Therapeutic exercise and manual therapy for persons with lumbar spinal stenosis

Lumbar spinal stenosis (LSS) may produce disabling back and leg pain, and is the leading cause of surgery in adults over 65 years old. No reviews have summarized the effects of manual therapy and therapeutic exercise for these patients. The objective of this article is to examine the design and effectiveness of therapeutic exercise and manual therapy for patients with LSS, and to identify the state of evidence for these interventions on pain, disability, function and impairments in patients with LSS. In the report, three physical therapists each evaluated the methodological quality of 11 studies obtained from a systematic search of computerized databases. Patients involved in the studies were subjects aged 40–80 years with low back and leg pain, and diagnosed with LSS for 1 month or more; with exercise or manual therapy as the primary intervention; and any type of study design. Non-English articles, dissertations, unpublished data and studies using steroid injections, surgery or medications such as muscle relaxants, or studies comparing modalities (i.e., ultrasound and electrical stimulation) with exercise were excluded. Interventions included aerobic, strengthening, stabilization, flexibility, balance exercise and manual therapy. The measurements used were the MacDermid's scale and the Sackett's Level of Evidence. Results from the study indicated that two of seven studies (28.5%) were classified as high-quality trials; two (28.5%) as moderate quality and three (43%) as low-quality studies. All studies demonstrated decreases in pain and disability and improvement in overall function and participation. A limitation of the report was that the studies were heterogeneous. Furthermore, only two studies were high-level randomized controlled trials. In conclusion, most studies assessed the benefits of mixed exercise interventions, rather than a single mode of exercise. Therapeutic exercises such as aerobic training, flexibility, strengthening exercise and manual therapy produce small-to-modest effects for pain, disability and function in patients with mild-to-moderate LSS. Aerobic exercise in combination with flexibility, strengthening exercise and manipulation may be more effective than aerobic, strengthening exercise, flexibility exercise or manual therapy alone.

KEYWORDS: degenerative ▪ lumbar spine ▪ manipulation ▪ stenosis ▪ therapeutic exercise

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Lumbar spinal stenosis (LSS) is a slowly progressing disease effecting five in 1000 adults older than 50 years in the USA and is the leading cause of surgery in adults 65 years and older [1,2]. LSS, defined as a narrowing of the spinal canal, can be classified based on its etiology as either congenital or acquired [2–4]. A congenitally narrowed spinal canal may result from shortened pedicles, thickened lamina and facets, or from congenital scoliosis or lordosis. Acquired LSS most commonly results from degenerative changes such as facet joint hypertrophy, spine osteoarthritis, intervertebral disc herniation, spondylolisthesis and degenerative disc disease [4–6]. LSS can also be classified based on anatomical location as either central or lateral stenosis [3].

Narrowing of the spinal canal is associated with low back and leg pain, numbness and fatigue in the legs [7,8]. This characteristic pattern of symptoms associated with LSS is termed 'neurogenic claudication'. Symptoms are posture-dependent [3,7,8], and pain is often aggravated by walking, prolonged standing or lying prone and relieved by sitting and lying down [1–3,7–10]. Patients with LSS frequently experience low back pain, maintain a stooped standing posture, experience lumbar spine stiffness and lumbar and hip decreased range of motion and muscle tightness [1,4,7]. Sensory deficits, motor weakness and pathological reflexes appear with walking. Elderly patients with severe stenosis have restricted walking capacity and exercise intolerance, leading to decreased function and quality of life [5,6,7,11,12].

Interventions for LSS include surgical or conservative approaches. Studies have compared the effects of surgical versus nonsurgical management [2,9,12–15]. Data indicate decompressive surgery is effective for 80% of patients with severe symptoms [9,11,13,15]. Although surgical treatments offer early symptomatic relief, nonsurgical interventions are recommended owing to the risks

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associated with surgery in the elderly and may be more cost-effective [1,15]. In 1987, the total annual inpatient cost for surgery in LSS was estimated to be approximately US$1 billion [2,9]. Therefore, nonoperative/conservative interventions are used in the initial stages of LSS [1,5,9,10,16] and are a preferred alternative to surgery for mild-to-moderate symptoms of LSS [2,3,7,17,18].

Nonoperative treatments include a combination of medications, bed-rest, epidural steroid injections, physical therapy and therapeutic exercise (e.g., aerobic conditioning, strengthening, stretching, lumbar stabilization exercises, spinal manipulation and mobilization, posture and balance training, physical modalities, braces, traction, and transcutaneous electrical nerve stimulation). Although nonsurgical treatments cannot change the underlying pathology, some patients report improvement in symptoms following treatment [18].

Therapeutic exercise is commonly prescribed for patients with mild-to-moderate symptoms [15,17,18]. Exercises focus on modifying the position of the lumbar spine, hence reducing spinal cord narrowing and decreasing the chance of nerve compression. As spinal extension causes a 20% reduction in the intervertebral foraminal cross-sectional area in the normal and degenerative spine [2,3,8], flexion-based lumbar stabilization exercises along with abdominal strengthening are encouraged [7,12,15,17]. Aerobic exercises such as treadmill walking with bodyweight support, cycling and swimming are prescribed in patients with back disorders [2,3,7,17,19–21]. Cycling places the lumbar spine in a flexed position, thereby increasing the intervertebral cross sectional area, and is better tolerated than walking [17,22].

Manual therapy includes manipulation and mobilization of tight structures as well as spinal stabilization to restore normal function [8]. Normal spinal mobility can be attained by stretching the tight structures such as hip flexors, adductors and myofascial tissues [8,10,21]. Postural exercises encourage lumbar flexion and flatten the lordotic curve [9,10,16]. Aqua therapy or pool exercises are also recommended because the physical properties of water minimize stress on the spine [3,10]. In a study examining the natural history of 32 untreated patients with LSS (mean age: 60 years) Johnsson *et al.* noted that symptoms remained constant in 70% of patients and worsened in 15% of patients [23]. Thus, exercise and physical therapy are recommended to manage symptoms. Simotas *et al.* suggest using epidural steroid injections prior to initiating physical therapy to reduce pain and enhance subject participation in exercise [19,20].

The Maine Lumbar spine study is a large prospective study examining long-term outcomes (4 and 8–10 years) of patients with LSS following surgical and nonsurgical interventions [14,21]. It reported that patients treated nonsurgically have decreased back and leg pain. Although nonsurgical treatment proved to be relatively effective in this cohort, there is no indication of the type of therapeutic exercise used. Also, the nonconservative group included interventions other than therapeutic exercise; therefore, the effect of therapeutic exercise alone on the improvement of symptoms cannot be determined.

This article examines the state of the evidence for therapeutic exercise and manual therapy for the conservative management of LSS, and describes the effects of these interventions on select outcomes. A few studies have compared the efficacy of surgical and nonsurgical treatments for LSS, but the exclusive effects of therapeutic exercise or manual therapy have not been addressed widely. This systematic review addresses the following guiding questions:

- What is the effect of strengthening, balance, postural and aerobic exercise on function, disability and impairments in patients with degenerative LSS?
- Which mode of exercise is most beneficial to manage the symptoms of LSS?

Methods

Definition of terms

For the purposes of this study, therapeutic exercise is defined as exercises that include aerobic, strengthening/stabilization and flexibility exercises, and endurance training, as well as manual therapy including mobilization and manipulation and postural exercises. Manual therapy includes manipulation and mobilization of the tight structures, and stabilization of the spine to restore normal function [8].

Search strategy

We searched medical literature published between January 1950 and March 2008. Specifically, we searched Medline 1950 to March 2008, Cumulative Index to Nursing & Allied Health Literature (CINAHL) 1982 to February week 4 2008, EBM Reviews Cochrane Database of Systematic Review 4th Quarter 2008, EBM Reviews-American College of Physician Journal Club (ACP) 1991 to January/February

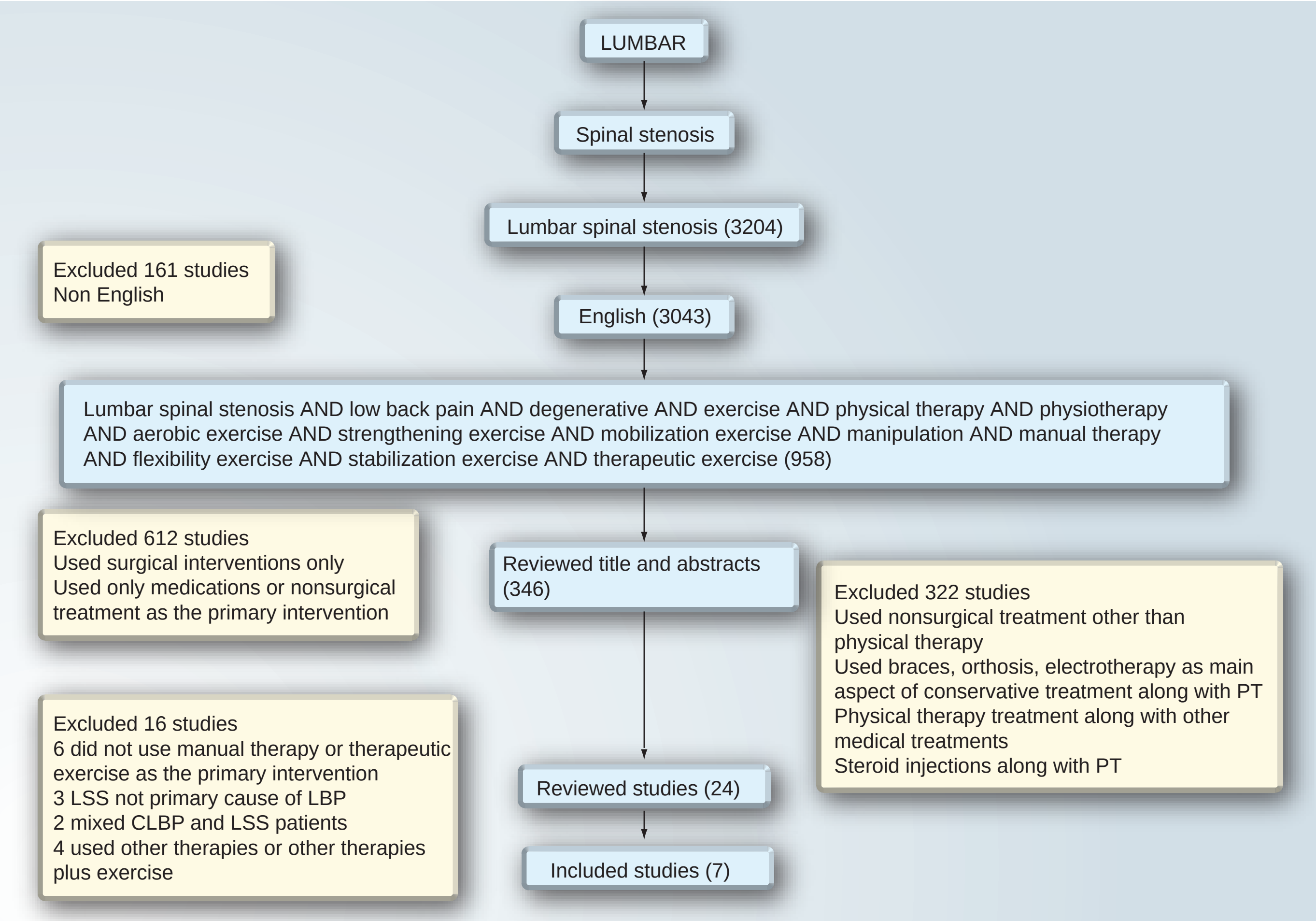

Figure 1. Article selection process.
CLBP: Chronic low back pain; LBP: Low back pain; LSS: Lumbar spinal stenosis; PT: Physical therapy.

2008, Database of Abstracts of Reviews of Effect (DARE) 1st Quarter 2008, PubMed to December 2009 and Physical therapy Evidence Database (PEDro). In each database, we used the search term *spinal stenosis* together with combinations of the following terms: *lumbar, lumbar spine, degenerative, physiotherapy, physical therapy, therapeutic exercise, aerobic exercise, endurance exercise, strengthening exercise* and *flexibility exercise*. We extended our search by reviewing the bibliographies of relevant publications.

Study selection

Papers that met the following criteria were included:

- Evaluated therapeutic exercise or manual therapy;
- Male and/or female subjects aged between 40 to 80 years;
- Subjects had a history of low back pain with or without radiating symptoms for 1 month or longer;
- Subjects had evidence of lumbar LSS on MRI or radiograph or a diagnosis of LSS by an orthopedic specialist or physician;
- Pain, disability and function were assessed;
- Available in English.

Any type of study design was accepted. Studies were excluded if they included surgical, orthopedic support devices or pharmacological interventions, compared physical modalities (e.g., heat, electrical stimulation and traction) to exercise and or manual therapy, assessed postoperative exercise or merely described the natural history of LSS.

Three reviewers (VC, SP and MDI) independently read and scored the studies using a standardized data abstraction form based on the MacDermid's quality rating scale (developed by Joy MacDermid in 2004) [24] and the Sackett's level of evidence [102,103]. Information extracted from the studies included: design, setting, sample demographics, intervention and

Table 1. Studies originally included based on review of abstract but excluded from the review after more detailed review of the study.

Study (year)	Reason for exclusion	Ref.
Onel *et al.* (1993)	Surgery versus conservative interventions	[36]
Freburger *et al.* (2006)	Mixed diagnoses and use of injections	[37]
Iversen *et al.* (2003)	Mixed LSS and CLBP patients	[38]
Hurri H *et al.* (1998)	Surgery and conservative interventions	[39]
Amundsen *et al.* (2000)	Surgery versus conservative interventions	[40]
Athiviraham *et al.* (2007)	Surgery versus conservative	[41]
Tadokoro *et al.* (2005)	Mixed conservative interventions	[42]
Atlas *et al.* (2005)	Mixed conservative interventions	[21]
Atlas *et al.* (2000)	Mixed conservative interventions	[14]
Joffe *et al.* (2002)	Single LBP not LSS patient	[43]
Critchley *et al.* (2007)	CLBP patients	[44]
Badke *et al.* (2006)	LBP patients and used cold or heat intervention	[45]
Simotas (2001)	Review – mixed conservative interventions included	[46]
Hurwitz *et al.* (2002)	Other conservative interventions included	[47]
Shabat *et al.* (2007)	Other conservative interventions included	[48]
Cleland *et al.* (2006)	Protocol – CLBP patients	[49]
Sculco *et al.* (2001)	Mixed LSS and LBP patients	[50]

CLBP: Chronic low back pain; LBP: Low back pain; LSS: Lumbar spinal stenosis.

control program features, data sources analysis and results. Discord between scoring aspects of the studies was resolved by further review of the studies and discussion among the reviewers. All the reviewers were trained in the use of these scales. The quality of the intervention and study design was evaluated and graded using the MacDermid Scale; this scale consists of 24 items and seven domains and is designed specifically for all study types [24]. The domains include: study description, study design, subject selection, intervention, outcomes, analysis and study recommendations. Each item was scored on a scale of 0, 1 or 2, yielding a maximum score of 48. The higher the score, the better the methodological quality of the study. A study score of 35 and above indicates high-quality studies, scores of 25–34 were classified as moderate-level studies and the studies that were scored below 24 were categorized as low-level studies. A 5-point grading scale developed by Sackett was also used to evaluate the evidence of the studies.

We inspected the results of each study to determine whether the intervention improved outcomes. Unfortunately, outcome measures and study designs were too heterogeneous to combine studies in a meta-analysis. Thus, percentage change in primary outcomes (pain, function and disability) were calculated to allow for a crude comparison across studies. Effect sizes were also calculated for outcomes from randomized controlled trials using standard equations [101].

Results

The study selection process is summarized in Figure 1. The search strategy identified 3204 articles with the term LSS. Of these, 958 were potentially relevant studies assessing the impact of therapeutic exercise and manual therapy. We reviewed all titles and abstracts, and subsequently excluded 934 studies that did not meet our inclusion criteria or were duplicates. We thoroughly reviewed the 24 remaining studies. After reviewing the full text of 24 articles, seven studies met the inclusion criteria [17,25–30]. Of these seven, two studies used radiology reports plus physician diagnosis to confirm LSS [17,25]. A total of 17 studies were excluded for the following reasons: the studies used surgery, medications and/or steroid injections in the design, assessed the impact of modalities as the primary intervention, did not recruit patients with LSS, or recruited patients with LSS and chronic low back pain, but did not report results separately for persons with LSS. The excluded studies are listed in Table 1.

Study characteristics

The general characteristics of the selected studies are summarized in Tables 2 & 3. Although our database search included articles published since 1950, the publication dates of all included studies were between the years 1993 and 2007. The methodological quality scores and the level of evidence of the included studies are provided in Table 4. Of seven included studies, two were randomized controlled trials [17,25], one was a prospective cohort [30] and four were case series/reports [26–29]. Study characteristics such as location, setting and sample size varied. Mean ages of subjects ranged from 58 to 72 years.

A wide variety of therapeutic exercise interventions were assessed in the seven studies. Most studies evaluated the effects of mixed interventions such as aerobic exercise in combination with flexibility exercise and manipulation/manual techniques [17,25–30]. One study assessed the impact of two different aerobic exercise interventions [25], one study provided an aerobic intervention in water [29], three studies incorporated manual therapy with exercise [17,26,30] and three studies assessed strengthening exercises as the primary mode of intervention [26–28]. The studies were divided into three groups: comparison of aerobic interventions, mixed interventions and individual interventions.

Two of seven studies (28.5%) were classified as high-quality trials using MacDermid's scale (scores of 40/48) and Sackett's level-1b;

Table 2. Characteristics and outcomes of studies of aerobic exercise alone or combined exercise and manual therapy for persons with lumbar spinal stenosis.

Study	Design	Subjects	Mean age (years)	Primary intervention	MacDermid/ Sackett's scores	Results	Ref.
Comparison of two modes of aerobic exercise							
Pua *et al.* (2007)	RCT	n = 68	58	Both groups received heat, traction in Fowler position at 30:10-s on/off cycle and 30–40% of bodyweight and shortwave diathermy to mobilize spine, plus performed home flexion and neural mobilization exercises daily for 6 weeks Rx 1: Treadmill with bodyweight support at 30–40% of bodyweight for 30 min, progressing from a gentle pace to pace at a BORG rating of 11 to 15 twice a week for 6 weeks Rx 2: Cycling on upright stationary bicycle at 50–60 rpm for 30 min twice a week for 6 weeks	40/1b	No difference between two groups: OSW ($p = 0.44$) and RMDQ ($p = 0.31$) Overall reduction: significant ($p = 0.001$) At week 3, test group perceive benefit two-thirds as often as control group Test group: 17% improvement in pain, 22% improvement in disability Control group: 16% improvement in pain, 28% improvement in disability	[25]
Combined manual therapy and therapeutic exercise interventions							
Whitman *et al.* (2006)	RCT	n = 58	70	Duration: twice a week for 6 weeks Rx 1: Flexion exercises, three repetitions for 30 s plus weight-supported treadmill walking for a max of 45 min (FExWG) Rx 2: Manual physical therapy consisting of thrust and nonthrust manipulation of the spine and lower extremity (three bouts of 30 s each), and manual stretching (three repetitions of 30 s each), flexion exercises plus treadmill walking with bodyweight support, as tolerated (MPTExWG)	40/1b	Mean improvement at 6 weeks: OSW: FExWG: 6.55; MPTExWG: 10.48 SSS: FExWG: 2.03; MPTExWG: 1.57 Walking: FExWG: 176.5 m; MPTExWG: 339.7 m NPRS: FExWG: 1.1; MPTExWG: 1.5 Mean improvement at 1 year: OSW: FExWG: 5.03; MPTExWG: 7.14 SSS: FExWG: 1.99; MPTExWG: 1.73 Walking: FExWG: 130.4 m; MPTExWG: 209.8 m NPRS: FExWG: 1.2; MPTExWG: 1.0 FExWG: 20% improvement in pain, 16% improvement in disability and 28% improvement in function MPTExWG: 30% improvement in pain, 29% improvement in disability and 50% improvement in function	[17]

FExWG: Flexion exercise and walking group; FLE: Flexibility exercise; MPTExWG: Manual physical therapy exercise and walking group; NPRS: Numerical Pain Rating Scale; OSW: Modified Oswestry Disability Index; RCT: Randomized clinical trial; RMDQ: Roland–Morris Disability Questionnaire; SSS: Satisfaction Subscale of Spinal Stenosis.

Table 2. Characteristics and outcomes of studies of aerobic exercise alone or combined exercise and manual therapy for persons with lumbar spinal stenosis.

Study	Design	Subjects	Mean age (years)	Primary intervention	MacDermid/ Sackett's scores	Results	Ref.
Comparison of two modes of aerobic exercise							
Whitman *et al.* (2003)	Case series	n = 3	72	FLE, strengthening and walking (nine to ten visits)	20/4	OSW score improved from ranges 66 to 95% and 33 to 82% from baseline to discharge and at follow-up Modified SSS scored improved to range 1.0 to 2.6 and 0.9 to 2.6 from baseline to discharge and at follow-up, respectively Symptom Severity Scale: improvement from 0.76 to 1.85 at discharge and 0.14 to 1.29 at follow-up 33% improvement in pain, 76% improvement in disability and 56% improvement in function	[26]
Fritz *et al.* (2006)	Case series	n = 2	67	FLE, strengthening and walking (three- to four-times per day for 6 weeks)	18/4	Both patients showed significant improvement in lumbar range of motion and ambulation Significant improvement in the muscle-force production of the gluteus maximus in the female and the quadriceps femoris muscle in the male 90% improvement in pain and 84% in disability	[27]
Greenman (2006)	Case series	n = 15	70	Balance, FLE, strengthening and aerobic exercise four times every week	15/4	▪ Walking tolerance improved in all patients ▪ Initial evaluation: 40% of patients were at grade 1 and 60% patients were at grade 2 ▪ Post-treatment: 20% were at grade 3 and 80% were at grade 4 level ▪ Overall: 57% improvement in function was achieved ▪ Visual analog scale: >75% of patients reported good improvement ▪ 25–75% reported a fair amount of improvement and <25% reported poor amount of pain relief	[28]

FExWG: Flexion exercise and walking group; FLE: Flexibility exercise; MPTExWG: Manual physical therapy exercise and walking group; NPRS: Numerical Pain Rating Scale; OSW: Modified Oswestry Disability Index; RCT: Randomized clinical trial; RMDQ: Roland–Morris Disability Questionnaire; SSS: Satisfaction Subscale of Spinal Stenosis.

Table 3. Characteristics of studies assessing individual interventions for the conservative management of symptoms of lumbar spinal stenosis.

Study	Design	Subjects	Mean age (years)	Primary intervention	MacDermid/ Sackett's scores	Results	Ref.
Murphy *et al.* (2006)	Prospective cohort	n = 57	65	Manual therapy two- to three-times per week for 3 weeks, then once or twice per week after 3 weeks	30/4	Statistically significant improvement from baseline to end of treatment ($p < 0.0001$) and from baseline to follow-up ($p = 0.0002$) RMDQ: improved by 5.1 points from baseline to end of treatment ($p < 0.0001$) RMDQ: improved by 5.2 points from baseline to follow-up ($p < 0.0001$) 30% improvement in pain and 40% improvement in disability	[30]
Kuck *et al.* (2005)	Case series	n = 6	63	Lumbar stabilization in water three-times per week for 6 weeks	27/4	Significant improvement in pain and disability levels ($p < 0.05$) RMDQ: $p = 0.028$ RMPRS: $p = 0.043$ 72% improvement in pain, 50% improvement in disability and 66% improvement in function	[29]

RMDQ: Roland–Morris Disability Questionnaire; RMPRS: Roland–Morris Pain Rating Scale.

two studies (28.5%) were moderate quality (MacDermid score: 27–33/ 48) and Sackett's level- 3b, 4 and three studies (43%) were rated as low-quality studies (MacDermid score: 15–20) and a Sackett's level of 4 (Figure 2).

Comparison of two modes of aerobic exercise

Pua *et al.* (score: 40; level 1b) compared the effects of two different aerobic exercise interventions for patients with LSS using a randomized controlled design [25]. Patients were allocated to either 30 min of treadmill walking with bodyweight support or cycling, twice a week for a 6-week period. Both groups were prescribed a home flexion-based exercise program to complete daily for 6 weeks and received mobilization techniques and heat prior to the aerobic exercise sessions. In weeks 1 and 2, patients walked/cycled at their own comfortable pace. In weeks 3–6, the intensity of aerobic exercise increased to a moderate level. Disability was assessed using the Oswestry Disability Index (OSW) [31] and the Roland–Morris Disability Questionnaire (RMQ) [32]. Both are well-validated and reliable measures. Back pain was measured on visual analog scale (VAS) [33]. The authors reported improvements disability in both groups at the 3- and 6-week assessments, although these differences were not statistically significant. Reductions in pain and disability were 17 and 22%, respectively, in the treadmill group, and 18 and 28%, respectively, in the cycling group. When the results of the two aerobic intervention groups were combined, there was a statistically significant improvement in disability ($p < 0.001$). The authors concluded that aerobic exercise can decrease disability, but there is no significant difference between the use of 6 weeks of weight-supported treadmill walking or stationary cycling in outcomes. Figure 3 illustrates effect sizes for specific outcomes.

Studies combining manual therapy & exercise

Of the studies included in this category, one was a randomized clinical trial [17], one was a prospective cohort study [30] and one was a small case series [26]. In a high-quality randomized clinical trial by Whitman *et al.* (score: 40; level 1b) patients were randomly allocated to either flexion exercises plus bodyweight-supported treadmill walking (treadmill group) or manual physical therapy, flexion exercise and bodyweight-supported treadmill walking (manual group) [17]. Total treatment sessions lasted 45–60 min twice a week for 6 weeks. Outcomes assessed included: perceived recovery, self-reported pain, disability, satisfaction and function. At 6 weeks and 1 year, the manual therapy group demonstrated greater improvements in disability, walking tolerance and higher satisfaction compared with the flexion exercise group. The mean improvement in disability assessed with the OSW was 10.5 and 6.5 at 6 weeks, and 7.1 and 5.0 at 1-year follow-up [31] in the manual therapy and flexion exercise group, respectively [17]. The mean improvement in treadmill walking distance was reported to

Table 4. Quality of studies based on the Joy MacDermid Scale†.

Study	Whitman *et al.* (2006) [17]	Pua *et al.* (2007) [25]	Murphy *et al.* (2006) [30]	Kuck *et al.* (2005) [29]	Whitman *et al.* (2003) [26]	Fritz *et al.* (2006) [27]	Greenman (2006) [28]
Background	2	2	2	2	2	2	2
Comparison	2	2	0	0	0	0	0
Patient status	2	2	2	2	2	2	2
Data collection	2	2	2	2	2	2	0
Randomization	2	2	0	0	0	0	0
Patient blinding	1	1	1	1	1	0	0
Provider blinding	1	1	1	1	1	0	0
Independent evaluator	2	2	0	0	0	0	0
Sampling procedure	2	2	1	1	0	0	1
Inclusion and exclusion criteria	2	2	2	0	0	0	0
Enrollment	2	2	0	0	0	0	0
Retention/ follow-up	1	1	2	2	2	2	1
Intervention according to principles	2	2	2	2	1	2	2
Biases of treatment provider	1	1	2	1	1	0	0
Intervention comparison	1	2	0	0	0	0	0
Define primary outcome	2	1	1	1	0	1	1
Appropriate secondary outcome	2	1	1	1	0	1	1
Appropriate follow-up period	2	1	2	1	2	2	1
Appropriate statistical test(s)	1	2	2	2	1	0	0
Significant power	0	1	0	0	0	0	0
Size and effect report	2	2	2	2	1	0	0
Analyses missing data	2	2	2	2	2	2	2
Clinical and practical significance for results interpretation	2	2	2	2	0	0	1
Conclusion/clinical recommendation	2	2	2	2	2	2	2
Total score	40	40	30	27	20	18	15
Level of evidence‡	Ib	Ib	4	4	4	4	4

†*Score ranges from 0, 1 or 2; with 2 indicating highest value.*
‡*Evidence criteria based on Sackett Scores* [101,103].

be 339.7 m in the manual therapy group compared with 176.5 m in flexion exercise group at 6 weeks, and 209.8 m and 130.4 m at 1-year follow-up in manual therapy and flexion exercise group, respectively. The manual therapy group reported higher satisfaction rates compared with the flexion group (1.57 and 2.03, respectively, at 6 weeks, and 1.7 and 2.0, respectively, at 1-year follow-up). The authors reported overall reductions in pain of 20 and 30%, disability of 16 and 29%, and function of 28 and 50% in the flexion exercise and treadmill walking group, and the manual therapy and treadmill walking group, respectively. However, these differences were not statistically significant. There was no difference in improvement in pain in the lower extremity on the Numerical Pain Rating Scale (NPRS) [33] from baseline to 1 year between the groups [17]. The authors concluded that although lumbar flexion exercises and walking were beneficial in treatment of LSS, additional gains may be obtained with the combination of manual therapy, exercise and treadmill walking. See Figure 3 for effect sizes.

Whitman *et al.* (score: 20; level 4) described outcomes of three patients with LSS managed with manual physical therapy, strengthening and stretching exercises [26]. Patients received five sessions of impairment-specific, individually tailored interventions, focusing on patient's prioritized impairments. The intervention included both rotational and posterior to anterior mobilization/manipulation to the spine for nine to ten sessions. Muscle stiffness was addressed by manually stretching the muscles followed by strengthening over five to six sessions. Patients were also instructed to engage in a walking program and perform specific home exercises to reinforce physical therapy outcomes. Patients 2 and 3 received treadmill walking with bodyweight support. In addition, Patient 3 was prescribed orthotics. Pain improved by 33%, disability by 76 and overall function by 56%. All patients reported substantial improvements from baseline to discharge and 10-week follow-up in pain, disability and symptoms as assessed with a modified Subscale of the LSS and Symptom Severity Scale [34,35].

Combined strengthening & aerobic exercise

Fritz *et al.* (score: 18; level 4) conducted a case report of two elderly patients diagnosed with degenerative LSS to evaluate the effect of flexion exercise on pain and disability [27]. Both patients received physical therapy treatment for 6 weeks, which included pelvic tilts, quadruped spinal flexion exercises and single knee-to-chest exercises for Patient 1, and quadruped spinal flexion for Patient 2. Patients performed ten repetitions of flexion exercises three- to four-times daily. Both patients performed treadmill walking as part of their intervention. Patient 2 engaged more in treadmill exercise as he was better tolerated to ambulation. Walking speed increased from 0.7 to 0.8 mph and from 1.5 to 2.5 mph in Patients 1 and 2, respectively, after 6 weeks of physical therapy. The maximum walking time increased from 7 1/6 to 15 min and from 5 1/6 to 15 min in Patients 1 and 2, respectively, at the end of therapy. Both patients reported no pain in the low back or leg at 6 weeks. The authors noted an improvement in pain and disability of 90 and 84% for Patients 1 and 2, respectively, and concluded that both patients improved significantly in their ambulation and lower extremity range-of-motion and strength (Figure 4).

Greenman (score: 15; level 4) determined the effect of strengthening and flexibility exercises on pain and walking capacity in 15 patients with LSS [28]. An intensive physical therapy program was provided in four stages: stage 1 included proprioceptive balance training; stage 2 included muscle stretching to address symmetry; stage 3 included retraining of weak and inhibited muscles; and stage 4 included aerobic conditioning. The author did not report any statistical data,

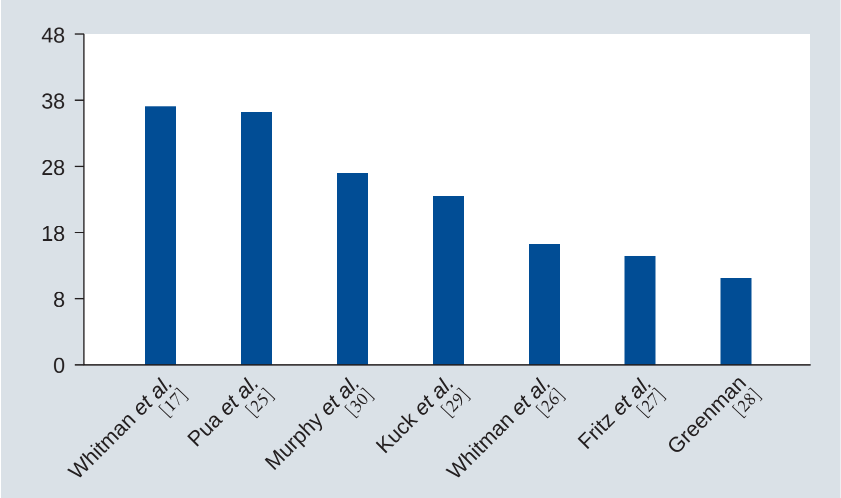

Figure 2. Quality ranking scores of the included studies using the MacDermid Scale.
Data taken from [17,25–30].

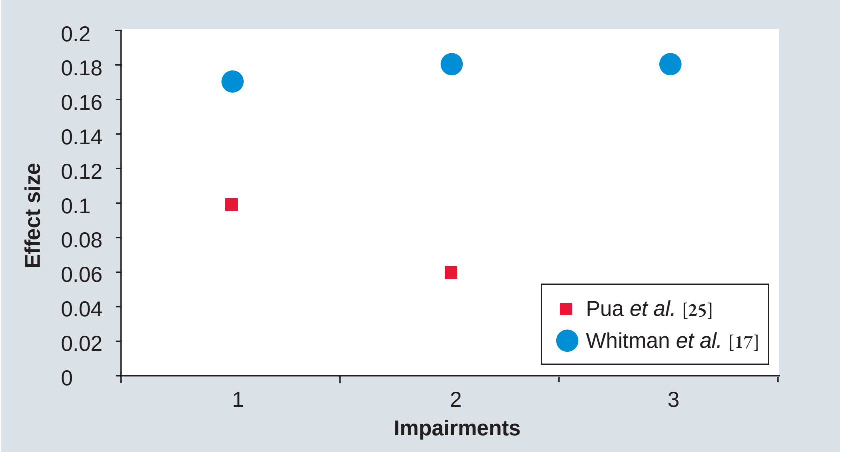

Figure 3. Effect sizes of specific outcomes for the two randomized controlled studies.
Data taken from [17,25].

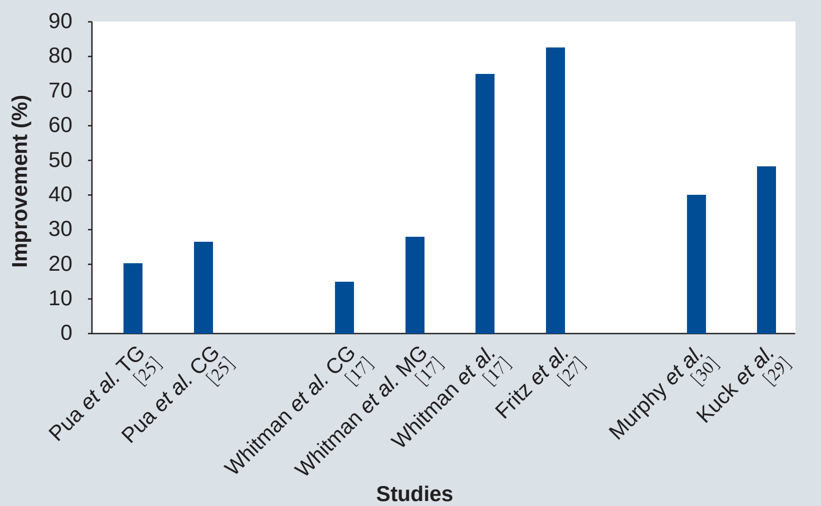

Figure 4. Percentage change in self-reported disability by study.
CG: Control group; MG: Manual therapy group; TG: Treatment group.
Data taken [17,25,27,29,30].

but stated that all patients improved in walking tolerance and pain at discharge, and were symptom free at follow-up.

Studies assessing individual interventions

In a study assessing the efficacy of aquatic spinal stabilization exercises on pain reduction and disability for persons with LSS, Kuck *et al.* (score: 30; level 4) enrolled six patients with LSS and neurogenic claudication [29]. The RMDQ and Pain Rating Scale were used to measure pain and disability pre- and post-intervention. A treadmill test was conducted to measure walking capacity. The stabilization exercise program included a warm-up session, followed by intervention for 30 min, three-times per week for 6 weeks. At the end of the intervention, patients reported a 1.8-point decrease in pain score ($p < 0.05$) and a 5-point decrease in disability. Furthermore, five of six patients demonstrated first neurogenic claudication symptoms after 15 min as compared with 6.3 min pre-treatment. Overall, pain improved by 72%, disability improved by 50% and function improved by 66% in all patients. No severe symptoms were reported post-treatment versus 10.8 min pre-treatment. Thus, the authors recommended the use of aquatic spinal stabilization in the management of patients presenting with LSS.

Murphy *et al.* (score: 27; level 4) conducted a prospective cohort study to determine the effect of distraction manipulation and neural mobilization in 55 patients with LSS on pain (PRS), function, disability (RMQD) and self-reported improvement [30]. All patients were seen two- to three-times a week for 3 weeks. The mean duration of follow-up was 16.5 months. Pain intensity improved by 30% post-treatment. The authors reported statistically significant and clinically meaningful changes in disability of 5.1 and 5.2 points (40%) on the RMQD scale from the baseline to end of treatment ($p < 0.0001$) and from baseline to long-term follow-up (16.5 months; $p < 0.0001$), respectively. The mean patient-rated improvement from baseline to after-treatment was 65.1% immediately following intervention ($p < 0.001$) and at long term follow-up was 75.6% ($p < 0.002$). The authors concluded that the combination of distraction manipulation and neural mobilization is a safe and effective approach to manage symptoms of patients with LSS.

Discussion

This article provides a summary of the current evidence for the effectiveness of therapeutic exercise and manual techniques in decreasing pain and disability and increasing function for individuals with LSS. Five studies used aerobic exercise as their primary mode or part of the primary intervention, one study demonstrated the effects of aquatic strengthening exercises only and one study reported the effects of manual therapy alone. Although the results of the studies were significant, variations were noted between outcomes. These differences between the outcomes could have occurred due to variations in the baseline status of the subjects enrolled in each trial and the biases inherent in the varied study designs; all studies assessed pain, but used different outcome measures. A majority of studies used either the 0–10 mm or the 0–100 mm VAS, others used the Brief Pain Inventory Scale or the LSS Symptoms Severity Scale. All seven studies measured function and disability. Studies selected disease-specific outcome measures to assess function, such as the OSW [32] and the RMQ [33]. The use of different measures made comparison of the results across studies difficult. To overcome these differences, the effect sizes of the outcomes were calculated for the two randomized controlled trials. These data suggest small-to-modest impacts on pain, function and disability. Of note is that both studies used a combination of interventions so that individual attribution of effect to a specific mode of therapy cannot be made.

This article clearly highlights the lack of high-quality, controlled trials assessing the impact of exercise and manual therapy for persons with LSS. The majority of the studies were case reports and case series designed to develop hypothesis about the use of exercise on specific outcomes. These studies are likely to be influenced by observational, volunteer and selection biases, and thus have inflated results. Thus, more controlled clinical trials of exercise are warranted to provide a scientific basis for the management of LSS versus reliance on empirical data and clinical impression.

Some strengths of this article include the strict selection criteria, the use of only subjects with confirmed LSS (confirmed on the MRI or radiograph), an older sample population, the use of an accepted scale to document study quality and inclusion of studies evaluating the effectiveness of exercise and manual therapy without the impact of oral medications or steroid injections. The MacDermid Scale and Sackett's Level of Evidence provide a means to objectively rank study quality regardless of the design employed, allowing a richer description of the study attributes. Some limitations of this article reflect the type and quality of the literature on this topic: there are few high-quality controlled trials and many interventions are of mixed modes. Mixed interventions preclude the assessment and attribution of outcomes to a single intervention. Studies were also heterogeneous with respect to the frequency, intensity and duration of the exercises and used a variety of outcome measures, making it difficult to compare results across the studies. Finally, most samples were small, limiting generalizability and increasing the likelihood of Type II Error. The majority of the studies were of moderate-to-low quality.

Future perspective

Given the growth in number of the aging population, the prevalence of persons with LSS is likely to increase over the next decade. As cuts of healthcare rise, it will be important to formally and accurately assess the impact of conservative treatments for LSS, such as exercise and manual therapy. More high-quality, randomized controlled trials should be conducted to compare the effects of different types of therapeutic exercises, as well as their relative cost–effectiveness. Although the studies showed positive results, there is a need for more studies with larger sample sizes as well as reasonable comparison and control groups to make definitive conclusions is warranted.

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Executive summary

- Therapeutic exercise and manual therapy appear beneficial in decreasing pain and disability and improving function in older patients with lumbar spinal stenosis.
- Low-to-moderate intensity aerobic exercise performed for at least 6 weeks and provided in combination with flexibility, strengthening exercise and manipulation is more effective than aerobic, strengthening, flexibility exercise or manual therapy alone.
- Due to limited evidence in literature, the need for high-quality, randomized controlled trials is warranted. Additionally, there is a need for studies with higher sample sizes with appropriate comparison or control groups.

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