JOURNAL OF MANUAL & MANIPULATIVE THERAPY
2019, VOL. 27, NO. 4, 208–214
https://doi.org/10.1080/10669817.2019.1580420

Pragmatic neural tissue management improves short-term pain and disability in patients with sciatica: a single-arm clinical trial

Renato Santos de Almeida [a,b], Eduardo Machado [c], Tiê Parma Yamato [d], Luciano Santos De Melo [e,f] and Leandro Alberto Calazans Nogueira [b,g]

[a]Physiotherapy Department, Serra dos Órgãos University Centre (UNIFESO), Teresópolis, Brazil; [b]Rehabilitation Science Postgraduation Progam, Augusto Motta University Centre (UNISUAM), Rio de Janeiro, Brazil; [c]Physiotherapy Department, Gaffrée and Guinle University Hospital, Rio de Janeiro, Brazil; [d]Musculoskeletal Health Sydney, School of Public Health, Sydney Medical School, The University of Sydney, Sydney, Australia; [e]Rheumatology Department, Royal North Shore Hospital, School of Medicine, University of Sydney, Australia; [f]Institute of Bone and Joint Research, Kolling Institute of Medical Research, University of Sydney, Australia; [g]Physiotherapy Department, Federal Institute of Rio de Janeiro (IFRJ), Rio de Janeiro, Brazil

ABSTRACT

Objectives: To evaluate the clinical effect of sciatic neural mobilization in combination with the treatment of surrounding structures for sciatica patients. Secondly, we were also interested in identifying possible baseline characteristics that may be associated with improvements in pain and disability for sciatica patients.

Methods: Twenty-eight patients with a clinical diagnosis of sciatica were treated with neural mobilization, joint mobilization and soft tissue techniques. Pain intensity and lumbar disability were assessed at baseline and after treatment using a Numerical Rating Scale (0–10) and the Oswestry Disability Index (0–100), respectively. The pre- and post-intervention data were compared. The research protocol was registered under the number NCT03663842.

Results: Participants attended an average of 16 (SD±5.6) treatment sessions over an average of 12 weeks. Decrease in pain scores (before median = 8, after median = 2; $p < 0.001$) and improvement in lumbar disability scores (before median = 33.3%, after median = 15.6%; $p < 0.001$) were observed. A multiple linear regression analysis showed that duration of pain and age of the patient predicted the disability improvement: F (2, 24) = 4.084, $p < 0.030$, $R^2 = 0.254$.

Discussion: Patients with sciatica may benefit from neural mobilization in combination with manual therapy for pain and lumbar disability. Longer pain duration and younger age had a negative influence on lumbar disability improvement.

KEYWORDS
Lumbosacral plexus; physical therapy modalities; manual therapies; disability evaluation

Introduction

Non-specific low back pain (LBP) and sciatica are the primary diagnoses related to back problems. Sciatica has been diagnosed in 36% of LBP patients in primary care settings [1]. Pain related to the sciatic nerve is characterized by radiating leg pain involving L4–S1 dermatomes, and may be accompanied by muscle weakness and reduced reflexes of the affected nerve root [2]. Sciatica is commonly considered more disabling, and with an adverse prognosis, when compared to non-specific LBP, and this condition can persist six months after the first complaint [1,3]. Thus, there is a need for the development of new treatment for this population due to its high prevalence and negative impact on health.

Many treatment options have been described for patients with sciatica. Medication, surgery, and physiotherapy are the most common approaches used [4]. Certain treatment procedures (i.e. disc surgery, epidural injections, non-opioid analgesia, manipulation, and acupuncture) have shown superior overall effect when compared to bed rest or conventional care (non-surgical treatment) [5]; and surgical procedures (discectomy, microdiscectomy, endoscopic discectomy, or nucleoplasty) have shown short-term effectiveness [6]. However, there is controversial evidence of their efficacy and there is still a need for a more effective evidence-based therapeutic approach for the management of sciatica. A low-cost and safe non-surgical intervention, such as neural mobilization, could be considered a feasible option for these patients [7–9]. Furthermore, a recent systematic review showed that neural mobilization was better than other commonly used interventions in physiotherapy (i.e. exercise, general physiotherapy, traction or manual therapy) for people with nerve-related chronic musculoskeletal pain [8].

Two recent systematic reviews with meta-analysis showed improvement in pain and disability using neural mobilization treatment for patients with LBP [9,10]. Although neural mobilization for the management of musculoskeletal pain has been commonly used by physiotherapists, its understanding and evidence of its

CONTACT Renato Santos de Almeida renato.fisio@gmail.com Centro Universitário Augusto Motta (UNISUAM), Praça das Nações, 34, Bonsucesso, Rio de Janeiro CEP 21041-010, Brasil

clinical benefits and effectiveness for patients with sciatica remains unknown. Some studies have also shown that adding a sciatic neural mobilization management to conservative treatment may improve pain scores in patients with lumbar radiculopathy when compared to conservative treatment alone [11–13]. Conversely, a recent systematic review concerning sciatica did not include neural mobilization as one of their search terms; therefore, neural mobilization was not considered a possible therapeutic approach [5].

The combination of neural mobilization techniques with other manual therapy techniques may favor the recovery of the patient. The mechanism of sciatica is related to distortion of the nerve, the effect of the local inflammation, or nonspinal causes [2]. The rationale is that surrounding tissues may entrap the neural tissue and impair its function. For instance, the sacroiliac joint, the piriformis muscle, and several other sites may contribute to a double crush syndrome and the symptoms of sciatica [14–16] Therefore, a treatment approach that targets these entrapment sites would contribute to the sciatic nerve recovery and facilitate the excursion of this nerve. The goal of our study is to evaluate the clinical effect of sciatic neural mobilization in combination with the treatment of surrounding structures for sciatica patients because there is no current evidence of its combination with the treatment of surrounding structures to improve pain and disability in patients with sciatica. Secondly, we were also interested in identifying possible baseline characteristics that may be associated with improvements in pain and disability for sciatica patients.

Methods

Study design and participants

This is a single-arm clinical trial. Participants were eligible for the study if they presented with LBP and radiating leg pain and/or paresthesia below the knee that followed the L5 and/or S1 dermatomal pattern and were aged 18 years or over. An examination was performed by a physiotherapist to confirm the clinical diagnosis of sciatica, this included: neurodynamic tests for the sciatic nerve; muscle weakness in L5/S1 myotomes, dermatomes and sclerotomes sensitivity; and the Achilles reflex test. A clinical diagnosis of sciatica was confirmed if the patients presented two or more positive findings. A recent study showed almost perfect discrimination for a reference standard for the clinical diagnosis of sciatica with five items, including positive neural tension tests, neurological deficit, pain below the knee, leg pain worse than back pain, and subjective sensory changes [17]. Patients with a history of lumbar and abdominal surgery, rheumatologic syndromes (e.g. rheumatoid arthritis) and lumbar stenosis were excluded. Patients were recruited from May to November 2010.

This study was approved by the Human Research Ethics Committees of a university hospital, and was conducted in accordance with the Helsinki Declaration for research in humans (number 25/2010). All patients provided written informed consent prior to the participation. The research protocol was registered under the number NCT03663842.

Procedures

A trained physiotherapist was responsible for explaining the protocol and interviewing the eligible participants for the study. At this time, the exam for the clinical diagnosis of sciatica was performed by the same physiotherapist (examiner 1). Subsequently, demographics and pain characteristics, the degree of pain intensity and lumbar disability level information were collected by self-administered questionnaires. Finally, the neural tissue management was performed by another trained physiotherapist who was blinded to the initial evaluation (examiner 2). After the period of treatment, pain intensity, and disability were re-evaluated by examiner 1.

Outcomes measures

The primary outcome measures were pain intensity, measured by the Numerical Rating Scale (NRS 0–10) commonly used in LBP research [18], and lumbar disability assessed by the Oswestry Disability Index (ODI), previously adapted into Portuguese and validated for used in Brazil [19]. The ODI consists of ten items addressing different aspects of disability. Each item is scored from 0 to 5, with higher values representing greater disability. The sum of the item scores is divided by the total possible score (50 if all sections are completed), and the resulting total multiplied by 100 to be described as a percentage score. The outcome measures were assessed at baseline and reassessed on the last day of attendance.

Neural and soft tissue management intervention

Individual treatment sessions were delivered by a physiotherapist (examiner 2) with more than 12 years of clinical experience in the application of manual therapy techniques and neuromusculoskeletal rehabilitation. The sessions were scheduled two to three times per week, taking into consideration the patient`s availability and the clinical decision of the physiotherapist; each session lasted for approximately 30 minutes. The frequency of the treatment was pragmatically adopted to improve patients´ adherence. The sessions included soft tissue mobilization and neural mobilization techniques. All participants presented with pain at baseline and were instructed to report any increase in symptoms during the sessions to avoid side effects. All procedures were conducted

at an outpatient physiotherapy department of a university hospital, in an individual room with a physiotherapy table. All patients underwent the same techniques, and there was no modification of the intervention protocol during the study. All patients were recruited in this service, and the sessions were structured as follows.

(1) Soft tissue mobilization was applied prior to the neural mobilization (sciatic nerve sliding technique) in order to reduce the entrapment of the sciatic nerve along the nerve pathway. Three maneuvers were applied three times:

   a. Myofascial release technique (piriformis muscle and biceps femoral muscle) was performed with the patient in prone. The therapist used their thumb to apply gentle sustained pressure to the muscle and slide in a longitudinal direction. Once a tissue barrier was located (myofascial trigger point), static pressure was applied for 90 seconds [20].
   b. Hip joint mobilization technique was performed for one minute, in an anterior-posterior direction, with the patient in supine. The therapist supported the knee with one hand and performed the posterior glide in the hip joint with the other hand located on the anterior portion of the proximal femur [21].
   c. Cross-fiber friction was applied over the sacroiliac joints bilaterally for 15 repetition with the patient prone. This myofascial technique was applied in a cranial-caudal orientation with manual contact directly over the sacroiliac joint ligaments [22].

(2) Neural mobilization was used to improve sciatic nerve excursion. We chose the sliding technique as a neural mobilization maneuver because this technique improves excursion of the sciatic nerve when compared to tensioning techniques [23]. The maneuver was realized identically to the procedure described by Shacklock [24] to improve sciatic nerve excursion. The physiotherapist performed three repetitions of 60 oscillations for one minute, with the patient lying in supine with knees straight. The degree of movement chosen was based on the patient`s symptoms; and the technique should not cause pain or paresthesia. The amplitude of the technique was increased gradually according to the patient's response to the application of the technique [24].

Statistical analysis

Descriptive analysis of the study population was presented, including means and standard deviations (SD) for continuous variables, and frequencies and proportions for categorical variables. Data distribution from the primary outcome of the study (pain intensity and lumbar disability) was assessed by the Shapiro-Wilk test. Comparison between pre- and post-intervention was performed by the Wilcoxon test due to the non-parametric distribution of the data.

Clinical relevance for pain and disability was attributed according to the minimal important difference (MID). We adopted the distribution-based approach to estimate the MID using the standard error of measurement (SEM) because it largely reflects within-person variability over time [25]. The SEM was calculated by taking the square root of within-patient variability (the standard deviation of change that patients experienced during the study) [25]. Differences greater than the SEM are consequently considered to indicate a real change related to the intervention.

A multivariate linear regression model was implemented to assess potential predictors of disability improvement and pain relief. Baseline characteristics (pain intensity, pain duration, disability level, age, body mass index, and gender) and the number of treatment sessions were screened for multivariate analysis. Only those variables that satisfied the screening cut-off $p < 0.1$ on univariate analyses were incorporated as covariates into the multivariate analysis. The dependent variables were the improvement percentages in pain intensity and lumbar disability, which were calculated using the following equation: (IV-FV/FV) * 100, where "IV' represents the initial value of pain or disability scale and 'FV' the final value. All significant tests were two-sided, with an alpha of 0.05. The statistical analysis was performed using SPSS version 22.0 (IBM Corporation, Armonk, New York).

Results

Forty-four patients were diagnosed with sciatica from a total of 432 patients that presented with musculoskeletal complaints to the physiotherapy department of a university hospital, of whom nine were not willing to participate. Thirty-five patients started the treatment, and seven patients dropped out during the study. Twenty-eight patients completed the study and made up the final sample. The baseline characteristics of the final sample (n = 28) (Table 1) were not different from the participants who were lost to follow-up (n = 16). The comparison was performed using a chi-square test for gender (p = 0.242), and Mann-Whitney U test for age (p = 0.316), body mass index (p = 0.333), pain duration (p = 0.785), pain intensity (p = 0.240), and lumbar disability (p = 0.329). Participants attended an average of 16 (SD ±5.6) treatment sessions over an average period of 12 weeks (SD ±17). Nine (32.1%) patients presented right leg pain, 13 (46.4%) presented left leg pain, and six (21.4%) presented bilateral pain at baseline.

Table 1. Descriptive characteristics of the treatment group (n = 28).

	Mean (SD)
Age (years)	59.5 (12.1)
Gender (female); n (%)	24 (85.7)this line is not aligned with others
Body Mass Index (kg/m^2)	28.0 (6.3)
Pain Duration (months)	26.5 (28.8)
Numerical Pain Rating Scale (0–10)	7.6 (1.8)
Oswestry Disability Index (0–100)	34.6 (15.7)

Table 2. Values of the multiple linear regression model.

	R^2	F	ß	Sig.	95% Confidence Interval for ß	
Model 1*	0.254	4.084		0.03		
Independent variables						
NPRS			−0.45	0,05	−0.89	0.03
Ageing			1.02	0,05	−0.04	2.07

Legend: *Predictors of Oswestry Disability Index Improvement – Numeric pain rating scale and Ageing; NPRS: Numeric pain rating scale

A Wilcoxon signed-rank test indicated that the median post-test score (median = 2; interquartile range (IQR) = 5) was significantly lower than the median pre-test score (median = 8; IQR = 2) in pain intensity ($Z = -4.465$, $p < 0.001$). Similarly, a Wilcoxon signed-rank test indicated that the median post-test score (median = 15.6%; IQR = 21.1%) was significantly lower than the median pre-test score (median = 33.3%; IQR = 22.0%) in lumbar disability ($Z = -4.167$, $p < 0.001$) (Figure 1).

The results of SEM showed a mean MID value of 1.5 for pain intensity and 15.5 for disability. Clinical relevance was found for pain intensity (mean change of −6.0) and functionality (mean change of −17.9).

A multiple linear regression analysis showed that pain duration and age significantly predicted disability improvement. A significant regression equation was found (F (2, 24) = 4.084, $p < 0.030$), with an R^2 of 0.254 (Table 2). The improvement of lumbar disability increased one percent for each 1.02 years of age. Also, an improvement in lumbar disability increased one percent for each reduction of 0.45 months in the pain duration.

All other variables (pain intensity, disability level, body mass index, sex, number of treatment sessions) did not exhibit statistical significance with the improvement of lumbar disability (Figure 2). There was no baseline characteristic that predicted improvement of pain intensity.

Discussion

The findings of the current study show that neural tissue management was beneficial in this group of patients with sciatica to improve short-term pain and lumbar disability. The benefits in pain and disability were clinically relevant, since the findings presented higher values than the mean MID. The results also revealed that sciatica patients with a long history of pain duration presented a minor improvement in lumbar disability after the neural tissue management intervention.

To our knowledge, this is the first study to describe the effect of neural tissue mobilization in combination with the treatment of surrounding tissues for the management of sciatica. Our findings showed clinical benefits of a pragmatic conservative approach for patients with sciatica, who have an unfavorable prognosis compared to patients with LBP. Pain relief was previously described in case studies using neural mobilization for sciatica patients [26,27]. A recent high-quality randomized controlled trial showed that adding four sessions of sciatic neural mobilization achieved a greater reduction in leg pain, lumbar pain, and function at four weeks follow-up compared to advice to stay active alone [28].

Our findings revealed that less pain duration and higher age increased the improvement in lumbar disability of patients with sciatica who underwent neural tissue management. We believe that these findings can be explained because prolonged neuropathic pain can potentially lead to tissue hypersensitivity and may be linked to central sensitization [29]. The central sensitization phenotype has been linked to more complex clinical presentation and less favorable rehabilitation outcomes in patients with musculoskeletal pain [30].

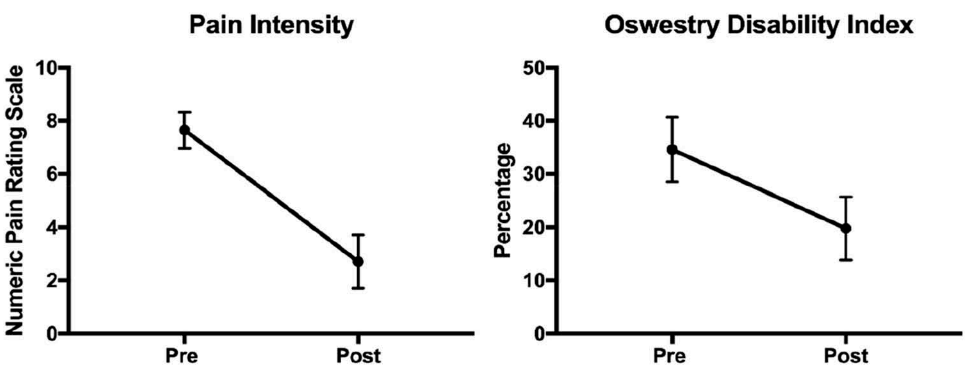

Figure 1. Pain intensity and lumbar disability measurement pre- and post-intervention in sciatica patients (n = 28).
Note: Data are presented as mean and 95% confidence interval.

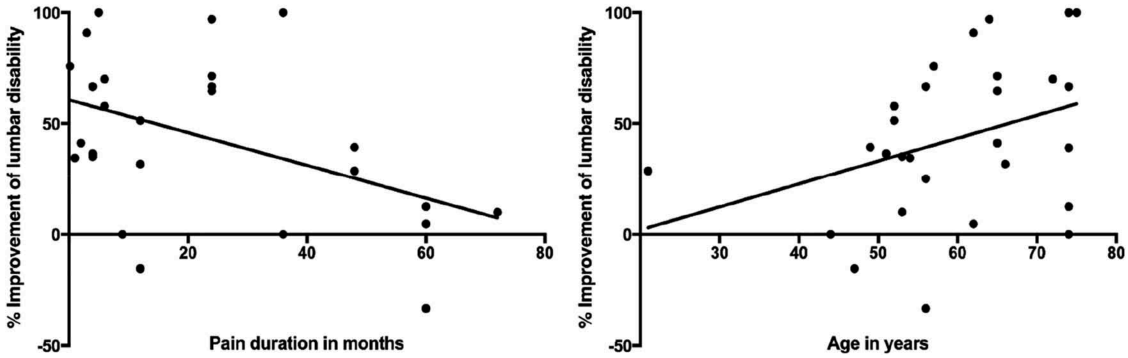

Figure 2. Relationship between lumbar disability improvement and pain duration and age in sciatica patients who underwent neural and soft tissue mobilisation (n = 28).

Clinicians can incorporate strategies to manage central sensitization signs (e.g. pain neurophysiology education) in patients with sciatica to achieve a more significant clinical outcome. Moreover, the impact of ageing in the regression model (as one of the predictors of lumbar disability improvement) needs further investigation. Presumably, older adults presented better results with neural tissue management because they usually have more stiffness in soft tissue [31]. However, the sample size and the clinical profile of the patients included in this study does not allow generalization of this finding for all sciatica patients.

Neural mobilization has demonstrated clinical benefits in other outcomes. Malik et al showed that the combination of lumbar stabilization exercises with straight leg raise mobilization or slump mobilization is superior to stabilization exercises alone for the straight leg raise range of movement in patients with low back and leg pain [32]. Neural mobilization in a modified slump position with tensioning technique also revealed an increase in the range of straight leg raise in healthy individuals [33]. We also suggest investigation of the range of motion as an outcome measure for the combination of soft tissue and neural mobilization for patients with sciatica pain in future studies.

The combination of manual therapy, movement control techniques, leisure physical activity and management of patients' expectations seem to be useful for sciatica [5,34]. Boogaard et al showed in a systematic review that negative outcome expectations and pain-related fear of movement are predictors for persistent radicular pain [35]. As we found, manual therapy techniques are a reasonable approach to treating sciatica.

Limitations

We acknowledge the limitations of the present study inherent in using a single-subject experimental study (i.e. the absence of a comparison group, selection bias, and small sample size). Furthermore, a long-term follow-up could produce a better picture of the effects of the neural tissue management on pain and disability in patients with sciatica. More studies are needed to conclude better the effect of neural mobilization in patients with sciatica and its combination with the treatment of surrounding tissues. We have a gap in the quality of studies in this area. Therefore, high-quality randomized clinical trials with large populations are still necessary. We delivered the treatment in a pragmatic model and did not use a standardized number of sessions for the intervention. Although the number of sessions was not related to pain relief in our study, Su and Lim [8] showed that the number of sessions was an independent predictor of the pain score in patients with nerve-related chronic musculoskeletal pain who were treated with neural mobilization.

Conclusion

We found that patients presenting with sciatica may show a significant reduction in pain and lumbar disability after a management that combined neural mobilization and manual therapy, based on a small sample size. The longer duration of pain and younger age seemed to affect the lumbar disability improvement scores negatively.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported in part by National Council for Scientific and Technological Development (CNPq), Brazil. TPY and LACN are supported by the National Council for Scientific and Technological Development (CNPq), Brazil. RA was partially supported by the National Council for the Improvement of Higher Education (CAPES).

Notes on contributors

Renato Santos de Almeida, is a Physiotherapist with 15 years of clinical experience in a University Hospital. He is also professor in the Faculty of Physical Therapy at Serra dos Órgãos University Center (UNIFESO) and researcher at

Rehabilitation Sciences Postgraduation Program at University Centre Augusto Motta (UNISUAM). His research interests include musculoskeletal pain, manual therapy, and patient centered care.

Eduardo Machado, is a Physiotherapist with 10 years of clinical experience in a University Hospital. He has large experience as a clinical physiotherapist in musculoskeletal rehabilitation area.

Tie Parma Yamato, is an associate researcher at Centre for Pain, Health and Lifestyle and finished her postdoc at University of Newcastle, Australia where she still collaborates elaborating projects related to children and adolescent's health. Tie has worked as a physiotherapist in Brazil between 2010 and 2013. After that, she has moved to Australia to do a PhD at University of Sydney and she was awarded in 2017. In the past 5 years Tie has published more than 45 manuscripts in peer-review journals. Tie is also one of the co-leaders of PEDrinho that has the aim of expanding the content of the Physiotherapy Evidence Database (PEDro) to Portuguese. Tie is also a co-leader of the International Collaboration for Early Career Researchers (ICECReam).

Luciano Santos De Melo, a physiotherapist from Brazil, moved to Australia in 2006 and was awarded a Masters in Musculoskeletal Physiotherapy by the University of Queensland. He has over 18 years of experience in health service delivery, clinical research and clinical education both overseas and in Australia. In the last 5 years, he has developed a keen interest in Knowledge Translation (KT) and was awarded a competitive grant to undertake KT studies in Canada, at the University of Toronto Medical School in 2016. Since then, he has applied those KT skills in developing and implementing evidence-based resources for consumers, healthcare providers, clinical researchers and policy makers as a knowledge broker. He is currently a PhD Candidate at the University of Sydney, Medical School.

More recently, he has been involved in the ongoing development and implementation of a multi professional and multi-centre collaboration National Strategy for the prevention and management of osteoarthritis, which is one of the most burdensome chronic diseases in Australia. He is also currently involved in other national projects that aim to impact the management of chronic MSK disorders in Australia by translating and implementing evidence into current clinical practice, such as the Lower Limb Health Care Awareness, the Experience and Preferences of consumers when using online support groups for osteoarthritis conditions project, as a Chair for the CRE and Program Training & Mentoring Committee for Early Career Researchers (ECR) and the OAChangeMap. He is interested in assisting people in making evidence-informed decisions about their health and contributing to an efficient healthcare system in Australia. He is currently responsible for developing a framework to allow the translation of the 45 and Up study evidence for policy and practice.

Leandro Alberto Calazans Nogueira, is a Physiotherapist and Osteopathy with 18 years of clinical experience and completed his post-doctoral fellowship at The University of Sydney in 2017. He is also Professor in the Faculty of Physical Therapy at Federal Institute of Rio de Janeiro and Researcher at Rehabilitation Sciences Postgraduation Program at Augusto Motta University Centre. His research interests include musculoskeletal pain, manual therapy, and motor control.

My ORCID number is: 0000-0002-0177-9816

ORCID

Renato Santos de Almeida http://orcid.org/0000-0003-2148-334X
Tiê Parma Yamato http://orcid.org/0000-0002-5228-1292
Luciano Santos De Melo http://orcid.org/0000-0003-4742-4401
Leandro Alberto Calazans Nogueira http://orcid.org/0000-0002-0177-9816

References

[1] Hill JC, Konstantinou K, Egbewale BE, *et al*. Clinical outcomes among low back pain consulters with referred leg pain in primary care. Spine (Phila Pa 1976). 2011;36(25):2168–2175. PubMed PMID: 21358478.
[2] Ropper AH, Zafonte RD. Sciatica. N Engl J Med. 2015;372(13):1240–1248. PubMed PMID: 25806916.
[3] Konstantinou K, Hider SL, Jordan JL, *et al*. The impact of low back-related leg pain on outcomes as compared with low back pain alone: a systematic review of the literature. Clin J Pain. 2013;29(7):644–654. PubMed PMID: 23328336.
[4] Valat JP, Genevay S, Marty M, *et al*. Sciatica. Best Pract Res Clin Rheumatol. 2010 Apr;24(2):241–252. PubMed PMID: 20227645.
[5] Lewis RA, Williams NH, Sutton AJ, *et al*. Comparative clinical effectiveness of management strategies for sciatica: a systematic review and network meta-analyses. Spine J. 2015;15(6):1461–1477. PubMed PMID: 24412033.
[6] Machado GC, Witzleb AJ, Fritsch C, *et al*. Patients with sciatica still experience pain and disability 5 years after surgery: a systematic review with meta-analysis of cohort studies. Eur J Pain. 2016;20(10):1700–1709. PubMed PMID: 27172245.
[7] Nee RJ, Vicenzino B, Jull GA, *et al*. Neural tissue management provides immediate clinically relevant benefits without harmful effects for patients with nerve-related neck and arm pain: a randomised trial. J Physiother. 2012;58(1):23–31. PubMed PMID: 22341379.
[8] Su Y, Lim EC. Does evidence support the use of neural tissue management to reduce pain and disability in nerve-related chronic musculoskeletal pain? A systematic review with meta-analysis. Clin J Pain. 2016 Nov;32(11):991–1004. PubMed PMID: 26710222.
[9] Neto T, Freitas SR, Marques M, *et al*. Effects of lower body quadrant neural mobilization in healthy and low back pain populations: a systematic review and meta-analysis. Musculoskelet Sci Pract. 2017;27:14–22. PubMed PMID: 28637597.
[10] Basson A, Olivier B, Ellis R, *et al*. The effectiveness of neural mobilization for neuromusculoskeletal conditions: a systematic review and meta-analysis. J Orthop Sports Phys Ther. 2017;47(9):593–615. PubMed PMID: 28704626.
[11] Ali M, Rehman SSU, Ahmad S, *et al*. Effectiveness of slump neural mobilization technique for the management of chronic radicular low back pain. RMJ. 2015;40(1):41–43.
[12] Sarkari E, Multani N. Efficacy of neural mobilisation in sciatica [online]. J Exercise Sci Physiot. 2007;3(2):136–141.
[13] Ahmed N, Tufel S, Khan MH, *et al*. Effectiveness of neural mobilization in the management of sciatica. J Musculoskeletal Res. 2013;16(03):1350012.

[14] Fortin JD, Vilensky JA, Merkel GJ. Can the sacroiliac joint cause sciatica? Pain Physician. 2003;6:269–271.

[15] Zhang Z, Song L, Meng Q, *et al*. Morphological analysis in patients with sciatica: a magnetic resonance imaging study using three-dimensional high-resolution diffusion-weighted magnetic resonance neurography techniques. Spine (Phila Pa 1976). 2009;34(7):E245–E250.

[16] Filler AG, Haynes J, Jordan SE, *et al*. Sciatica of nondisc origin and piriformis syndrome: diagnosis by magnetic resonance neurography and interventional magnetic resonance imaging with outcome study of resulting treatment. J Neurosurg Spine. 2005;2:99–115.

[17] Stynes S, Konstantinou K, Ogollah R, *et al*. Clinical diagnostic model for sciatica developed in primary care patients with low back-related leg pain. PLoS One. 2018;13(4):e0191852. PubMed PMID: 29621243; PubMed Central PMCID: PMCPMC5886387.

[18] Chapman JR, Norvell DC, Hermsmeyer JT, *et al*. Evaluating common outcomes for measuring treatment success for chronic low back pain. Spine (Phila Pa 1976). 2011;36(21):S54–S68. PubMed PMID: 21952190.

[19] Vigatto R, Alexandre NM, Correa Filho HR. Development of a brazilian portuguese version of the oswestry disability index: cross-cultural adaptation, reliability, and validity. Spine (Phila Pa 1976). 2007;32(4):481–486. PubMed PMID: 17304141.

[20] Chaitow L, DeLany J. Clinical application of neuromuscular techniques: practical case study exercises. Elsevier Churchill Livingstone; 2005. (v. 3).

[21] Edmond SL. Joint mobilization/manipulation: extremity and spinal techniques. Elsevier Health Sciences; 2016.

[22] Pilat A. Terapias miofasciales: inducción miofascial. McGraw-Hill Interamericana Editores; 2003.

[23] 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(10):731–737. PubMed PMID: 26304637.

[24] Shacklock M. Clinical neurodynamics. 2nd ed. Elsevier; 2005.

[25] Guyatt GH, Osoba D, Wu AW, *et al*. Methods to explain the clinical significance of health status measures. Mayo Clin Proc. 2002;77(4):371–383. PubMed PMID: 11936935.

[26] Talebi GA, Taghipour-Darzi M, Norouzi-Fashkhami A. Treatment of chronic radiculopathy of the first sacral nerve root using neuromobilization techniques: a case study. J Back Musculoskeletal Rehab. 2010;23 (3):151–159. PubMed PMID: 20858945.

[27] Cleland J, Hunt GC, Palmer J. Effectiveness of neural mobilization in the treatment of a patient with lower extremity neurogenic pain: a single-case design. J Manual Manip Ther. 2004;12(3):143–152.

[28] Ferreira G, Stieven F, Araujo F, *et al*. Neurodynamic treatment did not improve pain and disability at two weeks in patients with chronic nerve-related leg pain: a randomised trial. J Physiother. 2016;62(4):197–202. PubMed PMID: 27634158.

[29] Woolf CJ. Central sensitization: implications for the diagnosis and treatment of pain. Pain. 2011;152(3): S2–S15. PubMed PMID: 20961685; PubMed Central PMCID: PMC3268359.

[30] Nijs J, Van Houdenhove B, Oostendorp RA. Recognition of central sensitization in patients with musculoskeletal pain: application of pain neurophysiology in manual therapy practice. Manual Ther. 2010;15(2):135–141. PubMed PMID: 20036180.

[31] Paladini A, Fusco M, Coaccioli S, *et al*. Chronic pain in the elderly: the case for new therapeutic strategies. Pain Physician. 2015;18(5):E863–E876. PubMed PMID: 26431140.

[32] Malik N, Kataria C, Sachdev NB. Comparative effectiveness of straight leg raise and slump stretching in subjects with low back pain with adverse neural tension. Int J Health Rehabil Sci. 2012;1(1):2–10.

[33] Pietrzak M, Vollard NB. Effects of a novel neurodynamic tension technique on muscle extensibility and stretch tolerance: a counterbalanced cross-over study. J Sport Rehabil. 2016;19:1–31. PubMed PMID: 27992294.

[34] Shiri R, Falah-Hassani K, Viikari-Juntura E, *et al*. Leisure-time physical activity and sciatica: a systematic review and meta-analysis. Eur J Pain. 2016;20(10):1563–1572. PubMed PMID: 27091423; PubMed Central PMCID: PMCPMC5081102.

[35] Boogaard S, Heymans MW, de Vet HC, *et al*. Predictors of persistent neuropathic pain: a systematic review. Pain Physician. 2015;18(5):433–457. PubMed PMID: 26431122.