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# The Effectiveness of Neural Mobilization for Neuromusculoskeletal Conditions: A Systematic Review and Meta-analysis

**STUDY DESIGN:** Systematic review with meta-analysis.

**OBJECTIVES:** To determine the efficacy of neural mobilization (NM) for musculoskeletal conditions with a neuropathic component.

**BACKGROUND:** Neural mobilization, or neurodynamics, is a movement-based intervention aimed at restoring the homeostasis in and around the nervous system. The current level of evidence for NM is largely unknown.

**METHODS:** A database search for randomized trials investigating the effect of NM on neuromusculoskeletal conditions was conducted, using standard methods for article identification, selection, and quality appraisal. Where possible, studies were pooled for meta-analysis, with pain, disability, and function as the primary outcomes.

**RESULTS:** Forty studies were included in this review, of which 17 had a low risk of bias. Meta-analyses could only be performed on self-reported outcomes. For chronic low back pain, disability (Oswestry Disability Questionnaire [0-50]: mean difference, –9.26; 95% confidence interval [CI]: –14.50, –4.01; *P*<.001) and pain (intensity [0-10]: mean difference, –1.78; 95% CI: –2.55, –1.01; *P*<.001) improved following NM. For chronic neck-arm pain, pain improved (intensity: mean difference, –1.89; 95% CI: –3.14, –0.64; *P*<.001) following NM. For most of the clinical outcomes in individuals with carpal tunnel syndrome, NM was not effective (*P*>.11) but showed some positive neurophysiological effects (eg, reduced intraneural edema). Due to a scarcity of studies or conflicting results, the effect of NM remains uncertain for various conditions, such as postoperative low back pain, cubital tunnel syndrome, and lateral epicondylalgia.

**CONCLUSION:** This review reveals benefits of NM for back and neck pain, but the effect of NM on other conditions remains unclear. Due to the limited evidence and varying methodological quality, conclusions may change over time.

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The 2010 Global Burden of Disease study revealed that musculoskeletal disorders are the second biggest contributor to disability worldwide.[118] Low back–related leg pain and neck-related arm pain can arise from a lesion or disease affecting the peripheral nervous system.[69,99] The peripheral nervous system is also compromised in common entrapment neuropathies, such as carpal tunnel syndrome (CTS) and cubital tunnel syndrome, and may be affected in conditions such as lateral epicondylalgia[27] and plantar heel pain.[6] The effectiveness of neural mobilization (NM) for neuromusculoskeletal conditions remains unclear.

Neurodynamics (NM) is an intervention aimed at restoring the homeostasis in and around the nervous system, by mobilization of the nervous system itself or the structures that surround the nervous system.[32,34] Neural mobilization facilitates movement between neural structures and their surroundings (interface) through manual techniques or exercise.[83] Human and animal studies revealed that NM reduces intraneural edema,[101] improves intraneural fluid dispersion,[20,53] reduces thermal and mechanical hyperalgesia,[105] and reverses the increased immune responses[96,105] following a nerve injury. Three systematic reviews evaluated the effectiveness of NM. One review[77] focused on CTS (6 studies) and observed a possible trend toward improved outcomes following NM, but concluded that the efficacy of NM for CTS was unclear. Another review[45] included various musculoskeletal conditions (11 studies) and concluded that, although the evidence supported the

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use of NM, the evidence was limited. A recent review[108] (20 studies) assessed the effect of NM on chronic conditions and concluded that NM is not superior to other interventions. This review focused on chronic musculoskeletal conditions and only considered the outcome measures of pain and disability. A narrative review of NM for spinal radiculopathy concluded that NM might be beneficial for certain subgroups of patients.[44]

Since the publication of these reviews, additional randomized trials have been published on the effectiveness of NM. The objective of this systematic review was to assess the effectiveness of NM for neuromusculoskeletal conditions, as measured by outcomes related to pain, disability, and function. It was anticipated that an updated systematic review with meta-analysis would provide more definite answers regarding the effectiveness of NM for neuromusculoskeletal conditions.

## METHODS

### Protocol and Registration

THE PROTOCOL FOR THIS SYSTEMATIC review was published in the *Joanna Briggs Institute Database of Systematic Reviews and Implementation Reports* (registration number 1401).[12]

### Eligibility Criteria

**Studies** Randomized clinical trials, published in English, that evaluated the effect of NM in participants over the age of 18 years with neuromusculoskeletal conditions indicative of neural tissue dysfunction were considered for inclusion. Case reports and case-control and cohort studies were excluded. Studies that evaluated the effect of NM in systemic diseases, central nervous system disorders, and polyneuropathies were excluded. Animal studies or studies on healthy participants were also excluded.

**Interventions** Studies that evaluated the effect of NM on disorders where neurodynamic dysfunction was implicated were considered for inclusion. Neural mobilization could be achieved through active exercises or passive techniques. Included techniques could be directed to the nervous system itself (eg, sliding and tensioning techniques[30,32,33,46]) or to the structures that surround the nervous system (eg, cervical lateral glide[36,48] or lumbar foraminal opening[100] techniques).

**Outcome Measures** Outcome measures of primary interest were pain, disability, and/or function. Disability is defined as encompassing impairments, activity limitation, participation restriction, personal factors, and environmental factors.[62,107] Secondary outcomes included quality-of-life measures, limb or joint range of motion (ROM), neurodynamic test outcomes (eg, levels and region of symptom provocation, presence of neural structural differentiation and test sequence ROM), and neurophysiological changes (eg, changes in temporal summation, median nerve intraneural edema, and H-reflex latency).

### Search Strategy

The databases searched included MEDLINE (PubMed), CINAHL Plus, Cochrane Central Register of Controlled Trials, Physiotherapy Evidence Database, ProQuest Central (Family Health, Health and Medical Complete), Nursing and Allied Health Source, EBSCO MasterFILE Premier, ScienceDirect, and Scopus. The search was conducted to include articles from January 1980 to April 2016. The search for unpublished studies included EBSCO MasterFILE Premier. A previous review[45] searched from 1830, and the oldest article included in that review was from 1996.

The search terms included *neural*, *nerve*, *mobilization*, *manipulation*, *physical therapy*, *physiotherapy*, *manual therapy*, *exercises*, *treatment*, *intervention*, *management*, *modality*, *stretching*, *tension*, and *neurodynamics* (**APPENDIX A**, available at www.jospt.org).

### Methodological Quality

Two independent reviewers (A.B. and B.O.) considered records for inclusion, and full text was reviewed after identifying relevant titles and abstracts. Articles that met the inclusion criteria were assessed by 2 independent reviewers using the Joanna Briggs Institute (JBI) Meta-Analysis of Statistics Assessment and Review Instrument for critical appraisal (MAStARI)[63] (**APPENDIX B**, available at www.jospt.org). The MAStARI is a tool that was developed by experts and ratified by the JBI's International Scientific Committee. It has been designed for review and critical appraisal of methodology of individual studies and for meta-analysis following appraisal. In this regard, the MAStARI tool was used to establish the methodological quality of included studies and to conduct the relevant meta-analyses.[63] Disagreements were discussed between the 2 reviewers. Any unresolved issues were resolved through discussion with a third reviewer (R.E.). Agreement between reviewers was evaluated using Cohen's kappa. Risk of bias was assessed independently of study appraisal using the GRADE guidelines.[56] This takes into account randomization, concealment of allocation, blinding of outcomes assessment, incomplete outcome data, selective reporting, and other biases, such as stopping early for benefit or the use of nonvalidated outcome measures.

### Data Collection

Data extracted from studies were grouped together by patient subgroup, patient demographics, interventions, outcome measures, timing of assessments, and main results. Authors were contacted for clarification or missing data.

### Data Synthesis

Quantitative data, where possible, were pooled in a statistical meta-analysis using the MAStARI. Effect sizes, expressed as odds ratios for categorical data and weighted mean differences for continuous data, and their 95% confidence intervals (CIs) were calculated for analysis. Heterogeneity was assessed statistically using a standard chi-square test. Meta-analyses were not performed when the chi-square test had a $P$ value of less than .1.[63] Where statistical pooling was not possible, the findings are presented in a narrative form.

### Levels of Evidence

The JBI Levels of Evidence and Grades of Recommendation[64] (**APPENDIX C**, available at www.jospt.org) were used for making recommendations about treatment efficacy.

### Meta-analysis

Meta-analyses were conducted for CTS (outcomes: pain intensity, Phalen's test, grip strength, 2-point discrimination, and the Disabilities of the Arm, Shoulder and Hand questionnaire), nerve-related low back pain (N-LBP) (outcomes: modified Oswestry Disability Questionnaire and pain intensity), and nerve-related neck and arm pain (N-NAP) (outcome: pain intensity). It was not possible to perform a meta-analysis for lateral epicondylalgia, cubital tunnel syndrome, post–lumbar surgery, tarsal tunnel syndrome, or plantar heel pain.

## RESULTS

FORTY STUDIES, WITH A TOTAL OF 1759 participants, were included in the review, 19 of which were included in a meta-analysis for CTS, N-LBP, and N-NAP (**FIGURE 1**). Primary and secondary outcome measures for 1 study were reported separately in 2 papers, and these 2 papers were therefore treated as 1.[35,36] There were 12 studies for CTS, 11 for N-LBP, 10 for N-NAP, 3 for lateral epicondylalgia, and 1 each for cubital and tarsal tunnel syndrome, plantar heel pain, and postoperative low back pain. The excluded studies are listed in **APPENDIX D** (available at www.jospt.org).

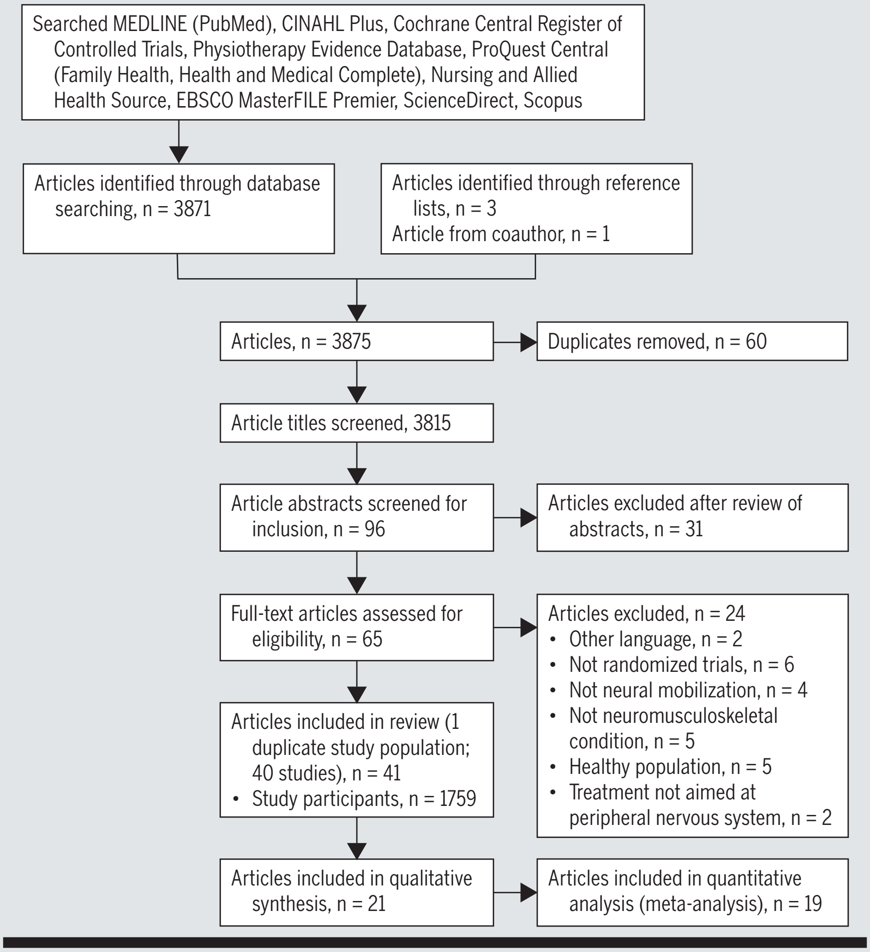


**FIGURE 1.** Flow diagram of search results and studies included.

### Risk of Bias Across Studies

The initial overall level of agreement between the 2 reviewers was $\kappa = 0.615$ (95% CI: 0.41, 0.82), indicating good reliability. The main areas of disagreement between reviewers were blinding of participants, whether groups were treated equally, and whether appropriate statistical analyses were performed. Seventeen studies had a low risk of bias and 23 studies had an unclear or high risk of bias. The assessment of risk of bias is presented in the study descriptions and in **APPENDIX E** (available at www.jospt.org). The most problematic domains were blinding of assessors and concealed allocation. Incomplete outcome data and high dropout rates were commonly listed as other forms of bias. Blinding of participants is often difficult in clinical trials, although some of the studies used a sham intervention that successfully blinded participants.[15,66]

### Techniques Used as NM

The NM techniques that were assessed most frequently were NM exercises for CTS; cervical lateral glides for N-NAP and lateral epicondylalgia; mobilization in the slump position for N-LBP; and straight leg raise (SLR) mobilization for N-LBP, tarsal tunnel syndrome, plantar heel pain, and postoperative low back pain.

### Nerve-Related Low Back Pain

The majority of studies had a high risk of bias (**TABLE 1**). Five studies evaluated mobilization in the slump position,[4,25,61,81,90] which resulted in significant improvements in pain and disability. Three studies compared mobilization in slump with exercises and lumbar mobilization,[25,61,81] and 1 compared it to stabilization exercises.[4] One study could not be included in the meta-analysis, as it measured the H-reflex and compared slump with SLR.[90] The treatment period varied between 1 and 6 weeks (**TABLE 2**). The remaining studies used a variety of techniques; SLR was compared to exer-

**TABLE 1** Results of Study Appraisals*

| | Question† | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Study** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| Ahmed et al[2] | Y | N | Y | U | N | Y | Y | Y | Y | Y |
| Akalin et al[3] | U | N | U | U | U | Y | Y | Y | Y | Y |
| Ali et al[4] | Y | N | N | U | U | Y | Y | Y | Y | Y |
| Allison et al[5] | Y | U | U | U | Y | Y | Y | Y | Y | Y |
| Anwar et al[7] | Y | N | N | U | N | Y | Y | Y | Y | N |
| Bardak et al[11] | Y | U | Y | U | Y | N | Y | Y | Y | Y |
| Baysal et al[13] | Y | U | Y | U | U | Y | Y | Y | Y | Y |
| Bialosky et al[15] | Y | Y | Y | N | Y | Y | Y | Y | Y | Y |
| Brininger et al[19] | Y | N | U | N | Y | Y | Y | Y | Y | Y |
| Cleland et al[25] | Y | U | Y | Y | Y | Y | Y | Y | Y | Y |
| Coppieters et al[35] | Y | Y | Y | U | Y | Y | N | Y | Y | Y |
| Coppieters et al[36] | Y | Y | Y | U | Y | Y | N | Y | Y | Y |
| Dabholkar et al[37] | U | N | U | N | N | U | Y | Y | Y | U |
| Drechsler et al[42] | Y | N | U | U | U | U | Y | Y | Y | Y |
| Dwornik et al[43] | Y | N | N | U | U | U | Y | Y | Y | Y |
| Gupta and Sharma[55] | Y | N | U | N | N | Y | N | Y | Y | Y |
| Heebner and Roddey[59] | Y | U | U | N | U | Y | Y | Y | Y | Y |
| Horng et al[60] | Y | N | Y | N | Y | Y | U | Y | Y | Y |
| Jain et al[61] | Y | U | U | U | U | Y | Y | Y | Y | Y |
| Kaur and Sharma[65] | Y | U | U | U | U | Y | Y | Y | Y | Y |
| Kavlak and Uygur[66] | N | Y | Y | Y | N | Y | Y | Y | Y | Y |
| Kumar[67] | Y | U | U | U | U | U | Y | Y | Y | Y |
| Langevin et al[68] | Y | N | Y | Y | Y | Y | Y | Y | Y | Y |
| Marks et al[76] | Y | U | N | Y | N | N | Y | Y | Y | Y |
| Mehta et al[78] | Y | U | U | Y | U | U | Y | Y | Y | Y |
| Nagrale et al[81] | Y | N | Y | Y | Y | Y | Y | Y | Y | Y |
| Nar[82] | Y | U | U | Y | U | Y | Y | Y | Y | N |
| Nee et al[84] | Y | N | Y | N | Y | U | Y | Y | Y | Y |
| Oskouei et al[86] | Y | Y | Y | U | Y | Y | Y | Y | Y | Y |
| Patel[87] | Y | N | U | U | U | Y | Y | Y | Y | Y |
| Pinar et al[88] | Y | N | U | Y | Y | Y | Y | Y | Y | Y |
| Ragonese[89] | Y | N | Y | N | Y | N | Y | Y | Y | Y |
| Rezk-Allah et al[90] | Y | N | N | U | U | Y | Y | Y | Y | Y |
| Saban et al[93] | Y | U | Y | Y | Y | Y | Y | Y | Y | Y |
| Schmid et al[101] | Y | N | Y | N | Y | Y | N | Y | Y | Y |
| Scrimshaw and Maher[102] | Y | N | N | Y | Y | Y | Y | Y | Y | Y |
| Svernlöv et al[109] | Y | U | U | N | Y | U | U | Y | Y | Y |
| Tal-Akabi and Rushton[111] | Y | U | U | Y | Y | Y | Y | Y | Y | Y |
| Vicenzino et al[115] | U | Y | Y | Y | Y | U | Y | Y | Y | Y |
| Mahmoud[75] | Y | N | N | Y | N | Y | N | Y | Y | Y |
| Wolny et al[119] | Y | N | Y | N | Y | N | Y | Y | Y | Y |

*Abbreviations: N, no; U, unclear; Y, yes.*

**See* **APPENDIX B** *for appraisal tool.*

*†1, Random allocation; 2, Participant blinding; 3, Concealment of allocation to groups; 4, Study withdrawal described and included in analysis; 5, Blinding of assessors; 6, Groups comparable at entry; 7, Groups treated identically; 8, Outcomes measured the same way for groups; 9, Outcomes measured reliably; 10, Appropriate statistical analysis.*

**TABLE 2** DESCRIPTIONS OF STUDIES ON N-LBP

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Ahmed et al[2] | n = 30 (14 male, 16 female). Overall age range, 45-67 y. Mean ± SD age: IG, 53.00 ± 1.91 y; CG, 52.60 ± 1.60 y. Duration of symptoms: IG, 4.87 ± 1.50 wk; CG, 5.26 ± 1.75 wk | n = 15 participants with sciatica<br>Same treatment as CG, plus SLR with tibial and peroneal bias<br>2 sets of 20 mobilizations of each bias<br>3 treatments per week for 2 wk | n = 15 participants with sciatica<br>Flexion and extension exercises[47] for 2 to 3 sets<br>TENS<br>Home exercises<br>3 treatments per week for 2 wk | Outcomes measured at baseline and end of treatment<br>1. NPRS<br>2. SF-12 | No baseline differences<br>Improvement in both measures in both groups, but significantly more and clinically relevant in the IG (NPRS, *P* = .001; SF-12, *P* = .001). NPRS IG, 3.47 ± 1.12 (95% CI: 2.85, 4.09) and NPRS CG, 4.93 ± 1.10 (95% CI: 4.34, 5.55)<br>Between-group difference favoring IG, 1.46 (14.6%). SF-12 IG, 65.57 ± 12.00 (95% CI: 58.97, 72.17); SF-12 CG, 54.53 ± 7.34 (95% CI: 50.49, 58.57)<br>Between-group difference favoring IG, 11.04 (11.04%) | Appraisal: 7; low |
| Ali et al[4] | n = 40 (10 male, 30 female)<br>Overall age range, 20-60 y. Mean ± SD age: IG, 34.32 ± 8.94 y; CG, 33.22 ± 7.16 y | n = 22 participants with chronic radicular LBP<br>Same treatment as CG, plus slump slider mobilization<br>5 d/wk for 3 wk | n = 18 participants with chronic radicular LBP<br>Lumbar stabilization exercises<br>Shortwave diathermy<br>5 d/wk for 3 wk | Outcomes measured at baseline and end of treatment<br>1. MODI<br>2. VAS (5-point scale) | Both groups had a significant improvement in pain on the VAS (95% CI: 2.85, 4.09)<br>Only the IG had a significant improvement in disability (MODI) (IG: *P* = .003, 2.91 ± 0.69; CG: *P* = .163, 1.49 ± 0.32) | Appraisal: 6; high |
| Cleland et al[25] | n = 30 (9 male, 21 female). Overall age range, 18-60 y. Mean ± SD age: IG, 40.0 ± 12.2 y; CG, 39.4 ± 11.3 y. Duration of symptoms: IG, 14.5 ± 8.0 wk; CG, 18.5 ± 12.5 wk | n = 16 participants with LBP<br>Same treatment as CG plus slumped stretching exercise (position held 30 s, 5 repetitions)<br>Home exercise slump stretches (2 repetitions for 30 s)<br>2 times per week for 3 wk | n = 14 participants with LBP<br>5-min cycle warm-up<br>Lumbar spine mobilization (PA mobilizations to hypomobile lumbar segments, grades 3-4)<br>Standardized exercise program (pelvic tilts, bridging, squats, quadruped alternate arm/leg activities; 2 sets, 10 repetitions each)<br>2 times per week for 3 wk | Outcomes measured at baseline and end of treatment<br>1. Body diagram (for distribution of symptoms)<br>2. NPRS<br>3. MODI<br>4. FABQ | No baseline differences between groups (*P*>.05). Participants who received slump stretching had significantly greater improvements in disability. Between-group difference favoring IG: MODI, 9.7 (95% CI: 5.4, 14.0; *P*<.001); NPRS, 0.93 (95% CI: 0.35, 1.6; *P* = .001); centralization of symptom distribution (*P*<.01) | Appraisal: 9; low |
| Dwornik et al[43] | n = 97 (44 male, 53 female). Mean ± SD age (IG and CG), 43 ± 10 y (range, 19-60 y). No other data available | n = 42 participants with neurogenic LBP; 5 did not complete treatment<br>10 treatments over 2 wk<br>NM techniques according to Butler and Jones[21] of femoral, sciatic, tibial nerves<br>Techniques not described | n = 45 participants with neurogenic LBP; 2 did not complete treatment<br>10 treatments over 2 wk<br>10 sets of TENS for 10-15 min<br>10 sets of laser over painful area<br>Movement exercises for intervertebral joints without axial loading | Outcomes measured at baseline and end of treatment<br>1. Resting muscle tone (quadriceps femoris, biceps femoris, tibialis anterior, gastrocnemius) measured by EMG<br>2. ROM of Lasègue sign and reverse Lasègue sign measured with inclinometer<br>3. Presence of Bragard sign and reverse Lasègue sign<br>4. VAS | NM had significant effect on resting muscle tone compared to control. Significant improvement in clinical tests (Lasègue, *P*<.001; between-group difference, 2.7° [6%] favoring IG) and pain (*P*<.001; difference, 1.5 [15%] favoring IG) in the NM group. No other values available<br>Dropouts, 7 of 87 participants | Appraisal: 5; high |

*Table continues on page 598*

**TABLE 2** Descriptions of Studies on N-LBP (continued)

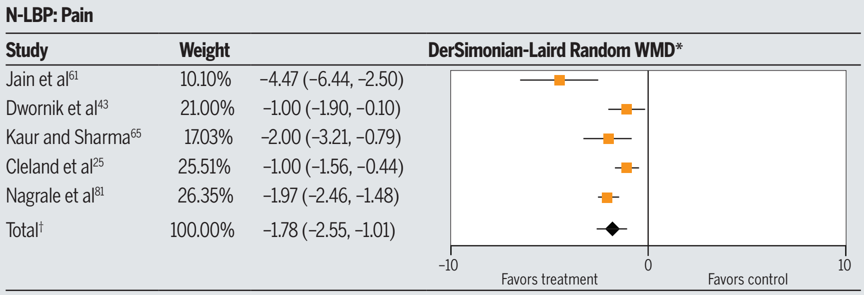
| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Jain et al[61] | n = 30 (11 male, 19 female). Overall age range, 19-60 y. Mean ± SD age: IG, 34.26 ± 5.66 y; CG, 33 ± 6.86 y. Duration of symptoms: IG, 8.067 ± 1.10 wk; CG, 8.266 ± 1.16 wk | n = 15 participants with LBP, unilateral limb pain, and positive slump<br>All participants were treated for 9 sessions (3 d/wk for first week and 2 d/wk for next 3 wk)<br>Same treatment as CG plus slump stretching from second week | n = 15 participants with LBP, unilateral limb pain, and positive slump<br>All participants were treated for 9 sessions (3 d/wk for first week and 2 d/wk for next 3 wk)<br>PA mobilization of lumbar spine, exercises | Outcomes measured at baseline and at 1, 2, 3, 4, and 5 wk<br>1. VAS<br>2. MODI | For pain (VAS), significant differences were found at the end of weeks 2, 3, 4, and 5 ($P = .019$, $P<.001$, $P<.001$, and $P<.001$, respectively) between the 2 groups, in favor of the IG<br>MODI between-group differences were nonsignificant at the end of weeks 1 ($P = .438$), 2 ($P = .452$), 3 ($P = .078$), and 4 ($P = .087$). No means or SD values available | Appraisal: 6; high |
| Kaur and Sharma[65] | n = 27. Age range, 18-45 y. No other data available | n = 12 participants with subacute neurogenic LBP: pain in lower lumbar region with or without radiation to lower limb; without any neurological deficits; and positive SLR<br>10 sessions over 2 wk<br>Passive SLR | n = 15 participants with subacute neurogenic LBP: pain in lower lumbar region with or without radiation to lower limb; without any neurological deficits; and positive SLR<br>10 sessions over 2 wk<br>Advice<br>Exercise | Outcomes measured at baseline and end of treatment<br>1. VAS<br>2. Hip flexion ROM<br>3. Werneke overlay template<br>4. MODI | Between-group analysis of all the variables demonstrated a significant postintervention difference ($P<.05$) in patient-reported VAS scores (mean change of 3 [30%], favoring IG; IG, 2; 95% CI: 0.74, 3.26 and CG, 4; 95% CI: 2.74, 5.26), hip flexion ROM (74.6° for the IG and 60° for the CG), and disability scores (MODI IG, 6; CG, 2). A statistically significant reduction in the area of reported symptoms for NM occurred within the IG (50.3%), but not in the CG (25.1%) | Appraisal: 6; high |
| Mahmoud[75] | n = 60. Overall age range, 30-50 y. Mean ± SD age: IG, 44.2 ± 6.16 y; CG, 42.93 ± 5.73 y. Duration of symptoms: pain for longer than 3 mo. No other data available | Group A: n = 30 participants with chronic radicular LBP<br>MRI compromise of nerve<br>SLR and slump mobilization to onset of symptoms<br>3 treatments per week for 6 wk<br>Group B: n = 30; PA mobilizations, 3-4 repetitions (Maitland)<br>Lumbar rotation with SLR, 3-4 repetitions | Note: used rotation SLR (Maitland) in comparison group, described as mobilization group | Outcomes measured at baseline and end of treatment<br>1. VAS<br>2. MODI<br>3. MRI compromise of nerve | Manipulation and NM: the lumbar manipulation (with SLR) techniques were more effective than NM techniques for leg pain (group A, 3.03 ± 1.88; 95% CI: 2.33, 3.73; group B, 1.83 ± 1.31; 95% CI: 1.34, 2.32; $P = .006$); a difference of 1.2 (12%) favored the CG. MODI (group A, 23.9 ± 4.9; 95% CI: 22.07, 25.73; group B, 18.4 ± 6.87; 95% CI: 16.57, 20.23; $P = .001$); a difference of 5.5% favored group B | Appraisal: 6; high |
| Mehta et al[78] | n = 50 (22 male, 28 female). Mean ± SD age: IG, 45.58 ± 6 y; CG, 46 ± 6.8 y. Sex: IG, 12 male and 13 female; CG, 10 male and 15 female. No other data available | n = 25 participants with subacute LBP and a capsular pattern of restriction<br>3 wk of treatment on alternate days and follow-up at week 4<br>Ultrasound<br>Exercise<br>NM from static opener, progressing to dynamic end-range closer<br>30 mobilizations of 3 sets, with 30 s of rest | n = 25 participants with subacute LBP and a capsular pattern of restriction<br>3 wk of treatment on alternate days and follow-up at week 4<br>Ultrasound<br>Exercise<br>Maitland joint mobilization | Outcomes measured at baseline and end of treatment<br>1. VAS<br>2. ROM: lumbar spine<br>3. ROM: slump test<br>4. MODI | Both treatment techniques improved pain and disability, but the IG improved sooner than the CG<br>VAS (IG, 4.6; CG, 6.3; $P = .013$; difference, 1.7 [17%]), slump ROM (IG, 2.4°; CG, 2.7°; $P = .004$) at 4 wk posttreatment<br>No SDs or other information available | Appraisal: 6; high |

*Table continues on page 599*

**TABLE 2** Descriptions of Studies on N-LBP (continued)

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Nagrale et al[81] | n = 60 (21 male, 39 female)<br>Mean ± SD age: IG, 38.2 ± 3.47 y; CG, 37.76 ± 4.70 y. Symptom duration: IG, 15.26 ± 2.57 wk; CG, 14.76 ± 1.79 wk | n = 30 participants with nonradicular LBP with positive slump and SLR >45°<br>Same treatment as CG plus slump stretching, 5 times with 30-s hold | n = 30 participants with nonradicular LBP with positive slump and SLR >45°<br>3 wk of treatment<br>PA mobilization of lumbar spine<br>Stabilization exercises according to Childs et al[24] | Outcomes measured at baseline and at 1, 2, 3, and 6 wk<br>1. NPRS<br>2. MODI<br>3. FABQ | There were large within-group changes for all outcomes ($P<.01$) and large between-group differences at weeks 3 (IG, 28 ± 3.93; CG, 39.5 ± 7.25) and 6 (IG, 28.2 ± 4.11; CG, 44.1 ± 6.40). Between-group difference favoring IG, 11.5; 95% CI: 8.51, 14.4 for the MODI, and at weeks 1 (IG, 5.4 ± 0.93; CG, 6.1 ± 1.09), 2 (IG, 3.6 ± 0.77; CG, 4.7 ± 0.94), 3 (IG, 2.1 ± 0.54; CG, 3.7 ± 0.95), and 6 (IG, 2.4 ± 0.80; CG, 4.3 ± 1.12) for the NPRS<br>Between-group difference favoring IG, 1.06; 95% CI: 0.67, 1.45 for the FABQ ($P<.01$). Significant differences favoring the slump stretching group ($P<.01$) | Appraisal: 9; low |
| Patel[87] | n = 50. Age range, 30-60 y. No other data available | Group A: n = 25 participants with LBP and a positive SLR of >15°<br>BLR[57] for 30 s × 3<br>4 treatments for a week<br>Group B: n = 25 participants with LBP and a positive SLR of >15°<br>Slump stretching exercise for 30 s × 3<br>4 treatments for a week | ... | Outcomes measured at baseline and end of treatment<br>1. VAS<br>2. ROM of SLR | Results of the study show that both techniques (BLR and slump) are effective in reducing pain and alter the ROM ($P\leq.05$) of passive SLR. However, group A showed greater improvement in pain and ROM of passive SLR ($P = .003$ pretest; mean, 67.6; posttest mean, 85) than group B ($P = .07$l; pretest mean, 70.4; posttest mean, 85.68); between-group difference, 14.6% favoring IG in participants with LBP. No SD or other measures available | Appraisal: 6; high |
| Rezk-Allah et al[90] | n = 40. Overall age range, 35-50 y. Mean ± SD age: group A, 43.95 ± 4.84 y; group B, 44.9 ± 4.55 y. No other data available | Group A: n = 20 (slump group). Positive findings on EMG, prolonged latency of H-reflex >30 ms<br>Slump to full range: held for 60 s × 5<br>3 treatments per week for 4 wk<br>Group B: n = 20 (SLR group). Positive findings on EMG, prolonged latency of H-reflex >30 ms<br>SLR to onset of symptoms or resistance: held for 60 s × 5<br>3 treatments per week for 4 wk | ... | Outcomes measured at baseline and end of treatment<br>1 VAS<br>2. H-reflex latency | Significant reduction in pain (group A, $t = 13.85$, $P<.001$; difference, 2.34; 95% CI: 1.54, 3.14; group B, $t = 14.25$, $P <.001$; difference, 2.67; 95% CI: 1.99, 3.35) and H-reflex latency (group A, $t = 2.92$, $P = .006$; difference, 27.77; 95% CI: 26.65, 28.88; group B, 29.67; 95% CI: 28.90, 30.44) in comparison to pretreatment values. No significant difference in pain intensity (VAS) between groups posttreatment. NM significantly improved symptoms and decreased nerve root compression | Appraisal: 6; high |

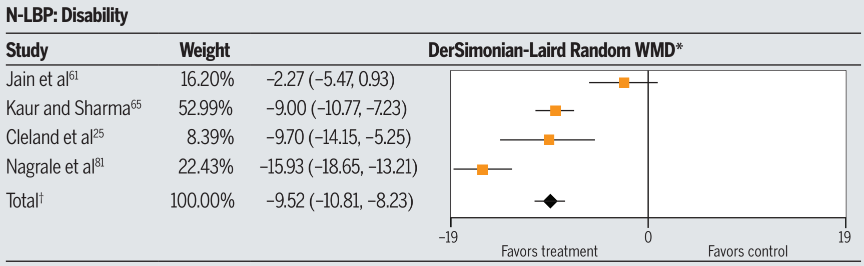
*Abbreviations: BLR, bent-leg raise; CG, control group; CI, confidence interval; EMG, electromyogram; FABQ, Fear-Avoidance Beliefs Questionnaire; IG, intervention group; LBP, low back pain; MODI, Modified Oswestry Disability Index; N-LBP, nerve-related low back pain; NM, neural mobilization; NPRS, numeric pain-rating scale; NRS, numeric rating scale; PA, posterior/anterior; ROM, range of motion; SF-12, Medical Outcomes Study 12-Item Short-Form Health Survey; SLR, straight leg raise; TENS, transcutaneous electrical nerve stimulation; VAS, visual analog scale.*


**N-LBP: Pain**

| Study | Weight | DerSimonian-Laird Random WMD* |
|---|---|---|
| Jain et al[61] | 10.10% | −4.47 (−6.44, −2.50) |
| Dwornik et al[43] | 21.00% | −1.00 (−1.90, −0.10) |
| Kaur and Sharma[65] | 17.03% | −2.00 (−3.21, −0.79) |
| Cleland et al[25] | 25.51% | −1.00 (−1.56, −0.44) |
| Nagrale et al[81] | 26.35% | −1.97 (−2.46, −1.48) |
| Total† | 100.00% | −1.78 (−2.55, −1.01) |

**Values in parentheses are 95% confidence interval.*
*†Heterogeneity: $\chi^2$ = 16.81 (P<.01). Test for overall effect: z = 4.52 (P<.001).*

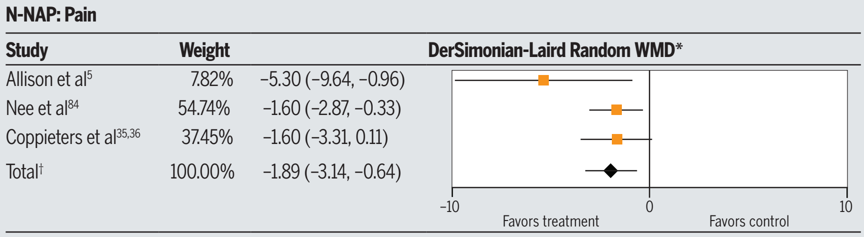
**FIGURE 2.** Meta-analysis for pain (visual analog scale and numeric pain-rating scale) in N-LBP. Abbreviations: N-LBP, nerve-related low back pain; WMD, weighted mean difference.


**N-LBP: Disability**

| Study | Weight | DerSimonian-Laird Random WMD* |
|---|---|---|
| Jain et al[61] | 16.20% | −2.27 (−5.47, 0.93) |
| Kaur and Sharma[65] | 52.99% | −9.00 (−10.77, −7.23) |
| Cleland et al[25] | 8.39% | −9.70 (−14.15, −5.25) |
| Nagrale et al[81] | 22.43% | −15.93 (−18.65, −13.21) |
| Total† | 100.00% | −9.52 (−10.81, −8.23) |

**Values in parentheses are 95% confidence interval.*
*†Heterogeneity: $\chi^2$ = 41.33 (P<.01). Test for overall effect: z = 14.48 (P<.001).*

**FIGURE 3.** Meta-analysis for disability (Modified Oswestry Disability Questionnaire) in N-LBP. Abbreviations: N-LBP, nerve-related low back pain; WMD, weighted mean difference.


**N-NAP: Pain**

| Study | Weight | DerSimonian-Laird Random WMD* |
|---|---|---|
| Allison et al[5] | 7.82% | −5.30 (−9.64, −0.96) |
| Nee et al[84] | 54.74% | −1.60 (−2.87, −0.33) |
| Coppieters et al[35,36] | 37.45% | −1.60 (−3.31, 0.11) |
| Total† | 100.00% | −1.89 (−3.14, −0.64) |

**Values in parentheses are 95% confidence interval.*
*†Heterogeneity: $\chi^2$ = 2.65 (P = .267). Test for overall effect: z = 2.96 (P<.001).*

**FIGURE 4.** Meta-analysis for pain (visual analog scale and numeric pain-rating scale) in N-NAP. Abbreviations: N-NAP, nerve-related neck and arm pain; WMD, weighted mean difference.

cises in 2 studies.[2,65] Neural mobilization techniques that aimed to open the intervertebral foramina[78] also reported improved pain (*P* = .01) in the NM group compared to a group receiving ultrasound, exercises, and lumbar mobilization. Three studies compared 2 types of NM with each other.[75,87,90] All NM groups had an improvement in pain (*P*<.05), but there were no significant between-group differences (*P*>.05).

The meta-analyses revealed that NM (slump and SLR mobilization) had a significant effect on both pain[25,43,61,65,81] (intensity [0-10]: mean difference, –1.78; 95% CI: –2.55, –1.01; *P*<.001) (**FIGURE 2**) and disability[25,61,65,81] (Oswestry Disability Questionnaire [0-50]: mean difference, –9.52; 95% CI: –10.81, –8.23; *P*<.001) (**FIGURE 3**) in participants with N-LBP when compared to exercises or to exercise and lumbar mobilization. Included studies had low, as well as high, risk of bias.

The H-reflex latency was improved in a study comparing slump and SLR mobilization,[90] and a decrease in nerve compression was reported in another study.[75] Four studies measured ROM in N-LBP.[43,65,78,87] They reported improvement in SLR[65,87] and slump[78] following NM, but no change in Lasègue's sign.[43]

## Nerve-Related Neck and Arm Pain

Five of the 10 studies had a low risk of bias (**TABLE 1**).[5,36,68,84,89] Two studies used only 1 intervention.[36,76] The study period and number of treatments varied greatly between studies (**TABLE 3**). Four studies evaluated cervical lateral glide techniques,[5,36,84,89] and all reported a significant improvement in pain for the groups receiving NM. Cervical lateral glide was compared to a wait-list group,[5] ultrasound,[35,36] and advice only,[84] and these studies were included in the meta-analysis (pain intensity: mean difference, –1.89; 95% CI: –3.14, –0.64; *P*<.001) (**FIGURE 4**). The fourth study was not included in the meta-analysis, as it compared cervical lateral glide techniques, sliders, thoracic mobilization, and exercise to strengthening exercises.[89]

Four studies used sliding and tensioning exercises.[55,67,76,82] The use of NM exercises resulted in significant improvements in pain (*P*<.001) compared to interferential therapy, traction, and exercises.[82] Sliding techniques improved pain compared to exercise and ergonomic advice[55] (*P*<.05). When comparing NM for the radial nerve to McKenzie exercises,[67] McKenzie exercises had better outcomes for pain (*P*<.001). The above studies all had a high risk of bias.

The effect of NM on disability could not be explored by meta-analysis, as different outcomes were used. One low-risk-of-bias study[84] reported better outcomes (number needed to treat) for the Neck Disability Index (NDI) and the Patient-Specific Functional Scale following NM compared to advice to stay active. Two other studies reported better outcomes (*P*<.05) on the NDI following

NM compared to joint mobilization and exercise.[7,55] One study did not report the outcomes for the NDI.[82] Another study also measured the NDI[68] but found that the NM group and comparison group improved to the same extent. One low-risk-of-bias study documented that NM resulted in no adverse effects.[84]

Pain was the only outcome measure for which a meta-analysis could be performed. Participants who received cervical lateral glides had a significantly better outcome for pain than the control groups (**FIGURE 4**).

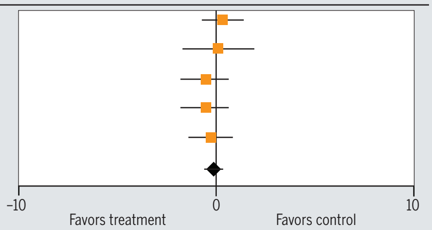
There were 3 studies on N-NAP that assessed ROM.[35,55,89] Two studies reported an improvement in neurodynamic test ROM following NM,[35,55] whereas 1 study found no difference.[89]

## Carpal Tunnel Syndrome

Five studies had a low risk of bias.[15,60,86,88,101] Four studies had an unclear risk of bias,[13,19,111,119] and the other 3 had a high risk of bias[3,11,59] (**TABLE 4**). Seven studies[3,11,13,19,59,60,88] used the original NM exercises as outlined by Totten and Hunter.[113]

**CTS: Pain**

| Study | Weight | DerSimonian-Laird Random WMD* |
|---|---|---|
| Bialosky et al[15] | 26.53% | 0.30 (–0.71, 1.31) |
| Baysal et al[13] | 8.65% | 0.10 (–1.67, 1.87) |
| Pinar et al[88] | 20.94% | –0.60 (–1.74, 0.54) |
| Tal-Akabi and Rushton[111] | 20.29% | –0.57 (–1.73, 0.59) |
| Schmid et al[101] | 23.60% | –0.30 (–1.37, 0.77) |
| Total† | 100.00% | –0.22 (–0.74, 0.30) |

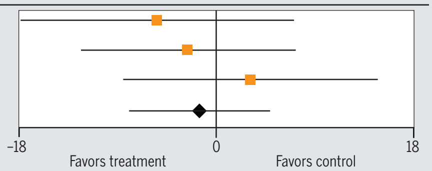


*Values in parentheses are 95% confidence interval.
†Heterogeneity: $\chi^2 = 1.94$ ($P = .747$). Test for overall effect: $z = 0.84$ ($P = .401$).

**FIGURE 5.** Meta-analysis for pain (visual analog scale) in CTS. Abbreviations: CTS, carpal tunnel syndrome; WMD, weighted mean difference.

**CTS: Disability**

| Study | Weight | DerSimonian-Laird Random WMD* |
|---|---|---|
| Bialosky et al[15] | 26.61% | –5.30 (–17.49, 6.89) |
| Horng et al[60] | 43.10% | –2.50 (–12.08, 7.08) |
| Heebner and Roddey[59] | 30.29% | 3.11 (–8.32, 14.54) |
| Total† | 100.00% | –1.55 (–7.84, 4.75) |



*Values in parentheses are 95% confidence interval.
†Heterogeneity: $\chi^2 = 1.04$ ($P = .598$). Test for overall effect: $z = 0.48$ ($P = .631$).

**FIGURE 6.** Meta-analysis for disability (Disabilities of the Arm, Shoulder and Hand questionnaire) in CTS. Abbreviations: CTS, carpal tunnel syndrome; WMD, weighted mean difference.

**TABLE 3** Descriptions of Studies on N-NAP

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Allison et al[5] | n = 30 (20 female, 10 male). Age range, 18-75 y. Median duration of symptoms: IG, 12 mo (n = 10); CG, 12 mo (n = 10); articular treatment, 72 mo (n = 10) | n = 17 participants with cervicobrachial pain<br>Cervical lateral glide, shoulder girdle oscillation, muscle re-education, home mobilization<br>Duration of treatment, 8 wk | n = 10 participants with cervicobrachial pain. Received no intervention for the initial 8 wk (at the end of the study, they were given neural treatment as a crossover protocol)<br>Articular treatment, n = 9 patients with cervicobrachial pain. Glenohumeral joint mobilization, thoracic mobilization, and home exercise<br>Duration of treatment, 8 wk | Outcomes measured at baseline, 4 wk into treatment, and posttreatment<br>1. McGill Pain Questionnaire<br>2. NPQ<br>3. Pain (VAS) | Both manual therapies combined with home exercises are effective in improving pain intensity, pain quality scores, and functional disability levels. A group difference was observed for the VAS scores at 8 wk, with the NM resulting in a significantly lower score ($P<.001$; relative change, 66%) | Appraisal: 7; low |
| Anwar et al[7] | n = 40. Age and duration of symptoms not available | n = 20 participants with cervical radiculopathy<br>Moist heat<br>Mobilization and isometric exercises<br>NM (technique not mentioned)<br>Treated over a period of 6 mo | n = 20 participants with cervical radiculopathy<br>Moist heat<br>Mobilization and isometric exercises<br>Treated over a period of 6 mo | Outcomes measured at baseline and end of treatment<br>1. VAS<br>2. NDI | Addition of neurodynamics to a multimodal program resulted in a significant improvement in disability ($P<.05$; 1.53 ± 0.52)<br>No other values available | Appraisal: 5; high |

*Table continues on page 602*

**TABLE 3** Descriptions of Studies on N-NAP (continued)

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Coppieters et al[35,36] | n = 20 (16 female, 4 male). Overall age range, 35-65 y. Mean ± SD age: IG, 49.1 ± 14.1 y; CG, 46.6 ± 12.1 y. Mean duration of symptoms: IG, 2.7 mo; CG, 3.2 mo | n = 10 participants with brachial or cervicobrachial neurogenic pain<br>Received NM treatment (contralateral glide of cervical segment)<br>One intervention and immediate follow-up | n = 10 participants with brachial or cervicobrachial neurogenic pain<br>Received ultrasound dose of 0.5 W/cm$^2$, 5-min sonation time, 20% size of head: 5 cm$^2$, frequency of 1 MHz<br>One intervention and immediate follow-up | Outcomes measured at baseline and end of treatment<br>1. Elbow E ROM during NTPT-1<br>2. Pain (NPRS) in neck and arm<br>3. Symptom distribution | Significant differences in treatment effects between 2 groups could be observed for all outcome measures ($P\leq.306$). For the mobilization group, the increase in elbow E from 137.3° to 156.7°, the 43% decrease in area of symptom distribution, and decrease in pain from 7.3 to 5.8 were significant ($P\leq.001$). For the ultrasound group, there were no significant differences | Appraisal: 8; low |
| Gupta and Sharma[55] | n = 34 (initially 37) (16 female, 18 male). Median age, 29.5 y (range, 18-40 y). No other data available | n = 16 participants with cervicobrachial pain (n = 2 discontinued)<br>Median slider applied 3 × 10 repetitions<br>5 treatments over 7 d | n = 18 participants with cervicobrachial pain (n = 1 discontinued)<br>Exercise (isometric), posture, advice to move regularly<br>Frequency not clear | Outcomes measured at baseline and end of 7 d<br>1. NDI<br>2. CBSQ<br>3. VAS<br>4. Pain-free elbow E | Both groups showed statistically significant improvement in pain intensity (0.95; Z = 4.94), elbow E ROM (12.50°; Z = 5.02), and NDI and CBSQ (both decreased by 5 in IG, compared to CG decrease of 2 for the NDI and 1 for the CBSQ) scores after completion of treatment ($P<.05$). The IG receiving NM showed better improvement compared to the conventional group | Appraisal: 5; high |
| Kumar[67] | n = 30 (20 female, 10 male). Age range, 25-68 y. No other data available | Group B: n = 10 participants with cervical radiculopathy<br>Active or passive through range and end-range oscillation in ULNDT-2a position, moving distal component<br>Shortwave<br>Traction<br>10 treatments over 10 d | Group A: n = 10 participants with cervical radiculopathy<br>McKenzie exercises<br>Shortwave<br>Traction<br>Group C: n = 10 participants with cervical radiculopathy<br>Shortwave<br>Traction<br>10 treatments over 10 d | Outcomes measured at days 1, 5, and 10<br>1. VAS<br>2. Pain recovery percentage<br>3. ROM | Pain reduction in first 5 d was greatest in patients treated with McKenzie method, and best symptom relief achieved (group A: $t$ = 10.24, $P<.001$; group B: $t$ = 5.106, $P$ = .001; group C: $t$ = 14.596, $P<.001$). Conventional method gave more relief between fifth and 10th day of treatment; ROM recovery was even in all groups. NM shows poor improvement, possibly because of provocation to the nerve roots | Appraisal: 5; high |
| Langevin et al[68] | n = 36 (12 male, 24 female). Mean age: IG, 42.8 ± 10.4 y; CG, 47.8 ± 11.3 y. Symptom duration: IG, 5.4 ± 3.2 wk; CG, 5.7 ± 3.7 wk | n = 18 participants with cervical radiculopathy<br>Stabilization and mobility exercises<br>Cervical mobilization techniques aimed at opening the intervertebral foramina (eg, lateral glide and F rotation away from pain)<br>Treatment period of 4 wk | n = 18 participants with cervical radiculopathy<br>Cervical and thoracic mobilizations, as well as stabilization and mobility exercises<br>Treatment period of 4 wk | Outcomes measured at baseline and at 4 wk and 8 wk posttreatment<br>1. NDI<br>2. QuickDASH<br>3. NPRS<br>4. Cervicothoracic mobility | Both groups showed statistically and clinically significant improvement from baseline to week 4 and to week 8 on the NDI ($F_{2,68}$ = 0.84, $P$ = .44), QuickDASH ($F_{2,62}$ = 0.36, $P$ = .70), and NPRS ($F_{2,68}$ = 1.87, $P$ = .16) scores ($P<.05$)<br>Manual therapy and exercises are effective in reducing pain and functional limitations related to cervical radiculopathy. NM yielded no significant ($P\geq.14$) additional benefits | Appraisal: 9; low |

*Table continues on page 603*

**TABLE 3** Descriptions of Studies on N-NAP (continued)

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Marks et al[76] | n = 20 (4 male, 16 female). Mean ± SD age: CG, 53.7 ± 9 y; IG, 52.6 ± 12.5 y. Symptom duration: CG, 215 ± 214.2 wk; IG, 323 ± 404.1 wk | n = 10 participants with cervicobrachial pain<br>Nerve tensioner depending on most painful test<br>Once for 15 min | n = 10 participants with cervicobrachial pain<br>Cervical spine mobilization and first rib<br>Once for 15 min | Outcomes measured at baseline, posttreatment, and 1-wk follow-up<br>1. VAS for neck and arm<br>2. Active ROM F/E/LF/rotation<br>3. ULNDT | Significant decrease observed in neck pain in both groups posttest (CG, 1.18; IG, 1.2). Significant improvement in CG for cervical E (CG, 5.2° ± 7.2°; IG, 1.2° ± 7.7°) and LF toward painful side. Significant improvement in range favoring the CG (*P* = .015) | Appraisal: 6; high |
| Nar[82] | n = 30 (9 male, 21 female). Mean ± SD age: IG, 43.93 ± 7.05 y; CG, 45.06 ± 7.46 y. Sex: IG, 11 female and 4 male; CG, 10 female and 5 male | n = 15 participants with cervical radiculopathy<br>Interferential therapy<br>Traction<br>Exercise<br>Advice<br>NM using ULNDT-1<br>10 treatments, 6 d/wk | n = 15 participants with cervical radiculopathy<br>Interferential therapy<br>Traction<br>Exercise<br>Advice<br>10 treatments, 6 d/wk | Measured pretreatment and posttreatment<br>1. VAS<br>2. NDI | NM along with conventional treatment is more effective than conventional treatment alone. VAS IG, 2.06 ± 1.33; CG, 3.53 ± 1.12; *P* = .01 | Appraisal: 6; high |
| Nee et al[84] | n = 60 (38 female, 22 male). Overall mean ± SD age, 47 ± 9 y. Mean age IG, 47 ± 8 y; CG, 48 ± 9 y. Mean ± SD duration of symptoms, 26 ± 12 wk. IG, n = 32; CG, n = 18. Sex: IG, 14 male and 26 female; CG, 8 male and 12 female | n = 40 participants with N-NAP<br>Advice to stay active<br>Brief education<br>Cervical lateral glide<br>Nerve gliding exercises<br>4 treatments over 2 wk | n = 20 participants with N-NAP<br>Advice to stay active | Outcomes measured at baseline and 3 to 4 wk after treatment<br>1. Global rating of change<br>2. Neck pain (NPRS)<br>3. Arm pain (NPRS)<br>4. PSFS<br>5. NDI | Numbers needed to treat favored the IG for the NDI (IG, 8.9 ± 5.4; CG, 11.2 ± 5), neck pain (IG, 2.6 ± 2.4; CG, 4.2 ± 2.2), arm pain (IG, 2.4 ± 2.1; CG, 4 ± 1.9), and PSFS (IG, 2.0 ± 2.1; CG, 0.4 ± 1). NM provides clinically relevant improvement with no evidence of harm. Risk difference for global rating of change between groups, –38 (95% CI: –16, 60), favoring the IG | Appraisal: 7; low |
| Ragonese[89] | n = 30. No other demographic data available | Group 1: n = 10 with cervical radiculopathy<br>Cervical lateral glide (grade 3-4)<br>ULNDT sliders, progressing to tensioners<br>Thoracic mobilization<br>3 times per week for 3 wk<br>Group 2: n = 10 with cervical radiculopathy<br>Treatments as above plus strengthening of deep neck flexors, lower and middle trapezius, and serratus anterior<br>3 times per week for 3 wk | n = 10 with cervical radiculopathy<br>Strengthening of deep neck flexors, lower and middle trapezius, and serratus anterior | Outcomes measured at baseline and end of week 1, week 2, week 3, and end of treatment<br>1. NPRS<br>2. NDI<br>3. Neck rotation ROM | All groups improved significantly in terms of pain (IG 1, 2.4 ± 1.1; IG 2, 0.9 ± 1.2; CG, 1.6 ± 1.5; *P*<.01), disability (IG 1, 17.2 ± 10.3; IG 2, 7.8 ± 5.5; CG, 10.2 ± 7.1), and ROM (IG 1, 74.3° ± 3.58°; IG 2, 71.4° ± 3.67°; CG, 74.4° ± 4.12°; *P*<.05). For pain and disability, the group receiving NM and exercise did significantly better than the other 2 groups | Appraisal: 7; unclear |

*Abbreviations: CBSQ, Cervicobrachial Symptom Questionnaire; CG, control group; CI, confidence interval; E, extension; F, flexion; IG, intervention group; LF, lateral flexion; NDI, Neck Disability Index; NM, neural mobilization; N-NAP, nerve-related neck and arm pain; NPQ, Northwick Park Neck Pain Questionnaire; NPRS, numeric pain-rating scale; NTPT, neural tissue provocation test; PSFS, Patient-Specific Functional Scale; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire; ROM, range of motion; ULNDT, upper-limb neurodynamic test; VAS, visual analog scale.*

**TABLE 4** DESCRIPTIONS OF STUDIES ON CTS

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Akalin et al[3] | n = 36 (2 male, 34 female). Overall mean ± SD age, 51.93 ± 5.1 y (range, 38-64 y); CG age, 52.16 ± 5.6 y; IG age, 51.7 ± 5.5 y. Duration of symptoms: CG, 47.6 ± 6.8 mo; IG, 49.6 ± 5.2 mo | n = 18 participants with CTS<br>Same as control plus tendon glides in 5 positions and median nerve exercises in 6 positions (each position was maintained for 5 s; 10 repetitions of each exercise were done 5 times a day)<br>Continued for 4 wk | n = 18 participants with CTS<br>Custom-made neutral volar wrist splint was instructed to be worn all night and during the day as much as possible for 4 wk | Outcomes measured at baseline and 8 wk posttreatment<br>1. Phalen's sign<br>2. Tinel's sign<br>3. 2-point discrimination<br>4. Grip strength<br>5. Pinch strength<br>6. Symptom severity score<br>7. Functional Status Score<br>A patient satisfaction investigation was undertaken by telephone 8.3 ± 2.5 mo posttreatment | At the end of treatment, a significant improvement was obtained in all parameters in both groups. The nerve and tendon glide group had slightly greater scores, but the difference between groups was not significant except for lateral pinch strength (*P* = .026; CG, 30.0 ± 9.3 and IG, 35.27 ± 9.7)<br>A total of 72% of the CG and 93% of the IG reported good or excellent results in the patient satisfaction investigation, but the difference between the groups was not significant | Appraisal: 5; high |
| Bardak et al[11] | n = 111 (3 male, 108 female). Mean ± SD age: group 1, 33 ± 9.6 y; group 2, 26 ± 10.3 y; group 3, 22 ± 9.9 y | Group 1: n = 40 participants with CTS<br>Splint for 3 wk worn day and night and 3 wk for night only<br>Cortisone injection<br>Nerve and tendon gliding exercises (Totten and Hunter[113]) followed once a week for 3 wk<br>Group 3: n = 36 who had only nerve and tendon gliding exercises | Group 2: n = 35 participants with CTS<br>Splint as for IG<br>Cortisone injection (group 3 not included in analyses) | Outcomes measured at baseline and end of treatment<br>1. Phalen's test<br>2. Tinel's test<br>3. Reverse Phalen's test<br>4. Compression test<br>5. 2-point discrimination<br>6. Total symptom scale<br>7. Functional symptom scale | All groups improved significantly in terms of pain and functionality. Groups 1 and 2 were better (*P*<.001) than group 3 (receiving only nerve and tendon gliding exercises; *P* = .02)<br>Three interventions and patient satisfaction were done via telephone at 11 mo<br>Within-group differences reported as percentages and means and SDs, but no between-group difference values available | Appraisal: 7; high |
| Baysal et al[13] | n = 36 (female patients with clinical and electrophysiological evidence of CTS, all with bilateral involvement). Mean ± SD age: group 1, 47.8 ± 5.5 y; group 2, 50.1 ± 7.3 y; group 3, 51.4 ± 5.2 y. Mean ± SD duration of symptoms: group 1, 1.5 ± 1.6 y; group 2, 1.4 ± 0.8 y; group 3, 1.4 ± 0.8 y | Group 1: n = 12 participants with CTS<br>Custom-made neutral volar splint (worn for 3 wk); exercise therapy (nerve and tendon gliding exercises as described by Totten and Hunter[113]): 5 sessions daily, each exercise repeated 10 times per session for 3 wk<br>Group 3: n = 12 (dropouts, n = 4). Custom-made neutral volar splint (worn for 3 wk); exercise therapy (nerve and tendon gliding exercises as described by Totten and Hunter[113]): 5 sessions daily, each exercise repeated 10 times per session and continued for 3 wk; ultrasound (as for CG) | Group 2: n = 12 participants with CTS (dropouts, n = 4). Custom-made neutral volar splint (worn for 3 wk); ultrasound (15 min per session to palmar carpal tunnel, 1 MHz, 1.0 W/cm$^2$, 1:4, 5-cm$^2$ transducer) once per day, every 5 d, for 3 wk (total, 15 treatments) | Outcomes measured at baseline, end of treatment, and 8-wk follow-up<br>1. VAS<br>2. Tinel's sign<br>3. Phalen's sign<br>4. Mean static 2-point discrimination (pulp of radial 3 digits)<br>5. Hand grip strength (handheld dynamometer)<br>6. Pinch strength (between thumb and little finger, with dynamometer)<br>7. Symptom-severity scale questionnaire (11 items)<br>8. Functional status scale questionnaire (8 items)<br>9. Median motor nerve conduction (motor distal latency EMG of abductor pollicis)<br>10. Sensory distal latency (EMG of abductor pollicis)<br>11. Needle EMG of abductor pollicis brevis<br>12. Patient satisfaction survey (at 8-wk follow-up only) | No significant differences between groups at the end of treatment and 8-wk follow-up for all measures of treatment effect (measures 1, 5, 6, 7, 8, 9, 10)<br>Significant improvement seen in all 3 groups in Tinel's and Phalen's signs at end of treatment and 8-wk follow-up (*P*<.05)<br>Significant improvement seen in all 3 groups in grip strength (group 1, 1.9 ± 2.7; group 2, 1.6 ± 2.5; group 3, 1.0 ± 1.7) and pinch strength (group 1, 0.8 ± 0.9; group 2, 0.6 ± 1.4; group 3, 0.9 ± 0.7) at 8-wk follow-up (*P*<.05)<br>No changes seen in 2-point discrimination<br>Significant improvement in pain (group 1, 2.2 ± 3.4; group 2, 2.5 ± 2.5; group 3, 4.5 ± 3.0), symptom (group 1, 6.3 ± 7.1; group 2, 5.8 ± 7.2; group 3, 8.2 ± 5.2), and functional scales (group 1, 7.8 ± 10.7; group 2, 10.5 ± 6.8; group 3, 14.4 ± 9.4) in all 3 groups at end of treatment and 8-wk follow-up<br>Group 3 had the best results at 8-wk follow-up patient satisfaction questionnaire (group 2: excellent, 3 [25.0%]; group 3: excellent, 8 [66.7%])<br>Dropouts, 8 out of 36; influenced results | Appraisal: 7; unclear |

*Table continues on page 605*

## TABLE 4 Descriptions of Studies on CTS (continued)

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Bialosky et al[15] | n = 40 CTS (females only). Mean ± SD age, IG, 44.3 ± 6.97 y; CG, 49.5 ± 12.35 y. Mean duration of symptoms, 156 wk | n = 19 participants with CTS (n = 1 lost to follow-up). Nerve gliding exercises and splint. Received treatment for 3 wk<br>Cycle 6 s, 5 sets of 10 cycles for first 3 treatments and 7 sets of 10 in treatments 4 through 6 | n = 20 participants with CTS. Sham technique to minimize strain on nerve and splint. Received treatment for 3 wk | Outcomes measured at baseline and end of treatment<br>1. NRS<br>2. DASH<br>3. Grip strength<br>4. Pressure pain sensitivity<br>5. Temporal summation | Significant improvement in both groups immediately postintervention and at 3 wk, but no intergroup differences. Mean ± SD decrease of self-report of temporal summation pain, −8.8 ± 14.7 (*P* = .02; Cohen's *d* = 0.35) in IG, a positive neurophysiological effect. Mean ± SD increase of temporal summation pain, 4.2 ± 16.0 (*P* = .26; Cohen's *d* = 0.13) in participants receiving the sham | Appraisal: 9; low |
| Brininger et al[19] | n = 61 (14 male, 47 female). Mean age, 50 y (range, 21-86 y). No other data available | Group 1: n = 16 participants with CTS (completed, n = 13)<br>Neutral splint plus nerve gliding exercises, according to Totten and Hunter,[113] 3-5 times per day, 10 repetitions<br>Group 3: n = 16 (completed, n = 13)<br>Cock-up splint and nerve gliding exercises as above | Group 2: n = 17 participants with CTS (completed, n = 14)<br>Neutral splint<br>Group 4: n = 12 (completed, n = 11)<br>Cock-up splint<br>All groups: exercise sheet and exercises shown once | Outcomes measured at baseline, 4 wk in clinic, and 8 wk by mail<br>1. Symptom-specific scale<br>2. Functional Status Score<br>3. Grip strength<br>4. Pinch strength | All groups improved over time, irrespective of exercise or no exercise: the groups with neutral splints had better outcomes<br>Symptom-specific scale: *P* = .014, $F_{1,14}$ = 6.45; Functional Status Score: *P* = .029, $F_{1,14}$ = 5.10 (mean, 2.045)<br>Dropouts, 10 of 61 patients; influenced results | Appraisal: 7; unclear |
| Heebner and Roddey[59] | n = 60 (9 male, 51 female). Mean age, 52 y (range, 32-72 y). No other data available | n = 30 participants with CTS randomized, 25 completed<br>Standard care<br>Nerve gliding exercises according to Sweeney and Harms (based on Totten and Hunter[113]): tensioner 3 to 5 times per day, 10 repetitions | n = 30 participants with CTS randomized, 20 completed<br>Standard care consisting of advice, splint, tendon gliding exercises | Outcomes measured at baseline, 1 mo, and 6 mo<br>1. DASH<br>2. Carpal Tunnel Symptom Questionnaire<br>3. Elbow extension range of ULNDT | Nerve gliding exercise did not improve outcomes: improvement similar in both groups (*P* values ranged from .308 to .966)<br>Group 1 (control) had better outcomes on functional status scale and Carpal Tunnel Symptom Questionnaire (CG mean, 2.2; IG mean, 2.9). There were no significant between-group differences in ULNDT (*P* = .366; values not available) | Appraisal: 6; high |
| Horng et al[60] | n = 60. Mean ± SD age: group 1, 48.9 ± 8.9 y; group 2, 51.9 ± 9.3 y; group 3, 53.6 ± 9.1 y. Sex (male/female): 3/57 | Group 2: n = 20 participants with CTS randomized, n = 19 participants completed<br>Splint<br>Paraffin<br>Nerve gliding exercise (Totten and Hunter[113])<br>Received sheet with exercises to do 3 times daily. Follow-up at 2 mo | Group 1: n = 20 participants with CTS randomized, n = 18 participants completed<br>Splint<br>Paraffin<br>Tendon gliding exercise<br>Group 3: n = 20 participants randomized, n = 16 participants completed<br>Splint<br>Paraffin | Outcomes measured at baseline and after 2 mo<br>1. DASH<br>2. WHO Quality of Life Questionnaire<br>3. Functional Status Score<br>4. Phalen's sign<br>5. Tinel's sign<br>6. BCTQ<br>7. Sensory testing using monofilament<br>8. VAS | Only the CG (group 1) showed significant improvements in their scores on functional status, the DASH questionnaire, and the physical domain of the WHO Quality of Life Questionnaire<br>Post hoc analyses detected a significant difference (*P* = .04; group 1, −0.4 ± 0.5; group 2, 0.1 ± 0.5; group 3, 0.2 ± 0.7) in functional status scores between groups 1 and 2, favoring the CG<br>One intervention: exercise sheet given to patients<br>Dropouts, 7 out of 60 patients; influenced results | Appraisal: 7; low |

*Table continues on page 606*

**TABLE 4** Descriptions of Studies on CTS (continued)

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Oskouei et al[86] | n = 20 patients, 32 hands. Mean ± SD age, 46.7 ± 11 y. Duration of symptoms, 19.6 ± 15.9 mo | n = 16 hands<br>Splint as much as possible for 4 wk<br>TENS<br>Ultrasound<br>NM starting in nerve off tension, progressing into tension using elbow F/E<br>3 treatments per week (15 repetitions) for 4 wk | n = 16 hands<br>Splint as much as possible for 4 wk<br>TENS<br>Ultrasound<br>3 treatments per week for 4 wk | Outcomes measured at baseline and end of treatment<br>1. BCTQ<br>2. Phalen's test<br>3. VAS<br>4. ULNDT | Routine physical therapy, including rest splint, TENS, and therapeutic ultrasound, seems to improve the symptom-severity scale (IG, 1.53 ± 0.53; CG, 1.7 ± 0.72), VAS (IG, 2.68 ± 1.62; CG, 3.31 ± 3.05), median nerve tension test (IG, 9.04 ± 9.6; CG, 18.41 ± 11.6), and Phalen's sign (IG, 19%; CG, 31%) in patients with CTS ($P<.05$)<br>The NM in combination with routine physical therapy improved the functional status scale and the median nerve distal motor latency. This combination can be used as an effective noninvasive treatment for patients with CTS | Appraisal: 9; low |
| Pinar et al[88] | n = 26 (female). Age range, 35-55 y. Mean ± SD duration of symptoms: CG, 47.6 ± 6.8 mo; IG, 49.6 ± 5.2 mo | n = 14 participants (19 hands)<br>Patients diagnosed with early to middle stages of CTS<br>Splint and patient training program: nerve gliding exercises (Totten and Hunter[113]), 10 repetitions for 5 sets a day for 10 wk, combined with a patient training program as for the CG | n = 12 participants (16 hands)<br>Patients diagnosed with early to middle stages of CTS<br>Treated in volar splint in neutral, worn day and night for 6 wk, then night only from weeks 6 to 10, and a patient training program for the modification of functional activities (avoid repetitive activities, etc) | Outcomes measured at baseline and after a 10-wk treatment program<br>1. Tinel test<br>2. Phalen test<br>3. Pain (VAS) over 1 d<br>4. Motor function: manual testing of grip and pinch strength with handheld dynamometer<br>5. Grip strength (Jamar hand dynamometer)<br>6. Sensory evaluation (Semmes-Weinstein monofilament and 2-point discrimination test)<br>7. Electrophysiological test: median and ulnar nerve distal latencies | Pretreatment and posttreatment intragroup analyses of both groups revealed that there were no statistically significant differences between the 2 groups in average muscle strength, functional sensitivity, normal sensory test, or manual muscle tests<br>Significant progress was detected in both control and experimental groups during the posttreatment phase compared with the initial phase ($P<.05$). When the 2 groups were compared, the experimental group, in which nerve gliding exercises were added, demonstrated more rapid pain reduction (IG, 1 ± 1.6; CG, 1.6 ± 1.8) and greater functional improvement, especially in grip strength (IG, 22.0 ± 6.8; CG, 21.7 ± 4.3) ($P<.05$) | Appraisal: 8; low |
| Tal-Akabi and Rushton[111] | n = 21. Mean ± SD age of IG and CG, 47.1 ± 14.8 y (range, 29-85 y). Mean ± SD duration of symptoms, 2.3 ± 2.5 y (range, 1-3 y). All subjects were on the waiting list for surgery | Group 1: n = 7 participants with CTS who received ULTT-2a mobilization based on physical therapist clinical reasoning<br>Number of treatments or treatment time not mentioned | Group 3: n = 7 participants with CTS who received no intervention<br>Group 2: n = 7 with CTS who received carpal bone mobilization (anterior to posterior and/or posterior to anterior) and a flexor retinaculum stretch<br>Treatment time not mentioned | Outcomes measured at baseline and end of treatment<br>1. Symptoms diary (24-h VAS)<br>2. Functional box scale<br>3. ROM wrist F/E<br>4. ULTT-2a<br>5. Pain-relief scale<br>6. Continuing to have surgery | Only the pain-relief scale demonstrated a statistically significant difference between the 3 groups ($P<.01$). VAS: group 1 mean, 1.57; group 2 mean, 0.71; group 3 mean, 0.71. Groups 1 and 2 were both significantly better than group 3<br>No statistically significant difference in effectiveness of treatment was demonstrated between the 2 IGs. The number of patients continuing to surgery was 2 in NM, 1 in carpal bone mobilization, and 6 in the CG<br>ULTT: group 1, 5 of 7 negative; group 2, 4 of 7 negative; group 3, all still positive | Appraisal: 8; unclear |

*Table continues on page 607*

**TABLE 4** DESCRIPTIONS OF STUDIES ON CTS (CONTINUED)

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Schmid et al[101] | n = 21 (12 male, 8 female). Mean ± SD age: IG, 49.9 ± 12.5 y; CG, 57.9 ± 16.3 y. Sex (male/female): IG, 5/5; CG, 7/3. Mean ± SD symptom duration: IG, 54.6 ± 47.6 mo; CG, 62.8 ± 56.1 mo. CTS severity: mild, 4 in IG and 3 in CG; moderate, 6 in IG and 7 in CG | n = 11 participants with CTS randomized (1 dropout)<br>Received neural gliding aimed at improving nerve excursion; exercises: 10 repetitions, 10 times per day for 1 wk | n = 10 participants with CTS randomized<br>Received night splint for 1 wk | Outcomes measured before, 10 min after, and 1 wk after intervention<br>1. Signal intensity at pisiform, radioulnar, and hamate<br>2. Ligament bowing at hamate<br>3. BCTQ<br>4. Pain (VAS)<br>5. Numbness (VAS)<br>6. Patient-Specific Functional Scale | The findings of this study suggest that a reduction in intraneural edema is a therapeutic mechanism of both nerve and tendon gliding exercises and splinting<br>The chronicity of the symptoms of the patients involved in this study and the short treatment period suggest that the reduction in intraneural edema is associated with the interventions rather than the result of the natural course of CTS<br>Signal intensity did not change in patients who were not treated<br>BCTQ: $F_{1,17} = 16.70$, $P = .001$; Patient-Specific Functional Scale: $F_{1,16} = 22.10$, $P<.001$<br>Post hoc comparisons revealed that both groups improved significantly after 1-wk intervention (all, $P<.004$). No significant interaction or main effects for pain intensity and numbness were found (all, $P>.16$) | Appraisal: 7; low |
| Wolny et al[119] | n = 160 initially analyzed (18 male, 122 female). Mean age: IG, 53.12 y; CG, 51.51 y. Sex (male/female): IG, 8/62; CG, 10/60 | n = 80 with CTS (not analyzed, n = 10)<br>Manual therapy and ULNDT-1 sliders and tensioners<br>2 treatments per week for 10 wk | n = 80 with CTS (not analyzed, n = 10)<br>Ultrasound and laser therapy<br>2 treatments per week for 10 wk | Outcomes measured before and at the end of treatment<br>1. 2-point discrimination | The outcomes of treatment on 2-point discrimination demonstrated that both methods had a significant therapeutic effect (IG, 2.6; 2.25-2.95 and CG, 0.5; 0.16-0.84; $P<.001$). It should be noted, however, that the groups differed significantly before starting the treatment cycle. Larger disturbances of 2-point discrimination sensation in symptomatic extremities occurred in the IG as compared with the CG. After a course of therapy, there were no statistically significant ($P>.05$) intergroup differences | Appraisal: 7; unclear |

*Abbreviations: BCTQ, Boston Carpal Tunnel Questionnaire; CG, control group; CTS, carpal tunnel syndrome; DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; EMG, electromyogram; F/E, flexion/extension; IG, intervention group; NM, neural mobilization; NRS, numeric rating scale; ROM, range of motion; TENS, transcutaneous electrical nerve stimulation; ULNDT, upper-limb neurodynamic test; ULTT, upper-limb tension test; VAS, visual analog scale; WHO, World Health Organization.*

The other studies[15,86,101,111,119] used a variety of different techniques. Treatment in comparison groups included in the meta-analyses consisted of splint only[3,19,88,101]; splint and ultrasound therapy[13]; splint and cortisone injections[11]; splint and sham NM[15]; splint, advice, and tendon gliding exercises[59]; splint and paraffin therapy[60]; and splint, ultrasound, and transcutaneous electrical nerve stimulation.[86] The majority of studies evaluated the effect of 1 treatment session in which exercises were shown to patients, who were then instructed to continue for a period of 1[101] to 10[88] weeks (see **TABLE 4** for information on interventions).

The clinical outcome measures assessed with meta-analyses were nonsignificant ($P>.11$) (**APPENDIX F**, available at www.jospt.org). **FIGURES 5** and **6** illustrate the meta-analyses for pain and disability. Meta-analysis included studies with a high and low risk of bias. There were several studies that reported on Tinel's sign and the Functional Status Score, but the heterogeneity was substantial ($P<.1$), and therefore a meta-analysis was not performed on these outcomes.[63]

In CTS, positive neurophysiological effects, such as decreased intraneural edema, decreased temporal summation, and median nerve latency, were observed in the groups that received NM.[15,86,101]

**TABLE 5** Descriptions of Studies on Lateral Epicondylalgia

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Dabholkar et al[37] | n = 40. No other data available | n = 20 participants with lateral epicondylalgia<br>Exercise program<br>Radial-head mobilization<br>NM aimed at radial nerve into tension without provoking symptoms<br>Treatment: 6 to 7 repetitions once a day, 4 times per week, for 4 wk | n = 20 participants with lateral epicondylalgia<br>Exercise program<br>Treatment: 6 to 7 repetitions once a day, 4 times per week, for 4 wk | Outcomes measured at baseline and posttreatment<br>1. VAS<br>2. Pain-free grip<br>3. Strength<br>4. Pressure pain threshold<br>5. PRTEE | Both groups improved significantly in all outcomes, but the Mulligan mobilization with movement of the radial head and NM showed more improvement than the exercise group in grip strength ($P<.001$; 30.16 ± 7.33), pressure pain threshold ($P = .031$; 4.7 ± 1.8), and PRTEE ($P = .027$; 22.75 ± 5.35) | Appraisal: 3; high |
| Drechsler et al[42] | n = 18 (10 female, 8 male). Age range, 30-57 y; overall mean age, 46 y; IG mean age, 46.4 y; CG mean age, 45.5 y | n = 8 participants with lateral epicondylalgia<br>Neural tension group: ULTT-2b with (1) graded flexion and/or shoulder abduction and (2) anterior/posterior mobilizations of radial head if radial head mobility was judged to be hypomobile<br>Home exercise plan to mimic ULTT-2b for 10 repetitions a day, increasing to but not exceeding 2 sets a day, 2 times per week for 6 to 8 wk | n = 10 participants with lateral epicondylalgia<br>Standard treatment group. Two times a week for 6-8 wk:<br>1. Ultrasound over common extensor tendon<br>2. Transverse friction to tendon (1 min per session)<br>3. Stretch and strengthen wrist extensors for 5-10 repetitions × 30 s. Dumbbells gradually increasing to 3 sets of 15 repetitions<br>4. Home exercise program to stretch and strengthen | Outcomes measured at baseline, posttreatment, and 3-mo follow-up<br>1. Self-report questionnaire<br>2. Grip strength<br>3. Isometric testing of extension of third finger<br>4. ULNDT-2b<br>5. Radial-head mobility<br>6. Elbow extension ROM during ULNDT | Subjects who received radial-head mobilizations improved over time ($P<.05$; 4.71)<br>Results from IG were linked to radial-head treatment, and isolated effects could not be determined. There were no long-term positive results in the CG | Appraisal: 5; high |
| Vicenzino et al[115] | n = 15 with lateral epicondylalgia (8 female, 7 male). Mean ± SD age, 44 ± 2 y (range, 22.5-66 y). Duration of symptoms, 8 ± 2 mo (range, 2-36 mo) | Contralateral grade 3 glide at C5-6, with affected arm in a predetermined position<br>All treatments were applied in 3 sets of 30 s, with 60-s rest periods<br>Subjects received 1 of the 3 treatment conditions for 3 d in a random order | Arm rested on abdomen with no manual contact. Placebo group: manual contact was applied as in the treatment group, with the patient's arm rested on abdomen, but no glide was applied | Outcomes measured at baseline (immediately before) and after treatment<br>1. ULNDT-2b (measuring degrees of abduction)<br>2. Pain-free grip strength (handheld dynamometer)<br>3. Pressure pain threshold<br>4. Pain VAS (over 24 h)<br>5. Function VAS (over 24 h) | The treatment group produced significant improvements in pressure pain threshold (mean, 45 kPa for IG), pain-free grip strength (mean, 33.2 N for IG), neurodynamics (mean, 7° for IG), and pain scores (mean, 1.7 cm) relative to the placebo and control groups ($P<.05$) | Appraisal: 8; low |

*Abbreviations: CG, control group; IG, intervention group; NM, neural mobilization; PRTEE, Patient-Rated Tennis Elbow Evaluation Questionnaire; ROM, range of motion; ULNDT, upper-limb neurodynamic test; ULTT, upper-limb tension test; VAS, visual analog scale.*

Two studies[3,13] reported improved patient satisfaction, and another study reported more rapid improvement in pain in the NM groups.[88] Three studies on CTS measured neurodynamic test ROM.[59,86,111] Two studies found no difference between groups,[59,86] whereas 1 study revealed an improvement following NM.[111]

## Lateral Epicondylalgia

Three studies used NM for the treatment of lateral epicondylalgia.[37,42,115] One study had a low risk of bias[115] and 2 had a high risk of bias (**TABLE 5**).[37,42]

The low-risk-of-bias study used cervical lateral glides,[115] resulting in significant improvements in pressure pain threshold, pain-free grip strength, neuro-

### TABLE 6 DESCRIPTIONS OF STUDIES ON OTHER CONDITIONS

| Study | Patient Demographics | Intervention Group | Control Group | Outcome Measures | Results | Risk of Bias |
|---|---|---|---|---|---|---|
| Kavlak and Uygur[66] | n = 28. Mean ± SD age: IG, 40.71 ± 12.84 y; CG, 43.64 ± 14.72 y. Duration of symptoms: IG, 3.40 ± 5.06 y; CG, 2.54 ± 2.43 y | n = 14 participants with tarsal tunnel syndrome<br>Strengthening and stretching exercise plus NM of the tibial nerve in slump for 6 wk. Follow-up every 10 d to check compliance | n = 14 participants with tarsal tunnel syndrome<br>Strengthening and stretching exercises for 6 wk. Follow-up every 10 d to check compliance | Outcomes measured at baseline and at 6 wk<br>1. VAS<br>2. ROM of talar and subtalar joints<br>3. Strength of muscles innervated by tibial nerve<br>4. 2-point discrimination<br>5. Light touch (Tinel's sign) | Conservative treatment of tarsal tunnel syndrome is effective in increasing ROM and muscle strength and alleviating pain; the addition of NM to this treatment did not enhance the treatment effects for these parameters. However, the decrease in Tinel sign (IG, 78.6% still positive; CG, 100%) and 2-point discrimination values (IG, 1.46 ± 0.30; CG, 1.39 ± 0.44) implies that sensory parameters may benefit from NM | Appraisal: 8; unclear |
| Saban et al[93] | n = 69 (30 male, 39 female). Mean ± SD age: IG, 54 ± 12 y; CG, 52 ± 13 y. Duration of pain at admission: IG, 19 ± 19 wk; CG, 25 ± 21 wk | n = 33 participants with plantar heel pain syndrome<br>Deep calf massage<br>Stretching exercises as for SLR<br>Ultrasound<br>SLR exercises with belt 3 times per day, with 5 repetitions for each stretch, using intermittent stretching of 20 s followed by 10 s of rest | n = 36 participants with plantar heel pain syndrome<br>Stretching exercises 3 times per day, with 5 repetitions for each stretch, using intermittent stretching of 20 s followed by 10 s of rest<br>Ultrasound | Outcomes measured at baseline and 4 to 6 wk posttreatment<br>1. Foot and ankle computerized adaptive test of lower extremity<br>2. Functional scale | The overall group-by-time interaction was statistically significant (*P* = .034) for functional scale points, with a mean change of 15 (95% CI: 9, 21) for the IG and 6 (95% CI: 1, 11) for the CG. Both treatment protocols resulted in an overall improvement for within-group changes on the functional scale (IG 95% CI: 9, 21 and CG 95% CI: 1, 11); however, IG treatment was significantly more effective in treating heel pain than CG treatment | Appraisal: 9; low |
| Scrimshaw and Maher[102] | n = 81 (30 female, 51 male). Mean ± SD age: IG, 55 ± 17 y; CG, 59 ± 16 y. Duration of symptoms: IG, <6 wk, n = 2; >6 wk, n = 19; >6 mo, n = 14. CG, <6 wk, n = 8; >6 wk, n = 14; >6 mo, n = 24 | n = 35 participants undergoing lumbar discectomy (n = 9), fusion (n = 6), or laminectomy (n = 20)<br>Same as control but with NM (SLR) added<br>Exercises were encouraged for up to 6 wk postdischarge | n = 46 participants undergoing lumbar discectomy (n = 7), fusion (n = 9), or laminectomy (n = 30)<br>Standard postoperative care (exercises for lower limb and trunk)<br>Exercises were encouraged for up to 6 wk postdischarge | Outcomes measured at baseline, 6 wk, 6 mo, and 12 mo<br>1. Global perceived effect<br>2. VAS<br>3. McGill Pain Questionnaire<br>4. Quebec disability scale<br>5. SLR<br>6. Time taken to return to work | All patients received the treatment as allocated, with 12-mo follow-up data available for 94% of those randomized. There were no statistically significant or clinically significant benefits provided by the NM treatment for any outcome | Appraisal: 8; low |
| Svernlöv et al[109] | n = 70. Mean ± SD age: group A, 43 ± 13.2 y (range, 18-72 y); group B, 44 ± 10.1 y (range, 26-67 y); group C, 44 ± 14.8 y (range, 17-72 y). Duration of symptoms: group A, 13.5 ± 15.7 mo (range, 3-72 mo); group B, 10.5 ± 9.6 mo (range, 3-42 mo); group C, 9.5 ± 5.8 mo (range, 3-24 mo). Sex: group A (9 female, 12 male); group B (8 female, 7 male); group C (10 female, 5 male) | Group B, n = 23 participants with cubital tunnel syndrome<br>Excluded from analysis, n = 8; final, n = 15 treated with nerve gliding/tensioning exercises.[22] Six exercises maintained for 30 s × 3 repetitions, with 1-min rest, twice a day. Increased to 3 times per day if not aggravated<br>Exercise sheet given to patients | Group A, n = 26 participants with cubital tunnel syndrome<br>Excluded from analysis, n = 5; final, n = 21<br>Elbow brace that prevents more than 45° of flexion for 3 mo at night<br>Group C, n = 21 included. Excluded from analysis, n = 6; final, n = 15<br>Information on condition | Outcomes measured at baseline and at 6 mo<br>1. Canadian<br>2. Occupational performance measure<br>3. Grip strength<br>4. Adduction strength of fifth digit<br>5. VAS | n = 57 patients were followed for 6 mo; 51 (89.5%) were improved at follow-up. There were no significant differences between groups in any of the recorded variables<br>Night splints and nerve gliding exercises did not add favorably to treatment outcomes | Appraisal: 5; high |

*Abbreviations: CG, control group; CI, confidence interval; IG, intervention group; NM, neural mobilization; ROM, range of motion; SLR, straight leg raise; VAS, visual analog scale.*

dynamic test ROM, and pain scores compared to the placebo and control groups ($P<.05$). Two studies[37,42] with a high risk of bias compared NM and radial-head mobilization to exercise[37] and to friction massage and exercise.[42] One study[42] revealed significant improvements ($P<.05$) in elbow and neurodynamic test ROM following radial-head mobilization. The other study[37] reported improved grip strength ($P<.001$), pressure pain threshold ($P = .031$), and Patient-Rated Tennis Elbow Evaluation Questionnaire score ($P = .027$) in the group receiving NM. Due to differences in outcome measures and techniques used, a meta-analysis could not be performed.

### Other Conditions

Four studies used NM for other conditions, including tarsal tunnel syndrome,[66] plantar heel pain,[93] cubital tunnel syndrome,[109] and post–lumbar surgery (**TABLE 6**).[102] Two studies had a low risk of bias,[93,102] 1 had unclear risk of bias,[66] and 1 had a high risk of bias.[109]

The combination of SLR mobilization, deep calf massage, and exercises compared to ultrasound and exercise resulted in a significant improvement in pain ($P = .034$) in the plantar heel.[93] Using SLR mobilization with a tibial nerve bias, compared to exercises and supportive inserts, improved Tinel's sign and 2-point discrimination ($P<.05$) in tarsal tunnel syndrome.[66] In tarsal tunnel syndrome, a decrease was observed in sensory parameters, namely Tinel's sign, light touch, and 2-point discrimination values.[66] Other outcomes, such as disability, muscle strength, and pressure and thermal pain thresholds, were not significantly different between the NM and usual-care groups.[66,93]

Post–lumbar surgery patients received SLR mobilization and usual care compared to usual care only.[102] Neural mobilization did not have added benefit to usual care post–lumbar surgery.[102] Last, NM exercises[109] did not result in improved pain and disability ($P>.05$) when compared to a control group and a group of patients who received an elbow brace for cubital tunnel syndrome.

## DISCUSSION

Neural mobilization is effective in reducing pain and disability in certain neuromusculoskeletal conditions. Conditions where NM can be recommended (JBI grades of evidence) are N-LBP, N-NAP, tarsal tunnel syndrome, and plantar heel pain. Currently, the available evidence is insufficient to support the use of NM for CTS, post–lumbar surgery, and cubital tunnel syndrome.

### Nerve-Related Low Back Pain

Evidence for effective management of patients with N-LBP is scarce.[70,92] Furthermore, N-LBP is also a risk factor for chronicity,[54] and therefore effective management is important. People with N-LBP distal to the buttocks, a positive slump test, and pain lasting longer than 3 months had a significant and clinically relevant[50] improvement in both pain and disability following NM.[25,61,81] Using other forms of NM, such as SLR mobilization,[65] techniques aimed at opening the intervertebral foramina,[78] bent-leg raise,[87] and mobilization of tibial and femoral nerves,[43] also resulted in improved pain and disability. The findings of the review support the suggestion of a previous study[100] that patient outcomes can be improved when treatment is targeted at subgroups of patients with N-LBP. A recent review on lower-quadrant NM for healthy populations and patients with low back pain also found that NM improved pain and disability.[85] Neural mobilization exercises incorporating slump and SLR mobilization can be recommended for N-LBP.

### Nerve-Related Neck and Arm Pain

As the evidence for nonsurgical management of N-NAP is scarce,[17,18,94] it is recommended that treatment be aimed at specific subgroups.[94] Using cervical lateral glide techniques for people with N-NAP had a positive effect on pain, with a clinically meaningful effect size.[1,26]

The effect of NM on disability in N-NAP also seems positive.[7,55,84,89] However, as this was not measured consistently, no firm conclusions can be made. Measuring function in these patients is important, as they are more disabled than patients with nonspecific neck pain.[38] Future studies should investigate function and disability using common outcome measures, such as the NDI or Patient-Specific Functional Scale.

### Carpal Tunnel Syndrome

Neural mobilization for CTS did not show significant effects for the clinical outcomes assessed. This finding is supported by a recent review of the effect of nerve gliding exercises on CTS.[10] The majority of studies had a low risk of bias, which should strengthen the confidence in the findings from a research methodological point of view. However, several studies gave patients home exercises with only 1 intervention before follow-up. One study had 3 interventions and a follow-up at 11 months.[11] Although these studies can inform clinicians about these types of treatment schemes, many clinicians favor a more progressive exercise regime with closer monitoring and follow-up. Perhaps as a consequence, some studies had high patient dropout rates.[19,60] Furthermore, many studies[3,11,13,19,59,60,88] evaluated tensioning techniques. Given the decrease in blood circulation in the median nerve in CTS,[16] along with increased neural mechanosensitivity in response to local inflammation,[41,51] increasing the tension in the nerve may further diminish circulation and aggravate symptoms. More studies that evaluate the effects of more modern NM concepts,[28] including "sliding techniques," are required before conclusions can be reached regarding the effect of NM on CTS (and other conditions). Sliding techniques resulted in a reduction in intraneural edema in CTS and improvement in pain and function.[101]

### Lateral Epicondylalgia

In a study with a low risk of bias, the use of cervical lateral glides improved pain in lateral epicondylalgia and can therefore be considered in the treatment of tennis elbow.[115] Due to the high risk of bias of the other studies,[37,42] differences in techniques used, and conflicting outcomes, it is not possible to make firm recommendations on the use of NM for lateral epicondylalgia.

### Other Conditions

Two studies support the use of SLR mobilization for patients with plantar heel pain and tarsal tunnel syndrome.[66,93] This is in accordance with other studies that illustrated that the SLR transmits movement to the tibial nerve[29] and can have an effect on pain, function, and movement of patients with subcalcaneal heel pain.[80] As this is supported by a low-risk-of-bias study, the use of NM for these conditions can be recommended.

Two studies[102,109] found no added benefit when using NM in addition to usual care for post–lumbar surgery and cubital tunnel syndrome. There is insufficient evidence for the use of NM in these conditions, and more studies are needed.

### Outcome Measures

In studies evaluating CTS and N-LBP, similar outcome measures were used, and therefore a meta-analysis could be performed. Unfortunately, this was not the case for most other conditions. Pain was measured in most studies, but the method of assessment was not consistent across studies. Future studies should consider a core set of clinical outcome measures to evaluate the clinical effectiveness of these interventions.

### Neurophysiological Effects

An improvement in neurophysiological parameters was observed in a number of studies, such as a decrease in intraneural edema.[101] This observed decrease in intraneural edema is supported by 2 studies on unembalmed cadavers, which demonstrated the ability of NM to disperse intraneural fluid.[20,53] One of the aims of NM is to restore the homeostasis in and around the targeted nerve.[34] As ischemia of the median nerve contributes to the symptoms of CTS,[58] a decrease in intraneural edema is important in the management of CTS. Sensory parameters may also benefit from NM.[66]

### NM Techniques

Two NM techniques consistently produced good results in conditions considered difficult to treat.[73,94] Mobilization in slump improved pain and disability in N-LBP,[25,61,81,87] and cervical lateral glides improved pain in N-NAP and epicondylalgia.[5,36,84,115]

Our findings showed that tensioning techniques were useful in the treatment of chronic nerve-related conditions, such as N-LBP[25] and plantar heel pain.[66,93] More recently, however,[28] sliding techniques have been typically advocated because they expose the nervous system to less strain and greater mobilization,[28] which might be more advantageous when nerve mechanosensitivity is still increased.[32] Therefore, the choice of technique should be based on sound clinical reasoning.[49,83] Unfortunately, the reasoning process behind the choice of techniques is absent or unclear in many studies.

The terminology can also be confusing. Some studies explicitly state whether "sliding techniques" or "tensioning techniques" were used,[4,55,76] but other studies use the more generic term "nerve gliding exercises." In order not to confuse generic "gliding" exercises with specific "sliding" exercises, we recommend to abandon the term "nerve gliding exercises" and use NM or "neurodynamic techniques" to refer to techniques that aim to mobilize the nerve or its surrounding structures. The need for consistent use of terminology is evident.

### Risk of Bias Across and Within Studies

This review was limited to the inclusion of randomized clinical trials. We included all randomized trials, regardless of quality, in an endeavor to include all conditions treated and techniques used. Seventeen studies had a low risk of bias. Two non-English studies were identified but not included.[9,71] Potential publication bias could not be assessed using funnel plots, as less than 10 trials were included in the meta-analyses.[8]

### Strengths and Limitations

This study included an additional 20 articles that were not included in the most comprehensive review to date.[108] An increase in studies on CTS, N-LBP, and N-NAP, and the ability to perform meta-analysis, provided a better overview of the clinical effectiveness of NM. However, there is still a paucity of information on many relevant conditions, such as cubital tunnel syndrome and post–lumbar surgery.

Although authors were contacted when necessary, some authors could not be reached, and not all required information was available. The majority of studies had low numbers of participants, and therefore results are not necessarily generalizable.

### Recommendations

- Cervical lateral glide mobilization improves pain in N-NAP (level A).
- Slump and SLR mobilization improves pain and disability in N-LBP (level A).
- Neural mobilization has positive neurophysiological outcomes in CTS (upper-limb neurodynamic test 1) and N-LBP (slump and SLR) (level A).
- Neural mobilization does not have a positive effect on most of the clinical outcome measures in CTS (level A).
- Neural mobilization improves pain in tarsal tunnel syndrome and plantar heel pain (low-risk-of-bias evidence from a single study)

## CONCLUSION

Slump and SLR mobilization and a cervical lateral glide technique have been shown to improve pain and function in groups of patients who are often resistant to treatment, such as those with chronic N-LBP and N-NAP and plantar heel pain. The findings of this review may help inform guidelines on the management of CTS and low back and neck pain. ◉

## KEY POINTS

**FINDINGS:** Neural mobilization (NM) is effective in the management of nerve-related low back pain, nerve-related neck and arm pain, and plantar heel pain and tarsal tunnel syndrome. Neural mobilization is not effective in the management of carpal tunnel syndrome. Positive neurophysiological effects were present in groups that received NM.

**IMPLICATIONS:** The findings of this review may help inform clinicians in regard to the management of chronic nerve-related low back pain, nerve-related neck and arm pain, and plantar heel pain. Sound clinical reasoning remains essential when treating nerve-related conditions with NM.

**CAUTION:** Due to the limited evidence and often small study samples, conclusions may change over time.

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## APPENDIX A

### EXAMPLE SEARCH STRATEGY (PUBMED/MEDLINE)

| Treatment Technique | Management Type | Condition | Study Type |
|---|---|---|---|
| Nerve tissue/therapy[mh] | Conservative intervention[tw] | Radiculopathy[mh] | Randomized controlled trial[mh] |
| Nerve treatment[tw] | Conservative approach[tw] | Musculoskeletal pain[mh] | Clinical trial[mh] |
| Neural treatment[tw] | Conservative management[tw] | Referred pain[mh] | Randomised control*[tw] |
| Neurodynamic*[tw] | Conservative therap*[tw] | Nerve tissue/injuries[mh] | Randomized control*[tw] |
| Nerve stretch*[tw] | Physical approach[tw] | Radicular pain[tw] | Randomised control trial[tw] |
| Nerve tension[tw] | Physical intervention[tw] | Nerve pain[tw] | Randomized control trial[tw] |
| Neural tension[tw] | Physical management[tw] | Neuropathy[tw] | Controlled clinical trial[tw] |
| Nerve mobili*[tw] | Physical therapy[tw] | | Randomi*[tw] |
| Neural mobili*[tw] | Physiotherapy[tw] | | RCT[tw] |
| Nerve modalit*[tw] | Manual therapy[tw] | | Trial[tw] |
| Neural modalit*[tw] | | | Placebo[tw] |
| Nerve glid*[tw] | | | Group*[tw] |
| Neural glid*[tw] | | | |

**Search Strategy in the PubMed Advanced Search Builder**

#1 Nerve tissue/therapy[mh] OR Nerve treatment[tw] OR Neural treatment[tw] OR Neurodynamic*[tw] OR Nerve stretch*[tw] OR Nerve tension[tw] OR Neural tension[tw] OR Nerve mobili*[tw] OR Neural mobili*[tw] OR Nerve modalit*[tw] OR Neural modalit*[tw] OR Nerve glid*[tw] OR Neural glid*[tw]. Number of articles found, 9022

#2 Conservative intervention[tw] OR Conservative approach[tw] OR Conservative management[tw] OR Conservative therap*[tw] OR Physical approach[tw] OR Physical intervention[tw] OR Physical management[tw] OR Physical therapy[tw] OR Physiotherapy[tw] OR Manual therapy[tw]. Number of articles found, 61848

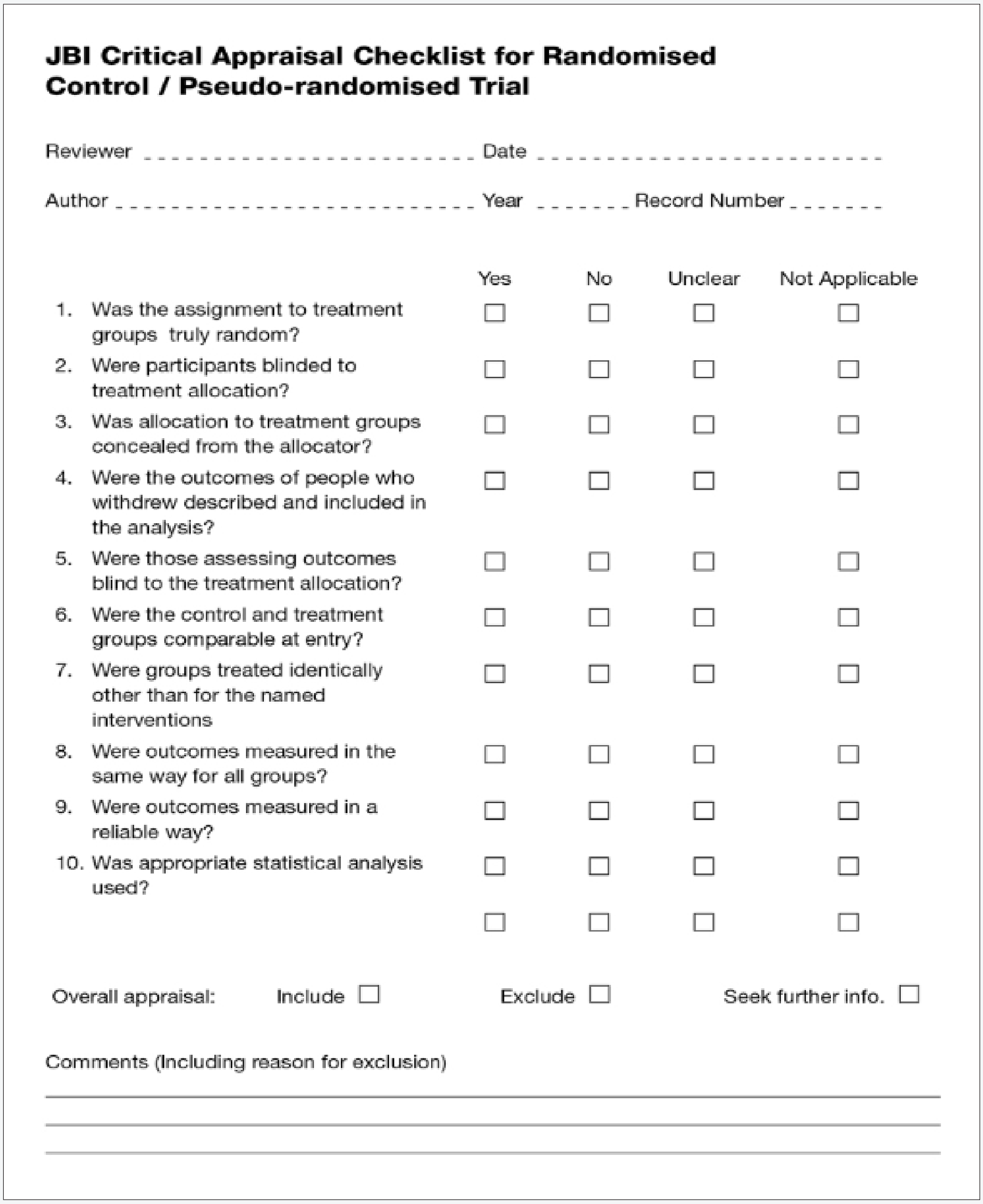
#3 Radiculopathy[mh] OR Musculoskeletal pain[mh] OR Referred pain[mh] OR Nerve tissue/injuries[mh] OR Radicular pain[tw] OR Nerve pain[tw] OR Neuropathy[tw]. Number of articles found, 57929

#4 Randomized controlled trial[mh] OR Clinical trial[mh] OR Randomised control*[tw] OR Randomized control*[tw] OR Randomised control trial[tw] OR Randomized control trial[tw] OR Controlled clinical trial[tw] OR Randomi*[tw] OR RCT[tw] OR Trial[tw] OR Placebo[tw] OR Group*[tw]). Number of articles found, 3446845

#5 #1 AND #2 AND #3 AND #4. Number of articles found, 26

## APPENDIX B

### JOANNA BRIGGS INSTITUTE CRITICAL APPRAISAL TOOL



**JBI Critical Appraisal Checklist for Randomised Control / Pseudo-randomised Trial**

Reviewer _______________________ Date _______________________

Author _________________________ Year ______ Record Number ______

| | Yes | No | Unclear | Not Applicable |
|---|---|---|---|---|
| 1. Was the assignment to treatment groups truly random? | ☐ | ☐ | ☐ | ☐ |
| 2. Were participants blinded to treatment allocation? | ☐ | ☐ | ☐ | ☐ |
| 3. Was allocation to treatment groups concealed from the allocator? | ☐ | ☐ | ☐ | ☐ |
| 4. Were the outcomes of people who withdrew described and included in the analysis? | ☐ | ☐ | ☐ | ☐ |
| 5. Were those assessing outcomes blind to the treatment allocation? | ☐ | ☐ | ☐ | ☐ |
| 6. Were the control and treatment groups comparable at entry? | ☐ | ☐ | ☐ | ☐ |
| 7. Were groups treated identically other than for the named interventions | ☐ | ☐ | ☐ | ☐ |
| 8. Were outcomes measured in the same way for all groups? | ☐ | ☐ | ☐ | ☐ |
| 9. Were outcomes measured in a reliable way? | ☐ | ☐ | ☐ | ☐ |
| 10. Was appropriate statistical analysis used? | ☐ | ☐ | ☐ | ☐ |
| | ☐ | ☐ | ☐ | ☐ |

Overall appraisal: Include ☐ Exclude ☐ Seek further info. ☐

Comments (Including reason for exclusion)

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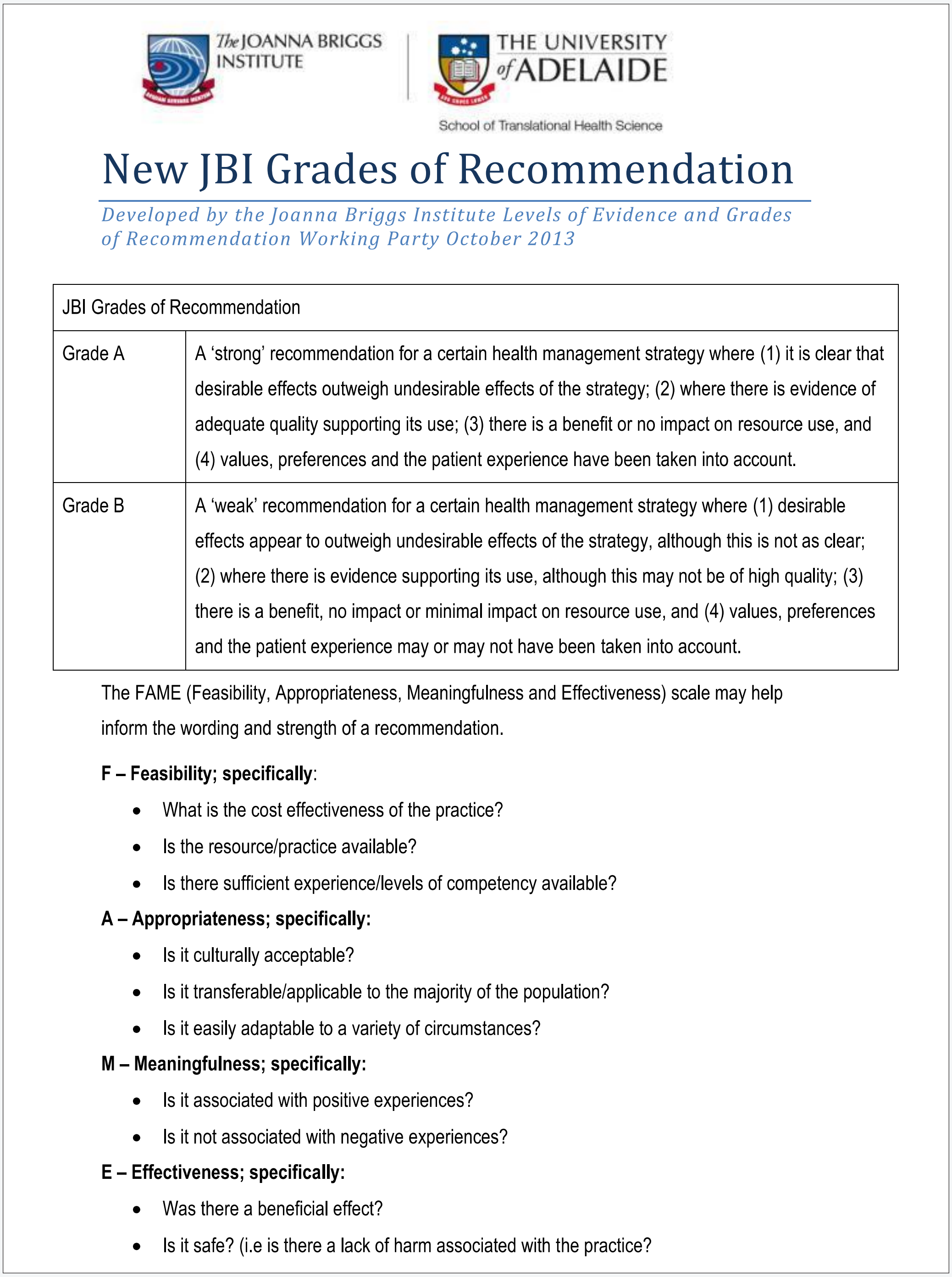
## APPENDIX C

## JOANNA BRIGGS INSTITUTE LEVELS OF EVIDENCE FOR RECOMMENDATIONS



The JOANNA BRIGGS INSTITUTE

THE UNIVERSITY of ADELAIDE

School of Translational Health Science

### New JBI Grades of Recommendation

*Developed by the Joanna Briggs Institute Levels of Evidence and Grades of Recommendation Working Party October 2013*

| JBI Grades of Recommendation | |
|---|---|
| Grade A | A 'strong' recommendation for a certain health management strategy where (1) it is clear that desirable effects outweigh undesirable effects of the strategy; (2) where there is evidence of adequate quality supporting its use; (3) there is a benefit or no impact on resource use, and (4) values, preferences and the patient experience have been taken into account. |
| Grade B | A 'weak' recommendation for a certain health management strategy where (1) desirable effects appear to outweigh undesirable effects of the strategy, although this is not as clear; (2) where there is evidence supporting its use, although this may not be of high quality; (3) there is a benefit, no impact or minimal impact on resource use, and (4) values, preferences and the patient experience may or may not have been taken into account. |

The FAME (Feasibility, Appropriateness, Meaningfulness and Effectiveness) scale may help inform the wording and strength of a recommendation.

**F – Feasibility; specifically**:

- What is the cost effectiveness of the practice?
- Is the resource/practice available?
- Is there sufficient experience/levels of competency available?

**A – Appropriateness; specifically:**

- Is it culturally acceptable?
- Is it transferable/applicable to the majority of the population?
- Is it easily adaptable to a variety of circumstances?

**M – Meaningfulness; specifically:**

- Is it associated with positive experiences?
- Is it not associated with negative experiences?

**E – Effectiveness; specifically:**

- Was there a beneficial effect?
- Is it safe? (i.e is there a lack of harm associated with the practice?

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## APPENDIX D

### EXCLUDED STUDIES

1. Bahrami et al.[9] Reason for exclusion: article in Arabic; could only locate abstract in English
2. Beneciuk et al.[14] Reason for exclusion: healthy population
3. Coppieters et al.[31] Reason for exclusion: case report
4. Castellote-Caballero et al.[23] Reason for exclusion: healthy population
5. Day et al.[39] Reason for exclusion: not a randomized controlled trial
6. De-la-Llave-Rincon et al.[40] Reason for exclusion: not a randomized controlled trial
7. Ferreira et al.[52] Reason for exclusion: design of a trial
8. Leonelli et al.[71] Reason for exclusion: other language (Italian)
9. Lorentzen et al.[72] Reason for exclusion: not a neuromusculoskeletal condition
10. Madenci et al.[74] Reason for exclusion: massage techniques used not aimed at neural tissue
11. Torres et al.[112] Reason for exclusion: rheumatologic condition and treatment not aimed at peripheral nervous system
12. Rozmaryn et al.[91] Reason for exclusion: not a randomized clinical trial
13. Sansare et al.[95] Reason for exclusion: healthy population; not neural mobilization
14. Saranga et al.[97] Reason for exclusion: healthy population
15. Savva and Giakas.[98] Reason for exclusion: case report
16. Schäfer et al.[100] Reason for exclusion: not a randomized clinical trial
17. Sharma et al.[104] Reason for exclusion: not a randomized clinical trial
18. Sharma et al.[103] Reason for exclusion: healthy population; not testing treatment effect
19. Sterling et al.[106] Reason for exclusion: treatment not aimed at peripheral nervous system
20. Szlezak et al.[110] Reason for exclusion: not neural mobilization; healthy population
21. Véras et al.[114] Reason for exclusion: not a neuromusculoskeletal condition
22. Villafañe et al.[116] Reason for exclusion: not a neuromusculoskeletal condition
23. Villafañe et al.[117] Reason for exclusion: not a neuromusculoskeletal condition
24. Young et al.[120] Reason for exclusion: manual technique used; not neural mobilization

## APPENDIX E

### RISK OF BIAS OF STUDIES AND MOTIVATION FOR JUDGMENTS

| Study | Judgment | Motivation |
|---|---|---|
| Ahmed et al[2] | Low | Domain 3 had unclear bias |
| Akalin et al[3] | High | Only domain 4 had low bias |
| Ali et al[4] | High | Domains 1 and 6 had low bias |
| Allison et al[5] | Low | Domain 2 had unclear bias |
| Anwar et al[7] | High | Only domain 1 had low bias |
| Bardak et al[11] | Unclear | Domains 4 and 6 had unclear bias and domain 5 had high bias |
| Baysal et al[13] | Unclear | Domains 4 and 6 had high bias |
| Bialosky et al[15] | Low | All domains had low bias |
| Brininger et al[19] | Unclear | Domains 2 and 6 had high bias |
| Cleland et al[25] | Low | All domains had low bias |
| Coppieters et al[35,36] | Low | Domain 2 had unclear bias |
| Dabholkar et al[37] | High | Domains 2 and 5 had unclear bias and domains 3 and 4 had high bias |
| Drechsler et al[42] | High | Domains 2, 3, and 5 had high bias |
| Dwornik et al[43] | High | Domains 2, 4, and 6 had high bias |
| Gupta and Sharma[55] | High | Domains 2, 3, and 6 had high bias |
| Heebner and Roddey[59] | High | Domains 3 and 5 had unclear bias and domains 2 and 6 had high bias |
| Horng et al[60] | Low | All domains had low bias |
| Jain et al[61] | High | Only domain 1 had low bias |
| Kaur and Sharma[65] | High | Only domains 1 and 5 had low bias |
| Kavlak and Uygur[66] | Unclear | Domains 1 and 2 had high bias; others had low bias |
| Kumar[67] | High | Domain 4 had high bias and domains 2, 3, and 6 had unclear bias |
| Langevin et al[68] | Low | All domains had low bias |
| Marks et al[76] | High | Domains 2, 3, and 5 had high bias |
| Mehta et al[78] | High | Domains 2, 3, and 5 had high bias |
| Nagrale et al[81] | Low | All domains had low bias |
| Nar[82] | High | Domains 2, 3, 5, and 6 had unclear bias |
| Nee et al[84] | Low | Domain 6 had unclear bias; others had low bias |
| Oskouei et al[86] | Low | Domain 6 had unclear bias; others had low bias |
| Patel[87] | High | Domains 2, 3, and 5 had unclear bias and domain 4 had high bias |
| Pinar et al[88] | Low | Domain 2 had unclear bias; others had low bias |
| Ragonese[89] | Unclear | Domain 4 had unclear bias and domain 6 had high bias |
| Rezk-Allah et al[90] | High | Only domain 1 had low bias |
| Saban et al[93] | Low | All domains had low bias |
| Schmid et al[101] | Low | Domain 6 had unclear bias |
| Scrimshaw and Maher[102] | Low | All domains had low bias |
| Svernlöv et al[109] | High | Domains 2, 3, and 6 had high bias |
| Tal-Akabi and Rushton[111] | Low | Domain 2 had unclear bias |
| Vicenzino et al[115] | Low | Domain 1 had unclear bias |
| Mahmoud[75] | High | Domains 1, 2, and 3 had high bias |
| Wolny et al[119] | Low | All domains had low bias |

## APPENDIX F

### SUMMARY OF FINDINGS OF META-ANALYSES FOR CARPAL TUNNEL SYNDROME

| Outcome | Relative Effect* | Participants/Studies, n | *P* Value | Low Risk of Bias, n |
|---|---|---|---|---|
| Pain (VAS) | −0.22 (−0.74, 0.3)<br>Favors treatment | 126/5[13,15,88,101,111] | .40 | 4 |
| Hand grip strength | 1.18 (−1.29, 3.66)<br>Neutral | 139/4[3,13,19,88] | .35 | 1 |
| Disability (DASH) | −1.55 (−7.84, 4.75)<br>Favors treatment | 153/3[15,59,60] | .63 | 2 |
| 2-point discrimination | 0.36 (−0.8, 0.08)<br>Favors treatment | 173/3[3,11,13] | .11 | 2 |
| Phalen’s sign | 0.81 (0.87, 1.86)<br>Favors treatment | 229/5[3,11,13,86,88] | .42 | 2 |

Abbreviations: DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; VAS, visual analog scale.
*Values in parentheses are 95% confidence interval.