

Research article

The Immediate Effect of Adding Lumbar Mobilization to A Static Stretching Program on Hamstrings Range of Motion: An Exploratory Study

James Villers ✉, Andrew Cardenas, Travis Gipson and Emily Man

Department of Physical Therapy, Angelo State University, San Angelo, TX, USA

Abstract

A contributing risk factor and a byproduct of a hamstrings strain is limited hamstrings range of motion (ROM). Some evidence supports static stretching (SS) and lumbar spinal mobilization therapy (LSMT) as an effective means for increasing hamstrings ROM. However, the efficacy of combining LSMT and SS for increasing hamstrings ROM is unknown. The objective of the study is to quantify the immediate effects of the combination of LSMT and SS compared to LSMT and SS on hamstrings ROM in a healthy population. Thirty participants were randomized by block allocation into one of three intervention groups: (1) LSMT (unilateral lumbar PA mobilization at L-4); (2) SS; or (3) combination of LSMT and SS. Hamstrings ROM was measured pre- and post-intervention by the active knee extension test (AKET). There was no group-by-time interaction effect ($p = 0.871$). Within group analysis revealed a significant statistical change and a large effect size: LSMT ($p = .037$, $RCI = 3.36$, $d = 0.771$); SS ($p = 0.035$, $RCI = 2.94$, $d = 0.781$); combination ($p = .005$, $RCI = 4.21$, $d = 1.186$). The findings suggest that the combination of LSMT and SS does not have a further effect on hamstrings ROM compared to the individual results of LSMT or SS.

Key words: Hamstrings Strain, Rehabilitation, Athletic Injury, Sports Medicine, Physical Therapy.

Introduction

Decreased hamstrings range of motion (ROM) is a common risk factor for musculoskeletal impairments throughout various populations. Improvement of hamstrings ROM will increase both hip and knee ROM, possibly help prevent hamstring injury, and reduce the impairments of other musculoskeletal pathology such as low back pain (Bradley and Portas, 2007; Mistry et al., 2014; Witvrouw et al., 2003). The hamstrings are frequently injured during the terminal swing phase of running or sprinting, as the hamstrings are in passive insufficiency (lengthen at the hip and knee) and are required to produce a large eccentric contraction to decelerate the swing limb in preparation for initial contact (Erickson and Sherry, 2017). There is a high incidence of hamstrings strains among recreational athletes and professional athletes (Prior et al., 2009). Prevalence of hamstrings strains vary due to different injury classifications and sporting populations; however, in various types of football (Australian rules, American, & soccer), to which most literature pertains, the prevalence ranges from 8% to 25% with each injury resulting in two to six weeks of absence from sport participation (Prior et al., 2009). Recurrence of hamstrings strains following initial injury is another prominent issue, with re-injury rates in excess of

30%, including rates of 60-70% in subsequent seasons (Prior et al., 2009). The greatest risk of re-injury is within the first two weeks of return to sport (Erickson and Sherry, 2017).

Due to the association between limited hamstrings ROM and hamstrings injuries, treatments that effectively increase hamstrings ROM must be identified (Erickson and Sherry, 2017). Static Stretching (SS) is a common technique to improve the flexibility of the musculotendinous structures in the hamstring muscles to reduce the incidence of injury, relieve pain, decrease recurrence and enhance muscle and athletic performance (de Weijer et al., 2003). Systematic and literature reviews by (Medeiros et al., 2016) and (Decoster et al., 2005) concluded SS is an effective means for increasing hamstrings flexibility in a young healthy population. Controversy persist over which stretching technique, SS, dynamic stretching (DS) or proprioceptive neuromuscular facilitation (PNF) stretching is the most effective in improving hamstrings ROM. When comparing SS and PNF stretching, (Lempke et al., 2018) concluded that each are equally effective in improving hamstrings length. A systematic review by (Behm et al., 2016) reported that SS, DS, and PNF have been shown to increase joint ROM, but it is not possible to rank the effectiveness. Of these stretching techniques, SS is an efficient and easily administered means for improving hamstrings range of motion. (Bandy et al., 1997; Halbertsma et al., 1996; Hartig and Henderson, 1999; Page et al., 2010).

Research has shown that hamstrings ROM as measured by active knee extension test (Chesterton et al., 2019; Chesterton and Payton, 2017; Chesterton et al., 2018); passive knee extension test (Chesterton et al., 2016); and straight leg raise (Szlezak et al., 2011) may be increased by the use of posterior to anterior (PA) lumbar spinal mobilization therapy (LSMT).

Lumbar spinal mobilization therapy is characterized by the delivery of a manual force using specific parameters of angulation, amplitude, and speed to an intervertebral articulation, which results in specific biomechanical and/or neurophysiological effect (Bialosky et al., 2009). The application of a unilateral L4-5 facet PA force has been found to be more effective than a central PA for increasing hamstrings ROM (Chesterton et al., 2018). The mechanism(s) by which LSMT improves hamstrings length is yet to be identified. Due to the indirect relationship, it may be deduced that the proposed neurophysiological effect of spinal mobilization is a factor (Bialosky et al., 2009; Slaven et al., 2013).

In summary, there is evidence to support the use of LSMT and SS to increase hamstrings ROM. However, the

efficacy of combining LSMT and SS for increasing hamstrings ROM is unknown. Therefore, given this lack of evidence, this study was conducted to investigate and quantify the immediate effects of the combination of LSMT and SS compared to LSMT and SS on hamstrings ROM in a healthy population. It was hypothesized that the combination of LSMT and SS would produce a greater increase in hamstrings ROM compared to LSMT and SS.

Methods

Study design and ethics

The study was a single blinded randomized clinical trial using a three-group pretest- posttest experimental design. Convenience sampling with blocked randomization was employed electronically by concealed allocation to one of three intervention groups.

The study was approved by Angelo State University's Institutional Review Board, ASUIRB, (Protocol

Number: VIL-062819) and was conducted in accordance with the policy statement of the Declaration of Helsinki. Prior to participating, all volunteers read and signed an ASUIRB approved informed consent.

Participants

Thirty-three participants were recruited from the campus of the affiliated university. Post-screening, three volunteers were excluded due to not meeting the hamstrings ROM criterion, resulting in a final sample of 30 participants (Figure 1). Participants were included if they were 18 years or older, had no prior musculoskeletal pathology in the lower extremity or lumbar spine in the past 6 months, and were lacking at least 20 degrees of knee extension during the active knee extension test (AKET). Volunteers were excluded if they had current symptomatic low back, hamstrings, hip, or knee pain, previous or current neurological disorders, a history of lumbar surgery or fractures, or any contraindication to spinal mobilization.

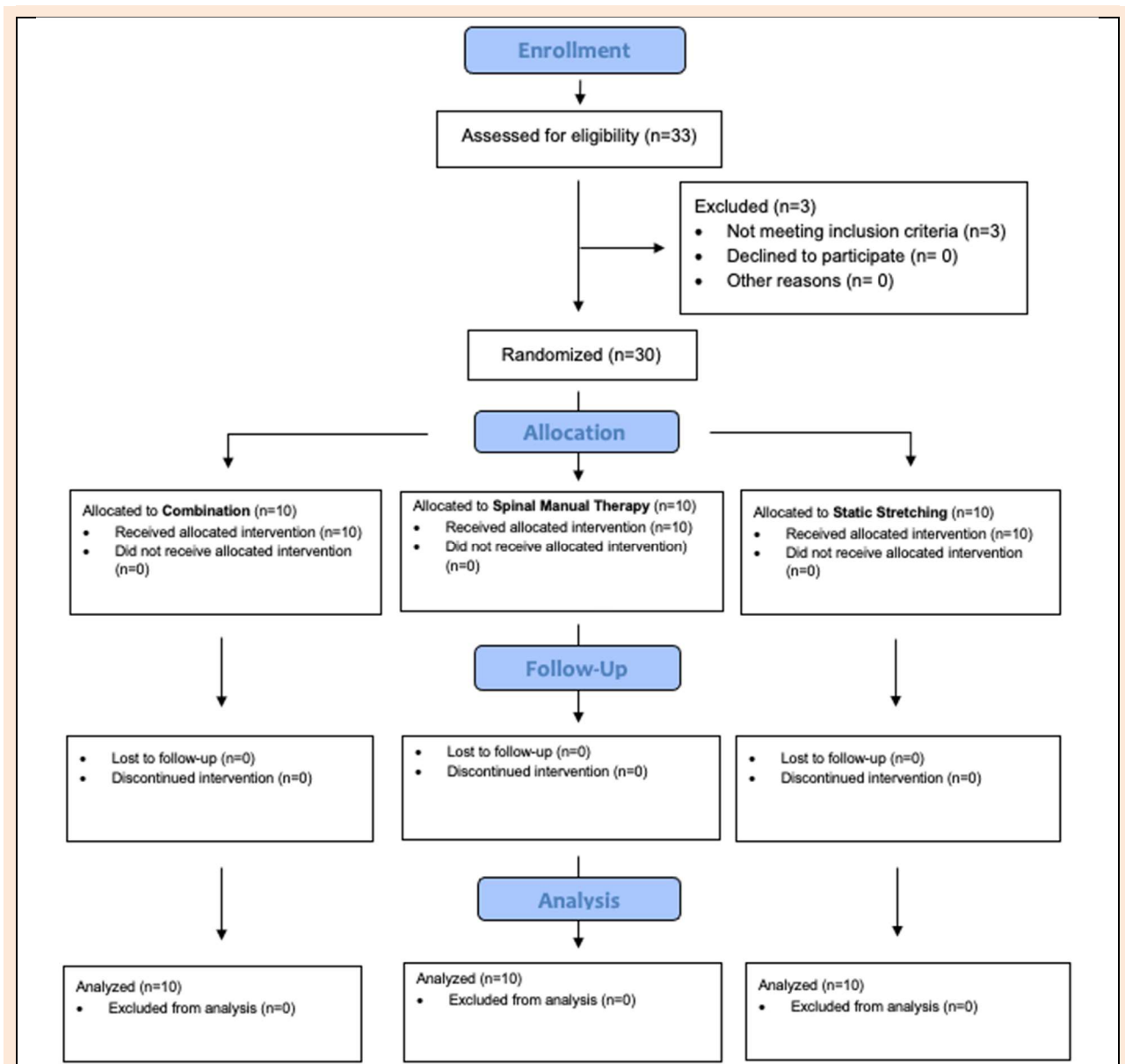


Figure 1. Flowchart of the study.

Pilot study-active knee extension test intrarater reliability

Prior to testing, a pilot study to determine the study's intrarater reliability for the AKET was completed utilizing four non-study participants and a previously established protocol (Chesterton and Payton, 2017) with an Acumar Digital Inclinometer Version 5.0. An intraclass correlation coefficients (ICC) of 0.75 - 0.90 and >0.90 are regarded as good and excellent respectively (Koo and Li, 2016). A pre-determined minimal standard for the current study was $ICC \geq 0.75$. The study's AKET rater demonstrated excellent intrarater reliability ($ICC = 0.98$) which was consistent with the ICC range of 0.78 - 0.97 for a healthy population in (Hamid et al., 2013).

Testing procedure

The participant completed a single visit at a musculoskeletal laboratory on the university's campus. Following informed consent, the participant completed a medical screening questionnaire. Next, the participant's height and weight were recorded and the dominant leg was determined by asking which leg would be used to kick a ball. Blocked randomization was employed to assign the participant to a single intervention group. Pre- and post-intervention AKET measures were recorded by a single rater who was blinded to the intervention. To ensure consistent intervention times, two minutes were added to the beginning of the SS and LSMT treatment groups.

Active knee extension test protocol

Hamstrings ROM is represented indirectly by angular movement at the knee or hip (Gajdosik et al., 1993). As such, in the study hamstrings ROM was operationally defined as the angular measurement of knee extension during the AKET. The AKET is considered the gold standard in assessing hamstrings ROM (Davis et al., 2008) and has demonstrated good to excellent intrarater reliability, ICC range of 0.78 - 0.99 (Hamid et al., 2013; Shamsi et al., 2019).

The participant's active hamstrings ROM was measured by the AKET per a previously established protocol (Chesterton and Payton, 2017). For consistency, the participant's dominant leg was chosen. The participant first laid supine on a treatment table with the pelvis stabilized using a stabilization belt across the anterior superior iliac spine. Another stabilization belt was placed across the non-dominant leg 20 cm proximal of the tibial tuberosity. To ensure consistency during re-measurement, belt positions were marked. A hip flexion frame was then placed in line with their greater trochanter as a guide to flex the hip to a true 90 degrees (Figure 2). Once the participant brought the test limb into 90 degrees of hip flexion, the instruction was given to extend the knee as far as possible while keeping the ankle relaxed and maintaining the thigh against the hip flexion frame. To accommodate for the effect of natural variations in hamstrings tissue extensibility from repeated measures, four active knee extensions were completed before the initial measurement was recorded on the fifth repetition (Chesterton et al., 2019; Chesterton and Payton, 2017; Chesterton et al., 2018). The ROM at the knee was measured by an Acumar Digital Inclinometer

Version 5.0 placed on the anterior tibial line midway between the inferior pole of the patella and a line between the malleoli. The location was marked to insure repeatability between measures. The degrees lacking from full knee extension, 180° , was recorded. The post intervention AKET was measured and recorded on the first repetition.

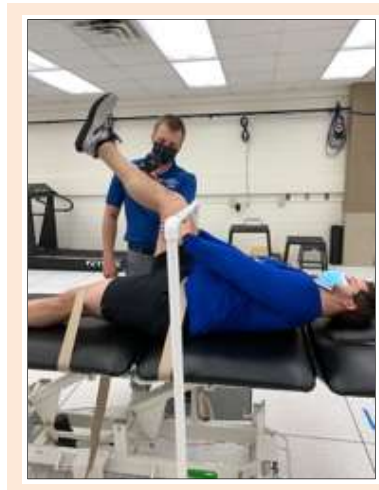


Figure 2. Active knee extension test.

Lumbar spinal mobilization therapy

A Doctor of Physical Therapy (DPT) with over 30 years of clinical experience and post graduate spinal manual therapy training performed the LSTM. The L4 and L5 vertebrae segments were identified by the same DPT by passive physiological intervertebral movement and spinal palpation. The corresponding spinous process was marked for locating the L4/5 facet joint on the dominant leg side. Next, an unilateral PA grade 3 mobilization [large amplitude rhythmic oscillatory force within and up to the limit of range (Dutton, 2008)] was directed to the identified L4/5 facet joint at a rate of 2 Hz maintained by a metronome with a force amplitude of 175 N (50-225 N) for three, 30-second sets with a 10 second rest between sets. To ensure consistency in force production, the DPT received force oscillation feedback through standing on an in-ground force plate (Bertec, Columbus, OH, USA). Real-time changes in force were displayed on a monitor using Vicon Nexus software (v2.7, Vicon, Centennial, CO, USA) and were viewed by the DPT while performing the intervention (Figure 3).



Figure 3. Lumbar spinal mobilization therapy.

The LSMT force parameters were based upon the findings that application of a Grade 3 lumbar PA mobilization at a force amplitude of 150 N (50-200N) will produce hypoalgesia (Krouwel et al., 2010) and that peak forces may reach 225N (Snodgrass et al., 2006). The oscillation rate of 2 Hz is consistent with Maitland’s recommendation of 0.5 to 3 Hz.(Snodgrass et al., 2006). The rationale for 90 seconds of mobilization was to standardize the treatment duration of LSMT and SS and to simulate a typical clinical LSMT application.

Static stretching protocol

A previously established SS protocol was employed (Bandy et al., 1997). The participant completed SS to the dominant hamstrings for three 30 second holds. The participant began by standing erect with the non-dominant foot planted on the floor and the toes pointing forward. The heel of the dominant leg was placed on an 18” step with the toes directed toward the ceiling. Once cued, the participant flexed forward at the hip, maintaining the spine in a neutral position while reaching the arms forward. The knee remained fully extended as the participant continued to flex at the hip until a gentle stretch was felt in the posterior thigh. Once the position was achieved, a timer was started (Figure 4) Verbal feedback was provided throughout the stretching protocol to ensure proper form was maintained.



Figure 4. Static stretching.

Combination protocol

The LSMT protocol was initially performed followed by the SS protocol as previously described.

Statistical analysis

Statistical analyses were performed by using IMB SPSS statistical software (v26, Armonk, NY, USA), excluding the paired Cohen’s *d* effect size (ES) and reliable change index (RCI). Initially, descriptive statistics, including mean and standard deviation were calculated for the dependent variable. Next, data were assessed for normality distribution and sphericity assumptions by calculating Shapiro Wilks and Mauchly’s tests, respectively. The alpha value was set at 0.05 for a statistically significant result. A one-way ANOVA was used to compare the between groups’ demographics. Differences between time and group were analyzed by calculating a mixed-model, 2-by-3 analysis of variance (ANOVA), with time (pre- to post-intervention) as the within-groups variable and group (LSMT, SS, or Combination treatments) as the between-groups variable.

Within each group, to determine the intervention’s effect over time the following tests were performed: paired t-test; Cohen’s *d* ES specifically accounting for paired scores and their resultant correlation (Effect Size Calculator, 2018); and an RCI by dividing the group’s mean change in score by the square root of the standard error of measurement (Copay et al., 2007). The magnitude of change expressed by an ES may be interpreted as minimal-0.20, moderate-0.50, large- 0.80 (Portney and Watkins 2015). An RCI of > 1.96 is considered to confer a true change with 95% confidence (Copay et al., 2007).

Results

The male to female ratio for each group was: LSMT 7/3, SS 8/2, and combination 8 /2. The groups were homogeneous in age, body mass index, and pre-intervention AKET measures (Table 1). There was a statistically significant time main effect ($p < 0.001$) as the AKET for the three groups combined, decreased from pre-intervention to post-intervention (Table 2). There was no group-by-time interaction effect ($p = 0.871$) or group main effect ($p = 0.280$) for the AKET dependent variable, negating the need for post hoc analysis (Table 2). Within group analysis revealed a significant statistical change and a large effect size: LSMT ($p = .037$, $RCI = 3.36$, $d = 0.771$); SS ($p = 0.035$, $RCI = 2.94$, $d = 0.781$); combination ($p = .005$, $RCI = 4.21$, $d = 1.186$). All participants completed their assigned intervention negating the need for intention to treat analysis.

Table 1. Demographic features and initial active knee extension test range of motion of the groups. Data are means ± SD.

	LSMT	SS	Combination	P
Sex (M/F)	7/3	8/2	8/2	
Age (years)	24.8 ± 2.97	25.6 ± 2.17	24.8 ± 2.54	0.533
Body Mass Index (Kg/h ²)	27.7 ± 4.20	27.2 ± 5.76	26.5 ± 4.26	0.790
Initial AKET ROM (degrees from 180)	39.9 ± 9.33	34.4 ± 8.92	35.7 ± 10.14	0.356

LSMT- lumbar spinal mobilization therapy; SS- static stretching; Combination- LSMT + SS; AKET- active knee extension test; ROM- range of motion; SD- standard deviation

Table 2. Effects of lumbar spinal mobilization therapy (LSMT), static stretching (SS), and the combination of LSMT and SS.

Dependent Variable	Group	Time		ANOVA Results		
		Pre-Intervention	Post-Intervention	Group Effect	Time Effect	Group X Time Interaction
Active Knee Extension Test (degrees)*†	LSMT	39.9 ± 9.33	36.4 ± 8.55	F = 1.334 p = 0.280	F = 23.024 p < 0.001	F = 0.203 p = 0.817
	SS	34.4 ± 6.90	29.7 ± 8.79			
	Combination	35.7 ± 10.1	30.9 ± 11.0			

Data are means ± SD. †The three groups combined exhibited a decrease from pre-intervention to post-intervention based on a level of 0.05.

Discussion

The treatment of hamstrings strains is a challenge in sports medicine leading to missed participation time and a high reoccurrence rate (Prior et al., 2009). Limited hamstrings ROM has been identified as a risk factor and a result of hamstrings injury (Erickson and Sherry, 2017). Therefore, interventions that effectively improve hamstrings ROM are keystone in prevention and recovery of hamstrings strains (Bradley and Portas, 2007; Erickson and Sherry, 2017; Mistry et al., 2014; Witvrouw et al., 2003). The aim of this study was to explore the efficacy of three interventions LSMT, SS and Combination of the two, on hamstrings ROM in a healthy population. The finding of no group-by-time interaction ($p = 0.817$) indicates that similar immediate gains in hamstrings ROM can be made with application of each intervention. Therefore, the experimental hypothesis that the combination of LSMT and SS will produce a greater effect on hamstrings ROM was rejected.

The concept of an MCID represents the smallest improvement that a patient considers worthwhile from an intervention. Therefore, an MCID can assist a clinician in determining the effectiveness of a treatment (Allison, 2013). There are two methods in determining an MCID, anchor based and distribution-based approaches (Copay et al., 2007). Due to there being no reported anchor based MCID for the AKET, a distribution-based method was used to determine the effectiveness of each intervention, consisting of a paired Cohen's d ES index and RCI. Based on the large ES (≥ 0.80) and an RCI > 1.96 , when prescribing either LSMT, SS, or combination of the two for limited hamstrings ROM as measured by the AKET, one may expect a patient to report great improvement immediately post-intervention and have 95% confidence that a true change occurred (Copay et al., 2007). Additionally, the within groups' $p < 0.05$ implies a statistically significant result should occur 95% of the time in a similar population. Thus, it may be inferred that each intervention produced a meaningful level of change.

This study's findings support previous research indicating that LSMT improves hamstrings ROM (Chesterton et al., 2019; Chesterton and Payton, 2017; Chesterton et al., 2018; Szlezak et al., 2011). The study's 9% hamstrings ROM gain from LSMT is smaller in comparison to other investigations using Grade 3 unilateral L 4-5 PA mobilizations (Chesterton et al., 2018) 17% and (Chesterton et al., 2019) 26%. A plausible explanation for the variance in the results is the duration of which the PA mobilization was applied. In the current study, the unilateral PA force was delivered over three 30 seconds sets for a total of 1.5 minutes compared to three 2 minutes sets for a total of 6 minutes in (Chesterton et al., 2018) and (Chesterton et al., 2019). Our results are closer aligned with (Szlezak et al., 2011) who used a grade 3 unilateral directed PA for 30 seconds at multiple segments T12-L5 producing a 12.5% gain measured by the neural base straight leg raise test. Additionally, the magnitude of the applied unilateral PA force between the studies could account for disparity in the outcomes. In (Chesterton et al. 2018), the mean force of the unilateral mobilizations was 74.5 ± 5.0 N (mean \pm SD) without upper and lower force parameters noted;

while in (Chesterton et al., 2019) and (Szlezak et al., 2011) no force data is documented. In contrast, we used real time visual monitoring for the production of the 175 N force amplitude (50-225 N), without computing the mean force to establish the accuracy between visual and actual force application. Nevertheless, it is evident a larger amplitude force nearing 100 N was used in the current study, when compared to (Chesterton et al., 2018). It may be argued that the duration of LSMT has a greater influence than the amplitude force on hamstrings ROM.

When comparing other studies that investigated the immediate change on AKET following a single session of SS, this study's increase of 4.6° is less (7.0° - 13.1°) (de Weijer et al., 2003; Nishikawa et al., 2015; O'Hora et al., 2011; Puentedura et al., 2011). The total duration of the SS sessions varied within the studies from 30 seconds (Nishikawa et al., 2015; O'Hora et al., 2011), 60 seconds (Puentedura et al., 2011), to 90 seconds (de Weijer et al., 2003) and the current study. Based on (Page, 2012) that the greatest gains from SS are produced with a duration of 15-30 seconds within the 2nd to 4th repetition it is unlikely that the SS duration is a factor in the differing results. In the current study, variation in hamstrings extensibility over repeated measures was accounted for by recording the baseline AKET on the fifth repetition, which may explain the smaller gains. In the aforementioned SS studies, the baseline AKET was recorded on either the initial repetition (de Weijer et al., 2003; Nishikawa et al., 2015; O'Hora et al., 2011) or calculated as an average of three repetitions (Puentedura et al., 2011). By accounting for the variability in hamstrings extensibility from repeated measures, one may have a greater confidence that the observed changes are from the effects of the interventions.

To understand the results of this study, the potential mechanisms by which hamstrings ROM was improved needs to be differentiated. The changes in hamstrings ROM within this study are likely attributed to mechanical and neurophysiological factors. The gains produced by SS may be related to an increase in the viscoelasticity and decreased stiffness of muscular and connective tissues which enhances muscular extensibility (Medeiros et al., 2016). This mechanical adaptation to SS has been questioned. An alternative explanation is that SS increases the sensory capacity to tolerate the discomfort associated with SS, resulting in improved muscle ROM (Behm et al., 2016; Konrad and Tilp, 2014; Medeiros et al., 2016). Regardless of the mechanism, evidence supports the use of SS for gains in muscle ROM (Lempke et al., 2018; Behm et al., 2016; Bandy et al., 1997; Nishikawa et al., 2015; O'Hora et al., 2011, Puentedura et al., 2011; Page, 2012). The neurophysiological effects associated with LSMT have been demonstrated to decrease hamstrings muscle activity (sEMG) allowing for an increase in hamstrings ROM (Chesterton and Payton, 2017; Chesterton et al., 2018; Szlezak et al., 2011). Additionally, from the hypoalgesia response associated with spinal mobilization (Lascrain-Aguirrebeña et al., 2016), it is possible there is an increased tolerance to stretching, resulting in greater hamstrings ROM. Specifically, it has been reported that spinal mobilization results in a central nervous system mediated endogenous pain inhibition system, which may produce a hypoalgesia effect

locally or distally from the site of mobilization (Coronado et al., 2012). These products of LSMT may account for the hamstrings ROM gains observed in the current study. Based on findings from the current study, there is not a greater gain in hamstrings ROM by combining LSMT and SS. This in part may be due to a ceiling effect of the physiological responses produced individually from LSMT and SS. Although, the physiological mechanisms of SS and LSMT may differ, we found both to have equally beneficial effects for increasing hamstrings ROM.

Limitations to this study include the lack of diversity in the population's age and power. It is possible that a more diverse age range and larger population may have resulted in different results. The population was reduced to asymptomatic participants thus the potential effects in individuals with a current or previous hamstrings injury are unknown. The study investigated the immediate effects of the interventions, therefore, the effect over time is undetermined.

Due to the limitations of the population's age range, investigations of the effects over a wider life span are warranted. In order to assess the viability of this research for clinical application, studies on individuals with pre-existing or current conditions associated with decreased hamstrings ROM are necessary. Future research is required on the location, grade, and duration of LSMT to determine the optimal effects on hamstrings ROM. The establishment of a patient reported anchored based MCID for the AKET would further aide in predicting the clinical outcome when selecting interventions for hamstrings ROM deficits.

Conclusion

Evidence is limited on the efficacy of adding LSMT to a SS program for increasing hamstrings ROM. The results provide preliminary evidence that the combination of LSMT and SS does not have a further effect on hamstrings ROM compared to the individual results of LSMT or SS. Clinicians may utilize this finding to support clinical management of the hamstring muscle group.

Acknowledgements

The authors acknowledge Lee Atkins, PT, PhD for his assistance in the study's methodology and statistical analysis. The experiments comply with the current laws of the country in which they were performed. The authors have no conflict of interest to report. The study's generated datasets are not publicly available, but may be obtained from the corresponding author who was an organizer.

References

- Allison, S. (2013) *MCID: The Minimal Clinically Important Difference [Class handout]*. Department of Physical Therapy, Hardin Simmons University.
- Bandy, W.D., Irion, J.M. and Briggler, M. (1997) The effect of time and frequency of static stretching on flexibility of the hamstring muscles. *Physical Therapy* **77**, 1090-1096. <https://doi.org/10.1093/ptj/77.10.1090>.
- Behm, D.G., Blazevich, A.J., Kay, A.D. and McHugh, M. (2016) Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: a systematic review. *Applied Physiology, Nutrition, and Metabolism* **41**, 1-11. <https://doi.org/10.1139/apnm-2015-0235>.
- Bialosky, J.E., Bishop, M.D., Price, D.D., Robinson, M.E. and George, S.Z. (2009) The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. *Manual Therapy* **14**, 531-538. <https://doi.org/10.1016/j.math.2008.09.001>
- Bradley, P.S. and Portas, M.D. (2007) The relationship between preseason range of motion and muscle strain injury in elite soccer players. *Journal of Strength and Conditioning Research* **21**, 1155-1159. <https://doi.org/10.1016/j.jse.2020.06.016>.
- Chesteron, P., Evans, W., Livadas, N. and McLaren, S.J. (2019) Time-course changes associated with PA lumbar mobilizations on lumbar and hamstring range of motion: a randomized controlled crossover trial. *Journal of Manual and Manipulative Therapy* **27**, 73-82. <https://doi.org/10.1080/10669817.2018.1542558>.
- Chesteron, P. and Payton, S. (2017) Effects of spinal mobilisations on lumbar and hamstring ROM and sEMG: A randomised control trial. *Physiotherapy Practice & Research* **38**, 17-24. <https://doi.org/10.3233/PPR-160081>
- Chesteron, P., Payton, S. and McLaren, S. (2018) Acute effects of centrally- and unilaterally-applied posterior-anterior mobilizations of the lumbar spine on lumbar range of motion, hamstring extensibility and muscle activation. *Journal of Back and Musculoskeletal Rehabilitation* **31**, 1013-1023. <https://doi.org/10.3233/BMR-171000>.
- Chesteron, P., Weston, M. and Butler, M. (2016) The Effect of Mobilising the Lumbar 4/5 Zygapophyseal Joint on Hamstring Extensibility in Elite Soccer Players. *International Journal of Physiotherapy and Rehabilitation* **1**, 1013-1023.
- Copay, A.G., Subach, B.R., Galssman, S.D., Polly, D.W. and Jr Schuler, T.C. (2007) Understanding the minimum clinically important difference: a review of concepts and methods. *The Spine Journal* **5**, 541-546. <https://doi.org/10.1016/j.spinee.2007.01.008>
- Coronado, R.A., Gay, C.W., Bialosky, J.E., Carnaby, G.D., Bishop, M.D. and George, S.Z. (2012) Changes in pain sensitivity following spinal manipulation: a systematic review and meta-analysis. *Journal of Electromyography and Kinesiology* **5**, 752-767. <https://doi.org/10.1016/j.jelekin.2011.12.013>.
- Davis, D.S., Quinn, R.O., Whiteman, C.T., Williams, J.D. and Young, C.R. (2008) Concurrent validity of four clinical tests used to measure hamstring flexibility. *Journal of Strength and Conditioning Research* **22**, 583-588. <https://doi.org/10.1519/JSC.0b013e31816359f2>.
- de Weijer, V.C., Gorniak, G.C. and Shamus, E. (2003) The effect of static stretch and warm-up exercise on hamstring length over the course of 24 hours. *Journal of Orthopaedic and Sports Physical Therapy* **33**, 727-733. <https://doi.org/10.2519/jospt.2003.33.12.727>.
- Decoster, L.C., Cleland, J., Altieri, C. and Russell, P. (2005) The effects of hamstring stretching on range of motion: a systematic literature review. *Journal of Orthopaedic and Sports Physical Therapy* **35**, 377-387. <https://doi.org/10.2519/jospt.2005.35.6.377>.
- Dutton, M. (2008) *Orthopaedic examination, evaluation, and intervention*. 2nd edition. New York: McGraw Hill Companies.
- Effect Size Calculator (2018). Updated October 7, 2018. [cited September 28, 2020]. Available from URL: https://memory.psych.mun.ca/models/stats/effect_size.shtml.
- Erickson, L.N. and Sherry, M.A. (2017) Rehabilitation and return to sport after hamstring strain injury. *Journal of Sport and Health Science* **6**, 262-270. <https://doi.org/10.1016/j.jshs.2017.04.001>.
- Gajdosik, R.L., Rieck, M.A., Sullivan, D.K. and Wightman, S.E. (1993) Comparison of four clinical tests for assessing hamstring muscle length. *Journal of Orthopaedic and Sports Physical Therapy* **18**, 614-618. <https://doi.org/10.2519/jospt.1993.18.5.614>.
- Halbertsma, J.P., van Bolhuis, A.I. and Göeken, L.N. (1996) Sport stretching: effect on passive muscle stiffness of short hamstrings. *Archives of Physical Medicine and Rehabilitation* **77**, 688-692. [https://doi.org/10.1016/s0003-9993\(96\)90009-x](https://doi.org/10.1016/s0003-9993(96)90009-x).
- Hamid, M.S., Ali, M.R. and Yusuf, A. (2013) Interrater and Intrarater Reliability of the Active Knee Extension (AKE) Test among Healthy Adults. *Journal of Physical Therapy Science* **25**, 957-961. <https://doi.org/10.1589/jpts.25.957>
- Hartig, D.E. and Henderson, J.M. (1999) Increasing hamstring flexibility decreases lower extremity overuse injuries in military basic trainees. *American Journal of Sports Medicine* **27**, 173-176. <https://doi.org/10.1177/03635465990270021001>
- Konrad, A. and Tilp, M. (2014) Increased range of motion after static stretching is not due to changes in muscle and tendon structures. *Clinical Biomechanics (Bristol, Avon)* **29**, 636-642. <https://doi.org/10.1016/j.clinbiomech.2014.04.013>

- Koo, T.K. and Li, M.Y. (2016) A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine* **15**, 155-163. <https://doi.org/10.1016/j.jcm.2016.02.012>
- Krouwel, O., Hebron, C. and Willett, E. (2010) An investigation into the potential hypoalgesic effects of different amplitudes of PA mobilisations on the lumbar spine as measured by pressure pain thresholds (PPT). *Manual Therapy* **15**, 7-12. <https://doi.org/10.1016/j.math.2009.05.013>
- Lascurain-Aguirrebeña, I., Newham, D. and Critchley, D.J. (2016) Mechanism of Action of Spinal Mobilizations: A Systematic Review. *Spine (Phila Pa 1976)* **41**, 159-172. <https://doi.org/10.1097/BRS.0000000000001151>
- Lempke, L., Wilkinson, R., Murray, C. and Stanek, J. (2018) The Effectiveness of PNF Versus Static Stretching on Increasing Hip-Flexion Range of Motion. *Journal of Sport Rehabilitation* **27**, 289-294. <https://doi.org/10.1123/jsr.2016-0098>
- Medeiros, D.M., Cini, A., Sbruzzi, G. and Lima, C.S. (2016) Influence of static stretching on hamstring flexibility in healthy young adults: Systematic review and meta-analysis. *Physiotherapy Theory and Practice* **32**, 438-445. <https://doi.org/10.1080/09593985.2016.1204401>
- Mistry, G.S., Vyas, N.J. and Sheth, M.S. (2014) Comparison of hamstrings flexibility in subjects with chronic low back pain versus normal individuals. *Journal of Clinical & Experimental Research* **2**, 85. <https://doi.org/10.5455/jcer.201413>
- Nishikawa, Y., Aizawa, J., Kanemura, N., Takahashi, T., Hosomi, N., Maruyama, H., Kimura, H., Matsumoto, M. and Takayanagi, K. (2015) Immediate effect of passive and active stretching on hamstrings flexibility: a single-blinded randomized control trial. *Journal of Physical Therapy Science* **27**, 3167-3170. <https://doi.org/10.1589/jpts.27.3167>
- O'Hora, J., Cartwright, A., Wade, C.D., Hough, A.D. and Shum, G.L. (2011) Efficacy of static stretching and proprioceptive neuromuscular facilitation stretch on hamstrings length after a single session. *Journal of Strength and Conditioning Research* **25**, 1586-1591. <https://doi.org/10.1519/JSC.0b013e3181df7f98>
- Page, P. (2012) Current concepts in muscle stretching for exercise and rehabilitation. *International Journal of Sports Physical Therapy* **7**, 109-19.
- Page, P., Frank, C.C. and Lardner R. (2010) Assessment and treatment of muscle Imbalance: the Janda approach. Chicago: Human Kinetics. <https://doi.org/10.5040/9781718211445>
- Portney, L.G. and Watkins, M.P. (2015) *Foundations of Clinical Research Applications to Practice*. 3rd edition. Philadelphia, PA: F.A. Davis Company.
- Prior, M., Guerin, M. and Grimmer, K. (2009) An evidence-based approach to hamstring strain injury: a systematic review of the literature. *Sports Health* **1**, 154-164. <https://doi.org/10.1177/1941738108324962>
- Puentedura, E.J., Huijbregts, P.A., Celeste, S., Edwards, D., In, A., Landers, M.R. and Fernandez-de-Las-Penas, C. (2011) Immediate effects of quantified hamstring stretching: hold-relax proprioceptive neuromuscular facilitation versus static stretching. *International Journal of Sports Physical Therapy* **12**, 122-126. <https://doi.org/10.1016/j.ptsp.2011.02.006>
- Shamsi, M., Mirzaei, M. and Khabiri, S.S. (2019) Universal goniometer and electro-goniometer intra-examiner reliability in measuring the knee range of motion during active knee extension test in patients with chronic low back pain with short hamstring muscle. *BMC Sports Science, Medicine, and Rehabilitation* **11**, 4. <https://doi.org/10.1186/s13102-019-0116-x>
- Slaven, E.J., Goode, A.P., Coronado, R.A., Poole, C. and Hegedus, E.J. (2013) The relative effectiveness of segment specific level and non-specific level spinal joint mobilization on pain and range of motion: results of a systematic review and meta-analysis. *Journal of Manual and Manipulative Therapy* **21**, 7-17. <https://doi.org/10.1179/2042618612Y.0000000016>
- Snodgrass, S.J., Rivett, D.A. and Robertson, V.J. (2006) Manual forces applied during posterior-to-anterior spinal mobilization: a review of the evidence. *Journal of Manipulative and Physiological Therapeutics* **29**, 316-329. <https://doi.org/10.1016/j.jmpt.2006.03.006>
- Szlezak, A.M., Georgilopoulos, P., Bullock-Saxton, J.E. and Steele, M.C. (2011) The immediate effect of unilateral lumbar Z-joint mobilisation on posterior chain neurodynamics: a randomised controlled study. *Manual Therapy* **16**, 609-613. <https://doi.org/10.1016/j.math.2011.06.004>
- Witvrouw, E., Danneels, L., Asselman, P., D'Have, T. and Cambier, D. (2003) Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. A prospective study. *American Journal of Sports Medicine* **31**, 41-46. <https://doi.org/10.1177/03635465030310011801>

Key points

- Lumbar spinal mobilization therapy (LSMT), static stretching (SS), and the combination (LSMT and SS) each immediately improve hamstring ROM.
- LSMT, SS, and Combination are equally effective in increasing hamstring ROM
- The addition of LSMT to a SS program does not produce a further effect on hamstring ROM

AUTHOR BIOGRAPHY



James VILLERS

Employment

Associate Clinical Professor
Department of Physical Therapy, Angelo State University

Degree

DPT, FAAOMPT

Research interests

Musculoskeletal rehabilitation with an emphasis on manual therapy

E-mail: james.villers@angelo.edu



Andrew CARDENAS

Employment

Department of Physical Therapy, Angelo State University

Degree

DPT

Research interests

Musculoskeletal rehabilitation with an emphasis on manual therapy

E-mail: andrew.cardenas0613@gmail.com



Travis GIPSON

Employment

Department of Physical Therapy, Angelo State University

Degree

DPT

Research interests

Musculoskeletal rehabilitation with an emphasis on manual therapy

E-mail: travisgipson5@gmail.com



Emily MAN

Employment

Department of Physical Therapy, Angelo State University

Degree

DPT

Research interests

Musculoskeletal rehabilitation with an emphasis on manual therapy

E-mail: emilyhuongman@gmail.com

✉ James Villers

Department of Physical Therapy ASU Station #10923, San Angelo, TX. 76909.