A Comparison of the Effects of Static Stretching Alone to Static Stretching Plus Slow Deep Breathing on Hip Flexion Range of Motion

Emilie Lamontagne
Sheridan College

Trevor G. Cottrell
Sheridan College

Article

A comparison of the effects of static stretching alone to static stretching plus slow deep breathing on hip flexion range of motion.

Emilie Lamontagne*, G. Trevor Cottrell*

*Kinesiology and health promotion, faculty of applied health and community studies, Sheridan College, Brampton, ON

Published: December 2021

Abstract: Restricted hip range of motion (ROM) is a common issue for both the general public due to muscle tightness associated with an increased sedentary lifestyle and individuals with diaphragmatic breathing dysfunction. There is evidence that both static stretching treatment and proper breathing mechanics, increase hip ROM, however, it is unclear whether ROM can be enhanced by combining these techniques. The purpose of this study is to compare the effects of static stretching (SS) to static stretching combined with slow deep breathing (SS+SDB) on hamstring flexibility as measured by hip flexion. Eleven healthy participants between the ages of 18-30 with no current musculoskeletal injury, or diagnosed respiratory disease, reported for two separate test days, 1 to 4 weeks apart. The SS intervention consisted of a standing one-legged hamstring stretch for 2 sets of 30 seconds bilaterally with 10 seconds rest between sets. The SS+SDB intervention consisted of the same stretching protocol as used in the SS intervention with the addition of slow deep diaphragmatic breathing at a rate of 4 seconds inhale, 2 seconds hold, 4 seconds exhale. The order of the interventions was randomly assigned. Pre-and post-intervention measurements of hip flexion were acquired through completing an active straight leg raise bilaterally with video analysis. Post-intervention left and right hip flexion was normalized to pre-intervention hip flexion, averaged by intervention, and then compared using a T-test. There was a significant increase in hip flexion for the SS+SDB when compared to SS for both the right leg (3.91% +/- 1.57 vs 9.17% +/- 1.77, $p < 0.05$), and left leg (2.88% +/- 1.03 vs 9.27% +/- 1.74, $p < 0.05$). A separate analysis was conducted comparing the different treatment effects by gender which revealed no significant differences. In conclusion, this data suggests that the addition of slow deep breathing to static stretching produces a greater increase in hip ROM when compared to static stretching alone. Therefore, when aiming to increase hip ROM through static stretching it is important to incorporate slow deep breathing.

Keywords: Stretching, slow deep breathing, hamstring, hip range of motion

1. Introduction

Hamstring flexibility plays an important role in human movement, yet a lack of hamstring flexibility due to tightness and shortening of the muscle is a common issue in the general public[1]. Tight hamstrings cause a restricted hip range of motion (ROM) which can limit activities of daily living and independence of individuals with neurological impairment[2]. A lack of hamstring flexibility may also result in major muscle imbalances which increases the incidence of musculoskeletal injury and reduced athletic performance[2,3]. As muscle extensibility has been found to impact end ROM, an increase in hamstring muscle compliance would be effective in enhancing ROM at the hip[4,5]. Individuals who have a sedentary lifestyle, nerve impingement such as sciatica, or diaphragmatic breathing dysfunction including chronic obstructive pulmonary disease (COPD) have been identified as being at risk for impaired hip ROM[1,6–8]. There is a need to consider interventions for increasing hip ROM as it has been found that from the age of 20, an individual's flexibility is reduced on average by 10% every 10 years which negatively impacts the activities of daily living, physical independence, and quality of life[9]. There are a variety of treatment methods proven to increase hip ROM and hamstring compliance which include a multitude of manual therapy, resistance training, and stretching techniques[2,10–13]

Stretching is a commonly used method to increase flexibility and ROM at various joints[14], in which intensity, duration, frequency, and stretch position influence the outcome[2]. Thomas et al. conducted a literature review that revealed that static stretching (SS) was significantly more effective in increasing ROM compared to proprioceptive neuromuscular facilitation (PNF) and dynamic stretching[2]. Although it is recommended for the general population to stretch for at least 5 minutes a day, the time spent stretching in a day is less significant than the frequency spent during a week[2]. A study by Cipriani et al. found similar results when they looked exclusively at hip ROM and SS where they found that the total time spent on stretching in a day was less significant than the frequency of stretching throughout the week[15]. Furthermore, the study indicates that there was a gradual increase in hip ROM from week one to four[15]. These findings support the evidence that acute SS has a significant effect on increasing hamstring flexibility and hip ROM with or without a warm-up and can gradually increase over a long period of time[15,16]. Overall, SS is a commonly used and safe method to acutely increase hip ROM by decreasing muscle-tendon stiffness[10,17].

Although breathing exercises are known to treat or improve respiratory conditions, hypertension, and anxiety disorders, it has recently started to be used as a technique to improve mobility[18–20]. Specifically slow deep breathing has been seen to be a component of mind-body therapy and is linked to having many physiological benefits including improving tolerance of pain perception and reducing stress and strain on the body[19–21]. In addition, improper breathing techniques have been found to be a contributing factor in restricted/limited hip ROM for both healthy individuals and those with respiratory dysfunction such as COPD[6,8,22]. A study by Valenza et al. found that restoring proper breathing mechanics in individuals with short hamstring syndrome using a manual technique known as the diaphragm doming which restores proper function of the diaphragm and consequently improved breathing, was found to significantly increase hip ROM acutely[1]. There is an anatomical theory that suggests that the anatomical link between the diaphragm and the pelvis floor muscles can affect respiratory function which impacts the tension of the muscles influencing hip ROM[23]. This theory may explain what is observed by Valenza et al. Other theories revolve around neurological connections in which breathing can reduce the tension, stress, and strains in muscles and improve tolerance to pain perception [19,21,24]. Although the precise mechanism is unclear it is believed that slow deep breathing modulates pain perception indirectly as a result of an increase in oxygen consumption, which then improves autonomic and cardiovascular function which in turn leads to increased muscle flexibility and thus increasing ROM [18,19,21,22,24].

Although there is limited research that examines the combination of stretching and slow deep breathing, evidence exists that this combined technique will result in improved ROM. In a case study of a 46-year-old female with a frozen shoulder, a treatment plan of PNF and slow deep breathing resulted in significantly increased shoulder ROM[24]. Further support of this approach can be seen in a study by Wongwilairat et al. which involved 32 participants who partook in SS or slow dynamic stretching and slow deep breathing which resulted in decreased neck pain and significantly decreased muscle tension which is linked to improving ROM[20,21]. To date, no study has examined the effects of static stretching with slow deep breathing (SS+SDB) on hamstring flexibility and hip ROM.

SS is an effective method to increase hip ROM, and slow deep breathing may enhance compliance of muscle tissue by improving tolerance of pain perception and reducing the passive neural drive to the muscle[10,17,19,21] . It is, therefore, possible SS+SDB could increase ROM and this could result in more effective treatment approaches for enhancing ROM in clinical practice. Therefore, the purpose of this study is to compare the effects of SS with SS+SDB on hamstring flexibility and hip flexion. As slow deep breathing holds additional benefits that positively impact flexibility and ROM compared to SS alone, it was hypothesized that SS+SDB will produce greater hip flexion gains when compared to SS.

2. Methods

2.1. Participants

Fourteen healthy college students were recruited to be participants in this study through class outreach and social media advertising. Eleven participants (5 women and 6 men) completed the study, three were removed due to scheduling conflicts that limited attendance. All participants met the participant criteria which consisted of; being between the ages of 18-30, not receiving treatment for any dysfunction or pain of the hip, and were not diagnosed with any inflammatory joint disease, injuries, chronic musculoskeletal disorder, diagnosed respiratory disease or hypermobility. Every participant signed an informed consent form that was approved by Sheridan College Research Ethics Board before participation.

2.2. Protocol

Participants in the study attended testing sessions on two separate occasions separated by one to four weeks. All participants partook in both the SS intervention and SS+SDB intervention on different days. Participants were randomly assigned to the first intervention dependent on the order that they entered the study. Therefore, the first and every odd number participant started with the SS intervention, whereas the second and every even number participant started with the SS+SDB intervention. Day 1 (D1) of the intervention started with the collection of personal information including name, age, medical and injury history, and consent form. Afterward, all participants were instructed and performed the FMS active straight leg raise to measure hip flexion on both the right and left leg followed by one of the two stretching interventions. The SS group consisted of a standing one-legged hamstring stretch for 2 sets of 30 seconds each leg with a 10-second rest in between reps. The SS+SDB group consisted of performing the same protocol as the SS with the addition of slow deep breathing at a rate of 4 seconds inhale, 2 seconds hold, 4 seconds exhale while using the diaphragm. Following the intervention, both SS and SS+SDB repeated the active straight leg raise to measure post-intervention hip flexion. Day 2 (D2) followed a similar format to D1; however, all participants partook in the opposite intervention in a crossover study fashion (Figure 1).

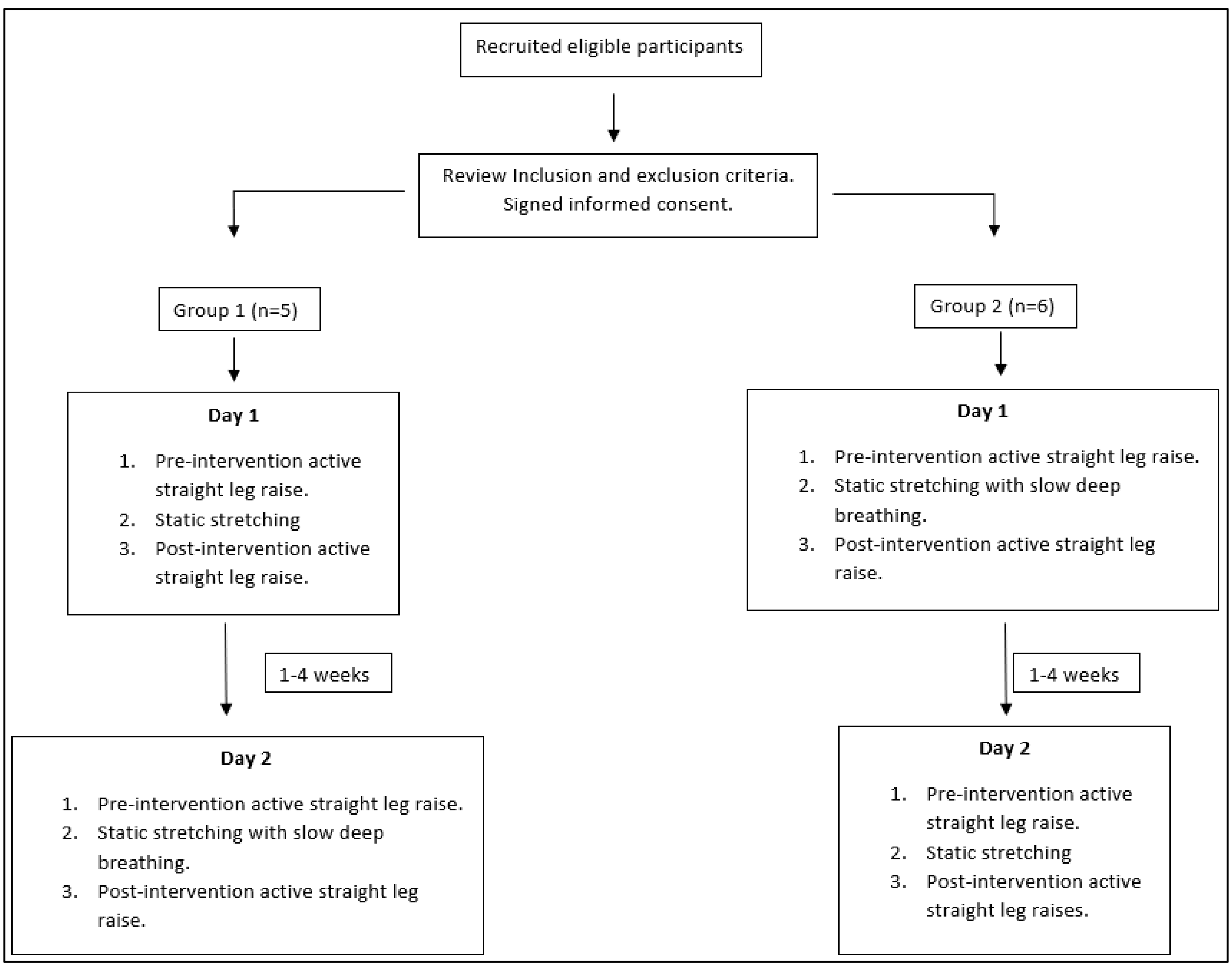

Figure 1. *Participants partook in a crossover design with half receiving the SS intervention on D1 and the other half receiving the SS+SDB intervention. Following a 1-4 week period, they then returned for the remaining intervention.*

2.3. Measuring Hip Flexion

Both pre-and post-intervention hip ROM was measured by performing the functional movement screen (FMS) active straight leg raise test (Figure 2). All participants were asked to wear tight clothing or expose the lateral aspect of the right and left gluteal by lowering the shorts past the greater trochanter. All participants were palpated on both sides to locate and mark their greater trochanter, lateral malleolus, and medial malleolus. The greater trochanter marker was the designated axis whereas the lateral malleolus of the raised leg and the medial malleolus marker of the resting leg were the angle lines. This test required the participant to lie supine with their arms resting at their side at 45–60-degree angles. The participant was required to raise the testing leg as much as possible while maintaining knee extension and dorsiflexion and holding it for at least 1 second. This was then repeated with the other leg. A camera was set upright on the floor horizontally 4 meters from the mid-length of the yoga mat, in which the participant's full body remained in the frame during the FMS active straight leg raise test. Each video was then analyzed using the angle measurement tool in Kinovea software (Kinovea version 0.8.15, kinovea.org) to measure the angle of hip flexion.

Figure 2. *FMS active straight leg raise for pre-and post-intervention measurements. The markers are placed on the greater trochanter to indicate the axis, the medial and lateral malleolus are the markers to indicate the angle line.*

2.4. Static Stretching (SS)

All participants performing the SS intervention were required to complete a standing one-legged hamstring stretch (Figure 3). The investigator cued the stretch and had the participant mimic the movement to ensure they understood the procedures and could replicate the proper position before performing the intervention. The starting leg was placed on an elevated surface at mid-shin level with the knee near full extension and the foot dorsiflexed pointing to the ceiling. The standing leg remained straight, with a soft bend at the knee, and toes pointing straight ahead. The hands were placed on the hips and while keeping the spine in neutral and the pelvis square, flexing at the hips and holding at the point of tension for 30 seconds. This was repeated for 2 sets on each leg with a 10 seconds rest between sets.

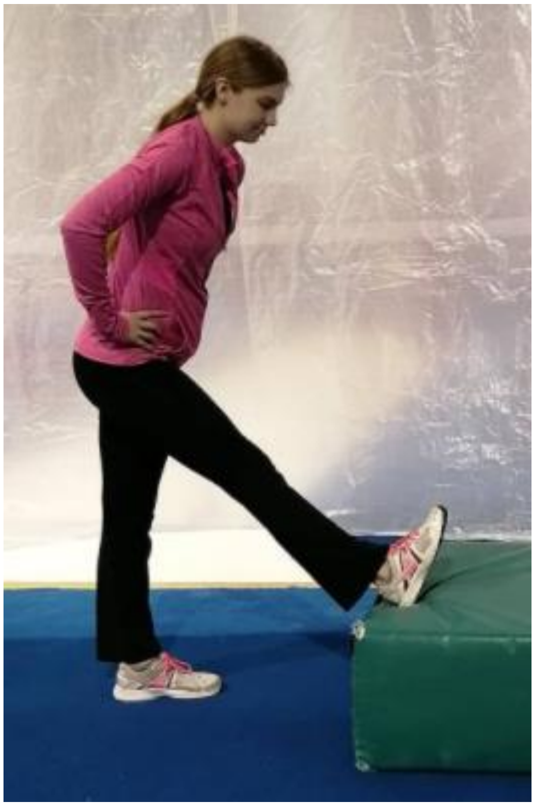

Figure 3. *Standing one-legged hamstring stretch for the SS and SS+SDB protocol. One heel will be resting at the participant's mid-shin height box with the knee in extension and ankle dorsiflexion. The supporting leg will have a soft bend with the foot pointing forwards. Keeping the hips square, they will lean forward with a neutral spine and their hands on their hips.*

2.5. Static Stretching and Slow Deep Breathing (SS+SDB)

All participants followed the same SS protocol with the addition of performing slow deep breathing. The investigator cued the stretch and slow deep breathing which the participant had to mimic to ensure they understood and can be in the proper position before performing the intervention. Participants followed a breathing timer by MindfulDevMag (https://mindfuldevmag.com/breathing-timer/), which consisted of 4 seconds inhale, 2 seconds hold, and 4 seconds exhale tempo with instruction on when to inhale, hold, and exhale. Each participant was instructed to breathe through their diaphragm which was monitored by observing the expansion and reduction at the stomach while ensuring the rise and fall of the chest was limited. This was completed for 2 sets of 30 seconds each with a 10 second rest between reps.

2.6. Data Analysis

Post-intervention ROM was normalized as a percent change of pre-intervention ROM for each leg and compared between intervention groups using a paired T-test with the significant level set at $p < 0.05$. A separate T-test was run to compare gender differences for each intervention.

3. Results

A significant difference between SS and SS+SDB was found in treatment effect of SS+SDB on hip flexion when compared to SS for both the right leg (3.91% ± 1.57 vs 9.17% ± 1.77, $p<0.05$) and left leg (2.88 ± 1.03 vs 9.27% ± 1.74, $p < 0.05$) (Figure 4). Also, no significant difference was found when comparing the different treatment effects on gender (Figure 5).

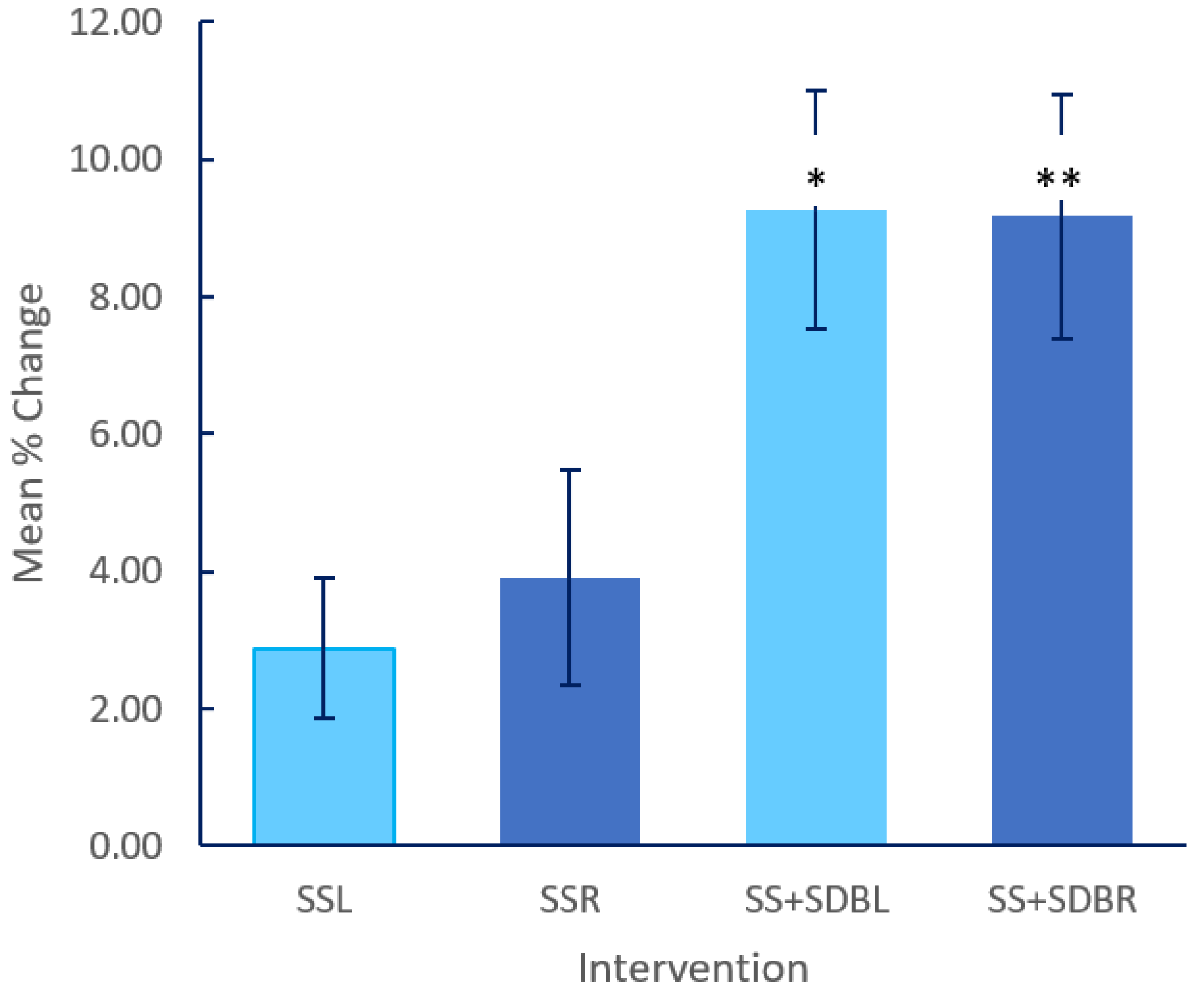

Figure 4. *Mean (+/- SEM) % change of hip flexion range of motion of the left (light blue) and right (dark blue) leg for both static stretching (SS) and static stretching and slow deep breathing (SS+SDB) protocol. There was a statistically significant improvement in the SS+SDB on both the left and right leg ($p<0.05$). * = significant difference from SSL. ** = significant difference from SSR.*

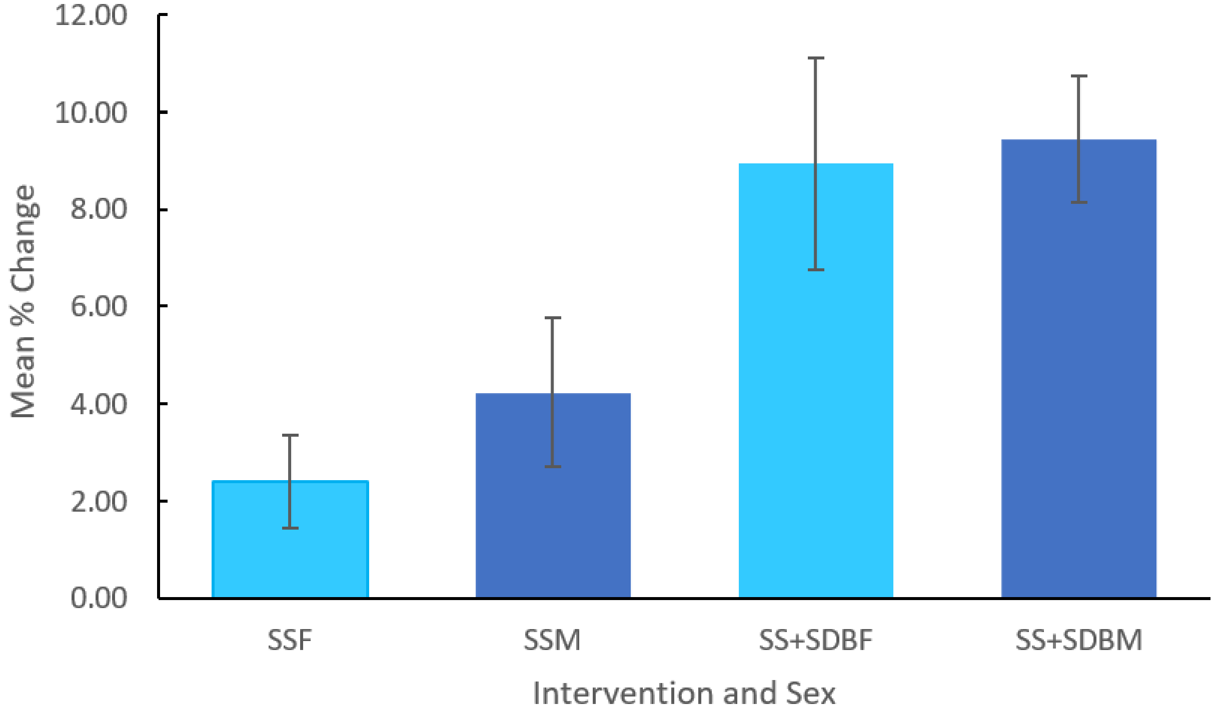

Figure 5. *Mean (+/- SEM) % change of hip flexion range of motion in females, (light blue, n=5) and males (dark blue, n=6) for both static stretching protocol (SS) and static stretching and slow deep breathing protocol (SS+SDB). There was no statistical significance found between genders in the same intervention.*

4. Discussion

The purpose of this study was to compare the effects of SS+SDB with SS on hamstring flexibility and hip flexion ROM. The results supported the hypothesis by revealing that SS+SDB was more effective in increasing hamstring flexibility and hip flexion ROM than SS alone. There was also no significant difference found for the effects of treatment by gender. The increase in hip flexion is likely due to the addition of slow deep breathing which is hypothesized to create a neurological feedback that signals the muscles and the body to relax allowing the individual to get into a deeper stretch[19,20,25].

There have been many studies that have examined the acute effects of SS on hip flexion with ranging repetitions and hold times, however, the majority of the studies revealed similar results to that presented here with an average of 4-5% increase in hip flexion[15,26,27]. A study by Puentedura et al. followed a similar SS protocol yet found an average 9.1% increase in hip flexion with SS which may be due to the participants being inexperienced with hamstring stretching, and/or the participants having a low flexibility baseline with the pre-intervention measurements averaging 56.05 degrees[28]. The participants in this current study had a greater baseline ROM which could account for the smaller increase in ROM with SS. A study by Donti et al. supports this assumption as they found that people who have less experience with stretching, including team sport athletes, achieve greater effect from SS when compared to those who are experienced and have a higher baseline level[29]. Future studies should look at the effects of SS+SDB on hamstring flexibility and hip flexion in individuals with different experiences with stretching and yogic practices.

Although the results of the SS+SDB intervention had a mean increase in hip ROM of 9-10%, it is unclear if these acute effects translate into chronic changes in ROM. A study by Cipriani et al. utilizing the same stretch as this current study had multiple groups with varying stretch frequencies over 4 weeks and collected the ROM data once a week. The group that was prescribed 2 sets of 30 seconds with 10 seconds rest in-between sets three days a week, experienced a 5.37% increase in ROM which is found to be similar to the SS intervention in this current study. The increase in hip ROM was seen to gradually increase throughout the four weeks with a total of 16.8% when compared to the pre-intervention measurements. Therefore, it is reasonable for us to predict that performing the protocol proposed here will result in an even greater ROM over a similar training period. It is recommended for future studies to look at the long-term effects of SS+SDB in relation to ROM to determine the long-term benefits of this stretching protocol.

The absence of a gender effect found in this study is similar to the results of other studies[15,30]. However, females typically have a higher baseline of flexibility when compared to males which were seen in this study, therefore it may be predicted that if a more extensive population were to be surveyed, differences may be found[15,30–32].

As previously mentioned, the mechanism by which breathing influences ROM is unclear. This is further complicated by the few studies that have examined this treatment effect. However, an article by Welge highlights the importance of breathing while stretching especially for large muscle groups attached to the lumbar spine and pelvic region as the mechanism of inhaling will cause a slight anterior tilt which indirectly creates an additional passive stretch which may facilitate Golgi tendon activation which would result in a decrease in muscle tension[25]. Yet, Welge states without clarification that when targeting the hamstring muscles the participant should be in a supported seated position[25]. Although the standing one-legged hamstring stretch was shown to be effective, future studies should compare the effects of SS+SDB in a standing and seated stretch as the support of sitting could further facilitate relaxation and proper breathing mechanics by eliminating the focus needed to balance.

5. Conclusion

In conclusion, this study has successfully demonstrated that SS+SDB is significantly more effective in increasing hamstring compliance and hip flexion ROM than SS alone. This is the first study of its kind to reveal a strong relationship between SS with breathing and muscle compliance and hip ROM. It would be interesting to investigate the long-term effects it can have on rehabilitation, human performance, and overall health and function in individuals. Other possible future research can include the difference in standing and seated stretch as well as experience level with stretching and yogic practices.

6. Practical application

Therapists, coaches, and trainers who utilize static stretching for the purpose of enhancing hip ROM should highly consider incorporating slow deep breathing techniques to maximize the results of the program goals.

References

1. Valenza M, Cabrera-Martos I, Torres Sánchez I, Garcés A, Mateos-Toset S, Valenza G. The Immediate Effects of Doming of the diaphragm technique in subjects with short hamstring syndrome: A randomized controlled trial. *J Sport Rehabil*. 2015;24. doi:10.1123/jsr.2014-0190

2. Thomas E, Bianco A, Paoli A, Palma A. The relation between stretching typology and stretching duration: The effects on range of motion. *Int J Sports Med*. 2018;39(04):243-254. doi:10.1055/s-0044-101146

3. Hiroaki Kaneda, Naonobu Takahira, Kouji Tsuda, et al. Effects of tissue Ffossing and dynamic stretching on hamstring muscles function. *J Sports Sci Med*. 2020;19(4):681-689. Accessed April 12, 2021. http://login.library.sheridanc.on.ca/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=147177027&site=ehost-live&scope=site

4. Weppler CH, Magnusson SP. Increasing muscle extensibility: A matter of increasing length or modifying sensation? *Phys Ther*. 2010;90(3):438-449. doi:10.2522/ptj.20090012

5. Page P. Current concepts in muscle stretching for exercise and rehabilitation. *Int J Sports Phys Ther*. 2012;7(1):109-119. Accessed September 21, 2020. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3273886/

6. Roig M, Eng J, MacIntyre D, Road J, Reid WD. Deficits in muscle strength, mass, quality, and mobility in people with chronic obstructive pulmonary disease. *J Cardiopulm Rehabil Prev*. 2011;31(2):120-124. doi:10.1097/HCR.0b013e3181f68ae4

7. Sakari E, Multani NK. Efficacy of neural mobilization in sciatica. *J Exerc Sci Physiother*. 2007;3(2):136-141.

8. FMS_Breathing_Manual.pdf. Accessed November 6, 2020. https://uprightmovement.com/wp-content/uploads/2017/09/FMS_Breathing_Manual.pdf

9. Halder K, Chatterjee DA, PAL R, Tomer O, Saha M. Age related differences of selected Hatha yoga practices on anthropometric characteristics, muscular strength and flexibility of healthy individuals. *Int J Yoga*. 2015;8:37-46. doi:10.4103/0973-6131.146057

10. Zhou WS, Lin JH, Chen SC, Chien KY. Effects of dynamic stretching with different loads on hip Joint range of motion in the elderly. *J Sports Sci Med*. 2019;18(1):52-57. Accessed October 18, 2020. http://login.library.sheridanc.on.ca/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=30787651&site=ehost-live&scope=site

11. Leite TB, Costa PB, Leite RD, Novães JS, Fleck SJ, Simao R. Effects of different number of sets of resistance training on flexibility. *Int J Exerc Sci*. 2017;10(3):354-364. Accessed October 28, 2020. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5609666/

12. Sullivan KM, Silvey DBJ, Button DC, Behm DG. Roller-massager application to the hamstring sit-and-reach range of motion within five to ten seconds without performance impairments. *Int J*

Sports Phys Ther. 2013;8(3):228-236. Accessed October 18, 2020. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3679629/

13. Winkelmann ZK, Roberts EJ, Games KE. Acute effects and perceptions of deep oscillation therapy for improving hamstring flexibility. *J Sport Rehabil*. 2018;27(6):570-576. Accessed October 18, 2020. http://login.library.sheridanc.on.ca/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=132580498&site=ehost-live&scope=site

14. Hancock C, Hansberger B, Loutsch R, et al. Changes in hamstring range of motion following proprioceptive neuromuscular facilitation stretching compared with static stretching: A critically appraised topic. *Int J Athl Ther Train*. 2016;21(5):1-7. doi:10.1123/ijatt.2015-0091

15. Cipriani DJ, Terry ME, Haines MA, Tabibnia AP, Lyssanova O. 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. *J Strength Cond Res*. 2012;26(8):2119-2129. doi:10.1519/JSC.0b013e31823b862a

16. de Weijer VC, Gorniak GC, Shamus E. The effect of static stretch and warm-up exercise on hamstring length over the course of 24 Hours. *J Orthop Sports Phys Ther*. 2003;33(12):727-733. doi:10.2519/jospt.2003.33.12.727

17. Konrad A, Stafilidis S, Tilp M. Effects of acute static, ballistic, and PNF stretching exercise on the muscle and tendon tissue properties. *Scand J Med Sci Sports*. 2017;27(10):1070-1080. doi:10.1111/sms.12725

18. Nivethitha L, Mooventhan A, Manjunath NK. Effects of various Prāṇāyāma on cardiovascular and autonomic variables. *Anc Sci Life*. 2016;36(2):72. doi:10.4103/asl.ASL_178_16

19. Pal GK, Velkumary S, Madanmohan. Effect of short-term practice of breathing exercises on autonomic functions in normal human volunteers. *Indian J Med Res New Delhi*. 2004;120(2):115-121. Accessed October 4, 2020. https://search.proquest.com/docview/195972292/abstract/D0DD485DBA6491DPQ/1

20. CNN DS Special to. Train yourself to breathe like a pro athlete. CNN. Accessed September 23, 2020. https://www.cnn.com/2015/10/08/health/breathe-like-pro-athlete/index.html

21. Wongwilairat K, Buranruk O, Eungpinichpong W, Puntumetakul R, Kantharadussadee-Triamchaisri S. Muscle stretching with deep and slow breathing patterns: a pilot study for therapeutic development. *J Complement Integr Med*. 2018;16(2). doi:10.1515/jcim-2017-0167

22. Jafari H, Courtois I, Van den Berg O, Vlaeyen HWS, Van Diest I. Pain and respiration: a systematic review. Published online 2017:1-32.

23. Bordoni B, Zanier E. Anatomic connections of the diaphragm: influence of respiration on the body system. *J Multidiscip Healthc*. 2013;6:281-291. doi:10.2147/JMDH.S45443

24. Lee BK. Effects of the combined PNF and deep breathing exercises on the ROM and the VAS score of a frozen shoulder patient: Single case study. *J Exerc Rehabil*. 2015;11(5):276-281. doi:10.12965/jer.150229

25. Welge M, Ninos J. Don’t forget to breathe. *Strength Cond J*. 2000;22(5):69. Accessed April 17, 2021. https://journals.lww.com/nsca-scj/Citation/2000/10000/Don_t_Forget_to_Breathe__Using_Deep_Breathing_to.19.aspx

26. Miyahara Y, Naito H, Ogura Y, Katamoto S, Aoki J. Effects of proprioceptive neuromuscular facilitation stretching and static stretching on maximal voluntary contraction. *J Strength Cond Res*. 2013;27(1):195-201. doi:10.1519/JSC.0b013e3182510856

27. Beltrão N, Ritti-Dias R, Pitangui A, Araújo R. Correlation between acute and short-term changes in flexibility using two stretching techniques. *Int J Sports Med*. Published online August 21, 2014. doi:10.1055/s-0034-1382018

28. Puentedura E, Huijbregts P, Celeste S, et al. Immediate effects of quantified hamstring stretching: Hold-relax proprioceptive neuromuscular facilitation versus static stretching. *Phys Ther Sport Off J Assoc Chart Physiother Sports Med*. 2011;12:122-126. doi:10.1016/j.ptsp.2011.02.006

29. Donti O, Gaspari V, Papia K, Panidi I, Donti A, Bogdanis GC. Acute Effects of intermittent and continuous static stretching on hip flexion angle in athletes with varying flexibility training background. *Sports*. 2020;8(3). doi:10.3390/sports8030028

30. Etnyre BR, Lee EJ. Chronic and acute flexibility of men and women using three different stretching techniques. *Res Q Exerc Sport*. 1988;59(3):222-228. doi:10.1080/02701367.1988.10605507

31. Bell RD, Hoshizaki TB. Relationships of age and sex with range of motion of seventeen joint actions in humans. *Can J Appl Sport Sci J Can Sci Appl Au Sport*. 1981;6(4):202-206.

32. Allander E, Björnsson OJ, Olafsson O, Sigfússon N, Thorsteinsson J. Normal range of joint movements in shoulder, hip, wrist and thumb with special reference to side: a comparison between two populations. *Int J Epidemiol*. 1974;3(3):253-261. doi:10.1093/ije/3.3.253