?

In this study 100 subjects were divided into group-A and group- B consisting 50 subjects in each group. The baseline demographic data and outcome variable were homogenous between static stretching group and PNF stretching group. All the subjects in both the groups were able to complete the study.

In group-A the pre score was 6.55 ± 0.93 and post score was 6.12 ± 1.02 which was statistically significant (P -value < 0.001). In group- B the pre score was 6.73 ± 1.22 and post score was 6.23 ± 1.10 which was statistically significant (P -value < 0.001). As such, this result supports the finding of Michael Samson et al. who concluded improvement in 20 yard sprint time after static stretching with activity specific warm-up.¹³ Little T. et al. found beneficial effects in sprinting time after 30 seconds of stretching for once among football players.³¹

In this study the major muscles of lower limb (iliopsoas, gluteus maximus, quadriceps, hamstring and gastrocnemius), which has been described by previous literature as the most important muscles involved in sprinting were focused to investigate the effects of stretching.³² The protocol employed during the study differs when compared to other studies found in the literature in terms of time gap between stretching and 40-yard sprint test and the muscle involved in the stretching. Here the effects of stretching on sprinting was measured immediately after stretching (0-60 seconds), whereas other studies investigated the effects of stretching on sprinting performance approximately 3-10 minutes following the performance of stretching. Other studies which included single muscle in the stretching protocol, the author did not find a significant difference between pre and post measures of 40-yard sprint times when subjects were stretched using static stretching, ballistic stretching, and dynamic stretching.³³

In static stretching subjects sprint time was reduced from 6.55 ± 0.93 to 6.12 ± 1.02 which was statistically significant ($P < .001$). A similar intervention was used by Michael Samson et al. who reported a decrease in 20 meter sprint time and increase in ROM after specific warm-up and

static stretching due to physiological changes.¹⁴ Rosenbaum et al. also reported a decrease time to peak force following static stretching and treadmill running warm-up.³⁴ Anthony et al. concluded that short duration of static stretching (< 60 secs) can be performed in pre-exercise routine without compromising the muscle performance. Turki et al. found increase in sprint performance due to post activation potentiation which increases cross bridge cycling via increase in myosin phosphorylation.³⁵

The neurophysiology behind static stretching is found as autogenic inhibition. Golgi Tendon Organs (GTOs) are sensitive to change in tension and rate of change of tension. Muscle spindles are sensitive to change in muscle length and the rate of change of muscle length. When the muscle is in tension during static stretching, GTOs send inhibitory signals to spinal cord causing decrease in the nerve impulse excitability. So further lengthening of muscle can be achieved. Static stretching decrease post exercise muscle soreness, soft tissue tearing which lead to improve in performance.¹⁶

Little and Williams reported that a static-stretch protocol produced significantly faster runs than did the no-stretch protocol for the 20 m sprint.²⁸ Fletcher et al reported an decrease in 50-m sprint time (improvement in sprint performance) in a group of competitive track and field athletes after warm-ups involving static dynamic stretches combined with active dynamic stretches or with the active dynamic stretches alone. Layec et al. suggested that static stretching increase motor unit recruitments and firing frequency and increase firing frequency increase rate of force development.³⁵

In PNF stretching subjects sprint time was reduced from 6.73 ± 1.22 to 6.23 ± 1.10 which was statistically significant ($P < .001$). According to Sharman et al. and Rowlands et al. this improvement in sprint time may be due to four theoretical physiological mechanisms (autogenic inhibition, reciprocal inhibition, stress relax and the gate control theory). Autogenic inhibition is what occurs in a contracted or stretched muscle in the form of a decrease in the excitability because of inhibitory signals send from the Golgi Tendon Organs (GTOs) of the same muscle. Accordance to Sharman et al. in PNF stretching (CR and CRA), contraction of the target muscle during stretching and contraction of the antagonistic muscle (CRAC), tension get decrease due to autogenic inhibition. PNF stretching takes of the advantage of the viscoelastic properties of the muscletendinous units

(MTU) allowing the muscle to creep and elongate, thus increasing the ROM and sprinting performance.²⁰

In PNF stretching the target muscle (TM) and its antagonist muscles work together. Sharman et al. reported that during CRAC method, when antagonist muscle contracts the TM relaxes allowing the muscle fibers of the TM to elongate even further, creating a greater stretching force for the TM and producing a larger inhibitory influence on the TM.

Sharman et al. stated that when the stretch is healed, the stress relaxation occurs and there is a decrease in the passive torque and the muscle stiffness thus allowing MTU to creep and slowly lengthen over period of time. It's effect last for short duration from 80 seconds to an hour after PNF stretching, Magnusson et al. This is the protective mechanism to prevent muscle tearing and maintain a healthy relationship between the contractile units of the muscle sarcomere.

In PNF stretching, the muscle is stretched forcefully, past to its normal ROM, which is sensed as noxious stimuli so the GTOs get activated in an attempt to reduce the injury. The GTOs get adaptation to the increased in length and force threshold as the process is repeated more, thus decreasing inhibition of GTOs. With increase ROM, and decrease GTO inhibition, the muscle may be able to increase its strength and force production.^{19,20}

Nikbakht et al. reported increase in vertical jump performance after PNF stretching. The study was design to determine the effect of PNF training on feet explosive power and agility among 40 female students.⁶ Ian shier et al. revealed regular stretching improves force, jump height and running speed.³⁶ Pornratshree et al. reported that the possible mechanisms responsible for the effects of stretching on performance and the minimal effects on injury prevention are considered with muscle dynamic flexibility. The mechanism by which stretching would affect running speed is more complicated. Running speed is dependent on running economy, force production and velocity of contraction.

However when comparing between static stretching group (6.12 ± 1.02) and PNF stretching group (6.23 ± 1.10) there were no significant difference between groups ($P > .605$). The possible mechanism may be physiological effects of warm-up which was performed by subjects of both groups before 40-yard sprint. McMillian et al revealed that warming the muscle up prior to an activity by engaging in dynamic warm-up exercise facilitates

physiological changes that may result in performance enhancement. An acute bout of stretching decreases the visco-elastic behavior of muscle and tendon. Due to decrease in stiffness less energy is required to move the muscles which might have improve the running speed. Other possible mechanisms include central programming of muscle contraction/coordination and decrease fatigue through increase warm-up activity. So the study concludes that the both the stretching techniques are effective in improving the sprint performance among collegiate sprinters.

Though study was done systematically some limitations has been found in this study, they are: joint range of motion and muscle length was not considered during the study, control group was not added to see the better results in the study, level of effort was not able to monitor during the study, track surface might have effect the study.

The further studies could be: use of trained runner to see if these same effects are seen in these athletes as well, individual with lower limb muscle tightness, different sport population, to address the effects of stretching on return to sprinting activity after injury, to fine the mechanisms of static and PNF stretching in improving sprinting performance.

CONCLUSION

The result of the present study indicates that static stretching and PNF stretching produce decrease in sprint time and no significant difference in sprint time between groups. Thus static stretching and PNF stretching with general warm-up can be performed before sprinting activity to increase the sprinting performance in collegiate sprinters. Hence study accepts Null hypothesis.

REFERENCES

1. Troy. Sprinting: A Tool for Developing Lean Muscle Mass and More. Available from url: <http://metroflexplano.com>.
2. Schmolinaky G. Track and field. 1983. Sportverlog, Berlin.
3. Ross H. Miller, Brian R. Umberger, Graham E. Coldwell. Limitation to maximum sprinting speed impose by muscle mechanical properties. Journal of biomechanics. 2012;45(6):1092-7.
4. Jack H. Wilmore, David L. Costill. Optimizing Performance in Sports. Physiology of Sports and Exercise. 3rd edition;2004.
5. Bundle, Weyand. key to performance for elite sprinters and running mechanics, Available from

url:<http://www.redorbit.com/news/science>. (Accessed August 1, 2012).

6. NikbakhtHojatallah, AmirtashAlimohammd, HossiniFatemeh, MasuodiNezhad Monire. The effects of the proprioceptive neuromuscular facilitation (PNF) stretching on explosive power and agility. *Scholars Research Library, Annals of Biological Research*.2012; 3(4):1904-1908
7. Frank G. Shellock, William E. Prentice. Warming-up and stretching for improved physical performance and prevention of sports related injuries. *Journal of Sports Medicine*. 1985; 2: 267-278.
8. Smith CA. The warm-up procedure: to stretch or not to stretch- A brief review. *Journal of Orthopedic and Sports Physical Therapy*.1994; 19(1):12-17.
9. Bixler B, Jones RL. High school football injuries: effects of a post-halftime warm-up and stretching routine. *Journal of Family Practice Research*.1992; 12(2):131-139.
10. Marc R. Safran, Anthony V. Seaber, William E. Garrett. Warm-up and muscular injury prevention an update. *Journal of Sports Medicine*. 1989; 8(4):239-249.
11. Alter MJ. *Science of Flexibility*. 3rd ed. Champaign (IL): Human Kinetics: 2004.
12. Woods k, Bishop P, Jones E. Warm-up and stretching in the prevention of muscular injury. *Journal of Sports Medicine*. 2007; 37(12):1089-99.
13. Peter Brukner, Karim Khan. *Principles of injury prevention*. Clinical sports medicine. 3rd edition;2008.
14. Michael Samson, Duane C. Button, AnisChaouachi and David G. Behm. Effects of dynamic and static stretching within general and activity specific warm-up protocols. *Journal of Sports Science and Medicine*. 2012;11(2): 279-285.
15. Nelson AG, Chambers RS, McGOwn CM, Penrose KW. Proprioceptive neuromuscular facilitation verses weight training for enhancement of muscular strength and athletic performance. *Journal of Orthopedic and Sport Physical therapy*. 1986; 7 (5): 250-253
16. Carolyn Kisner, Lynn Allen Colby. *Resistance Exercise for Impaired Muscle Performance*. Therapeutic Exercises. 5th ed; 2007.
17. Bandy WD, Irion JM, Briggler M. The effects of time and frequency of static stretching on flexibility of the hamstring muscles. *Journal of Physical Therapy*. 1997; 77(10):1090-6.
18. Kay AD, Blazeovich AJ. Reductions of active planter flexor moment are significantly correlated with static stretch duration. *European Journal of Sport Science*. 2008;8(1):41-6.
19. Kayla B. Hindle, Tyler J. Whitcomb, Wyatt O. Briggs, and Junggi Hong. Proprioceptive Neuromuscular Facilitation (PNF): Its Mechanisms and Effects on Range of Motion and Muscular Function. *Journal of Human Kinetics*. 2012; 31:105–113.
20. Sharman M, Cresswell A, Riek S. Proprioceptive Neuromuscular Facilitation stretching: Mechanisms and clinical implication. *Journal of Sport Medicine* 2006; 36(11):929-939.
21. Funk, Daniel C, Swank AM, Mikla Benjamin M, Fagan Todd A, Farr Brian K. Impact of Prior Exercise on Hamstring Flexibility: A Comparison of Proprioceptive Neuromuscular Facilitation and Static Stretching. *Journal of Strength & Conditioning Research*. 2003; 17(3):489-492.
22. Feland JB, Marin HN. Effects of submaximal contraction intensity in contract-relax proprioceptive neuromuscular facilitation stretching. *British journal of sports medicine*. 2004; 38(4):e18.
23. Marek SM, Cramer JT, Fincher AL, Massey LL, Dangelmaier SM, Purkayastha S, Fitz KA, Culbertson JY. Clinical Studies - Acute Effects of Static and Proprioceptive Neuromuscular Facilitation Stretching on Muscle Strength and Power Output. *Journal of Athletic Training*. 2005; 40(2):94-103.
24. Bradley PS, Olsen PD, Portas MD. The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. *Journal of Strength and Conditioning Research*. 2007; 21(1):223–226.
25. Mikolajec K, Waskiewicz Z, Maszczyk A, Bacik B, Kurek P, Zajac A. Effects of Stretching and Strength Exercises on Speed and Power Abilities in Male Basketball Players. *Isokinet Exercise Science*. 2012; 20(1):1-22.
26. Caplan N, Rogers R, Parr MK, Hayes PR. The effect of proprioceptive neuromuscular facilitation and static stretch training on running mechanics. *Journal of Strength and Conditioning Research*. 2009; 23(4):1175–1180.
27. Nelson AG, Kokkonen J, Arnall DA. Acute Muscle Stretching Inhibits Muscle Strength and Endurance. *Journal of Strength and Conditioning Research*. 2005; 19(2):338–343.
28. Sayers Adam L, Farley Richard S, Fuller Dana K, Jubenville Colby B. The Effect of Static Stretching on Phases of Sprint Performance in Elite Soccer Players. *Journal of Strength & Conditioning Research*. 2008; 22(5):1416-21.

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29. Melanie J. Sharman, Andrew G. Cresswell and Stephan Riek. Proprioceptive Neuromuscular Facilitation Stretching Mechanisms and Clinical Implications. *Sports Medicine*. 2006;36 (11): 929-939.
 30. Mojock CD, Kim JS, Eccles DW, Panton LB. The effects of static stretching on running economy and endurance performance in female distance runners during treadmill running. *Journal of Strength and Conditioning Research*. 2011; 25(8):2170-6.
 31. Little T, Williams AJ. Effects of differential stretching protocols during warm-ups on high speed motor capacities in professional footballers. *J Strength Cond Res*. 2006 ;20(1):203-7.
 32. Mann RA, Moran GT, Dougherty SE. Comparative electromyography of the lower extremity in jogging, running, and sprinting. *Journal of Sports Medicine*. 1986; 14(6):501-510.
 33. Wallmann HW, Christensen SD, Perry C, Hoover DL. The acute effects of various types of stretching static, dynamic, ballistic, and no stretch of the iliopsoas on 40-yard sprint times in recreational runners. *International Journal of Sports Physical Therapy*.2012;7(5):540-7
 34. Rosenbaun D., Henning E. The influence of stretching and warm-up exercises on Achilles tendon reflex activity. *Journal of sport science*.1995; 13(6):481-90.
 35. Michael Samson, Duane C. Button, Anis Chaouachi and David G. Beham. Effects of Dynamic and static stretching within general and activity specific warm-up protocol. *Journal of sports science and medicine*. 2012; 11 (2): 279-285.
 36. Ian Shrier. Does Stretching Improve Performance? A Systematic and Critical Review of the Literature. *Clinical Journal of Sport Medicine*. 2004;14(5):267–273

Citation

Jayaram Maharjan, & Mallikarjunaiah .H .S. (2015). PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION STRETCHING VERSUS STATIC STRETCHING ON SPRINTING PERFORMANCE AMONG COLLEGIATE SPRINTERS. *International Journal of Physiotherapy*, 2(4), 619-626.