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Literature Review

Effects of neurodynamic treatment on hamstrings flexibility: A systematic review and meta-analysis

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ABSTRACT

Objective: To provide detailed information on the effectiveness of neurodynamic treatment on hamstrings flexibility.
Methods: Systematic review in the following databases: PubMed, Google Scholar, and ScienceDirect. Articles were included if the intervention followed a neurodynamic treatment and the study was a randomized clinical trial including at least one measurement related to hamstrings flexibility. Articles were independently screened for inclusion and data were extracted by two researchers. It was registered in the PROSPERO database (CRD42015020707).
Results: Finally, 6 articles (n = 294 participants) were included. Neurodynamic treatment was compared with no treatment, placebo, and with other manual therapy techniques such as active and passive stretching, muscle inhibition and proprioceptive neuromuscular facilitation. Meta-analysis shows benefits of neurodynamic treatment for knee-extension range of motion (1 trials compared with no intervention, MD = −2.23, 95% CI = −3.02 to −1.44, and 4 trials compared to other techniques, MD = −0.40, 95% CI = −1.09 to 0.29, $I^2 = 81.55\%$) and passive straight leg raise test measures (2 trials compared with no intervention, MD = 2.26, 95% CI = 1.78 to 2.74, $I^2 = 0\%$, and 3 trials compared with other techniques MD = 2.26, 95% CI = 1.78 to 2.74, $I^2 = 0\%$).
Conclusions: This review and meta-analysis shows the effectiveness of neurodynamic treatment on hamstrings flexibility compared with no intervention and other techniques.

1. Introduction

Neurodynamics (ND) is the term used to describe the integration of the morphology, biomechanics, and physiology of the nervous system (Shacklock, 2005). ND is described as a method of neural mobilization in which force is applying to nerve structures through posture and multi-joint movement (Coppieters & Butler,2008) with the primary objective of restore the dynamic balance between the neural tissues and surrounding mechanical interfaces, thereby allowing reduced intrinsic pressures on the neural tissues and promoting optimum physiologic function (Ellis & Hing,2008). However, there is an ongoing debate in the literature regarding the contributions of neural and non-neural tissues, given that many non-neural structures may also be responsible for some of the symptoms elicited during neurodynamic testing (Coppieters et al., 2005). In 1999, Barker and Briggs declared that continuity of the fascial system may provide an alternative explanation for changes in knee range of motion (ROM) and pain perception during neurodynamic testing (Barker & Briggs, 1999). Coppieters et al. (2005) affirmed that there is no doubt that neurodynamic tests not only load the nervous system, but also challenge non-neural structures. In a practical sense, the co-existence of several differing effects for *neurodynamics* appears to have triggered the development of a tension between traditional 'scientific' (precise, anatomically descriptive) and relatively recent 'holistic' (more expansive, functionally oriented) interpretations of this treatment. In this sense, neurodynamic testing and mobilization have been widely used in multidimensional treatments for improving neural and non-neural tissue function (Castellote-Caballero, Valenza, Puentedura, Fernández-de-las-Peñas, & Alburquerque-Sendín, 2014), being the hamstring musculature one of the main focus of current research.

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Limited flexibility within the posterior thigh compartment has been reported to be one of the most commonly accepted causes of hamstring injuries (Davis, Ashby, McCale, McQuain, & Wine, 2005; Jonhagen, Nemeth, & Eriksson, 1994). Numerous factors have been reported to influence hamstrings flexibility including age, gender, ethnicity, tissue temperature, strength training, altered postural types and reduced warm-up period during exercise (Fasen et al., 2009). Stretching exercise is the most used technique to improve and maintain muscle length (Nagarwal, Zutshi, Ram, Zafar, et al., 2010). Nevertheless, a recent Cochrane review found no evidence for stretching as a sole intervention for prevention hamstrings injury (Goldman et al., 2010). Other physical therapy interventions are focused on hamstring muscle tightness such as suboccipital muscle inhibition techniques, proprioceptive neuromuscular facilitation, local heat application or stretching (Singh, Grover, & Singh, 2015). In addition, studies that use neurodynamic techniques are increasing (Ahmed & Samhan, 2016; Park, Cha, Kim, & Asakawa, 2014) but there has been no previous systematic review of this area.

The purpose of this review and meta-analyses was to provide detailed information on the effectiveness of neurodynamic treatment on hamstrings flexibility.

2. Methods

2.1. Search strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematics Reviews and Meta-Analyses (PRISMA) guideline statement, and was registered in the International prospective register of systematic reviews PROSPERO database (CRD42015020707).

An extensive electronic search was conducted in the following databases: Medline, Google Scholar, Web of Science and Science-Direct. Potentially relevant studies were identified by the following search strategy: ("neurodynamic techniques") OR ("neural mobilization") OR ("neurodynamic treatment") OR ("neurodynamics) OR ("nerve mobilization") AND ("hamstrings flexibility") OR ("knee range of motion"). The search was limited to articles in English, Spanish or French language and included all articles that existed in the database until 2019. The search strategy was developed by two researchers, who consulted a third one if there was any disagreement regarding the inclusion or exclusion of a paper. Fig. 1 shows the flow diagram.

2.2. Eligibility criteria

Articles were included if they met the following criteria: randomized clinical trials, participants aged ≥18 years, and no restriction of gender, ethnicity or setting. The conditions to include trials were the use of neurodynamic techniques and to include an outcome report on at least one measure of hamstring flexibility (e.g. knee extension range of motion or passive straight leg raise measures). Exclusion criteria were: animal studies, reviews and meta-analyses, books, notes, conference proceedings, theses or dissertations, letters and abstracts. The records retrieved from the search strategy had their titles and abstracts were screened for eligibility by two independent reviewers. Disagreements were solved by discussion and a third author was available to resolve differences if necessary.After the screening of titles and abstracts, the full texts of potentially eligible studies were screened, and those meeting the inclusion criteria were included.

2.2.1. Methodological quality assessment

The methodological quality of all included studies was assessed according to the Jadad Scale, also known as Jadad or Oxford score which allows assessing the methodological quality of a clinical trial and presents the best evidence of validity and reliability (Olivo et al., 2008). It consists of 5 questions that encompass issues such as design and randomization of subjects, monitoring and masking measures. The score ranges from 0 to 5, with 5 being the highest score. A clinical trial is methodologically rigorous if the score is 5, and on the contrary, very poor if the score is < 3.

2.3. Data analysis

Data were extracted independently by two authors using a standardized form that recorded design, intervention details, sample characteristics, variables related to hamstrings flexibility, time frame and main results. Where appropriate, study results were pooled and a meta-analysis was undertaken using Review Manager software (RevMan version 5.1, updated March 2011). The meta-analysis was limited owing to the clinical heterogeneity of the included studies. The I^2 statistic was utilized to determine the degree of heterogeneity, where the percentages quantified the magnitude of heterogeneity: 25% = low, 50% = medium, and 75% = high heterogeneity. Using this scale, if I^2 was 50%, a random effects model was used. All the included outcomes were of continuous data of ROM and passive straight leg raise (PSLR) test and the MD with 95% CI was used in analysis. Forest plots were generated to illustrate the overall effect of interventions on ROM and PSLR test.

3. Results

A total of 6 articles were included in this review and meta-analysis and 294 participants were analyzed (Castellote-Caballero et al., 2014; Areeudomwong, Oatyimprai, & Pathumb, 2016; Sharma, Balthillaya, Rao, & Mani, 2016; Castellote-Caballero et al., 2013; Muragod & Pathania, 2017; Ganesh, 2017). The PRISMA diagram for the study selection process is shown in Fig. 1.

3.1. Characteristics of studies

A total of 68 studies were retrieved from the electronic search, of which 62 studies were excluded because they did not fulfill the eligibility criteria. The characteristics of the studies are shown in Table 1.

The number of participants varied from 20 (Muragod & Pathania, 2017) to 120 (Castellote-Caballero et al., 2014). In three studies there were only men (Areeudomwong et al., 2016; Ganesh, 2017; Muragod & Pathania, 2017), in one study there were women and men (Castellote-Caballero et al., 2014) and the gender was not reported in two articles (Castellote-Caballero et al., 2013; Sharma et al., 2016). Mean age of the participants included in the studies was 31.63 years. The outcomes used to assess the effects of the proposed interventions were the passive knee-extension ROM and the hamstrings extensibility evaluated by the PSLR test.

The detailed quality assessment of the included studies is presented in Table 2.

According to the quality assessment, three studies scored five points (Areeudomwong et al., 2016; Castellote-Caballero et al., 2014; Sharma et al., 2016), two scored three points (Castellote-Caballeroet al., 2013; Muragod & Pathania, 2017) and the rest obtained two points (Ganesh, 2017). None of the articles scored less than 2 points.

3.2. Effects of neurodynamic treatment on passive knee-extension ROM

Of the 6 articles reviewed, 4 all of them used the passive knee-

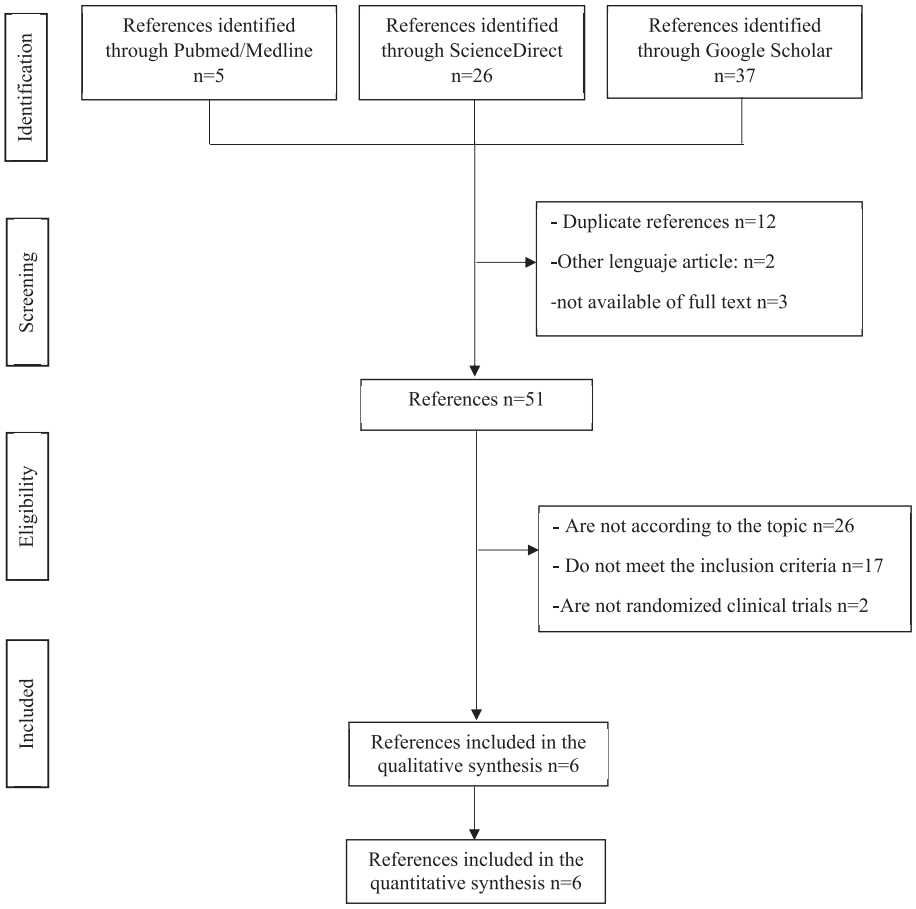

Fig. 1. PRISMA diagram.

extension ROM to evaluate the knee joint range (Areeudomwong et al., 2016; Sharma et al., 2016; Muragod & Pathania, 2017; Ganesh, 2017). Ganesh et al. (2017) randomized participants into two intervention groups. One group received a neurodynamic sliding technique while the other group received a suboccipital muscle inhibition technique. The results show that those participants included in the neurodynamics group exhibited significant changes in ROM compared with those of the group receiving a suboccipital muscle inhibition technique ($p < 0.05$). In the same line, Areeudomwong et al. (2016) revealed a significant improvement ($p < 0.05$) in passive knee ROM after 4 weeks of neurodynamic treatment compared with a placebo intervention (pulse shortwave during 10 min). Other article (Muragod & Pathania, 2017) compared a neurodynamic treatment to stretching. After 10 sessions during 2 weeks, participants in both groups obtained a significant improvement in ROM; however, mean change in the neurodynamic treatment (7.62 ± 1.15 vs $3.02 \pm 1.15°$) was higher.

The study conducted by Sharma et al. (2016) randomized the participants into three groups who received 3 sessions during a week of static stretching, static stretching and neurodynamic sliders and static stretching with neurodynamic tensioner. All the participants showed significant improvements in passive knee-extension ROM, but there were no significant differences between stretching and neurodynamic slider group and stretching and neurodynamic tensioner group.

Meta-analysis of four trials with a total of 164 participants demonstrated that neurodynamic treatment was better in knee-extension ROM than control group or other treatments (MD: 0.74, 95% CI: -1.44 to −0.05, I^2: 81.55%). The meta-analysis results with included effect sizes are presented in Fig. 2.

3.3. Effects of neurodynamic treatment on hamstrings extensibility

Of the 6 articles reviewed, 4 of them used the PSLR test (Castellote-Caballero et al., 2013; Castellote-Caballeroet al., 2014; Ganesh, 2017; Muragod & Pathania, 2017). Castellote et al. (2013) compared the effects of 3 sessions of neurodynamic sliding versus a control group. The group that received neurodynamics improved the PSLR test values significantly over time ($p < 0.001$), whereas the control group did not ($p = 0.684$).

In a later study, Castellote et al. (2014) randomized asymptomatic participants with short hamstring syndrome into three groups. One group received passive hamstring stretching, other group received a neurodynamic sciatic sliding technique and the last got a passive mobilization of the intrinsic foot joints (placebo). The immediate effects after a total of 180 s of technique showed that subjects in the neurodynamic group increased PSRL values to a greater degree. Other article (Ganesh, 2017) showed significant improvements in PSLR comparing a neurodynamic treatment to a manual therapy treatment after 2 weeks ($p < 0.05$).

Finally, the study of Muragod et al. (2017) included participants aged 65–75 years with hamstring tightness. They were randomized to a static stretching group or to a neurodynamic mobilization group. The results show not significant between-group differences on passive knee extension ($p = 0.06$) and PSLR test ($p = 0.40$).

Meta-analysis of the four trials with a total of 238 participants demonstrated that neurodynamic treatment was also better in hamstrings extensibility than control group or other treatments

Table 1
Main aspects of studies considered.

Authors	Design	Interventions (intervention per group, duration of sessions, days per week, period of time)	Characteristics of the sample	Variables	Time frame	Results	Quality (Jadad)
Ganesh SH et al. (2017)	Experimental trial	Group1: Passive neurodynamic sliding technique. Group2: Suboccipital muscle inhibition technique 180s each session 6 days per week for 2 weeks	n = 30 Gender: men Age: 22.5 y	PSLR test, passive knee extension ROM	Baseline, after technique, 1st, 4th, 8th and 12th days later	Neurodynamics sliding intervention improved ROM and PSLR greater than sub-occipital muscles inhibition intervention ($p < 0.05$)	2
Castellote-CaballeroY et al. (2013)	Randomized experimental trial.	Group1: Active neurodynamic sliding intervention Group2: Control group. 60s each session 3 sessions on alternate days during a week	n = 28 Gender: Not reported Age: 24.6 y	PSLR test	Baseline, after technique.	The group that received neurodynamic interventions improved significantly over time ($p < 0.001$), whereas the control group did not ($p = 0.684$).	3
Castellote-Caballero Y et al. (2014)	Randomized double-blinded controlled trial.	Group 1: Passive neurodynamic sliding sciatic nerve. Group 2: Passive hamstring stretching. Group 3: Placebo (mobilization to their dominant foot) 30 s, 6 times on their dominant leg for a total stretching time of 180 s.	n = 120 Gender: 60 women and 60 men Age:33.43 y	PSLR test	Baseline, after technique	Mean PSLR values were significantly higher for both the neurodynamic and stretching groups compared to the control group ($p < 0.001$) and for the neurodynamic group compared to the Stretching group ($p = 0.006$).	5
Areeudomwong P et al. (2016)	Randomised assessor-blind, placebo-controlled trial	Group 1: Active neurodynamic sliders (on the sciatic nerve) Group 2: Placebo (pulse shortwave during 10 min) 60 s, 5 times for a total stretching time of 300 s. 3 sessions of treatment per week during 4 weeks	n = 40 Gender: men Age:19.95 y	Passive knee extension ROM	Baseline, 1 day after the intervention	The group that received neurodynamic interventions improved significantly ($p < 0.001$), whereas the control group did not ($p = 0.11$).	5
Sharma S et al. (2016)	Three-arm assessor-blinded randomized controlled trial.	Group1: SS-NS Group2: SS-NT Group3: SS 3 sessions (Day-1; Day-4 and Day-7)	n = 56 Gender: not reported Age: 22 y	Passive knee extensión ROM	Baseline, after technique	There was no significant difference between NS-SS and NT-SS groups ($p > 0.05$).	5
Muragod A R et al. (2017)	Randomized experimental trial.	Group1: Static hamstring stretching. Group2: Neurodynamic mobilization 10 sessions for 2 weeks.	n = 20 Gender: men Age: 67.3 y	Passive knee extension ROM and PSLR test	Baseline, after technique	There was non-significant differences between groups ($p > 0.05$).	3

PSLR: passive straight leg raise test; ROM: knee range of motion; y: years; SS: Static stretching; NT: Neurodynamic tensioner; NS: Neurodynamic sliders.

Table 2
Checklist for Measuring Quality' criteria and scores for included papers.

Authors	Randomization	Appropriateness of randomization	Double-blinding	Appropriateness of double-blinding	Withdrawals and dropouts	Total (out of 5)
Ganesh SH et al. (2017)	1	1	0	0	0	2
Castellote-CaballeroY et al. (2013)	1	1	1	0	0	3
Castellote-Caballero Y et al. (2014)	1	1	1	1	1	5
Areeudomwong P et al. (2016)	1	1	1	1	1	5
Sharma S et al. (2016)	1	1	1	1	1	5
Muragod A R et al. (2017)	1	1	1	0	0	3

Coding: 1 = yes; 0 = no/not mentioned/insufficient detail.
Total score: 0–2 = low-quality study; 3 or greater = high-quality study.

Study or subgroup	Neurodynamic			Standard Therapy			Weight	Mean difference	Effect size	Mean difference
	Mean	SD	Total	Mean	SD	Total		IV, Random, 95% CI		IV, Random, 95% CI
1.Neurodynamic vs no treatment										
Areeudomwong 2016	11.67	6.81	20	23.42	2.61	20	24.39	-2.23 [-3.02, -1.44]	-2.28	
Subtotal (95%CI)			20			20	24.39	-2.23 [-3.02, -1.44]		
Heterogeneity: not applicable										
Test for overall effect: not applicable										
2. Neurodynamic vs treatment										
Ganesh 2013	29.67	5.6	15	33.27	9.05	15	18.29	-0.52 [-1.47, 0.61]	-0.48	
Sharma 2016 a	14.7	6.5	18	21.5	12.3	19	22.56	−0.68 [−1.34, −0.02]	-0.69	
Sharma 2016 b	9.9	7.2	18	21.5	12.3	19	22.56	−1.13 [−1.83, −0.44]	-1.15	
Muragov 2017	27.41	2.33	10	28.01	3.37	10	12.19	−0.20 [−1.08, 0.68]	-0.21	
Subtotal (95%CI)			61			63		−0.40 [−1.09, 0.29]		
Heterogeneity:Tau^2=0.3552, Chi^2= 3.54 , df=3(P=0.013), I^2= 71.76%										
Test for overall effect: Z= -1.136 (P=0.2559)										
Total (95%CI)			81			83	100%	-0.74 [-1.44. -0.05]		
Heterogeneity:Tau^2=0.6056, Chi^2=5.42, df= 5 (P=<0.001), I^2=81.55 %										
Test for overall effect: Z=-2.1092, (P=0.034)										

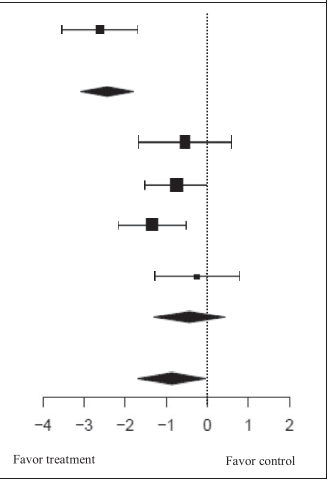

Fig. 2. Pooled MD (95% CI) of effect of neurodynamic in knee extension ROM.

Study or subgroup	Neurodynamic			Standard Therapy			Weight	Mean difference	Effect size	Mean difference
	Mean	SD	Total	Mean	SD	Total		IV, Random, 95% CI		IV, Random, 95% CI
1.Neurodynamic vs no treatment										
Castellote 2013	67.4	3.2	14	59.1	3.3	14	11.76	2.48 [1.49, 3.46]	2.55	
Castellote 2014 a	69.7	3.69	40	59.4	5.45	40	33.61	2.19 [1.64, 2.75]	2.21	
Subtotal (95%CI)			54			54	45.37	2.26 [1.78, 2.74]		
Heterogeneity: Tau^2=0,Chi^2=0,df= 1 (P= 0.6185),I^2=0 %										
Test for overall effect: Z= 9.171 (P<0.001)										
2. Neurodynamic vs treatment										
Ganesh 2013	77.66	3.99	15	71.66	7.05	15	12.60	1.02 [0.26, 1.78]	1.05	
Castellote 2014 b	65.5	7.97	40	59.4	5.45	40	33.61	0.88 [0.43, 1.34]	0.89	
Muragov 2017	63.9	2.8	10	61.65	6.74	10	8.40	0.42 [−0.47, 1.30]	0.44	
Subtotal (95%CI)			65			65	54.61	0.84 [0.48, 1.20]		
Heterogeneity:Tau^2=0 ,Chi^2= 0,df= 2 (P= 0.5704), I^2= 0%										
Test for overall effect: Z=4.5703 (P<0.001)										
Total (95%CI)			119			119	100%	1.25 [0.63, 1.87]		
Heterogeneity:Tau^2=0.4708,Chi^2=5.79,df= 5 (P<0.001), I^2= 82.72%										
Test for overall effect: Z=3.9732 (P<0.001)										

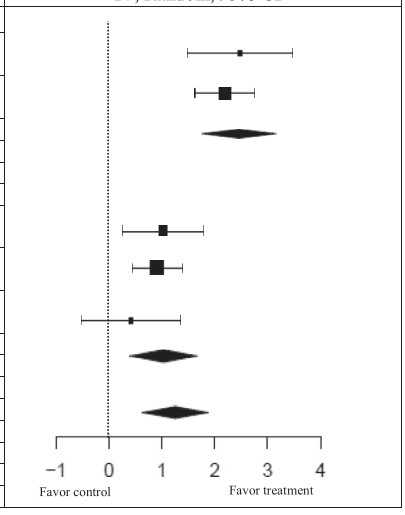

Fig. 3. Pooled MD (95% CI) of effect of neurodynamic in extensibility.

(MD: 1.25, 95% CI: 0.63 to 1.87, I^2: 82.72%) (Fig. 3).

4. Discussion

This systematic review and meta-analysis aimed to provide detailed information on the effectiveness of neurodynamic treatment on hamstrings flexibility. Our results have shown that a neurodynamic approach could be considered more effective on passive knee-extension and PSLR measures compared with no intervention and other physical therapy treatments.

Hamstrings flexibility plays an important role in preventing lower extremity injuries (Malliaropoulos et al., 2004). With numerous factors influencing this flexibility like age, gender, race, tissue temperature, strength training, stiffness, awkward posture and reduced warm up period during exercise (Fasen et al., 2009)

The majority of the interventions focused on increasing flexibility have explored the varying modes of stretching (static, plyometric, and ballistic stretching) and the intensity and frequency of them (Puentedura et al., 2011; Samuel et al., 2008). But, unfortunately the interindividual factors that can modulate the tissue changes after stretching have not been taken into account.

Very few studies have examined the effects of neurodynamic interventions on hamstrings flexibility (Hansberger, Nasypany, Baker, & May, 2016; Pietrzak & Vollaard, 2018). Nevertheless, the results of this meta-analysis have shown benefits of neurodynamic treatment, specifically for knee-extension ROM and PSLR measures compared with other techniques.

Neurodynamics have been included among the recognized techniques to counter the hamstring tightness (Nagarwal, Zutshi, Ram, Zafar, et al., 2010). With expectable results comparable to PNF, due to the tissue changes reported in both techniques (Czaprowski et al., 2013). None of the included studies compare both techniques, with a particular limitation in the PNF methods that has to be applied. Specifically those involving reciprocal activation such as hold relax, have shown the greatest potential for muscle lengthening, under the assumption that greater motor pool inhibition reduces muscle contractibility and therefore allows more muscle compliance (Etynre & Abraham, 1986).

McHugh et al. (2012) declared that the change in nerve tension is often proposed to explain the distant decrease in ROM at the knee joint, and that extensibility of neural structures can contribute to musculoskeletal flexibility. Additionally, Weppler and Magnusson (2010) reported that altered posterior lower extremity neurodynamics could influence resting muscle length and, therefore, individual's perception of stretch. Consequently, changes in the mobility of neurodynamics could modify such sensation (Shacklock, 2005).

There is no consensus about the application of neurodynamic treatment. There is heterogeneity with respect to the number of sessions, that range between one (Castellote-Caballero et al., 2014) and 10 (Muragod & Pathania, 2017), the frequency, and the way to apply the treatment. Of the 6 articles, 2 applied active neurodynamic treatment (Castellote-Caballero et al., 2014), 2 passive neurodynamic treatment (Areeudomwonget al., 2016; Castellote-Caballero et al., 2013), one an active-assisted treatment (Sharma et al., 2016) and one article did not report it (Muragod & Pathania, 2017).

In the review conducted by Ballestero-Pérez et al. (2017), authors suggested that in future studies neural mobilization with glissade or tension parameters should be distinguished in order to analyze the effects of both neural techniques separately. In this review, one article compared both techniques (Sharma et al., 2016) and authors declared that there were not significant differences between them. Nevertheless, receiving a hamstring stretching previous to the neurodynamic treatment may have altered the results.

A limitation of this study is that we considered only those studies in English, Spanish and French, and studies in other languages were not included. Additionally, electronic searches were not complemented with additional sources. The heterogeneity of the articles included in this review is another limitation. However, all the manuscripts were randomized clinical trial and results were pooled through meta-analysis reporting the highest-level evidence. Further studies should standardize the number of sessions using rigorous trial designs and a follow-up to evaluate the long-term benefits of neurodynamic treatment. Thus, more research is needed due to the limited information on long-term success and heterogeneity of data.

5. Conclusions

Neurodynamic treatment seems to be the most appropriate option to improve the passive knee extension ROM and the extensibility on hamstring musculature, proving to be more effective than other methods such as stretching. Nonetheless, although neural mobilization may represent a good option to improve hamstrings flexibility, due to the heterogeneity of the articles, it should be considered with caution. Despite these concerns, this review and meta-analysis provides promising results and useful information for applicability.

Ethical statement

The manuscript has been read and approved by all authors, who have fulfilled the authorship requirements and ethical responsibilities. It was registered in the PROSPERO database (CRD42015020707).

Ethical approval

Non applicable.

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Declaration of competing interest

The manuscript has been read and approved by all authors, who have fulfilled the authorship requirements and ethical responsibilities. All authors declare that there is no conflict of interest.

References

Ahmed, A. R., & Samhan, A. F. (2016). Short term effects of neurodynamic stretching and static stretching techniques on hamstring muscle flexibility in healthy male subjects. *International Journal of Medical Research & Health Sciences[Internet], 5*(5), 36–41.

Areeudomwong, P., Oatyimprai, K., & Pathumb, S. (2016). A randomised, placebo-controlled trial of neurodynamic sliders on hamstring responses in footballers with hamstring tightness. *The Malaysian journal of medical sciences: MJMS, 23*(6), 60.

Ballestero-Pérez, R., Plaza-Manzano, G., Urraca-Gesto, A., Romo-Romo, F., de los Ángeles Atín-Arratibel, M., Pecos-Martín, D., et al. (2017). Effectiveness of nerve gliding exercises on carpal tunnel syndrome: A systematic review. *Journal of manipulative and physiological therapeutics, 40*(1), 50–59.

Barker, P. J., & Briggs, C. A. (1999). Attachments of the posterior layer of lumbar fascia. *Spine, 24*(17), 1757.

Castellote-Caballero, Y., Valenza, M. C., Martín-Martín, L., Cabrera-Martos, I., Puentedura, E. J., & Fernández-de-las-Peñas, C. (2013). Effects of a neurodynamic sliding technique on hamstring flexibility in healthy male soccer players. A pilot study. *Physical Therapy in Sport, 14*(3), 156–162.

Castellote-Caballero, Y., Valenza, M. C., Puentedura, E. J., Fernández-de-las-Peñas, C., & Alburquerque-Sendín, F. (2014). Immediate effects of neurodynamic sliding versus muscle stretching on hamstring flexibility in subjects with short hamstring syndrome. *Journal of sports medicine, 2014*.

Coppieters, M. W., & Butler, D. S. (2008). Do 'sliders' slide and 'tensioners' tension? An analysis of neurodynamic techniques and considerations regarding their application. *Manual Therapy, 13*(3), 213–221.

Coppieters, M. W., Kurz, K., Mortensen, T. E., Richards, N. L., Skaret, I.Å., McLaughlin, L. M., et al. (2005). The impact of neurodynamic testing on the perception of experimentally induced muscle pain. *Manual Therapy, 10*(1), 52–60.

Czaprowski, D., Leszczewska, J., Kolwicz, A., Pawłowska, P., Kędra, A., Janusz, P., & Kotwicki, T. (2013). The comparison of the effects of three physiotherapy techniques on hamstring flexibility in children: A prospective, randomized, single-blind study. *PLoS One, 8*(8), e72026.

Davis, D. S., Ashby, P. E., McCale, K. L., McQuain, J. A., & Wine, J. M. (2005). The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. *The Journal of Strength & Conditioning Research, 19*(1), 27–32.

Ellis, R. F., & Hing, W. A. (2008). Neural mobilization: A systematic review of randomized controlled trials with an analysis of therapeutic efficacy. *Journal of Manual & Manipulative Therapy, 16*(1), 8–22.

Etynre, B., & Abraham, L. D. (1986). H- reflex changes during static stretching and two variations of proprioceptive neuromuscular facilitation techniques. *Clinical neurophysiology, 63*(2), 174–179.

Fasen, J. M., O'connor, A. M., Schwartz, S. L., Watson, J. O., Plastaras, C. T., Garvan, C. W., et al. (2009). A randomized controlled trial of hamstring stretching: Comparison of four techniques. *The Journal of Strength & Conditioning Research, 23*(2), 660–667.

Ganesh, S. H. (2017). Comparative study of the effects of neurodynamic sliding vs suboccipital muscle inhibition technique on flexibility of hamstring in asymptomatic subjects with hamstring syndrome. *International Journal of Clinical Skills, 11*(4).

Goldman, E. F., & Jones, D. E. (2010). Interventions for preventing hamstring injuries. *Cochrane Database of Systematic Reviews, 1*.

Hansberger, B. L., Nasypany, A., Baker, R. T., & May, J. (2016). Incorporating neurodynamics in the treatment of lower leg pain: A case review. *Athletic Training and Sports Health Care, 8*(1), 36–39.

Jonhagen, S., Nemeth, G., & Eriksson, E. (1994). Hamstring injuries in sprinters: The role of concentric and eccentric hamstring muscle strength and flexibility. *The American Journal of Sports Medicine, 22*(2), 262–266.

Malliaropoulos, N., Papalexandris, S., Papalada, A., & Papacostas, E. (2004). The role of stretching in rehabilitation of hamstring injuries: 80 athletes follow-up. *Medicine and science in sports and exercise, 36*(5), 756–759.

McHugh, M. P., Johnson, C. D., & Morrison, R. H. (2012). The role of neural tension in

hamstring flexibility. *Scandinavian Journal of Medicine & Science in Sports, 22*(2), 164–169.
Muragod, A. R., & Pathania, T. (2017). Effects of static stretching and neurodynamic mobilization on hamstring flexibility in elderly population-A randomized clinical trial. *International Journal of Advanced Research, 3*(8), 520–523.
Nagarwal, A. K., Zutshi, K., Ram, C. S., & Zafar, R. (2010). Improvement of hamstring flexibility: A comparison of two PNF stretching techniques. *International Journal of Sports Science and Engineering, 04*(01), 025–033.
Nagarwal, A. K., Zutshi, K., Ram, C. S., Zafar, R., & Hamdard, J. (2010). Improvement of hamstring flexibility: A comparison between two PNF stretching techniques. *International Journal of Sports Science and Engineering, 4*(1), 25–33.
Olivo, S. A., Macedo, L. G., Gadotti, I. C., Fuentes, J., Stanton, T., & Magee, D. J. (2008). Scales to assess the quality of randomized controlled trials: A systematic review. *Physical Therapy, 88*(2), 156–175.
Park, J., Cha, J., Kim, H., & Asakawa, Y. (2014). Immediate effects of a neurodynamic sciatic nerve sliding technique on hamstring flexibility and postural balance in healthy adults. *Physical Therapy Rehabilitation Science, 3*(1), 38–42.
Pietrzak, M., & Vollaard, N. B. (2018). Effects of a novel neurodynamic tension technique on muscle extensibility and stretch tolerance: A counterbalanced crossover study. *Journal of Sport Rehabilitation, 27*(1), 55–65.
Puentedura, E. J., Huijbregts, P. A., Celeste, S., Edwards, D., In, A., Landers, M. R., et al. (2011). Immediate effects of quantified hamstring stretching: Hold-relax proprioceptive neuromuscular facilitation versus static stretching. *Physical Therapy in Sport, 12*(3), 122–126.
Samuel, M. N., Holcomb, W. R., Guadagnoli, M. A., Rubley, M. D., & Wallmann, H. (2008). Acute effects of static and ballistic stretching on measures of strength and power. *The Journal of Strength & Conditioning Research, 22*(5), 1422–1428.
Shacklock, M. (2005). Improving application of neurodynamic (neural tension) testing and treatments: A message to researchers and clinicians. *Manual Therapy, 3*(10), 175–179.
Sharma, S., Balthillaya, G., Rao, R., & Mani, R. (2016). 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. *Physical Therapy in Sport, 17*, 30–37.
Singh, S., Grover, V., & Singh, S. (2015). Effect of neural mobilization and PNF stretching on hamstring flexibility in working women. *International Journal of Health Sciences and Research, 5*(8), 361–368.
Weppler, C. H., & Magnusson, S. P. (2010). Increasing muscle extensibility: A matter of increasing length or modifying sensation? *Physical Therapy, 90*(3), 438–449.