European Journal of Sport Science

ISSN: 1746-1391 (Print) 1536-7290 (Online) Journal homepage: https://www.tandfonline.com/loi/tejs20

Neurodynamic sliders promote flexibility in tight hamstring syndrome

PhD Roel De Ridder, PT Cedric De Blaiser, PhD Ruth Verrelst, PT Roeland De Saer, PT Andreas Desmet & PhD Joke Schuermans

To cite this article: PhD Roel De Ridder, PT Cedric De Blaiser, PhD Ruth Verrelst, PT Roeland De Saer, PT Andreas Desmet & PhD Joke Schuermans (2019): Neurodynamic sliders promote flexibility in tight hamstring syndrome, European Journal of Sport Science, DOI: 10.1080/17461391.2019.1675770

To link to this article: https://doi.org/10.1080/17461391.2019.1675770

Accepted author version posted online: 03 Oct 2019.

Publisher: Taylor & Francis & European College of Sport Science

Journal: *European Journal of Sport Science*

DOI: 10.1080/17461391.2019.1675770

Neurodynamic sliders promote flexibility in tight hamstring syndrome.

Roel De Ridder[1], PhD; Cedric De Blaiser[1], PT; Ruth Verrelst[1], PhD; Roeland De Saer[1], PT; Andreas Desmet, PT[1]; Joke Schuermans[1], PhD

[1]Department of Rehabilitation Sciences and Physiotherapy, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

Conflicts of Interest and Source of Funding:

The authors declare no conflict of interest. No funding was received for the current study.

Word count:

Abstract: 193

Manuscript: 3107

Corresponding author:

Roel De Ridder

Department of Rehabilitation Sciences and Physiotherapy, Ghent University

De Pintelaan 185, 3B3, 9000 Ghent, Belgium

Tel: 0032 (0)9 332 04 53

Fax: 0032 (0)9 332 38 11

Roel.DeRidder@ugent.be

ABSTRACT

Hamstring injury prevention puts emphasis on optimizing the muscle's strength - length relationship. To assure appropriate muscle length, flexibility training is imperative. As neurodynamics play an important role herein, the goal of this study was to explore the intervention effect of home-based neurodynamic slider program on hamstring flexibility. Fifty physically active male subjects were randomly assigned to either performing a neurodynamic sliding technique (3x20 reps) or a static stretching protocol (3x30") on a daily basis for a 6-week period. Hamstring flexibility was assessed by means of the Straight Leg Raise at baseline, immediately after the intervention and after 4 weeks follow up. There was no between group baseline difference in hamstring flexibility. The repeated measure ANOVA showed a significant interaction effect for group x time ($p<0.001$). Independent sample T-test showed a significantly higher increase in flexibility gain in the neurodynamic group immediately after the intervention ($p<0.001$), as well as at 4 weeks retention-analysis ($p=0.001$) compared to the static stretch group. In conclusion, neurodynamic sliders might be more efficient than regular static stretching in affecting hamstring flexibility in the long run.

Key words: neurodynamics, hamstrings, range of motion, flexibility

INTRODUCTION

Hamstring injuries are highly common in sports involving high volumes of high speed running and sprinting.[1-3] Repeated intense explosive eccentric hamstring loading causes the hamstrings to get stronger and stiffer. This 'tight hamstring syndrome' might be the consequence of repeated sports exposure[2,4], however, it has also been described in sedentary subjects and as a symptom of spinal pathology.[5] Although these increments in strength and stiffness are associated with improved sprinting performance, they might also add up to the development of hamstring muscle tightness, which might cause them to become more vulnerable for strain injury.[6] Therefore, hamstring injury prevention puts emphasis on optimizing eccentric and plyometric muscle function, to optimize the muscle's strength - length relationship and to make sure that the hamstring is able to generate maximal eccentric strength in the end range of motion.[7] To do so, functional strength and flexibility training are imperative.[8]

In terms of stretching, the applied methods are diverse and the 'optimal' stretching method differs based on timing and purpose of the stretch and individual opinion.[9-14] To increase or maintain muscle length (both in terms of performance and injury prevention), static stretching is preferred over dynamic variants due to the importance of the time under tension in the visco-elastic behavior of connective tissues.[15] Notwithstanding important local within muscle factors as viscoelastic properties and the number of sarcomeres in series, muscle flexibility is also dependent of subject's 'stretch tolerance' and of the link with adjacent connective and nerve tissue. For the latter, abnormal mechanosensitivity of the sciatic nerve has been shown to result in poor hamstring flexibility in both healthy subjects and individuals with hamstring strain.[16] Thus, treatment modalities should not only focus on improving visco-elastic properties of muscle tissue.

As the hamstrings act as a mechanical interface for the sciatic nerve, which innervates and surpasses the hamstring muscles group, neurodynamics can play a role in hamstrings flexibility as well.[17,18] Impaired neurodynamics due to adhesions between the hamstrings and the sciatic nerve might cause mechanosensitivity. If this is the case, the hamstring flexibility might be limited because mechanosensitivity will cause an earlier onset of the sensation of discomfort within the muscle elongation ROM causing an earlier protective hamstring muscle contraction.[18,19] Abnormalities in mechanosensitivity are generally treated with neurodynamic slider techniques, which evoke a sliding movement of neural structures relative to their adjacent soft tissue structures by alternating tension at one end of the nervous system with slack at the other.[20,21] Although the precise working mechanism remains unclear, performing neurodynamic sliders on the sciatic nerve and its mechanical interface has shown to increase immediate and short-term hamstring flexibility both as an isolated intervention and adjunct to a static stretch in subjects with tight hamstring syndrome.[4,22,23] These results might be very useful in the clinical practice in both primary and secondary injury prevention. However, whether these techniques also have a beneficial effect on muscle flexibility in the long run, is not known at this moment. Moreover, previous studies have only considered the effect of sliders performed by a therapist questioning the efficacy when performed by athletes or patients themselves.

Therefore, the objective of this study was to explore the intervention effect of a 6-week home-based neurodynamic slider program on hamstring flexibility in a recreationally active population. Next to assessing the effect immediate flexibility gains after the 6-week intervention, hamstring flexibility was reassessed after 4 weeks after termination of the slider and stretching intervention, to verify to what extent the intervention was sustainable in both groups. Our hypothesis was that performing the neurodynamic sliding technique would have a larger effect on both immediate and residual hamstring flexibility gains.

MATERIALS AND METHODS

Subjects

A total of 50 male subjects were recruited to participate in this randomized controlled trial. To be eligible, participants had to meet the following in- and exclusion criteria. Subjects needed to be (1) male, (2) aged between 18-30yrs, (3) recreationally/competitively active and (4) had to have limited hamstring flexibility (Tight Hamstring Syndrome) (SLR≤75°). Subjects were excluded if they reported having

(1) a history of any musculotendinous hamstring injury in the previous year; (2) a history of neurological or orthopedic disorder affecting the lower extremities; (3) a history of lumbar disc herniation; or (4) a history of a cervical whiplash injury. This study was performed according to international ethical standards [24] and approved by the ethics committee of the XXX University Hospital (approval number 2016/1422). All participants signed the informed consent prior to study participation.

Measurement of hamstring flexibility

Hamstring flexibility of the dominant side was assessed by means of the passive Straight Leg Raise (SLR) test. Subjects were asked to adopt a supine lying position on the examination table. The passive SLR was then performed by lifting the testing leg going into hip flexion by supporting the participant's heel and assuring the maintenance of full knee extension and neutral pelvic posture. The hip joint was gradually flexed until the participant indicated perceiving of first signs of discomfort in the region of the posterior thigh. This point in the hip flexion ROM has been referred to as P1.[25] No compensatory movements of the pelvis or hip were allowed.

The SLR excursion was evaluated using the smartphone Multi Clinometer application (Calmatics©, version 1.11).[26] The smartphone was attached to the lower leg parallel to the fibula above the lateral malleolus using a strap. The inclinometer was calibrated to zero in the baseline relaxed supine position (0° of hip flexion). The degree of SLR excursion at P1 was registered. This procedure was repeated 3 times and the average value over trials was used for further analysis.

These flexibility measurements were performed by two researchers (RD & AD). Each individual subject was evaluated by the same researcher at all of the 3 testing sessions (before and after the intervention, and at 4 weeks retention) to maximize the reliability of the outcome. Reliability of the passive SLR test was obtained a priori by running a pilot study in which the intra- and interrater reliability of the passive SLR was verified by randomly testing 10 healthy male subjects from a convience sample (not participating in the actual study) twice, separated by a one-week interval with Intraclass Correlation Coefficients of 0.97 and 0.95 respectively.

Procedure

Eligible candidates were randomly assigned to one of two intervention groups using a block randomization. Based on the allocation, subjects were instructed to perform either the neurodynamic sliding technique or the static stretching protocol (= control group) (dominant side only). The SLR was assessed for each subject at baseline, at the end of the intervention and 4 weeks after this second assessment to evaluate the sustainability of the intervention response.

Neurodynamic sliding technique

Subjects in the neurodynamic group performed the 'Seated Straight Leg Slider' (SSLS) (Fig.1). To execute this sliding technique, subjects assumed a seated slump position (thoracic and lumbar flexion) which they needed to maintain throughout the exercise. This SSLS consisted of alternating movements towards knee extension and ankle dorsiflexion (increase of neural tension) combined with cervical extension (decrease of neural tension) on one hand, and knee flexion and ankle plantar flexion (decrease neural tension) combined with cervical flexion (increase of neural tension) on the other. In order to make sure that the participants performed this technique correctly, the researchers provided them with a comprehensive word of explanation and a clear demonstration. To make sure that this information would not be subject to decay throughout the 6-week intervention period, participants were provided with a short video and an instruction guide with pictures to take home. During this 6-week period, each subject in this neurodynamic slider group was instructed to perform 3 sets of 20 repetitions on a daily basis for 6 weeks.

Static stretch

Subjects in the control group were instructed to perform a standard standing static stretch with the heel of the dominant leg taking support on a chair. Then they had to move the pelvis into anteversion, simultaneously inducing a forward lean of the trunk, until the clear sensation of hamstring stretch was perceived at the posterior aspect of the thigh. Again, the execution of the exercise was thoroughly explained and evaluated by the researchers and subjects sent home with a comprehensive instruction guide and supporting pictures. Each subject was instructed to do 3 repetitions of 30 second static stretches on a daily basis during the 6-week intervention.

Statistics

Statistical analyses were performed using SPSS, version 24 (SPSS Inc., Chicago, Illinois 60606, USA). After verifying the normality of the data-distribution, baseline comparison of group characteristics (height, length, BMI, leg dominance and history of hamstring injury) was analyzed using the independent sample T-test and Pearson chi square. Based on the pilot study, the standard error of the measurement ($SEM = SD \times \sqrt{(1-ICC)}$) and minimal detectable change were calculated ($MDC_{95} = 1.96 \times SEM \times \sqrt{2}$). To analyze the intervention effect, a 2x3 repeated measures ANOVA was performed, with the factor 'group' acting as the between-subject variable (neurodynamic, static stretch) and the factor 'time' as the within subject variable (baseline – post intervention – follow up). The primary outcome of interest was the interaction effect (group x time). If significant, post hoc pairwise comparisons with Bonferroni correction were performed to analyze both within and between group differences at the study time points. In addition, an independent sample T test on the difference in the intervention effect between groups was performed. The latter was defined as the difference in degrees of SLR between two time points, resulting in 3 intervention effects of interest: exercise effect (post intervention value minus baseline value), sustainability (follow up value minus post intervention value) and the residual effect (follow up value – baseline value).. The level of significance was set at $p<0.05$. Effect sizes (Cohen's d) were calculated for both independent and dependent pairwise comparisons.[27,28]

RESULTS

In total 73 subjects were screened at baseline, of which 23 subjects were excluded based on the eligibility criteria. The remaining 50 subjects were randomly assigned to the neurodynamic group or control group. Baseline comparison revealed no significant difference between groups for height, length, BMI, leg dominance and history of hamstring injury ($p > 0.05$, table 1). There was also no difference in baseline hamstring flexibility, objectified by means of the SLR (Mean diff: -0.08; 95%CI: -1.34, 1.41; p=0.965). Only for the variable age, there appeared to be a significant statistical between-group difference (table1). The baseline SEM and associated MDC_{95} equaled 1.14° and 3.18° respectively.

The repeated measure ANOVA showed a significant interaction effect for group x time ($p<0.001$). The paired sample T-test (table 2) clearly demonstrated similar results for both neurodynamic and the control group. The SLR significantly increased after the intervention ($p<0.001$), surpassing the MDC_{95} for all subjects. After the follow up period, a significant decrease in the intervention-associated flexibility gain was observed ($p<0.001$). However, SLR values at this third and final analysis session were still significantly higher compared to the baseline measurements ($p<0.001$). More specific, 24 out of 25 subjects in the neurodynamic group still surpassed the MDC_{95} compared to 18 out of 25 subjects in the control group. Effect sizes for changes in SLR values between time points were all large (>0.8, Table 2).

Although both groups demonstrated similar changes over time (table 2), independent sample T-test revealed a significantly higher flexibility gain in the neurodynamic group compared to the control group both immediately after the intervention ($p=0.037$) and after four-week follow up ($p=0.033$) with moderate effect sizes (=0.63) (table 2). Table 3 presents a significantly higher increase in flexibility in the neurodynamic group compared to the control group immediately after the intervention ($p<0.001$), as well as at 4 weeks retention-analysis ($p=0.001$). The loss in flexibility gain during this retention-analysis period was similar in both groups ($p=0.747$).

DISCUSSION

This was the first study to investigate the effect of a 6 week home-based neurodynamic intervention program on hamstring flexibility compared to a static stretch in subjects with reduced flexibility. Both interventions significantly increased hamstring flexibility, exceeding the MDC_{95} of 3.18° for all subjects. However, our results clearly showed the potential beneficial effect of using neurodynamic sliders over the regular method, with a significantly higher increase in hamstrings flexibility (12.6° versus 9.3°), confirming our study hypothesis. In terms of sustainability of the intervention effect, there was a comparable loss in gain for both groups over the 4 weeks after termination (respectively 3.5° and 3.6°). When comparing the residual gain, there still a significantly higher increase in hamstring flexibility of 9.1° for the neurodynamic slider technique (24/25 still exceeding the MDC_{95}) versus 5.7° for the static stretch (18/25 still exceeding the MDC_{95}). These results advocate the impact of neurodynamics on flexibility which could be indispensable in primary and secondary prevention of hamstring injuries.

Our study results on neurodynamics are in line with those of Castellote-Caballero et al.[4,22] This research group established both an immediate (one session, 9.9°) and tight term (one week with three sessions, 11.3°) increase in hamstring flexibility after applying neurodynamic sliders in subjects with tight hamstring syndrome. They also described a significantly greater increase in hamstring flexibility after performing sliders compared to static stretching.[4] Other studies have evaluated the (immediate) effect of sliders as an adjunct intervention to static stretch in subjects with reduced hamstring extensibility[23] and in male soccer players (one week, 3 sessions)[29]. They found a greater increase in hamstring extensibility when combining both interventions, again advocating the beneficial effect of neurodynamic sliders. These findings could, however, not indicate to what extent this neurodynamic stretching method has an additional effect on the sustainability of the treatment effect as well. In addition, when considering implementing these techniques in prevention or rehabilitation programs one must ascertain the same treatment effect when performed by athletes or patients without supervision. Our study results demonstrate that a 6 week home-based intervention program renders a significant effect on muscle flexibility, which seems to be retained 4 weeks after the intervention.

The underlying mechanism, explaining the greater increase in hamstring flexibility after neurodynamic sliders, could be attributed to several possible theories. First of all, sliders might affect the extraneural interface where adhesions between neural and surrounding tissue may limit the neural tissue excursions within the mechanical interface and may lead to increased tension and apprehension during passive stretch.[16] Neurodynamic sliders provide linear excursion of the sciatic nerve[17,30] which could prevent or modify these adhesions, thus leading to a decrease in neural mechanosensitivity and an increase in neural tissue viscoelasticity, thus increasing hamstring mobility.[19] Another potential explanation for the observed flexibility gains might be the reported analgesic effect of neurodynamic mobilization, which would delay the onset of pain sensation and therefore the associated protective muscle contraction.[31] A similar effect has been described as the 'sensory theory' which is not related to direct analgesia but rather to the individual's perception of stretch or pain (stretch tolerance) due to an improved neurodynamic function. Whether this adaptation in stretch tolerance is a peripheral or central phenomenon or a combination remains as of yet unclear.[32] Finally, it is important to note that the neurodynamic sliding technique implies a dynamic method and could be considered as a dynamic stretching method potentially affecting both neural and non-neural structures. Explanation of increased muscle extensibility following static stretching are described elsewhere and not the main focus of this manuscript.[32]

From a functional perspective, it is imperative to strive for an optimal hamstring muscle strength – length relationship. Especially during end range explosive eccentric loading, the hamstring muscle is susceptible for microscopic lesions eventually reducing stretch tolerance. When not addressed, this could make the hamstring more susceptible for strain injury.[6] Our results demonstrate that neurodynamic sliders performed over a longer time have a sustainable training effect, suggesting neurodynamic sliders to be a viable alternative in view of primary and secondary prevention. Normal mechanical behavior of the nerve structures within their mechanical interface should also considered essential for normal neuromuscular coordination, certainly in explosive actions like sprinting efforts. When being subject to excessive traction or compression throughout its mechanical interface, this will not only cause the hamstring to increase its muscle tone to protect the nerve from further mechanical irritation, but this might also lead to deficient efferent guidance of the hamstrings, making them more prone to fatigue and thus, overload and injury.

Additionally, although static stretching has a similar effect on flexibility of the muscle unit, it has the reported disadvantage of stretch-induced strength-loss, negatively affecting the crucial strength-length relationship. A potential explanation for this stretch-induces strength-loss, might be a temporary neuromuscular coordination dysfunction due to an irritated nerve and an abnormal efferent function as a result of prolonged tension imposed on the sciatic nerve during static stretching.[18] As sliders predominantly improve the nerve's mechanical function and mobility within the mechanical interface with limited neural tension, they might provide the ideal alternative to effectively address stretch tolerance and functional mobility in training, prevention and rehabilitation. To what extent this neurodynamic technique also renders a beneficial effect on muscle performance, cannot be stated based on the present study and should be subject of future research.

Limitations

Although this study is the first in demonstrating that neurodynamic sliders for the sciatic nerve result in significant and sustainable improvements in hamstring flexibility in recreationally/competitively active persons, it is not without limitations. First of all, the subjects nor the assessors were blinded to group allocation, so the present results might be subject to selection bias to some degree. Second, the intervention consisted of a home-program, so compliance might have been different in both groups although all subjects were contacted on a weekly basis as a motivational reminder, also effecting the study results. Another potential limitation is the exercise dosage. Currently there is no consensus in literature on the ideal modalities as attested by the various used protocols.[4,23] Our dosage of 3 sets of 20 sliders has proven to be a viable option, however future research should compare various protocols to recommend most optimal dosage. Finally, the hypothesis of this study was based on the premise that muscle flexibility plays a role in primary and secondary prevention and muscle performance. Although our study results do indicate beneficial treatment effects of neurodynamics on muscle flexibility, longitudinal randomized controlled trials with injury registration and performance indicators are mandatory to able to truly determine the potential beneficial effects.

Conclusion

This study demonstrated that neurodynamic sliders might be more effective than regular static stretching in affecting hamstring flexibility in the long run. Moreover, this effect seemed to be sustainable over a longer period in time (4 weeks). As flexibility of the entire posterior thigh unit is crucial in sports involving high volumes of high speed running, this technique is most probably more appropriate in maintaining and restoring functional hamstring flexibility in the prevention and rehabilitation of hamstring strain injuries.

DECLARATION OF INTEREST STATEMENT

None to declare

Reference list

1. Woods C, Hawkins RD, Maltby S, et al. The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries. *Br J Sports Med.* 2004;38:36-41.

2. Askling CM, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings. *Am J Sports Med.* 2007;35:197-206.
3. Duhig S, Shield AJ, Opar D, Gabbett TJ, Ferguson C, Williams M. Effect of high-speed running on hamstring strain injury risk. *Br J Sports Med.* 2016;50:1536-1540.
4. Castellote-Caballero Y, Valenza MC, Puentedura EJ, Fernandez-de-Las-Penas C, Alburquerque-Sendin F. Immediate Effects of Neurodynamic Sliding versus Muscle Stretching on Hamstring Flexibility in Subjects with Short Hamstring Syndrome. *J Sports Med (Hindawi Publ Corp).* 2014;2014:127471.
5. Kayser R, Mahlfeld K, Heyde CE, Grasshoff H, Mellerowicz H. Tight hamstring syndrome and extra- or intraspinal diseases in childhood: a multicenter study. *Eur Spine J.* 2006;15:403-408.
6. Opar DA, Williams MD, Shield AJ. Hamstring strain injuries: factors that lead to injury and re-injury. *Sports Med.* 2012;42:209-226.
7. Gajdosik RL. Passive extensibility of skeletal muscle: review of the literature with clinical implications. *Clin Biomech (Bristol, Avon).* 2001;16:87-101.
8. Hickey JT, Timmins RG, Maniar N, Williams MD, Opar DA. Criteria for Progressing Rehabilitation and Determining Return-to-Play Clearance Following Hamstring Strain Injury: A Systematic Review. *Sports Med.* 2017;47:1375-1387.
9. Herbert RD, Gabriel M. Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review. *BMJ.* 2002;325:468.
10. Marek SM, Cramer JT, Fincher AL, et al. Acute Effects of Static and Proprioceptive Neuromuscular Facilitation Stretching on Muscle Strength and Power Output. *J Athl Train.* 2005;40:94-103.
11. Nelson AG, Kokkonen J, Arnall DA. Acute muscle stretching inhibits muscle strength endurance performance. *J Strength Cond Res.* 2005;19:338-343.
12. Shrier I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clin J Sport Med.* 1999;9:221-227.
13. Riley DA, Van Dyke JM. The effects of active and passive stretching on muscle length. *Phys Med Rehabil Clin N Am.* 2012;23:51-57, x.
14. Taylor DC, Dalton JD, Jr., Seaber AV, Garrett WE, Jr. Viscoelastic properties of muscle-tendon units. The biomechanical effects of stretching. *Am J Sports Med.* 1990;18:300-309.
15. Medeiros DM, Martini TF. Chronic effect of different types of stretching on ankle dorsiflexion range of motion: Systematic review and meta-analysis. *Foot (Edinb).* 2018;34:28-35.
16. Turl SE, George KP. Adverse neural tension: a factor in repetitive hamstring strain? *J Orthop Sports Phys Ther.* 1998;27:16-21.
17. Ellis RF, Hing WA, McNair PJ. Comparison of longitudinal sciatic nerve movement with different mobilization exercises: an in vivo study utilizing ultrasound imaging. *J Orthop Sports Phys Ther.* 2012;42:667-675.
18. McHugh MP, Johnson CD, Morrison RH. The role of neural tension in hamstring flexibility. *Scand J Med Sci Sports.* 2012;22:164-169.
19. Kornberg C, Lew P. The effect of stretching neural structures on grade one hamstring injuries. *J Orthop Sports Phys Ther.* 1989;10:481-487.
20. Butler D. *The sensitive nervous system.* Adelaide, Australia: Noigroup Publications; 2000.
21. Shacklock M. *Clinical neurodynamics. A new system of musculoskeletal treatment.* Philadelphia: Elsevier Butterworth-Heinemann; 2005.

22. Castellote-Caballero Y, Valenza MC, Martin-Martin L, Cabrera-Martos I, Puentedura EJ, Fernandez-de-Las-Penas C. Effects of a neurodynamic sliding technique on hamstring flexibility in healthy male soccer players. A pilot study. *Phys Ther Sport.* 2013;14:156-162.
23. Sharma S, Balthillaya G, Rao R, Mani R. Short term effectiveness of neural sliders and neural tensioners as an adjunct to static stretching of hamstrings on knee extension angle in healthy individuals: A randomized controlled trial. *Phys Ther Sport.* 2016;17:30-37.
24. Harriss DJ, Atkinson G. Ethical standards in sport and exercise science research: 2014 update. *Int J Sports Med.* 2013;34:1025-1028.
25. Maitland GDH, E.; Banks, k.; English, K. *Maitland's vertebral manupilation.* 7 ed ed. Philadelphia: Elsevier Butterworth-Heinemann; 2005.
26. Werner BC, Holzgrefe RE, Griffin JW, et al. Validation of an innovative method of shoulder range-of-motion measurement using a smartphone clinometer application. *J Shoulder Elbow Surg.* 2014;23:e275-282.
27. Morris SB, DeShon RP. Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. *Psychol Methods.* 2002;7:105-125.
28. Cohen J. *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ, USE: Lawrence Erlbaum Associates; 1988.
29. Mendez-Sanchez R, Alburquerque-Sendin F, Fernandez-de-las-Penas C, et al. Immediate effects of adding a sciatic nerve slider technique on lumbar and lower quadrant mobility in soccer players: a pilot study. *J Altern Complement Med.* 2010;16:669-675.
30. Coppieters MW, Andersen LS, Johansen R, et al. Excursion of the Sciatic Nerve During Nerve Mobilization Exercises: An In Vivo Cross-sectional Study Using Dynamic Ultrasound Imaging. *J Orthop Sports Phys Ther.* 2015;45:731-737.
31. Neal Hanney R, Ridehalgh C, Dawson A, Lewis D, Kenny D. The effects of neurodynamic straight leg raise treatment duration on range of hip flexion and protective muscle activity at P1. *J Man Manip Ther.* 2016;24:14-20.
32. Weppler CH, Magnusson SP. Increasing muscle extensibility: a matter of increasing length or modifying sensation? *Phys Ther.* 2010;90:438-449.

FIGURE LEGENDS

Figure 1 Seated straight Leg Slider: Alternating movement towards knee flexion and ankle plantar flexion combined with cervical flexion on one hand (see picture on the left), and on the other knee extension and ankle dorsiflexion combined with cervical extension (see picture on the right)

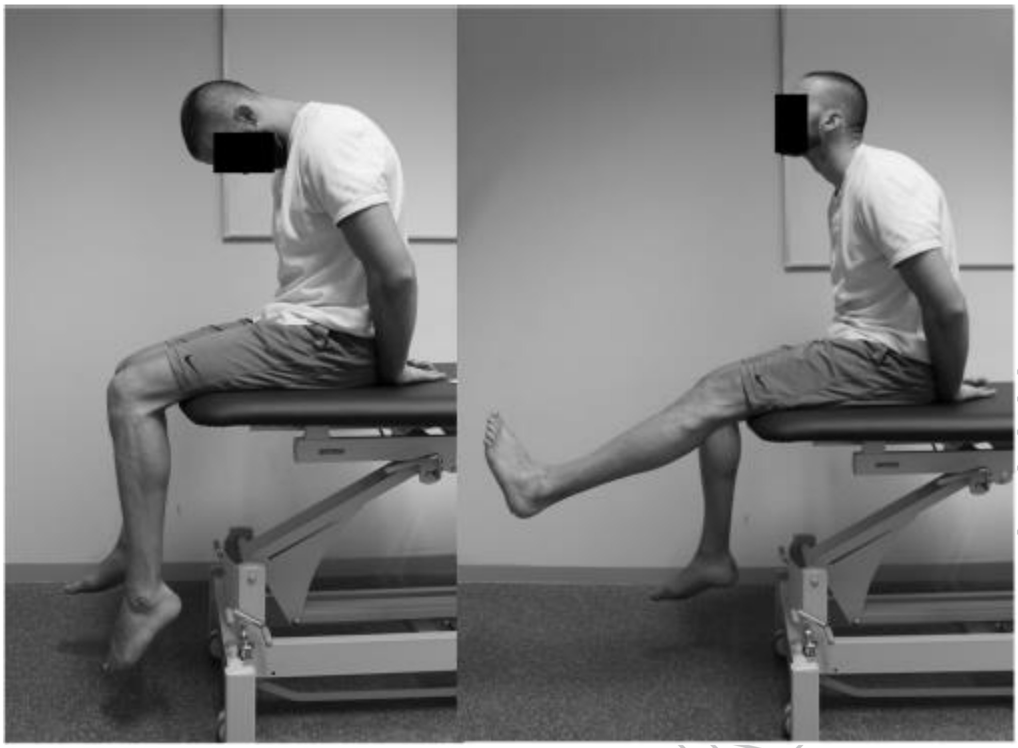

Table 1 baseline group characteristics

	Neurodynamic group (SD) n=25	Control group (SD) n=25	p-value
Age (yrs)	23.4 (2.02)	21.8 (2.39)	0.014[a] *
Height (cm)	179.2 (7.34)	178.1 (5.31)	0.569[a]
Weigth (kg)	73.8 (7.01)	72.8 (9.81)	0.656[a]
BMI	23.0 (1.71)	23.0 (2.93)	0.957[a]
Baseline SLR (°)	57.5 (7.57)	57.6 (4.98)	0.965[a]
History of hamstring injury	3/25	3/25	1.000[b]
Leg dominance (R/L)	21/4	21/4	1.000[b]

*[a]Independent T-test result; [b]Pearson chi-square; * significant at level p<0.05*

Table 2 Paired sample T-test for within group differences (horizontally) and Independent sample T-test for between group differences (vertically)

	Baseline (SD)	Post intervention (SD)	Follow up (SD)	Mean diff (95% CI)	p-value	Effect size

Neurodynamic Group	57.5° (7.57)	70.1° (6.22)		-12.6° (-13.65,-11.55)	<0.001*	-5.78
		70.1° (6.22)	66.6° (6.18)	3.5° (2.78, 4.10)	<0.001*	2.17
	57.5° (7.57)		66.6° (6.18)	-9.1° (-10.50, -7.82)	<0.001*	-3.10
Control group	57.6° (4.98)	66.9° (3.98)		-9.3 (-10.76, -7.96)	<0.001*	-2.85
		66.9° (3.98)	63.3 (4.38)	3.6° (2.83, 4.37)	<0.001*	1.97
	57.6° (4.98)		63.3 (4.38)	-5.7 (-7.32, -4.20)	<0.001*	-1.53
Mean diff (95% CI)	-0.1 (-3.74, 3.58)	3.2 (0.19, 6.13)	3.3 (0.27, 6.38)			
p-value	0.965	0.037*	0.033*			
Effect size	0.02	0.63	0.63			

**significant at level p<0.05*

Table 3 intervention effect between groups

	Neurodynamic group	Control group	Mean diff (95% CI)	p-value	Effect size
Exercise effect	12.6° (2.55)	9.4° (3.39)	3.24 (1.53, 4.95)	<0.001*	1.077
Sustainability	-3.4° (1.61)	-3.6° (1.87)	0.2 (-0.83, 1.15)	=0.747	-0.115
Residual effect	9.16° (3.24)	5.8° (3.77)	3.4 (1.40, 5.40)	=0.001*	0.959

*significant at level p<0.05