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REVIEW ARTICLE (META-ANALYSIS)

Effectiveness of Conservative Nonpharmacologic Therapies for Pain, Disability, Physical Capacity, and Physical Activity Behavior in Patients With Degenerative Lumbar Spinal Stenosis: A Systematic Review and Meta-Analysis

Samantha Jacobi, BScKin,[a] Amber Beynon, BSc,[b] Stephan U. Dombrowski, PhD,[a] Niels Wedderkopp, MD, PhD,[c,d] Richelle Witherspoon, MSc, MLIS,[e] Jeffrey J. Hébert, DC, PhD[a,f]

From the [a]Faculty of Kinesiology, University of New Brunswick, Fredericton, New Brunswick, Canada; [b]College of Science, Health, Engineering and Education, Murdoch University, Perth, Australia; [c]Department of Sports Science and Clinical Biomechanics, Exercise Epidemiology, Center for Research in Childhood Health, University of Southern Denmark, Odense, Denmark; [d]The Orthopedic Department, Hospital of Southwest Jutland, Esbjerg, Denmark; [e]University of New Brunswick Libraries, Fredericton, New Brunswick, Canada; and [f]School of Psychology and Exercise Science, Murdoch University, Perth, Australia.

Abstract

Objective: To investigate the effectiveness of conservative nonpharmacologic therapies on pain, disability, physical capacity, and physical activity outcomes in patients with degenerative lumbar spinal stenosis (LSS).

Data Sources: Systematic search of MEDLINE, EMBASE, CENTRAL, and PsycINFO from inception to November 4, 2019, without language restrictions.

Study Selection: Pairs of review authors independently identified randomized controlled trials published in peer-reviewed scientific journals reporting on the effects of rehabilitation interventions on pain intensity (back or leg), disability, symptom severity, physical capacity, physical activity behavior, or adverse events (secondary outcome) in adults with LSS. The search identified 1718 records; data from 21 reports of 19 trials (1432 patients) were included.

Data Extraction: Review author pairs independently extracted data and assessed included studies. We assessed risk of bias with the Cochrane tool, and overall study quality with the Grading of Recommendations Assessment, Development and Evaluation classification.

Data Synthesis: We pooled data using random-effects meta-analyses; treatment effects were reported as mean differences (MD) and 95% confidence intervals (CI). Directed exercise and manual therapy was superior to self-directed or group exercise for improving short-term walking capacity (MD, 293.3 m; 95% CI, 61.7-524.9 m; low-quality evidence), back pain (MD, −1.1; 95% CI, −1.8 to −0.4; moderate quality evidence), leg pain (MD, −.9; 95% CI, −0.2 to −1.5; moderate-quality evidence), and symptom severity (MD, −0.3; 95% CI, −0.4 to −0.2; low quality evidence). There is very low quality evidence that rehabilitation is no better than surgery at improving intermediate- or long-term disability. Single trials provided conflicting evidence of effectiveness for a variety of therapies.

Conclusions: For patients with LSS, there is low- to moderate-quality evidence that manual therapy with supervised exercises improves short-term walking capacity and results in small improvements in pain and symptom severity compared with self-directed or group exercise. The choice between rehabilitation and surgery for LSS is very uncertain owing to the very low quality of available evidence.

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Approximately 1 in 5 adults 65 years or older experience degenerative lumbar spinal stenosis (LSS).[1,2] LSS results from spinal canal narrowing that affects the spinal cord and nerve roots[3] and causes neurogenic claudication, pain and paresthesia in the gluteal region and legs, and limited walking capacity.[4,5] Consequently, people with LSS engage in less physical activity than those with hip or knee osteoarthritis.[6] Only 4% of people with LSS meet guideline recommendations for health-related physical activity,[7] and LSS is associated with a higher prevalence of heart disease and hypertension.[8]

Treatments for LSS include surgical and nonsurgical options. LSS is the most common reason for older adults to undergo spine surgery.[9] Many nonsurgical treatments exist, including epidural steroid injections,[10-13] exercise,[5] and combined therapies such as manual therapy and exercise.[11,14] Traditionally, outcomes such as pain and pain-related disability have been used to judge the effectiveness of therapies for LSS. However, the deleterious effect of LSS on physical capacity highlights the importance of assessing the effect of therapy on other patient-centered outcomes such as walking capacity and health-related physical activity behavior.

There is insufficient evidence to guide clinical decision making regarding the effectiveness of rehabilitation for LSS.[15] Therefore, this systematic review aimed to investigate the effectiveness of conservative nonpharmacologic therapies on pain, disability, physical capacity, and physical activity in patients with degenerative LSS.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement guidelines.[16] The review protocol was developed prior to the conduct of the review and was prospectively registered with PROSPERO (CRD42020157848).

Eligibility

We included full reports published in peer-reviewed scientific journals of randomized controlled trials of adults (≥18y) with degenerative LSS treated with conservative nonpharmacologic interventions. Conservative interventions included physical treatments (eg, exercise or manual therapy) and psychological approaches (cognitive-behavioral therapy or behavior change interventions).We considered all comparison types, including sham therapy, active comparators, usual care, and no treatment. We excluded trials of mixed clinical populations and those evaluating the effects of postoperative therapy only. To be included, studies needed to report at least 1 of the following outcomes: quantitative measures of back pain intensity, leg pain intensity, symptom severity, pain-related disability, physical capacity (eg, muscle strength, walking distance), or self-reported or objectively measured physical activity behavior. Secondary outcomes were adverse events or other harms reportedly associated with the interventions.

List of abbreviations:

CI	**confidence interval**
GRADE	**Grading of Recommendations Assessment, Development and Evaluation classification**
LSS	**lumbar spinal stenosis**
MD	**mean difference**

Search strategy

We conducted a comprehensive search of MEDLINE, EMBASE, CENTRAL, and PsycINFO from inception to November 4, 2019 without language restrictions. Key search terms included terms related to the relevant anatomy (eg, spine, spinal), pathology (eg, stenosis), and therapies (eg, rehabilitation, exercise, behavior change). Details of the search strategies applied to all databases are included in supplemental appendix S1 (available online at http://www.archives-pmr.org/). Reference lists of included articles were searched.

Screening

A 2-stage screening process was performed independently by pairs of review authors from a panel of 3 (S.J., N.W., J.H.). We first screened titles and abstracts to identify studies that potentially met the eligibility criteria. We then independently assessed the full-text of articles to determine eligibility. Disagreements were resolved via discussion and arbitration with a third review author (S.D.) if needed.

Data extraction and management

Two review authors (S.J., A.B.) independently extracted data into a customized form. Disagreements were resolved via discussion and arbitration with a third review author (J.H.) if needed. We extracted information on study populations (age, sex, clinical status), intervention and comparator descriptions, outcome measures, and the main findings of the included trials.

Risk of bias

Two review authors (S.J., A.B.) independently assessed the risk of bias of included studies using the Cochrane Risk of Bias tool.[17] Disagreements were resolved via discussion and arbitration with a third review author (J.H.) if needed. We considered a study to be at low risk of bias if we rated 5 of the 6 bias domains as having low risk of bias.[18]

Interpretation of treatment effects

Pooled outcomes comprised walking capacity measured with the self-paced walking test (meters walked), back and leg pain intensity measured with the 0- to 10-point numeric pain rating scale, pain related disability measured with the 0- to 100-point Oswestry disability index, and symptom severity and physical function measured with the Zurich Claudication Questionnaire. Reporting on the Zurich Claudication Questionnaire differed between trials; 2 trials[14,19] reported the mean score across questions, whereas another trial[11] reported the sum of individual question scores. We converted the latter to reflect the average question score so that unstandardized mean differences could be compared across trials. The clinical importance of each treatment effect was interpreted as meeting estimates of the minimum clinically important difference for patients with LSS when available: 1.25 points for back pain intensity, 1.5 points for leg pain intensity, 5.0 points for pain-related disability, .36 points for symptom severity, and .10 points for physical function.[20]

Data synthesis

We categorized outcomes into 4 follow-up time points after randomization: immediate (≤2wk), short-term (>2wk to ≤3mo), intermediate (>3mo to <12mo), and long-term (≥12mo). When

multiple time points occurred in the same category, we used data closest to 1 week (immediate), 8 weeks (short-term), 6 months (intermediate), and 12 months (long-term).[18]

Pairs of review authors from a panel of 4 (S.J., A.B., N.W., J.H.) independently assessed the clinical diversity of the included trials and grouped these based on differences in trial populations, interventions, comparators, and outcomes, using clinical judgment. Results of clinically homogenous trials were pooled with random-effects models using Review Manager, version 5.3, software.[a] Treatment effect estimates were adjusted mean differences (MD) and 95% confidence intervals (CI) of change scores for pain, disability, and walking capacity. When change scores or adjusted estimates were not available, we used final scores and crude estimates. We assessed statistical heterogeneity by visually inspecting the forest plots for concordance of point estimates and confidence intervals, and with the I^2 statistic. We interpreted I^2 as follows: 0%-40% (heterogeneity might not be important), 30%-60% (may represent moderate heterogeneity), 50%-90% (may represent substantial heterogeneity), and 75%-100% (may represent considerable heterogeneity).[17]

Two review authors (S.D., J.H.) independently assessed the overall quality of the evidence for each pooled estimate using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) classification.[21] Disagreements were resolved by discussion. We downgraded ratings from "high quality" by 1 level for each limitation related to study design or execution (ie, risk of bias), inconsistency of results, and imprecision. Specifically, the quality of evidence was downgraded by 1 level when (1) greater than 50% of participants were from studies judged not to be at low risk of bias, (2) I^2 values were greater than 50% or when noting discordance between point estimates or confidence intervals (inconsistency), or (3) when the overall sample size was less than 400 or when CIs indicated imprecise treatment effect estimation (imprecision).[22] We did not assess indirectness as this review focused on a specific population, comparisons, and outcomes. We did not consider publication bias owing to the small number of trials in each analysis.[17]

Results

Search results

The search identified 1718 records, of which 41 full-text studies were assessed after title and abstract screening. In total, 21 reports of 19 unique trials with data from 1432 patients were included (fig 1). Supplemental appendix S2 (available online at http://www.archives-pmr.org/) reports the reasons for exclusion of studies evaluated at the full-text assessment stage.

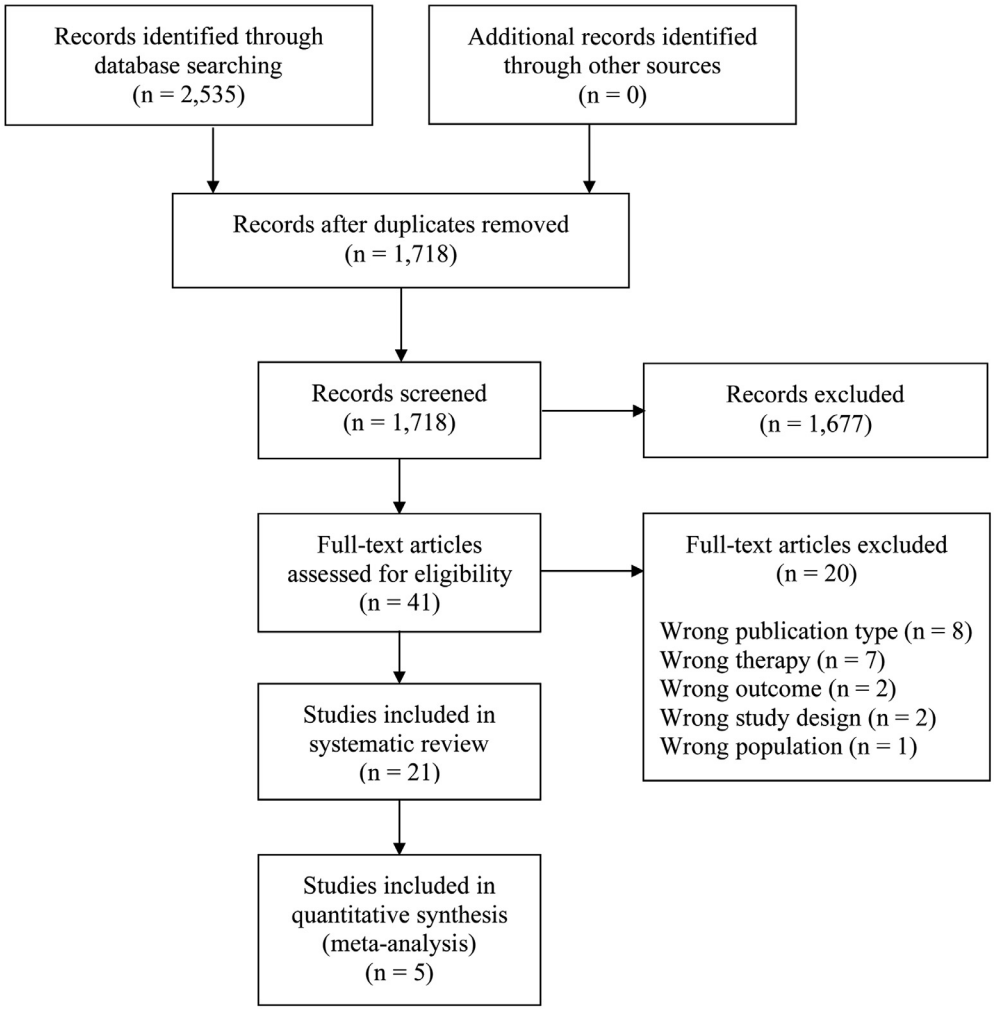

Fig 1 Flow diagram of study selection.

Included studies

Table 1 summarizes the sample populations, interventions, comparators, outcomes, and main findings of the included trials. The mean age of participants ranged from 49.1 to 75.3 years. Trials reported 32 different outcomes. Pain intensity measured with a numeric rating scale (9 trials; 47%) or visual analog scale (8 trials; 42%), and pain-related disability measured with the Oswestry disability index (14 trials; 74%) or Roland-Morris disability index (2 trials; 11%) were the most commonly reported outcomes. Only 7 trials (37%) included adverse events as a formal trial outcome. Five trials (26%) measured walking capacity with the self-paced walking test.

There was large diversity in the types of interventions and comparisons. Multimodal interventions were tested in most trials (14 trials; 74%). Common rehabilitation components included exercise (14 trials; 74%), manual therapy or traction (8 trials; 42%), passive physical modalities (7 trials; 37%), as well as psychological (eg, cognitive behavioral therapy) and educational components (4 trials, 21%).

Treatment comparisons most often included active therapies such as rehabilitation interventions (9 trials, 47%), oral or injected medications (5 trials, 26%), and surgery (2 trials, 11%). Few trials included sham therapy (3 trials, 16%), minimal treatment (3 trials, 16%), or no treatment (2 trials, 11%) comparisons.

We categorized intervention contrasts as: supervised exercise and manual therapy versus self-directed or group exercise (3 trials), multimodal rehabilitation versus surgery (3 reports of 2 trials), multimodal rehabilitation versus epidural steroid injection (3 trials), passive modalities versus sham therapy (3 trials), rehabilitation versus minimal treatment (3 trials), multimodal treatment contrasts (3 trials), and other comparisons (4 reports of 3 trials). Data from 3 trials comparing supervised exercise and manual therapy versus self-directed or group exercise and data from 2 trials comparing rehabilitation versus surgery were pooled for meta-analysis.

Risk of bias and quality of evidence

Risk of bias outcomes are reported in figures 2 and 3. Six trials were found to have a low risk of bias.[11,12,14,26,35,36] Performance bias was the most common source of bias (91% of trials), which is to be expected given the nature of the therapies evaluated in this review. Reporting bias (36% of trials) and detection bias (32% of trials) were also common. Tables 2 and 3 provide summaries of findings and quality of evidence (GRADE) ratings for the pooled treatment effect estimates. The overall quality of evidence ranged from very low to moderate.

Effectiveness of interventions

Supervised exercise and manual therapy versus self-directed or group exercise

We identified 3 trials (2 with low risk of bias) reporting on the effects of supervised exercise and manual therapy versus self-directed or group exercise interventions on walking capacity, back pain intensity, leg pain intensity, symptom severity, or self-reported physical function (fig 4). Pooled effects from 3 trials (n=316)[11,14,19] provided low quality evidence that exercise and manual therapy increase short-term walking capacity (MD, 293.3 m; 95% CI, 61.7-524.9 m; I^2=79%), whereas pooled effects from 2 trials (n=214)[11,14] showed no difference in intermediate-term walking capacity (low quality evidence).

Pooled effects from 2 trials (n=180) provided moderate quality evidence (downgraded for imprecision) that exercise and manual therapy result in short-term improvements in back pain (MD, −1.1; 95% CI, −1.8 to −.4; I^2=15%) and leg pain (MD, −.9; 95% CI, −1.5 to −.2; I^2=0%) intensity less than thresholds for clinical importance.[14,19] Pooled effects from 3 trials (n=326) provided low quality evidence (downgraded for inconsistency and imprecision) that exercise and manual therapy improve short-term symptom severity (MD, −0.3; 95% CI, −0.4 to −0.2; I^2=54%), with differences less than estimates of clinical importance.[14,19] Pooled effects from 2 trials showed no intermediate-term differences (moderate quality evidence, downgraded for imprecision) in symptom severity.[11,14] Pooled results provided low (downgraded for inconsistency and imprecision) to moderate (downgraded for imprecision) quality evidence of no difference in self-reported physical function in the short term (3 trials, n=326)[11,14,19] or intermediate term (2 trials, n=220).[11,14]

Two trials reported adverse event outcomes; however, these data could not be pooled owing to reporting differences. One trial of 104 patients reported 15 adverse events among patients receiving supervised exercise and manual therapy, and 24 adverse events among patients receiving self-directed exercise (eg, worsened back or extremity pain).[14] One serious, pain-related adverse event (requiring hospital care) was reported in each treatment group. Another trial of 259 patients reported 226 minor adverse events (eg, transient muscle soreness): 80 by patients receiving supervised exercise and manual therapy, 79 among patients receiving medical care comprising oral medications, with or without epidural steroid injections and activity advice, and 67 among patients participating in group exercise classes.[11] No serious adverse events were reported.

Multimodal rehabilitation versus surgery

We identified 3 reports of 2 high-risk-of-bias trials reporting on the effects of multimodal rehabilitation versus surgery on intermediate- and long-term pain-related disability. Pooled effects from 2 trials[23,24] (n=243-245) provide very low quality evidence (downgraded for risk of bias, inconsistency, and imprecision) of no difference in disability between rehabilitation and surgery in the intermediate or long-term (fig 5). Two-year outcomes of the trial originally reported by Malmivaara et al[24] showed lower disability in surgically treated patients and no between-group differences in leg pain, back pain, walking ability, or walking capacity after 6 years.[25]

Both trials included adverse event reporting but reporting limitations prevented the pooling of data for this outcome. One trial reported 33 surgery-related and 9 rehabilitation-related events.[23] Another trial reported 8 perioperative and 4 postoperative events among patients receiving surgical treatment with no apparent tracking of adverse events among patients in the rehabilitation group.[24]

Multimodal rehabilitation versus epidural steroid injection

Clinically heterogeneous data from 2 trials comparing rehabilitation with epidural steroid injections, with or without other therapies, provided conflicting results. A low-risk-of-bias trial reported greater intermediate-term improvements in leg pain, back pain, disability, claudication symptoms, and walking capacity favoring manual therapy and acupuncture, with or without herbal

Table 1 Characteristics of included studies

Study	Sample Population	Rehabilitation Description	Comparison Treatment	Outcomes	Main Findings
Supervised exercise and manual therapy versus self-directed or group exercise					
Minetama et al[19]	86 patients (G1=43, G2=43) with clinical and imaging-confirmed LSS Mean age (G1=72.3, G2=73.2) Female (G1=53.5%, G2=55.8%)	G1: 12 sessions of manual therapy and supervised stretching and strengthening exercises for the trunk and lower extremities, cycling, and body weight-supported treadmill walking HEP with daily walking, and trunk muscle exercises (per G2)	G2: 6-wk HEP with daily walking, and trunk muscle exercises	ZCQ (symptom severity, physical function), SPWT, NRS (back pain, leg pain), daily steps upon completion of 6 wk of therapy	Improved ZCQ score, walking capacity, leg pain, and daily steps favoring supervised therapy plus HEP
Schneider et al[11]	259 patients (G1= 84, G2=87, G3=88) with clinical and imaging-confirmed LSS Mean age (G1=72.9, G2=72.1, G3=72.0) Female (G1=46%, G2=60%, G3=52%)	G1: 12 sessions of cycling, spinal mobilizations, and individualized stretching and/or strengthening exercises	G2: 12 supervised group exercise classes G3: 3 visits to physician providing medications (nonnarcotic analgesics, anticonvulsants, antidepressants), and/or ESIs Guidance on gentle stretching and remaining active	SSS (symptom severity, physical function), SPWT (walking capacity), physical activity (accelerometer), adverse events at 2 and 6 mo	Improved SSS score favoring G1 at 2 months Improved physical activity favoring G2 versus G3 at 2 months No between-group differences in walking capacity but more responders in G1 No between-group differences at 6 months Minor adverse events: G1: 80, G2: 67, G3: 79 No serious adverse events
Ammendolia et al[14]	104 patients (G1=51, G2=53) with clinical and imaging-confirmed LSS; unlikely surgical candidates Mean age (G1=69.4, G2=71.7) Female (G1=65%, G2=49%)	G1: 13 15- to 20-min sessions of supervised cognitive-behavioral education, manual therapy as well as stretching, strengthening, and conditioning exercises as part of an HEP	G2: 6-wk self-directed training program with instructional video, workbook, pedometer to monitor steps, and single 15- to 30-min face-to-face session	SPWT, ZCQ (symptom severity, physical function), ODI, ODI walking score, NRS (back and leg pain), physical performance, adverse events at 8 wk, and 3, 6, and 12 mo	Improved walking capacity favoring supervised treatment at all time points Improved ZCQ score favoring supervised treatment at 12 mo No consistent between-group differences in other outcomes Adverse events: G1: 15, G2: 24 Serious adverse events (requiring hospital care): G1: 1, G2: 1
Multimodal rehabilitation versus surgery					
Delitto et al[23]	169 patients (G1=82, G2=87) with clinical and imaging-confirmed LSS deemed candidates for decompression surgery Mean age (G1= 69.8, G2=66.6) Female (G1=46%, G2= 49%)	G1: 12 sessions of lumbar flexion exercises, general conditioning (stationary cycling or treadmill walking, lower extremity strengthening and stretching), and patient education	G2: lumbar decompression without fusion performed at the levels of radiographic stenosis	ODI, NASS outcome assessment at 10 wk, and 6, 12, and 24 mo	No between-group differences in any outcome 33 surgery-related and 9 rehabilitation-related complications
Malmivaara et al[24]	94 patients (G1=44, G2=50) with clinical and imaging-confirmed LSS deemed candidates for conservative or surgical treatment	G1: 1 to 3 treatment sessions including educational brochure, postural/ergonomic instruction, trunk muscle endurance/stretching	G2: lumbar decompression with or without fusion	ODI, walking ability, walking capacity, NPRS (leg and back pain during walking), at 6, 12, and 24 mo	Improved disability, leg pain, back pain favoring surgery at all time points No differences in walking ability or walking capacity

(*continued on next page*)

Table 1 (*Continued*)

Study	Sample Population	Rehabilitation Description	Comparison Treatment	Outcomes	Main Findings
	Mean age (G1=62, G2=63) Female (G1=55%, G2=78%)	exercises, and passive modalities NSAIDs as indicated			8 perioperative and 4 postoperative adverse events
Slatis et al[25*]	94 patients (G1=44, G2=50) with clinical and imaging-confirmed LSS deemed candidates for conservative or surgical treatment Mean age (G1=62, G2=63) Female (G1=55%, G2=78%)	G1: 1 to 3 treatment sessions including educational brochure, postural/ ergonomic instruction, trunk muscle endurance/ stretching exercises, and passive modalities NSAIDs as indicated	G2: lumbar decompression with or without fusion	ODI, walking ability, walking capacity NPRS (leg and back pain during walking) at 6 y	Improved disability favoring surgery at 6 y No differences in leg pain, back pain, or walking ability or walking capacity
Multimodal rehabilitation versus epidural steroid injection					
Kim et al[12]	34 patients (G1=12, G2=11, G3=11) with clinical and imaging-confirmed LSS Mean age (G1=65, G2=66, G3=62) Female (G1=83%, G2=67%, G3=50%)	G1: 20 sessions of Moknuri Chuna therapy, acupuncture, and herbal medication G2: 20 sessions of Mokhuri Chuna therapy and acupuncture	G3: oral pain medication, 3 interlaminar ESIs, and 20 treatment sessions including heat therapy and TENS	Adverse event occurrence, ODI, treadmill walking test, OCS (physical function), VAS (leg pain and back pain) upon therapy completion, 3 and 6 mo	No treatment-related adverse events Improved leg pain, back pain, disability, OCS score, and walking capacity favoring the Moknuri groups compared with medical care at various time points
Koc et al[13]	29 patients (G1=10, G2= 10, G3= 9) with clinical and imaging-confirmed LSS Mean age (G1=62.6, G2=61.1, G3=53.1) Female (G1=50%, G2=20%, G3=11%)	G1: 10 sessions of ultrasound therapy, hot pack, and TENS, as well as diclofenac and a 6-mo stretching and strengthening HEP	G2: ESIs, diclofenac and a 6-mo stretching and strengthening HEP G3: diclofenac and a 6-mo stretching and strengthening HEP	RMDI, FFD, treadmill walk test, sit-to-stand, weight carrying test, and VAS (pain) at 2 wk, 1, 3 and 6 mo	Improved pain and disability favoring G2 versus G3 at 2 wk No other between-group differences Two adverse events (unknown treatment group) reported
Passive modalities versus sham therapy					
Ammendolia et al[36]	104 patients (G1=51, G2=53) with clinical and imaging-confirmed LSS Mean age (G1=69.4, G2=71.7) Female (G1=65%, G2=49%)	G1: single session of TENS therapy for 2 min prior to and during the SPWT	G2: single session of sham therapy (detuned TENS) for 2 min prior to and during the SPWT	SPWT and adverse events during therapy	No between-group difference in walking capacity No reported adverse events
Aydin et al[27]	49 patients (G1=25, G2=24) with clinical and imaging-confirmed LSS Mean age (G1=61.6, G2=64.6) Females (G1=72%, G2=71%)	G1: 10 sessions of pulsed electromagnetic field therapy, home lumbar flexion exercises, paracetamol as needed	G2: 10 sessions of "sham" electromagnetic therapy sessions, lumbar flexion exercises, paracetamol as needed	ODI, TUG, VAS (resting leg or low back pain), immediately post therapy at 2 and 5 wk	Improved low back and leg pain, disability, and functional mobility favoring pulsed electromagnetic field therapy at 2 and 5 wk
Cambron et al[28]	59 patients (G1=15, G2=15, G3=15, G4=14) with clinical and imaging-confirmed LSS Mean age (G1=63.7, G2=59.4,	G1: 8 sessions of flexion-distraction, hot and/or cold packs G2: 12 sessions of flexion-	G4: 8 sham treatments: upside down low-level laser device, detuned mechanical manipulation	SSS (symptom severity), ODI, walking performance, VAS (leg and low back pain), adverse events	Incomplete and unclear reporting of treatment effects No apparent between-group differences in SSS scores, no

(*continued on next page*)

Table 1 (*Continued*)

Study	Sample Population	Rehabilitation Description	Comparison Treatment	Outcomes	Main Findings
	G3=64.5, G4=61.3) Female (G1=53%, G2=40%, G3=13%, G4=27%)	distraction, hot and/or cold packs G3: 18 sessions of flexion-distraction, hot and/or cold packs	instrument	post therapy at 3 and 6 mo	between-group reporting on remaining outcomes No reported adverse events
Rehabilitation versus minimal treatment					
Marchand et al[29]	40 patients (G1=20, G2=20) with clinical and imaging-confirmed LSS awaiting LSS surgery Mean age (G1= 66.7, G2=71.5) Female (G1=45%, G2=40%)	G1: 18 sessions of supervised exercises including trunk stabilization, posterior chain strength and endurance, and lower limb strengthening exercises	G2: regular preoperative management and advice	NPRS (leg and back pain), ODI, adverse events, trunk muscle and knee extension strength/endurance, lumbar range of motion, and walking and aerobic capacity after 6 wk (completion of therapy), 6 wk after surgery and 6 mo after surgery (self-reported only)	Improved leg pain, trunk muscle strength/endurance, range of motion, and walking capacity favoring exercise group at 6 wk No between-group differences at other time points No reported adverse events
Comer et al[30]	76 patients (G1=38, G2=38) with clinical LSS deemed candidates for conservative care with neurogenic claudication causing limitation of walking Mean age (G1=70.8, G2=75.3) Female (G1= 47%, G2=58%)	G1: condition-specific home exercises twice daily for 6 wk, advice and education	G2: Advice and education	SSS (symptom severity), ODI, walking tolerance, and VAS (leg and back pain) at 8 wk and 12 mo	No between-group differences in any outcome No reported adverse events
Goren et al[31]	45 patients (G1=15, G2=15, G3=15) with clinical and imaging-confirmed LSS deemed candidates for conservative care (ultrasound treatment) Mean age (G1=57.4, G2=49.1, G3=53.1) Female (G1=53%, G2=87%, G3=73%)	G1: 15 sessions of ultrasound therapy, supervised exercise: flexibility, strengthening and cycling exercises, paracetamol as indicated G2: 15 sessions of sham ultrasound, supervised exercise: flexibility, strengthening and cycling exercises, paracetamol as indicated	G3: no treatment/no exercise control, paracetamol as indicated	ODI, time to first symptoms with walking, ambulation time, VAS (leg and low back pain), and consumption of analgesics upon completion of 3 wk of therapy	Improved disability and leg pain favoring exercise groups Improved analgesic use favoring ultrasound group compared to the control group No between-group differences between the 2 exercise groups
Multimodal rehabilitation contrasts					
Homayouni et al[32]	50 patients (G1=25, G2=25) with clinical and imaging-confirmed LSS Mean age (G1=55.6, G2=55.7) Female (G1=52%, G2=56%)	G1: 24 supervised aquatic exercise sessions	G2: 10-sessions of ultrasound, TENS, supervised trunk muscle endurance and stretching exercises, with an HEP	VAS (pain with movement) and 6MWT at 7 wk and 3 mo	Improved pain and walking capacity favoring aquatic exercise at 7 wk No between-group differences at 3 mo No reported adverse events
Pua et al[33]	68 patients (G1=33, G2=35) with clinical and imaging-confirmed LSS, and deemed candidates for	G1: 12 sessions of treadmill walking with body weight support, HEP, heat, lumbar	G2: 12 sessions of cycling, HEP, heat, lumbar traction	ODI, RMD, and VAS (pain) at 3 wk (therapy midpoint) and 6 wk (post	No between-group differences in disability or pain

(*continued on next page*)

Table 1 (*Continued*)

Study	Sample Population	Rehabilitation Description	Comparison Treatment	Outcomes	Main Findings
	exercise therapy Mean age (G1=58.2, G2=58.5) Female (G1=42%, G2=52%)	traction		therapy)	
Whitman et al[34]	58 patients (G1=29, G2=29) with clinical and imaging-confirmed LSS Mean age (G1=68.9, G2=70.0) Female (G1=33%, G2=57%)	G1: 12 sessions of manual therapy, body weight supported treadmill walking, and lumbar flexion and impairment targeted exercises	G2: 12 sessions of lumbar flexion exercises, a treadmill walking program, and subtherapeutic ultrasound	ODI, treadmill walking test, NPRS (leg pain) at 6 wk, 1 y and approximately 2.5 y	No between-group differences in disability, walking capacity, or pain
Other contrasts					
Passmore et al[35]	14 patients (G1=7, G2=7) with clinical and imaging-confirmed LSS from a surgical waitlist Mean age (G1= 59.1, G2=58.9) Female (G1=57%, G2=43%)	G1: 1 session of lumbar spinal manipulation	G2: no treatment control	NPRS (back and leg pain), lumbar range of motion, movement time, reaction time, and kinematic motor performance immediately after treatment	No between-group differences in any outcome No reported adverse events
Hammerich et al[10]	54 patients (G1=23, G2=31) with clinical and imaging-confirmed LSS Mean age (G1=66.3, G2=67.8) Female (G1=52.2%, G2=50.0%)	G1: 8 to 10 sessions of manual therapy and mobility, aerobic, muscle endurance and stabilization exercises plus up to 3 transforaminal ESIs and education	G2: up to 3 transforaminal ESIs plus education	ODI, NPRS (pain) at 10 wk, at 6 mo and 1 y	No between-group differences in ODI. Improved pain at 6 months and 1 year favoring ESI and education. 3 adverse events reported in G2 (2 mild allergic reaction, 1 increased pain)
Ammendolia et al[26]	104 patients (G1=52, G2=52) with clinical and imaging-confirmed LSS Mean age (G1=68.9, G2=72.3) Female (G1=56%, G2=58%)	G1: inflatable belt designed to reduce lumbar lordosis	G2: generic lumbar support belt	SPWT performed when wearing the inflatable or generic belt Adverse events	No between-group difference in walking capacity Unclear adverse event reporting
Comer et al[37] (phase 1)	40 patients (G1=20, G2=20) with clinical LSS Mean age (G1=71.0, G2=70.8) Female (NR)	G1: 2 wk of walking stick use	G1: No treatment control group	ZCQ (symptom severity, physical function), VAS (leg and back pain, ODI after 2 wk	No between-group differences in any outcome
Comer et al[37] (phase 2)†	40 patients with clinical LSS Median age=70 Female (NR) (crossover trial)	G1: walking stick followed by no walking stick	G2: No walking stick followed by walking stick	Shuttle walking test during intervention	No between-condition difference in walking capacity

Abbreviations: 6MWT, 6-minute walk test. EQ5D, EuroQol-5D visual analogue scale; ESI, epidural steroid injection; FFD, Finger to Floor distance; HEP, home exercise program; NASS, North American Spine Society; NPRS, numeric pain rating scale; NR, not reported; NRS, numerical rating scale; NSAID, nonsteroidal anti-inflammatory drug; OCS, Oxford Claudication score; ODI, Oswestry Disability Index; RMDI, Roland Morris Disability Index; SSS, Swiss Spinal Stenosis; SPWT, self-paced walk-test; TENS, transcutaneous nerve stimulation; TUG, timed Up and Go test; VAS, visual analog scale; ZCQ, Zurich Claudication Questionnaire.

* Long-term follow-up.

† Crossover trial.

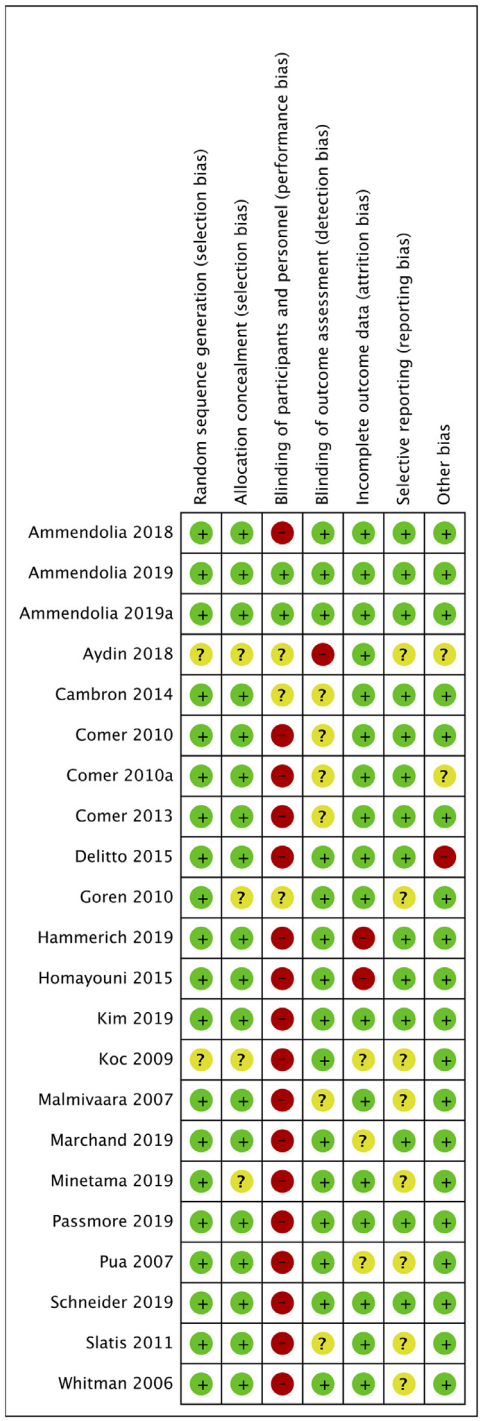

Fig 2 Risk of bias assessment.

medication, compared with epidural steroid injections, oral pain medication, heat, and transcutaneous electrical nerve stimulation.[12]

A trial with high risk of bias reported no short- or intermediate-term differences in disability, physical capacity, or pain in patients receiving ultrasound, heat, transcutaneous electrical nerve stimulation, oral nonsteroidal anti-inflammatories, and a home exercise program compared with patients receiving oral nonsteroidal anti-inflammatories and a home exercise program with or without epidural steroid injections.[13] Two adverse events were reported without identifying the treatment group or groups in which they occurred.

Passive modalities versus sham therapy

Clinically heterogeneous data from 3 trials provided mixed results. A low-risk-of-bias trial found no immediate-term difference in walking capacity between patients receiving a single session of either transcutaneous electrical nerve stimulation or sham therapy.[36] No adverse events were reported.

A high-risk-of-bias trial found improved low back and leg pain, disability, functional mobility, and quality of life favoring pulsed electromagnetic field therapy compared with sham therapy at immediate- and short-term follow-up.[27] Another high-risk-of-bias trial with incomplete and unclear outcome reporting showed no apparent between-group differences in Swiss Spinal Stenosis questionnaire scores (symptom severity and function subscales), disability, walking performance, and pain intensity in the intermediate-term and reported no adverse events.[28]

Rehabilitation versus minimal treatment

Three clinically heterogeneous high-risk-of-bias trials compared the effects of rehabilitation with minimal treatment. One trial reported improved short-term leg pain, trunk muscle strength and endurance, lumbar range of motion, and walking capacity favoring supervised exercise versus usual care.[29] No adverse events were reported. A second trial found no short- or long-term between-group differences in back pain, leg pain, symptom severity, disability, or walking tolerance between patients participating in a self-directed exercise program with advice and education, compared with advice and education alone.[30] No adverse events were reported. The third trial reported improved short-term disability and leg pain favoring 3 weeks of supervised exercise and paracetamol (as indicated) versus paracetamol (as indicated) alone with no reported adverse events.[31]

Multimodal treatment comparisons

Three clinically heterogenous trials with high risk of bias compared various therapy combinations. Short-term improvements in pain and walking capacity favored aquatic exercise versus land-based exercise and physical modalities at 8 weeks that became nonsignificant by 3 months, with no adverse events reported.[32] A second trial found no short-term differences in disability or pain between patients receiving body weight-supported treadmill walking, home exercises, heat, and traction compared to cycling exercise, home exercises, heat, and traction.[33] A third trial reported no short- or long-term differences in disability, walking capacity, or leg pain between patients receiving manual therapy, body weight-supported treadmill walking, and lumbar flexion and other exercises versus lumbar flexion exercises, treadmill walking, and subtherapeutic ultrasound therapy.[34]

Other treatment comparisons

Four trials reported the effects of other therapies. One low-risk-of-bias trial comparing spinal manipulation to no treatment found no immediate between-group differences in back pain, leg pain, or lumbar range of motion, and reported no adverse events.[35] Another low-risk-of-bias trial compared the effect of an inflatable belt to a generic lumbar support, with no immediate difference in walking capacity and unclear adverse event reporting (adverse events measured but not reported).[26]

One high-risk-of-bias trial reported no between-group differences in disability but improved pain at intermediate- and long-term

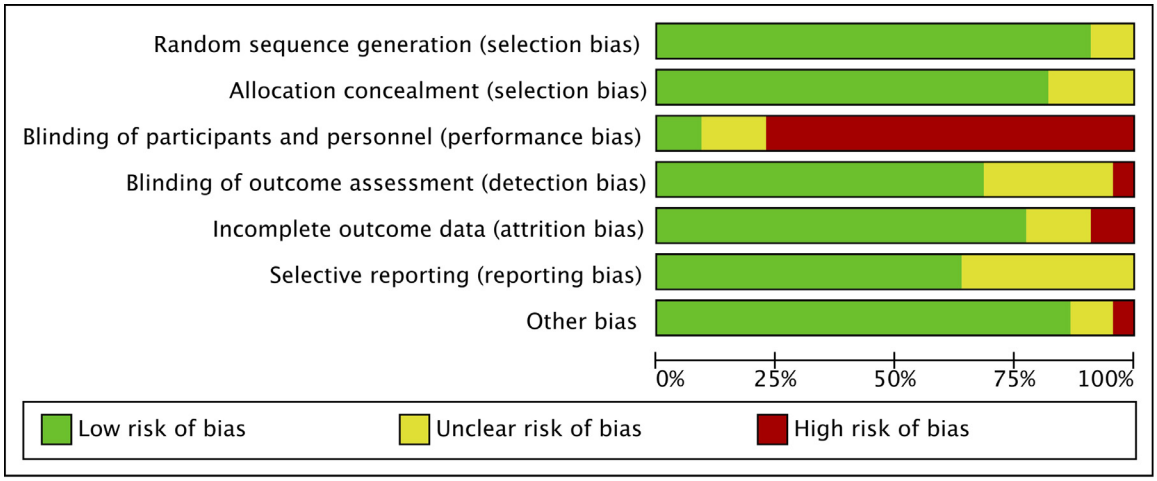

Fig 3 Review authors' judgements about each risk of bias item presented as percentages across all included studies.

Table 2 Directed exercise and manual therapy compared with self-directed or group exercise for degenerative lumbar spinal stenosis

Sample Size	Follow-Up	Mean Difference (95% CI)	Quality of the Evidence (GRADE)
Walking capacity*			
316 (3 trials[11,14,19])	short-term	293.3 (61.7-524.9)†	⊕⊕○○LOW (inconsistency,‡ imprecision§)
214 (2 trials[11,14])	intermediate-term	231.1 (−147.0 to 609.1)	⊕⊕○○ LOW (inconsistency,‡ imprecision§)
Back pain‖			
180 (2 trials[14,19])	short-term	−1.1 (−1.8 to −0.4)†	⊕⊕⊕○ MODERATE (imprecision§)
Leg pain‖			
180 (2 trials[14,19])	short-term	−0.9 (−0.2 to −1.5)†	⊕⊕⊕○ MODERATE (imprecision§)
Symptom severity¶			
326 (3 trials[11,14,19])	short-term	−0.3 (−0.2 to −0.4)†	⊕⊕○○ LOW (inconsistency,‡ imprecision§)
220 (2 trials[11,14])	intermediate-term	0.0 (−0.2 to 0.1)	⊕⊕⊕○ MODERATE (imprecision§)
Physical function#			
326 (3 trials[11,14,19])	short-term	−0.2 (0.0 to −0.4)	⊕⊕○○ LOW (inconsistency,‡ imprecision§)
220 (2 trials[11,14])	intermediate-term	−0.1 (−0.2 to 0.1)	⊕⊕⊕○ MODERATE (imprecision§)

Abbreviations: CI, confidence interval; GRADE, Grading of Recommendations Assessment, Development and Evaluation
* Measured in meters walked using the self-paced walked test.
† Statistically significant. Negative values favor directed exercise and manual therapy, except walking capacity where positive values favor directed exercise and manual therapy.
‡ I^2>50%.
§ N<400.
‖ Measured with a 0- to 10-point numeric pain rating scale.
¶ Measured with the 1- to 5-point Zurich Claudication Questionnaire symptom severity subscale. #Measured with the 1- to 4-point Zurich Claudication Questionnaire physical function subscale.

Table 3 Rehabilitation compared with surgery for degenerative LSS

Sample Size	Follow-Up	Mean Difference (95% CI)	Quality of the Evidence (GRADE)
Disability*			
245 (2 trials[23,24])	intermediate-term	3.0 (−5.7 to 11.7)	⊕○○○ VERY LOW (risk of bias,† inconsistency,‡ imprecision§)
243 (2 trials[23,24])	long-term	5.62 (−5.2 to 16.4)	⊕○○○ VERY LOW (risk of bias,† inconsistency,‡ imprecision§)

* Measured using the 0- to 100-point Oswestry Disability Index.
† >50% of sample comes from studies not rated at low risk of bias.
‡ I^2>50%.
§ N<400.

follow-up favoring epidural steroid injections and education compared with manual therapy, exercise, epidural steroid injections, and education.[10] This trial reported 3 adverse events, all among patients assigned to the epidural steroid injection and education group. Another high-risk-of-bias trial was conducted in 2 phases.[37] Phase 1 comprised a parallel-group trial reporting no immediate-term between-group differences in symptom severity, function, leg pain, back pain, or disability, with 2 weeks of walking stick

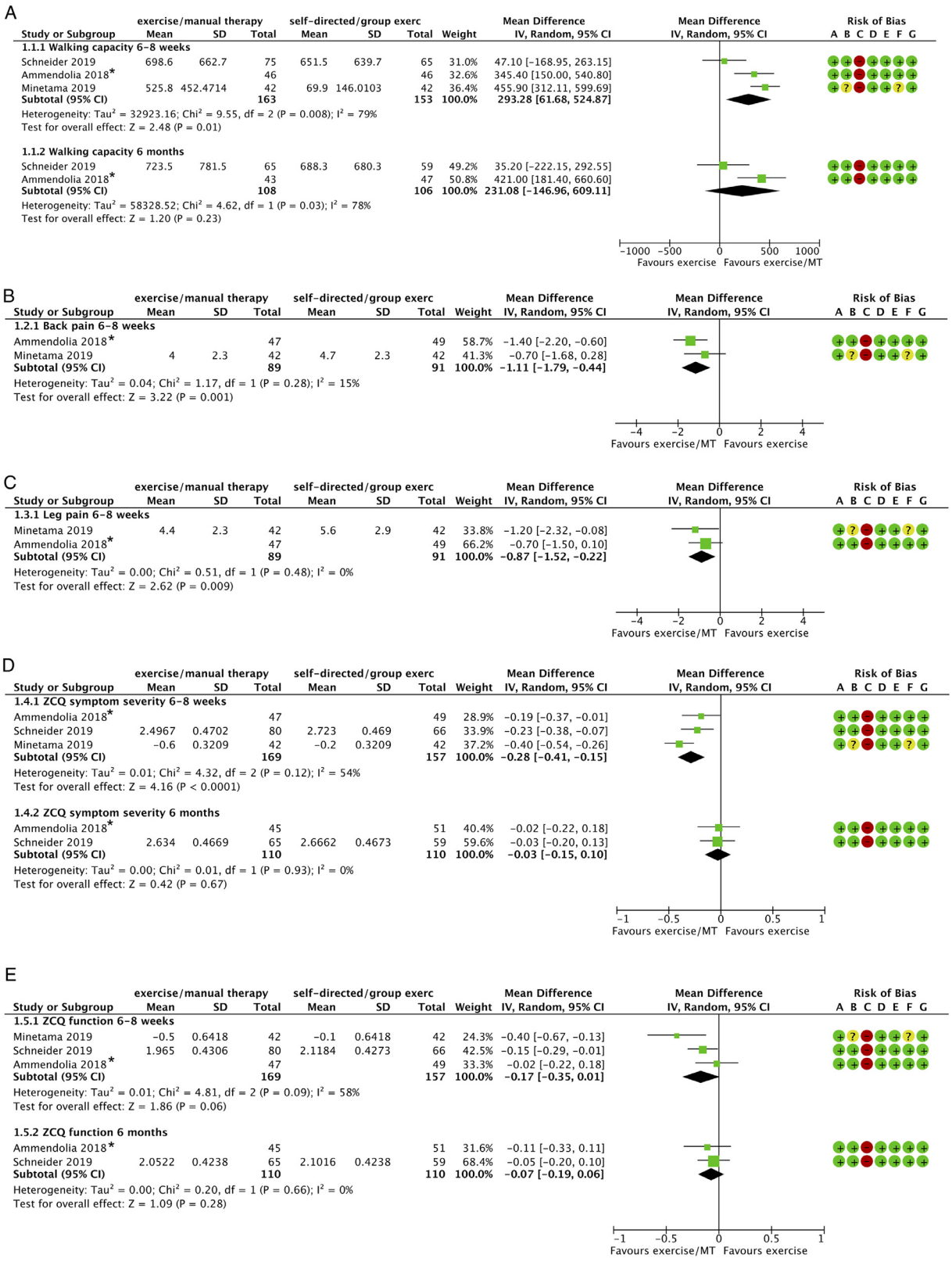

Fig 4 Exercise and manual therapy versus self-directed or group exercise outcome: (A) walking capacity at 6-8 weeks and 6 months, (B) back pain at 6-8 weeks, (C) leg pain at 6-8 weeks, (D) Zurich Claudication Questionnaire symptom severity at 6-8 weeks and 6 months, and (E) Zurich Claudication Questionnaire function at 6-8 weeks and 6 months. *Adjusted between-group mean differences reported without adjusted means and standard deviations. Risk of bias notations: random sequence generation (A), allocation concealment (B), blinding of participants and personnel (C), blinding of outcome assessment (D), incomplete outcome data (E), selective reporting (F), and other bias (G).

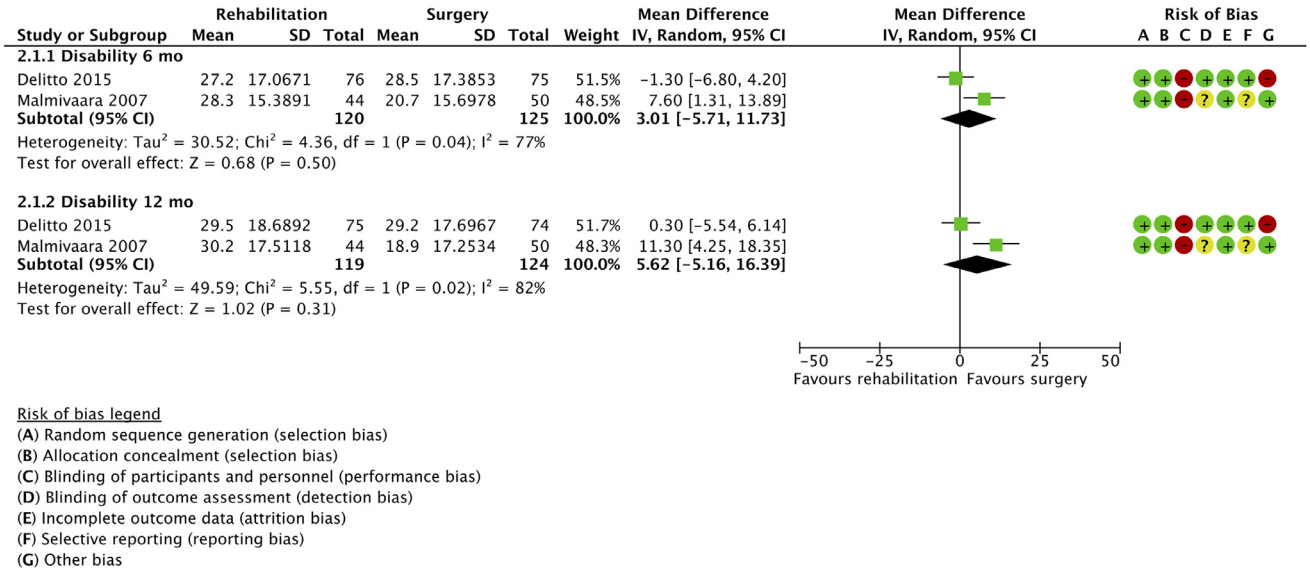

Fig 5 Rehabilitation versus surgery outcome: disability at 6 and 12 months. Risk of bias notations: random sequence generation (A), allocation concealment (B), blinding of participants and personnel (C), blinding of outcome assessment (D), incomplete outcome data (E), selective reporting (F), and other bias (G).

use compared to no treatment. Phase 2 comprised a cross-over trial showing no immediate-term change in walking capacity (shuttle walking test) with or without a walking stick.

Discussion

The findings of this systematic review provide low to moderate quality evidence that some modes of rehabilitation affect short-term outcomes for people with LSS. Meta-analyses with data from 2 or 3 trials showed that directed exercise and manual therapy is superior to self-directed or group exercise for improving short-term walking capacity (low quality evidence), back and leg pain intensity (moderate quality evidence), and symptom severity (low quality evidence). These findings support the use of manual therapy with supervised exercises for patients with LSS. However, the treatment effect estimates from our meta-analyses for back pain (1.1 points on a 0- to 10-point scale), leg pain (.9 points on a 0- to 10-point scale), and symptom severity (.3 points on a 1- to 5-point scale) were just less than thresholds for clinically important differences among patients with LSS.[20] There is no estimate for minimally important change in walking capacity. Patients and clinicians will need to judge the meaningfulness of our pooled estimate of improved walking capacity (approximately 300 m). The quality rating of this evidence means that data from future trials are likely (pain) or very likely (walking capacity, symptom severity) to change these treatment effect estimates.[21]

Pooled results from 2 trials provided very low quality evidence that rehabilitation is no better than surgery at improving intermediate- or long-term disability. The quality rating of this evidence means that the treatment effect estimates are very uncertain.[21]

Clinical heterogeneity prevented the quantitative synthesis of additional intervention contrasts. Fifteen individual trials (4 low risk of bias), evaluating a variety of therapies, provided conflicting evidence of rehabilitation effectiveness. One trial with low risk of bias reported manual therapy and acupuncture to be superior to oral pain medication, epidural steroid injections, and passive modalities[12] for pain, disability, and walking capacity. Three additional low risk of bias trials showed no immediate benefit of transcutaneous electrical nerve stimulation compared to sham stimulation[36] or an inflatable compared to a lumbar support[26] for walking capacity, as well as a single spinal manipulation compared with no treatment for pain or function.[35]

The current review findings accord with and advance the results of related systematic reviews. Two previous reviews evaluated the effectiveness of nonoperative treatments for pain, function, or walking ability.[15,38] These reviews found very low to low quality evidence that rehabilitation was not superior to various comparators for improving walking ability. Evidence from single trials suggested that rehabilitation was better than no treatment for leg pain and that treadmill walking and stationary cycling result in similar outcomes.[15] The current review included data from additional trials that allowed for the first pooled estimates of treatment effect.

Three previous systematic reviews compared the effects of surgery with conservative therapy with results consistent with the current review findings.[15,39,40] Two Cochrane reviews reported very low to low quality evidence of no intermediate- (6mo) or long-term (12mo) differences in pain-related disability between surgically treated patients and those receiving multimodal nonoperative care for LSS.[15,39] A more recent systematic review reported the same result.[40] These reviews included data from a trial identified by our systematic search.[41] However, we excluded this trial at the full-text assessment stage as rehabilitation therapies were not provided to all patients not receiving surgery. We also included trial data not available when the Cochrane reviews were performed.[23] Despite these differences, the results of the pooled analyses were consistent across all 4 reviews.

As with other common musculoskeletal conditions, relatively few trials have compared the effects of surgery with conservative interventions for LSS.[42] Trials comparing surgical with nonsurgical interventions face a number of challenges that may explain the lack of comparative effectiveness evidence. These challenges include treatment nonadherence and crossover between treatment arms: patients with severe symptoms often cross over to the surgery group, whereas patients with a preference for surgery or

conservative treatments tend to pursue their preferred treatment option, irrespective of treatment assignment.[41] Furthermore, the stark differences between surgical and conservative therapies may increase the difficulty of patient blinding. Therefore, understanding the comparative effectiveness of surgical versus conservative interventions for patients with LSS will be an important future research priority, and these trials should account for the unique challenges inherent to these treatment comparisons.

Although LSS has potential to adversely affect health-related physical activity behavior, we identified only 2 trials with a physical activity outcome. A low-risk-of-bias trial found group exercise, but not manual therapy and directed exercise, superior to medical care for increasing time in light to vigorous intensity physical activity in the short-term.[11] A high-risk-of-bias trial reported greater steps (pedometer measured) among people receiving a supervised versus self-directed exercise program.[19] Neither trial included behavior-change techniques[38] in the treatment protocols. Rehabilitation programs that include specific evidenced-based behavior change techniques might have the potential to improve physical activity behaviors and cardiovascular health in spinal stenosis patients, as has been shown in coronary heart disease patients.[43] Trials to date have focused on measures of pain, disability, and physical capacity. Although these outcomes are relevant to clinicians and patients, the systematic development of evidence-based behavior change interventions to improve physical activity behavior for patients with LSS will be an important focus for future research.

Study limitations

The strengths of this systematic review include the a priori study protocol registration, sensitive search strategy of multiple databases with supplemental searching, the use of the Cochrane tool to assess risk of bias, and the GRADE system to appraise the overall quality of the evidence. The review results should be interpreted in the context of the limitations of the review and the included trials. The outcomes reported in our a priori protocol were pain intensity, disability, physical capacity, and physical activity. We made a postprotocol decision to also include trials reporting outcomes measured with the Zurich Claudication Questionnaire (also known as the Swiss Spinal Stenosis Scale). We believed that this protocol deviation was warranted, as the constructs measured by this tool (symptom severity and function) are sufficiently similar to our predefined outcomes. We were unable to pool data for most intervention contrasts owing to important differences in study interventions, comparators, outcomes, or populations. In particular, few trials tested similar interventions and the processes of intervention development were unclear.

We rated more than 2 out of 3 (68%) of the included trials as high risk of bias, and this resulted in additional downgrading of evidence quality for the rehabilitation versus surgery contrasts. The sample sizes of included trials were generally small (median group size, 26; range, 7-86); consequently, the quality rating of all pooled estimates was downgraded for imprecision. Detailed descriptions of the treatments were often lacking, a common limitation of exercise-based intervention reporting.[44] Moreover, some intervention contrasts comprised treatments or approaches that do not reflect usual clinical practice (eg, exclusive use of passive modalities), thus limiting the utility of some trial results. Harms associated with treatment were often not reported or inconsistently reported. For example, some trials reported the number of patients who experienced an adverse event,[14] or the number of event occurrences,[11] whereas others reported events within only 1 treatment arm[24] or not at all.[19]

These findings imply that larger, low-risk-of-bias trials with detailed reporting of interventions and adverse events are warranted. Specifically, future trials should focus on a limited number of interventions, therapeutic protocols that can be easily applied by clinicians, and standard outcomes to facilitate future meta-analyses. Trials with a surgical treatment arm should address the challenges that make such comparisons particularly challenging, including treatment nonadherence and crossover, as well as difficulty with blinding.

Conclusions

For people living with LSS, there is low-to-moderate quality evidence that supervised exercise with manual therapy improves short-term walking capacity and results in small improvements in pain and symptom severity compared with self-directed or group exercise. The choice between rehabilitation and surgery for LSS is very uncertain owing to the very low quality of available evidence. Larger, high quality trials with complete reporting of interventions and adverse events are urgently needed.

Supplier

a Review Manager, version 5.3; Cochrane Training.

Keywords

Exercise; Lumbosacral region; Meta-analysis; Rehabilitation; Spinal stenosis; Systematic review

Corresponding author

Jeffrey J. Hebert, DC, PhD, University of New Brunswick, 90 Mackay Drive, Fredericton, New Brunswick, Canada E3B 5A3. *E-mail address:* J.Hebert@unb.ca.

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Appendix 1. Search strategies applied to EMBASE, MEDLINE, PsycINFO, and CENTRAL

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November 4, 2019

No.	Query	Results
#53	#8 AND #51 AND #52	**951**
#52	('randomized controlled trial' OR randomized:ab OR randomised:ab OR placebo:ab OR randomly:ab OR trial: ab OR groups:ab) NOT 'nonhuman'/exp	**3,372,699**
#51	#9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 OR #48 OR #49 OR #50	**1,271,556**
#50	'pedometer'/exp	**2,115**
#49	'lifestyle modification'/exp	**36,147**
#48	'rehabilitation'/exp	**384,662**
#47	'orthosis'/exp	**31,482**
#46	'massage'/exp	**14,379**
#45	'exercise'/exp	**334,742**
#44	'spinal brace'/exp	**595**
#43	'corset'/exp	**563**
#42	'chiropractic'/exp	**4,655**
#41	'chiropractor'/exp	**609**
#40	'spine manipulation'/exp	**586**
#39	'transcutaneous electrical nerve stimulation'/exp	**7,942**
#38	'traction therapy'/de	**12,065**
#37	'physiotherapy'/de	**86,114**
#36	'bed rest'/exp	**8,076**
#35	'conservative treatment'/de	**76,636**
#34	(strength NEAR/2 abdom*):ti,ab	**401**
#33	pedomet*:ti,ab	**3,528**
#32	'aerobic activit*':ti,ab	**933**
#31	'lifestyle modif*':ti,ab	**9,452**
#30	'lifestyle change*':ti,ab	**11,118**
#29	rehab*:ti,ab	**232,362**
#28	orthosis:ti,ab	**4,678**
#27	'massage therap*':ti,ab	**1,679**
#26	'swim therap*':ti,ab	**4**
#25	'pool therap*':ti,ab	**45**
#24	exerci*:ti,ab	**379,659**
#23	brace:ti,ab	**6,360**
#22	'abdominal corset*':ti,ab	**15**
#21	'lumbar corset*':ti,ab	**48**
#20	'non pharmacol*':ti,ab	**14,602**
#19	'non surg*':ti,ab	**18,587**
#18	chiropract*:ti,ab	**5,713**
#17	'spinal manipulat*':ti,ab	**1,817**
#16	'transcutaneous electrical nerve stimulat*':ti,ab	**2,506**
#15	tens:ti,ab	**15,231**
#14	decompression:ti,ab NOT 'surgery'/exp	**12,629**
#13	traction:ti,ab	**24,225**
#12	'physiotherap*':ti,ab	**43,708**
#11	'physical therap*':ti,ab	**32,158**
#10	'bed rest':ti,ab	**6,760**
#9	(conservative NEAR/2 treat*):ti,ab	**46,691**
#8	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7	**20,392**
#7	'radicular pain'/exp AND (lumbar:ti,ab OR spin*:ti,ab)	**2,639**
#6	'vertebral canal stenosis'/exp	**11,984**
#5	lss:ab,ti	**2,624**
#4	'lumbar radicular pain':ab,ti	**293**
#3	(lumb* NEAR/3 spondyl*):ab,ti	**2,787**
#2	(lumb* NEAR/3 stenosis):ab,ti	**5,152**
#1	(spin* NEAR/3 stenosis):ab,ti	**8,051**

MedLine @ Ovid

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1	(spin* adj3 stenosis).ab,ti.	5968
2	(lumb* adj3 stenosis).ab,ti.	3867
3	(lumb* adj3 spondyl*).ab,ti.	2112
4	"lumbar radicular pain".ab,ti.	203
5	lss.ab,ti.	1876
6	Spinal Stenosis/	5846
7	(lumb* or spin*).ab,ti. and Radiculopathy/	2934
8	1 or 2 or 3 or 4 or 5 or 6 or 7	14569
9	(conservative adj2 treat*).ab,ti.	33996
10	"bed rest".ab,ti.	5127
11	"physical therap* ".ab,ti.	21129
12	"physiotherap*".ab,ti.	24071
13	traction.ab,ti.	18097
14	decompression.mp. not exp Surgical Procedures, Operative/ [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	18939
15	tens.ab,ti.	14881
16	"transcutaneous electrical nerve stimulation".ab,ti.	1845
17	"spinal manipulat* ".ab,ti.	1658
18	"chiropract*".ab,ti.	5618
19	"non surg* ".ab,ti.	12129
20	"non pharmacol* ".ab,ti.	8878
21	"lumbar corset* ".ab,ti.	28
22	"abdominal corset* ".ab,ti.	8
23	brace.ab,ti.	4890
24	"exerci*".ab,ti.	280556
25	"pool therap* ".ab,ti.	27
26	"swim therap* ".ab,ti.	2
27	"massage therap* ".ab,ti.	1249
28	orthosis.ab,ti.	3545
29	"rehab*".ab,ti.	158561
30	"lifestyle change* ".ab,ti.	7506
31	"lifestyle modif* ".ab,ti.	6245
32	"aerobic activit* ".ab,ti.	664
33	"pedomet*".ab,ti.	2570
34	(strength adj2 abdom*).ab,ti.	309
35	Conservative Treatment/	2277
36	Bed Rest/	3882
37	exp Physical Therapy Modalities/	147009
38	Traction/	6665
39	exp Exercise/	184779
40	exp Orthotic Devices/	12654
41	rehabilitation/ or dance therapy/ or early ambulation/ or exercise therapy/ or neurological rehabilitation/ or occupational therapy/ or recreation therapy/ or rehabilitation, vocational/ or telerehabilitation/	80093
42	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41	780350
43	((randomized controlled trial or controlled clinical trial).pt. or randomized.ab. or randomised.ab. or placebo.ab. or drug therapy.fs. or randomly.ab. or trial.ab. or groups.ab.) not (exp animals/ not humans.sh.)	3963162
44	8 and 42 and 43	719

PsycINFO @ EBSCO

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#	Query	Results
S71	S68 AND S69 AND S70	19
S70	S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35 OR S37 OR S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR S47 OR S48 OR S49 OR S50 OR S51 OR S52 OR S53 OR S54 OR S55 OR S56 OR S57 OR S58 OR S59 OR S60 OR S61 OR S62 OR S63 OR S64 OR S65 OR S66 OR S67	373,420
S69	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10	483
S68	(PT("randomized controlled trial") OR AB(randomized OR randomised OR placebo OR randomly OR trial OR groups)) NOT (MH "Animals+")	1,003,216
S67	DE "Behavior Change" OR DE "Readiness to Change" OR DE "Stages of Change" OR DE "Lifestyle Changes"	14,597
S66	DE "Rehabilitation" OR DE "Cognitive Rehabilitation" OR DE "Criminal Rehabilitation" OR DE "Neuropsychological Rehabilitation" OR DE "Neurorehabilitation" OR DE "Occupational Therapy" OR DE "Physical Therapy" OR DE "Psychosocial Rehabilitation" OR DE "Rehabilitation Centers" OR DE "Telerehabilitation"	40,495
S65	DE "Massage"	673
S64	DE "Hydrotherapy"	85
S63	DE "Exercise" OR DE "Aerobic Exercise" OR DE "Weightlifting" OR DE "Yoga"	31,187
S62	DE "Physical Therapy"	2,720
S61	AB strength N2 abdom*	32
S60	TI strength N2 abdom*	1
S59	AB pedometer*	807
S58	TI pedometer*	157
S57	AB "aerobic activit*"	154
S56	TI "aerobic activit*"	22
S55	AB "lifestyle modif*"	648
S54	TI "lifestyle modif*"	104
S53	AB "lifestyle change*"	1,944
S52	TI "lifestyle change*"	246
S51	AB rehab*	51,551
S50	TI rehab*	17,714
S49	AB orthosis	255
S48	TI orthosis	98
S47	AB "massage therap*"	367
S46	TI "massage therap*"	137
S45	AB "swim therap*"	0
S44	TI "swim therap*"	0
S43	AB "pool therap*"	5
S42	TI "pool therap*"	1
S41	AB exerci*	62,472
S40	TI exerci*	15,394
S39	AB brace	255
S38	TI brace	34
S37	AB "abdominal corset*"	0
S36	TI "abdominal corset*"	0
S35	AB "lumbar corset*"	1
S34	TI "lumbar corset*"	0
S33	AB "non pharmacol*"	2,335
S32	TI "non pharmacol*"	310
S31	AB "non surg*"	293
S30	TI "non surg*"	44
S29	(TI(decompression) OR AB(decompression)) NOT (DE "Surgery" OR DE "Postsurgical Complications" OR DE "Sterilization (Sex)" OR DE "Transection" OR DE "Amputation" OR DE "Bariatric Surgery" OR DE "Circumcision" OR DE "Cochlear Implants" OR DE "Colostomy" OR DE "Dental Surgery" OR DE "Endocrine Gland Surgery" OR DE "Gender Reassignment" OR DE "Heart Surgery" OR DE "Hysterectomy" OR DE "Induced	443

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#	Query	Results
	Abortion" OR DE "Neurosurgery" OR DE "Organ Transplantation" OR DE "Plastic Surgery" OR DE "Stereotaxic Techniques")	
S28	AB chiropract*	401
S27	TI chiropract*	103
S26	AB "spinal manipulat*"	66
S25	TI "spinal manipulat*"	22
S24	AB "transcutaneous electrical nerve stimulation"	269
S23	TI "transcutaneous electrical nerve stimulation"	142
S22	AB tens	214,431
S21	TI tens	5,539
S20	AB traction	715
S19	TI traction	47
S18	AB physiotherap*	2,903
S17	TI physiotherap*	528
S16	AB "physical therap*"	3,244
S15	TI "physical therap*"	779
S14	AB "bed rest"	349
S13	TI "bed rest"	81
S12	AB conservative N2 treat*	449
S11	TI conservative N2 treat*	43
S10	AB lss	324
S9	TI lss	15
S8	AB "lumbar radicular pain"	18
S7	TI "lumbar radicular pain"	8
S6	AB (lumb* N3 spondyl*)	23
S5	TI (lumb* N3 spondyl*)	10
S4	AB (lumb* N3 stenosis)	68
S3	TI (lumb* N3 stenosis)	34
S2	AB (spin* N3 stenosis)	126
S1	TI (spin* N3 stenosis)	41

Cochrane CENTRAL
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ID	Search	Hits
#1	(spin* NEAR/3 stenosis)	1129
#2	lumb* NEAR/3 stenosis	778
#3	lumb* NEAR/3 spondyl*	336
#4	lumbar radicular pain	95
#5	lss	305
#6	MeSH descriptor: [Spinal Stenosis] explode all trees	356
#7	MeSH descriptor: [Radiculopathy] explode all trees	393
#8	#7 AND (lumb* OR spin*)	318
#9	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #8	1907
#10	conservative NEAR/2 treat*	5507
#11	bed rest	1452
#12	physical therap*	64
#13	physiotherap*	17512
#14	decompression	2964
#15	MeSH descriptor: [Surgical Procedures, Operative] explode all trees	114011
#16	#14 NOT #15	2149
#17	traction	1918
#18	tens	2021
#19	transcutaneous electrical nerve stimulation	1801
#20	spinal manipulat*	0
#21	chiropract*	1273
#22	non surg*	7
#23	non pharmacol*	2

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ID	Search	Hits
#24	lumbar corset*	8
#25	abdominal corset*	4
#26	brace	1316
#27	exerci*	94566
#28	pool therap*	0
#29	swim therap*	0
#30	massage therap*	0
#31	orthosis	1210
#32	rehab*	62102
#33	lifestyle change*	680
#34	lifestyle modif*	4
#35	aerobic activit*	1
#36	pedometer*	1551
#37	strength NEAR/2 abdom*	104
#38	MeSH descriptor: [Conservative Treatment] explode all trees	92
#39	MeSH descriptor: [Bed Rest] explode all trees	447
#40	MeSH descriptor: [Physical Therapy Modalities] explode all trees	23520
#41	MeSH descriptor: [Traction] explode all trees	197
#42	MeSH descriptor: [Braces] explode all trees	406
#43	MeSH descriptor: [Exercise] explode all trees	22647
#44	MeSH descriptor: [Rehabilitation] explode all trees	33047
#45	#10 OR #11 OR #12 OR #13 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44	168442
#46	#9 AND #45	846

Appendix 2. Reasons for study exclusion (ordered by study reference)

Study	Reason for Exclusion
Abdu, W. A., Sacks, O. A., Tosteson, A. N. A., Zhao, W., Tosteson, T. D., Morgan, T. S., Pearson, A., Weinstein, J. N., & Lurie, J. D. (2018). Long-Term Results of Surgery Compared With Nonoperative Treatment for Lumbar Degenerative Spondylolisthesis in the Spine Patient Outcomes Research Trial (SPORT): *SPINE, 43*(23), 1619—1630. https://doi.org/10.1097/BRS.0000000000002682	Wrong therapy
Akuthota, V., Hammerich, A. S., Mintken, P. E., Cleland, J. A., Whitman, J. M., Singh, J. R., Knight, E., & Santo, K. J. (2012). Effectiveness of Physical Therapy as an Adjunct to Epidural Steroid Injections in the Treatment of Lumbar Spinal Stenosis: A Pilot Randomized Controlled Trial. *The Spine Journal, 12*(9), S146. https://doi.org/10.1016/j.spinee.2012.08.379	Wrong publication type
Ammendolia, C., Cote, P., Southerst, D., Schneider, M., Budgell, B., Bombardier, C., Hawker, G., & Rampersaud, Y. (2017a). Improving walking ability in degenerative lumbar spinal stenosis: A randomized trial comparing 2 self-management training programs. *Arthritis & Rheumatology, 69*(0).	Wrong publication type
Ammendolia, C., Cote, P., Southerst, D., Schneider, M., Budgell, B., Bombardier, C., Hawker, G., & Rampersaud, Y. (2017b). Non-operative management of lumbar spinal stenosis: A randomized controlled trial comparing a comprehensive vs. A self-directive approach. *Chiropractic & Manual Therapies, 25*(0).	Wrong publication type
Amundsen, T., Weber, H., Nordall, H. J., Magnaes, B., Abdelnoor, M., & Lilleås, F. (2000). Lumbar spinal stenosis: Conservative or surgical management? A prospective 10-year study. *Spine, 25*(11), 1424—1436.	Wrong outcome

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Study	Reason for Exclusion
Anderson, P. A., Tribus, C. B., & Kitchel, S. H. (2006). Treatment of neurogenic claudication by interspinous decompression: Application of the X STOP device in patients with lumbar degenerative spondylolisthesis. *Journal of Neurosurgery: Spin, 4*(6), 463–471.	Wrong therapy
Chang, C.-W., Lee, S.-T., Chen, C.-Y., & Lin, Y.-H. (2015). Functional recovery of early rehabilitation in the elderly patients after lumbar decompression surgery: A short-term follow up. *Physiotherapy, 101*, e212. https://doi.org/10.1016/j.physio.2015.03.379	Wrong publication type
Chantraine, A., Fournier, P. E., & Barbezat, S. (1992). Lumbar traction for treatment of lumbar spine stenosis. *Annales de Readaptation et de Medecine Physique, 35*(5), 403–405.	Wrong study design
Kaulhausen, T., Knoell, P., Stein, G., Siewe, J., Hellmich, M., Otto, C., Sayar, A., Yagdiran, A., Beyer, F., Zarghonni, K., Eysel, P., & Sobottke, R. (2012). Efficacy of an interspinous decompression device versus nonoperative treatment for lumbar spinal stenosis: An example for a randomized, controlled trial. *Clinical Investigation, 2*(12), 1163–1169. https://doi.org/10.4155/cli.12.128	Wrong study design
Konstantinovic, L. M., Kanjuh, Z. M., Milovanovic, A. N., Cutovic, M. R., Djurovic, A. G., Savic, V. G., Dragin, A. S., & Milovanovic, N. D. (2010). Acute Low Back Pain with Radiculopathy: A Double-Blind, Randomized, Placebo-Controlled Study. *Photomedicine and Laser Surgery, 28*(4), 553–560. https://doi.org/10.1089/pho.2009.2576	Wrong population
Lurie, J. D., Tosteson, T. D., Tosteson, A., Abdu, W. A., Zhao, W., Morgan, T. S., & Weinstein, J. N. (2015). Long-term Outcomes of Lumbar Spinal Stenosis: Eight-Year Results of the Spine Patient Outcomes Research Trial (SPORT). *Spine, 40*(2), 63–76. https://doi.org/10.1097/BRS.0000000000000731	Wrong therapy
Mu, W., Shang, Y., Mo, Z., & Tang, S. (2018). Comparison of two types of exercises in the treatment of lumbar spinal stenosis. *Pakistan Journal of Medical Sciences, 34*(4). https://doi.org/10.12669/pjms.344.15296	Wrong outcome
Schnake, K. J., Schreyer, S., & Disselhorst-Klug, C. (2018a). Impact of a newly developed flexion orthosis on clinical parameter in patients with neurogenic claudication. A prospective randomized trial. *Global Spine Journal, 8*(1), 330S.	Wrong publication type
Schnake, K. J., Schreyer, S., & Disselhorst-Klug, C. (2018b). Short-term effects of conservative treatment of lumbar spinal stenosis with a dynamic flexion orthosis. A prospective randomized trial. *European Spine Journal, 27*(11), 2900.	Wrong publication type
Traistaru, M. R., Rogoveanu, O., & Popescu, R. (2013). Benefits of rehabilitation program in patients with l5-s1 degenerative foraminal stenosis. *Annals of Rheumatic Diseases, 72*(0).	Wrong publication type
Ürper, S., Günaydin, R., Karatepe, A. G., & Kaya, T. (2011). Effects of physical therapy and exercise program on clinical findings, functional status and disability in patients with lumbar spinal stenosis. *Turkiye Fiziksel Tip ve Rehabilitasyon Dergisi, 57*(0), 248.	Wrong publication type
Weinstein, James N, Lurie, J. D., Tosteson, T. D., Zhao, W., Blood, E. A., Tosteson, A. N., Birkmeyer, N., Herkowitz, H., Longley, M., Lenke, L., Emery, S., & Hu, S. S. (2009). Surgical Compared with Nonoperative Treatment for Lumbar Degenerative Spondylolisthesis: Four-Year Results in the Spine Patient Outcomes Research Trial (SPORT) Randomized and Observational Cohorts. *The Journal of Bone and Joint Surgery-American Volume, 91*(6), 1295–1304. https://doi.org/10.2106/JBJS.H.00913	Wrong therapy
Weinstein, J. N., Lurie, J. D., Tosteson, T. D., Hanscom, B., Tosteson, A. N., Blood, E., Birkmeyer, N. J. O., Alan, S., Herkowitz, H., Cammisa, F., Albert, T., Emery, S., Lenke, L., Abdu, W. A., Longley, M., Errico, T., & Hu, S. S. (2007). Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. *The New England Journal of Medicine, 356*(22), 2257–2270.	Wrong therapy

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Study	Reason for Exclusion
Weinstein, J.N., Tosteson, T. D., Lurie, J. D., Tosteson, A., Blood, E., Herkowitz, H., Cammisa, F., Albert, T., Boden, S. D., Hilibr, A., Goldberg, H., Berven, S., & An, H. (2010). Surgical versus nonoperative treatment for lumbar spinal stenosis four-year results of the spine patient outcomes research trial. *Spine, 35*(14), 1329—1338	Wrong therapy
Weinstein, J.N., Tosteson, T. D., Lurie, J. D., Tosteson, A. N., Hanscom, B., Herkowitz, H., Cammisa, F., Albert, T., Boden, S. D., & Hilibr, A. (2008). Surgical versus nonsurgical therapy for lumbar spinal stenosis. *New England Journal of Medicine, 358*(8), 794—810.	Wrong therapy