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REVIEW

The effectiveness of physical exercise in patients with lumbar spinal stenosis: a systematic review

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Abstract

Background To our knowledge, no other systematic review comprehensively demonstrated the effectiveness of exercise and conventional physiotherapy in lumbar spinal stenosis (LSS).
Aims The purpose of the present systematic review was to provide a comprehensive review of exercise therapy on LSS.
Methods A literature search was carried out in the following databases on October 2021: PubMed, Scopus, ScienceDirect, Cochrane Library, and Web of Science (WoS) database. The study quality assessment was independently determined according to the PEDro scores by two reviewers. A narrative synthesis was used to synthesize the data of the compiled studies and express their results.
Results Records identified through database searching; PubMed ($n=352$), Web of Science ($n=180$), Science Direct ($n=2801$), Cochrane Library ($n=423$) and Scopus ($n=12$). A total of 3768 papers were screened. Studies unrelated to the question, another study language, undesired study design, duplicate articles, undesired intervention, undesired sample feature ($n=3757$) were excluded. An analysis was conducted on the full text of 11 journals. The vast majority (90.9%) of articles received a PEDro score of 6–8 ("good"). The mean PEDro score of the studies was 6.8 ± 1.5 (min:1, max:8). Four of the studies (36.3%) focused on neurogenic claudication in the LSS. Other studies have focused on LSS due to various causes (e.g., degenerative).
Conclusions The review results showed that supervised exercise was more effective in LSS than self-management or home exercise. In addition, core stabilization, aqua therapy or aerobic (e.g., treadmill, cycling) exercises can be advantageous in different parameters.

Keywords Exercise · Physiotherapy · Stenosis · Review

Introduction

Spinal stenosis is an age-related degenerative disease that causes narrowing of the spinal canal and reduced blood flow to the nerve roots [1]. Spinal stenosis occurs in about 5 out of 1000 patients over 50 years of age [2]. The compiled prevalence estimate of lumbar spinal stenosis (LSS) is 11% in the general population [3]. The prevalence of tandem spinal stenosis ranges from 7.6% to 60% in the population with spinal stenosis, and is higher in women [4].

Depending on the nature and place of stenosis, individuals may encounter signs, such as pain, neurogenic claudication, radiculopathy, weakness, and loss of motor skills [2]. LSS-related symptoms worsen with lumbar extension and improve with lumbar flexion. Gait produces an extra reduction in the spinal canal and increased epidural stress, increasing some symptoms. Some promising results have been demonstrated with surgical interventions, but reoperations have also been reported, especially in multi-level spinal stenosis. Moreover, the total hospital charge for LSS in 2009 was approximately "US$1.65 billion", a sizeable socioeconomic catastrophe. It is an undeniable fact that surgeries have a large share in this economic bill. The treatment of spinal stenosis without the need for surgery

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may respond well, and many other treatments have been proposed [5–8].

Physiotherapists in the UK consider flexion and stabilization exercises appropriate, along with advice [6]. In addition, the "World Federation of Neurosurgical Societies Spine Committee" suggested that exercise-based conservative treatment could be the first choice in patients with LSS who do not have severe neurological deficits [9]. It has been reported that multimodal therapy, including exercise, in the treatment of neurogenic claudication may lead to improvement in leg pain [10]. It has been shown that education and advice in patients with lumbar spinal stenosis lead to less negative feelings towards the disease process [11]. Evidence is presented to provide exercise therapy in these patients. For example, the feasibility of home-based cycling exercise is demonstrated in the LSS [5]. It has been revealed that patients with LSS are not satisfied with the exercises that cause pain, the poor quality of the physiotherapy received, and the exercises they think they can do on their own [12]. Therefore, it should be kept in mind that supervision or home-based exercises or quality are effective. Another opinion; pain and problems with physical function are considered the most important outcome in older adults with spinal stenosis.

Exercise therapy, as evidenced above, provides pain control, relief of weakness, emotional recovery, and restoration of motor functions. Furthermore, it brings the economic advantage in terms of cost-effectiveness. However, it has also been reported that agents, such as acupuncture, analgesics, and herbal medicines are included in the LSS treatment beliefs of Korean medical doctors [13].

For these reasons, we aimed to search the databases in order to compile the results of the effectiveness of exercise therapy in people with spinal stenosis and to give an idea in the treatment stages. The ultimate aim of our review is to systematically review studies involving exercise therapy versus other non-invasive and non-medicational treatment modalities in patients with spinal stenosis.

Methods

Search strategy and selection criteria

A literature investigation was carried out in the following databases on October 2021: "PubMed, Scopus, ScienceDirect, Cochrane Library, and Web of Science (WoS)" database. The language was limited only to English. Two researchers of the study conducted a literature review to identify keywords. Afterwards, they discussed the words they obtained at the consensus meeting and the determined words were brought to the second meeting, where all researchers were present. During the meeting held here, the final keywords were determined. The searching was conducted using the combination of keywords and "Medical Subject Headings (MeSH)". The search terms were ("spinal stenosis or canal stenosis or vertebral stenosis") and ("exercise or therapy or rehabilitation or physiotherapy") and ("randomized controlled trial or random allocation") (Appendix 1).

Eligibility criteria

Studies were included concerning the following criteria: (a) studies involving human participants published in peer-reviewed scientific journals in English between 2000 and 2021, (b) studies involving adult cases of lumbar spinal stenosis aged 18 years and over, (c) randomized controlled trials (RCT's), and (d) studies involving exercise only or exercise plus physiotherapy agents in a treatment group.

Studies meeting any of the following criteria were excluded: (a) non-RCTs, (b) Literature reviews, (c) Case reports or expert opinions, (d) Studies involving only invasive approaches such as steroid injection or surgery, and (e) English full-text unavailable studies.

Study selection and data extraction

The present systematic review was based on the PRISMA guidelines [14]. The titles and abstracts of all identified studies were screened for suitability. The study selection process is shown in Fig. 1. The Rayyan software were used to comprehensively investigate the studies. Rayyan is a helpful tool that allows researchers to detect duplicate studies for systematic reviews. Rayyan was also used by the researchers (İT, FÖ) to include or exclude studies by note-taking in different colors. Studies were excluded from the review if their title and abstract were irrelevant to the subject of our study. A total of 3768 studies [PubMed ($n = 352$), Web of Science ($n = 180$), Science Direct ($n = 2801$), Cochrane Library ($n = 423$), and Scopus ($n = 12$)] were reached by database search by two authors (FÖ, İT). The full texts of all accessed studies were reviewed, and their suitability was determined using eligibility criteria. At all stages of the study selection process, decisions regarding the eligibility of studies to the screening criteria were made by two authors (FÖ and İT). Decisions were approved by a third author (ZY). The selected 11 studies were included in the study. The data of the studies are shown in Table 1, information was collected on the study design, objective, disease of the sample, age, number of participants, interventions, outcomes/follow-up, and results.

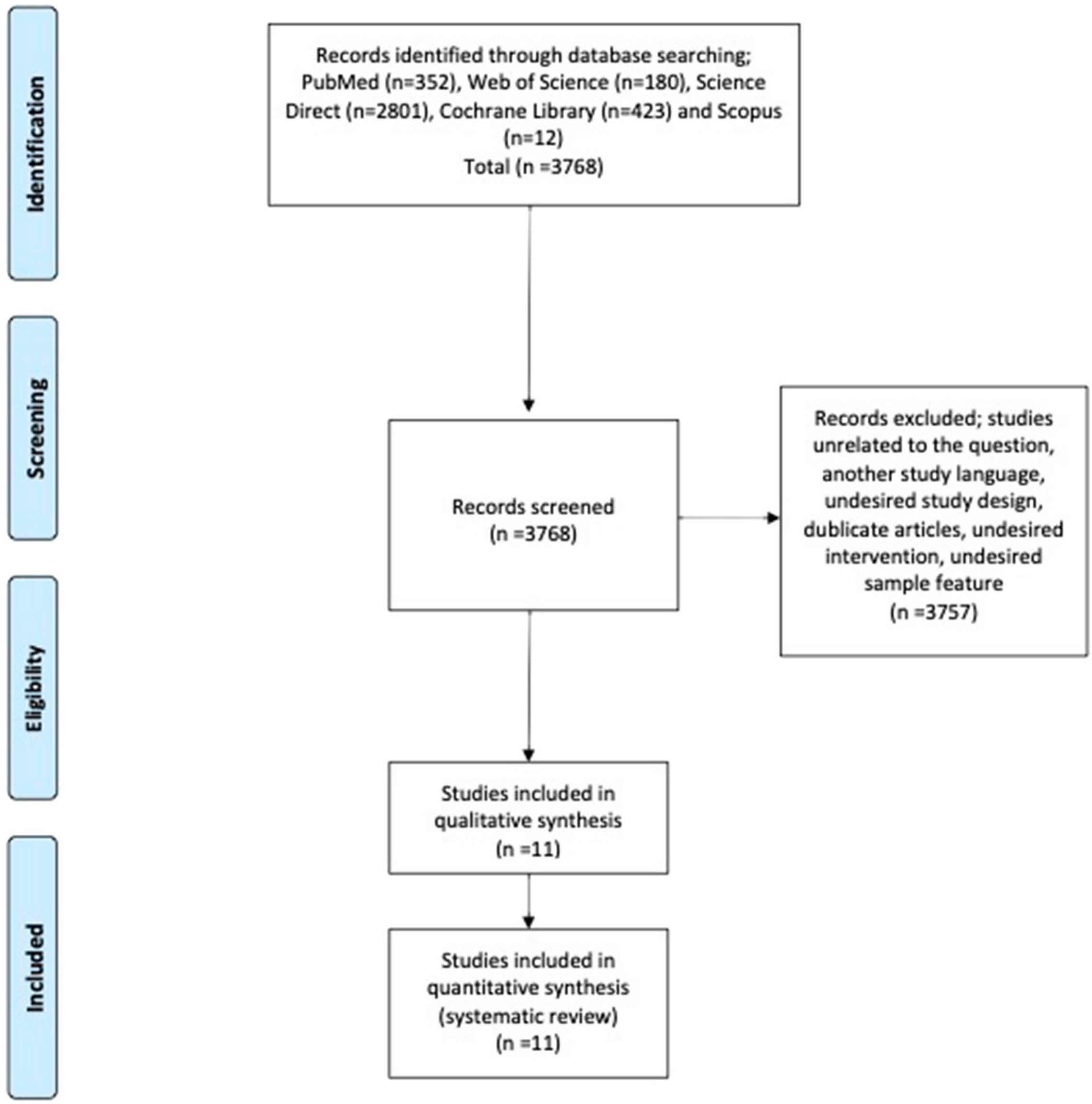

Fig. 1 PRISMA flow diagram of the study

Quality assessment

Study quality assessment was independently determined according to the PEDro scores by two reviewers. Disagreements were controlled by the third researcher. The PEDro contains 11 questions that address the following domains: eligibility criteria, randomization of groups, concealing the allocation, similarity in terms of the most important prognostic indicators, blinding of subjects, blinding of therapists, blinding of assessors, obtaining at least one key outcome measure from more than 85% of subjects, "intention to treat", where outcome measures are not available, the results of between-group statistical comparisons and, providing both point measures and measures of variability. Each question had two possible answers: "Yes" or "No". Points were awarded when a criterion was clearly satisfied. PEDro scores of 0–3 are considered 'poor', 4–5 'fair', 6–8 'good', and 9–10 'excellent'. Moreover, for trials evaluating complex interventions, a total PEDro score of 8/10 is optimum [15]. PEDro scores are shown in Table 2.

Evidence synthesis

A narrative synthesis was used to synthesize the data of the compiled studies and express their results. The three phases of narrative synthesis included "developing a preliminary synthesis, exploring relationships within and between studies, and determining the robustness of the synthesis" [16]. The data of the included studies were described qualitatively, and the results were evaluated by the authors.

Table 1 Summary of included articles

Article	Objective	Disease of the Sample	Age	Control Group (CG)	Intervention Group (IG)	Interventions	Outcomes	Results
Pua et al. [18]	Comparison of the effectiveness of treadmill and cycling ergometers in LSS	Degenerative LSS	≥ 50	$n = 35$ *F*: %52	$n = 33$ *F*: %42	**IG:** Treadmill walking exercise with the Biodex unweighting system (max. 30 min. duration)[a]	mODI, RMDQ, VAS at baseline, 3 and 6 weeks	Disability and pain between groups at week 0 and 3 or 0 and 6: NS differences
						CG: Cycling exercise on an upright bicycle (max. 30 min. duration). [a]	Patient Perceived Benefit at 3 and 6 weeks	Both groups disability reduced over time ($p < 0.001$)
Comer et al. [19]	Comparison of the effectiveness of NC participants who received a 6-week home exercise program and a control of advice and training	Participants with a diagnosis of spinal stenosis and complaints of bilateral NC	≥ 50	$n = 38$ *F*: %47.4	$n = 38$ *F*: %57.9	**IG:** Specific home exercises given twice a day (e.g., flattening of the lumbar lordosis, abdominal muscle activation, aerobic fitness)	SSS, GWBI, ODI, HADS and VAS (leg, back) at baseline, 8 weeks, 12 months	SSS, SWT, ODI, GWBI and VAS between groups at week 0 and 8: NS differences
						CG: Verbal and written advice and training was given to the control group in the first session	SWT at baseline, 8 weeks	SSS, ODI, GWBI and VAS between groups at 12 months: NS differences
Homayouni et al. [20]	Comparison of the effectiveness of water-based physiotherapy and conventional physiotherapy in participants with LSS	LSS	50–80	$n = 25$ *F*: %52	$n = 25$ *F*: %56	**IG:** Therapeutic pool treatment (walking, stretching, mini-squat, pelvic tilt, knee to chest etc.)[b]	VAS, 6MWT at before therapy, after therapy and three months after the end of intervention	VAS between groups before therapy: NS differences; after therapy significantly higher in CG ($p = 0.001$); three months after NS differences
						CG: Continuous mode ultrasound (US) 1.5 W/cm^2 for 10 min and heat pack and trans-electrical nerve stimulation (TENS) for 20 min. Endurance, William's flexion and stretching[c]		6MWT between groups before therapy NS differences; after therapy significantly higher in IG ($p = 0.02$); three months after NS differences
Delitto et al. [21]	Comparing decompression and physiotherapy in the LSS and to evaluate gender differences	With lumbar spinal stenosis who consented to surgery	≥ 50	$n = 87$ *F*: %49	$n = 82$ *F*: %46	**IG:** ROM, strength, aerobic and stretching exercises, patient education[d]	SF-36 (physical function score), ODI, NASS at baseline, 10, 26, 52, 104 weeks	SF-36 Physical Function, NASS, ODI between groups at baseline, 10, 26, 52, 104 weeks NS differences
						CG: The surgical treatment of patients in was performed similar to that described by Rothman and Simeone. The post-operative course included a graduated ambulation program		Subgroup analysis from gender revealed no difference in treatment effects over time for men and women

Table 1 (continued)

Article	Objective	Disease of the Sample	Age	Control Group (CG)	Intervention Group (IG)	Interventions	Outcomes	Results
Ammendolia et al. [1]	Comparison of the effectiveness of non-surgical comprehensive treatment program and self-directed practice on walking in LSS	With neurogenic claudication and imaging confirmed LSS	≥ 50	$n=53$ *F*: %49	$n=51$ *F*: %65	**IG:** Education, stretching, strengthening, and aerobic exercises, manual therapy[e] **CG:** Video education, diary and pedometer, plus a single training session with chiropractor (licensed)	SPWT, ZCQ, ODI, NPS, FES, SPPB, SF-36, CESDS at baseline, 8 weeks, 3, 6 and 12 months	SPWT between groups at 8 weeks 3, 6 and 12 months significantly higher in IG ($p=0.0005$; $p=0.08$; $p=0.0006$; $p=0.0007$) ODI walk between groups at 6 month significantly more improvement in IG ($p<0.0001$)
Mu et al. [17]	Comparison of the effectiveness of conventional exercises and core stabilization exercises in participants with LSS	LSS	40–69	$n=29$ *F*: %37,9	$n=33$ *F*: %36.3	**IG:** Planks, gluteal muscles strength and modified push up[f] **CG:** Sit-ups, lumbar extension exercises[f]	JOA, self-reported walking capacity and lumbar lordosis angle at baseline and after treatment	JOA and self-reported walking capacity in groups after treatment increased ($p<0.05$) JOA and self-reported walking capacity between groups at after treatment significantly higher in IG ($p<0.05$) Lumbar lordosis angle in groups and between groups at after treatment NS differences
Minetama et al. [23]	Comparing the effectiveness of supervised physiotherapy and unsupervised physiotherapy in the LSS	With neurogenic claudication and imaging confirmed LSS	> 50	$n=43$ *F*: %53,4	$n=43$ *F*: %55,8	**IG:** Manual therapy, strength and stretch exercises, cycling and treadmill ergometer[g] **CG:** Daily walk, knee-to-chest exercises, trunk raise and bridging, kneeling exercise at least twice daily[g]	ZCQ, SPWT, NRS, JOABPEQ, SF-36, HADS, PCS, PASS-20, TSK-11 at baseline and 6 weeks	ZCQ and NRS leg pain between groups at 6 weeks significantly higher in CG SPWT, SF-36 physical functioning, bodily pain, role physical and vitality between groups at 6 weeks significantly higher in IG

Table 1 (continued)

Article	Objective	Disease of the Sample	Age	Control Group (CG)	Intervention Group (IG)	Interventions	Outcomes	Results
Schneider et al. [26]	Comparison of the effectiveness of 3 non-surgical treatments in LSS	LSS	> 60	**Medical group** $n=88$ *F*: %48	$n=84$ *F*: %54	**IG:** Participation in supervised group exercise classes for older adults at local senior community centers. 2 times a week for 6 weeks	SSS, SPWT and arm-band accelerometer at baseline, 2 and 6 months	SSS between groups at 2 months significantly lower in IG
				Manual therapy Group $n=87$ *F*: %40		**CG:** Medical care included non-narcotic analgesics anticonvulsants antidepressant agents. Manual therapy arm included stationary bicycle, joint mobilizations, neural mobilizations, spinal stabilization exercises and home stretching		SPWT between groups NS differences Physical activity between groups NS differences
Minetama et al. [22]	To compare the effects of physiotherapy session frequency on clinical outcomes in LSS	LSS	> 50	**P1[h] Group** $n=38$ F: %65.7 **P2[i] Group** $n=43$ F: %53.4	$n=43$ *F*: %55.8	**IG**: Flexion and strengthening home exercises **CG**: P1 manual therapy, flexion and strengthening exercises, body weight supported treadmill exercise and home exercises P2 manual therapy, flexion and strengthening exercises, body weight supported treadmill exercise and home exercises	ZCQ, NRS, JOABPEQ, SF-36, HADS, PCS, PASS-20 at baseline and 6 weeks after	ZCQ between groups at 6 weeks significantly more improvement in P2 NRS back and leg pain between groups at 6 weeks significantly more improvement in P2 JOABPEQ lumbar dysfunction gait disturbance and social life dysfunction between groups at 6 weeks significantly more improvement in P2

Table 1 (continued)

Article	Objective	Disease of the Sample	Age	Control Group (CG)	Intervention Group (IG)	Interventions	Outcomes	Results
Marchand et al. [25]	To compare the effectiveness of exercise-based pre-rehabilitation and a prerehabilitation program including usual care in LSS	Patients with degenerative LSS awaiting surgery	≥ 18	$n=33$ *F*: %42	$n=35$ *F*: %40	**IG**: Warm-up, concentric or isometric exercises for improve walking capacities'	NRS, ODI, EuroQol-5D, TSK, BDI, modified Sorensen test, muscles strength, walking capacities, 30 s-CSTS and TUG, Patient Global Impression of Change	NRS leg pain, LSS disability, TSK, trunk muscles strength, modified Sorensen test, total ambulation time and sit to stand repetitions between groups at post-intervention significantly more improvement in IG
						CG: Participants were not prevented from performing physical activity or exercise		Back disability between groups at 3 and 6 month post-surgery significantly worse in CG
Minetama et al. [24]	To compare the 1 year outcomes of patients with lumbar spinal stenosis treated with supervised physical therapy or unsupervised exercise	With symptoms of neurogenic claudication caused by LSS	> 50	$n=43$ *F*: %53.4	$n=43$ *F*: %55.8	**IG**: Lumbar flexion and strengthening exercises and walking **CG**: Manual therapy, individually tailored stretching and strengthening exercises, cycling, and body weight-supported treadmill walking[k]	ZCQ, NRS, JOABPEQ, SF-36, HADS, PCS, TSK-11, Pain anxiety symptoms scale-20 at baseline 6 weeks and 1 year	ZCQ, SF-36 bodily pain and general health, JOABPEQ lumbar dysfunction, HADS depression between groups at 1 year significantly more improvement in CG

LSS Lumbar spinal stenosis, *VAS* Visual analogue scale, *NS* Not significant, *IG* Intervention group, *CG* Control group, *F* Female, *QF* Quadriceps femoris, *mODI*: Modified Oswestry Disability Index, *ODI* Oswestry Disability Index, *RMDQ* Roland-Morris Disability Questionnaire, *NRS* Numeric rating scale, *BDI* Beck depression inventory, *WAI* Work ability index, *FBE* The frequency of back exercise training, *NPG* Number of physiotherapy visits or guided gym/training, *NC* Neurogenic claudication, *SSS* Swiss Spinal Stenosis Questionnaire, *GWBI* General Well-Being Index, *HADS* The Hospital Anxiety and Depression Scale, *SWT* Shuttle Walking Test, *6MWT* Six Minute Walk Test, *SF-36* Short Form 36, *NASS* North American Spine Society Pain and Disability, Neurogenic Symptoms, and Expectation for treatment outcome scales, *SPWT* Self-Paced Walk Test, *ZCQ* Zurich Claudication Questionnaire, *NPS* Numeric Pain Scale, *FES* Fall Efficacy Scale, *SPPB* Short Physical Performance Battery, *CESDS* Center for Epidemiological Studies-Depression Scale, *JOA* Japanese Orthopedic Association score, *JOABPEQ* Japanese Orthopaedic Association Back Pain Evaluation Questionnaire, *PCS* Pain Catastrophizing Scale, *PASS-20* Pain Anxiety Symptoms Scale, *TSK-11* Tampa Scale for Kinesiophobia, *BDI* Beck Disability Index, *RCT* Randomized Controlled Trial, *30 s-CSTS* 30 Second Chair Sit to Stand Test, *TUG* Timed up and Go Test

[a] In addition, both groups received a warm-up (heat, traction) and home exercise programme

[b] Water temperature of 29°–30 °C. Total duration 24 sessions

[c] Physiotherapist supervised duration 10 sessions. Total duration 8 weeks

[d] Frequency of 2 visits per week. Total duration 6 weeks

[e] Two 15 to 20-minute treatment sessions per week over a 6-week period followed by a single (booster) session, 4 weeks later

[f] Middle frequency electrotherapy 30 min each time, once daily for four weeks. And exercises performed ten times, once daily for four weeks

[g] Twice a week for 6 weeks

[h] Physiotherapy with once of week sessions

[i] Physiotherapy with twice of week sessions

[j] Supervised exercise sessions 3 times per week for 6 weeks, prior to their surgery

[k] Twice a week for 6 weeks

Results

In a literature review, records identified through database searching; PubMed ($n = 352$), Web of Science ($n = 180$), Science Direct ($n = 2801$), Cochrane Library ($n = 423$), and Scopus ($n = 12$). A total of 3768 papers were screened. Studies unrelated to the question, another study language, undesired study design, duplicate articles, undesired intervention, undesired sample feature.

($n = 3756$) were excluded. An analysis was conducted on the full text of 11 journals meant to follow the screening requirements.

According to the results of the quality analysis of 11 articles included in this systematic review (Table 2); 1 article was "poor" [17] and 10 studies were "good" [1, 18–26] level of evidence. The vast majority (90.9%) of articles received a PEDro score of 6 to 8. The mean PEDro score of the studies was 6.8 ± 1.5 (min:1, max:8). According to this result, the study's average score was at the "good" level of evidence according to the PEDro classification [15]. All of the studies explained the elimination criteria in detail, indicated random allocation and compared the characteristics for the baseline and beyond. Only two studies did not specify whether the allocation was concealed or not [17, 22]. No study has emphasized that subjects' and therapists' blinding. Six studies emphasized that the raters were blind [1, 18, 20, 21, 23, 24]. A vast majority of the studies ("9") fulfilled the patient follow-up period with the appropriate follow-up period [1, 18–25]. Eight studies reported that statistics were performed with intention-to-treat analysis [1, 18, 21–26]. Point measure and variability were not given in only one study [17].

Four of the studies (36.3%) focused on neurogenic claudication in the LSS [1, 19, 23, 24]. Other studies have focused on LSS due to various causes (e.g., degenerative) [17, 18, 20–22, 25, 26]. Except for two studies, individuals aged 50 and over constituted the sample in all studies. In these two exceptions, it was reported that individuals aged 18 years or older were included in one study and individuals aged 40–69 years in the other [17, 25]. Almost all of the studies included aging and older adults.

The study results are presented in Table 1. In one of the studies, aerobic exercises performed with treadmill and cycling ergometers were compared. There was no difference between the two groups regarding improvement in pain and disability ($p < 0.001$) [18]. In another study conducted on individuals with LSS with claudication symptoms, it was reported that home exercises were not effective ($p > 0.05$) [19]. In a study examining the efficacy of aqua therapy in LSS, positive results were reported on pain but negative results on disability ($p < 0.05$) [20].

Only one study compared exercise with surgery. There was no difference between the two groups in terms of pain, disability and quality of life ($p > 0.05$) [21]. In two studies comparing supervised and unsupervised exercise within the scope of conventional physiotherapy, it was emphasized that supervised exercises were more effective in pain, physical performance, and quality of life ($p < 0.05$) [1, 23]. In another study, the effectiveness of core stabilization exercises was emphasized. The authors were reported that stabilization exercises gave better results in terms of walking and functions than conventional exercises ($p < 0.05$) [17].

In the study in which exercise was compared with the untreated control group, it was emphasized that significant improvements were observed in LSS patients in terms of pain, disability, trunk muscle strength, walking, and physical performance ($p < 0.05$) [25]. There were three studies comparing exercise alone with exercise plus manual therapy. One of them emphasized the advantage of manual therapy in terms of LSS symptoms in addition to exercise. The other study stated that manual therapy and exercise are more effective in terms of pain, claudication, walking, and social function. Similarly, in the third study, the authors indicated that additional manual therapy was more effective in pain, claudication, quality of life, walking, and depression ($p < 0.05$) [22, 24, 26].

Discussion

The present systematic review was purposed to demonstrate a comprehensive report of the effectiveness of physical exercise in patients with lumbar spinal stenosis. It is crucial to emphasize the effectiveness of exercise practices in spinal stenosis, which is one of the most important causes of low back pain in aging individuals and older individuals due to neurogenic claudication, radicular or central symptoms [27]. Rehabilitation applications and specific prescriptions should be organized regarding the efficacy of the exercise types [28]. To our knowledge, there is no comprehensive systematic review on LSS focusing only on therapeutic exercises and physical therapy applications. The results of our study were systematically compiled in articles with different levels of evidence regarding the necessity of different types of exercises, supervised practices, and manual therapy in addition to exercise.

Effectiveness of the exercise interventions

Pua et al. aimed to demonstrate the effectiveness of a 6-week body supported treadmill walking practice by comparing it with a cycling ergometer. Individuals in both groups received conventional physiotherapy based on a combination of warming, lumbar traction, and flexion exercises in addition to these aerobic exercises. Individuals were evaluated for disability, pain, and perceived benefit from treatment

Table 2 PEDro scores of the trials

Article	Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7	Q-8	Q-9	Q-10	Q-11	Total
Pua et al.	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Comer et al.	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6
Homayouni et al.	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	8
Delitto et al.	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Ammendolia et al.	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Mu et al.	Y	Y	N	Y	N	N	N	N	N	Y	N	3
Minetama et al.	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Schneider et al.	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	6
Minetama et al.	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Marchand et al.	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Minetama et al.	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Total	11	11	9	11	0	1	6	9	8	11	10	

Q-1: Eligibility criteria; Q-2: Random allocation; Q-3: Concealed allocation; Q-4: Baseline comparability; Q-5: Blind subjects; Q-6: Blind therapists; Q-7: Blind assessors; Q-8: Adequate follow-up; Q-9: Intention-to-treat analysis; Q-10: Between-group comparisons; Q-11: Point estimates and variability

halfway through the intervention (week 3) and at week six post-treatment. No significant difference was observed between the groups. However, both groups benefited from the treatment [18]. The study revealed that both aerobic exercise practices performed on body-weight required and non-weight-bearing ergometers can be effective in LSS.

Comer and colleagues investigated the effectiveness of a specific home exercise program in individuals with LSS who have symptoms of neurogenic claudication and difficulty walking. The control group received only training and advice. Improvements in symptoms related to spinal stenosis, pain, physical function, and general well-being were questioned up to the 8th and 12th-week post-treatment. According to the study results, it was concluded that the specific home exercise program was not effective in LSS. The importance of patient education and advice should not be underestimated as it confirms the evidence, we have presented [6, 11]. Neither evaluators nor subjects were blinded in this study. Since the article was a pragmatic randomized controlled trial, we thought the results might have been in this direction. As a matter of fact, the inclusion of 28 different evaluators in the study may have brought about the inability to support the hypothesis [19]. In this respect, future studies may re-examine the LSS home program by blinding at a high level of evidence.

Homayouni et al. presented the only study examining aqua therapy in LSS with a unique purpose. Fifty cases participated in this trial, in which cases were randomized into two groups by comparison with conventional therapy. In the conventional group, a home exercise program was drawn in addition to the physical therapy agents. Pain and disability status of individuals were recorded before and after treatment and at three-month follow-up. It has been observed that aqua therapy gives more effective results in terms of pain in the early period after treatment. Aqua therapy has not been found to be effective in the long term in terms of improving the disability level [20]. In applications such as aqua therapy and hydrotherapy, it is expected to perceive short-term improvements in pain due to the water's temperature (heat effect) and, in some cases, the relaxing effect of the water [29]. The long-term effectiveness of aqua therapy in LSS has not been demonstrated.

Delitto et al. compared the effectiveness of exercise and surgery on LSS. It is essential for surgeons in deciding the appropriateness of conservative or surgical treatment [30]. In this study, decompression surgery was preferred as the surgical application. It was emphasized that there was no significant difference between the two groups in terms of pain, disability and quality of life at 24-month follow-up [21]. Before deciding on surgery, the patient and health professionals must have a session and plan the treatment comprehensively. It may be advantageous both for the health costs and for the patient to get the same effects with conservative treatment without undergoing the operation and to resort to surgery only in the most necessary cases [31].

Ammendolia et al. compared supervised and self-controlled exercise to improve walking ability in LSS patients. In this sample, where the average age of the participants is approximately 70, two groups were given supervised and self-controlled exercise for six weeks. Physical performance was questioned at the 6-month follow-up. The results were in favor of the supervised group [1]. Especially in populations consisting of older adults (> 65 years), the ability to understand or correctly perform home exercise programs decreases. Cognitive states of the patients can sometimes lead to the inability to remember the exercises correctly or to neglect the exercise program by forgetting it [32]. In such cases, monitoring patients with telemedicine may provide an advantageous intervention. Future studies may focus on home exercise by providing patient monitoring with telerehabilitation apps or software [33].

Mu et al. questioned the effectiveness of core stabilization exercises compared to a conventional exercise program in their study with a low level of evidence related to PEDro ("3"). Individuals in both groups were additionally followed up with electrotherapy agents with medium-frequency pain relief. According to the results of this study, core stabilization exercises provided effective results in terms of increasing walking performance and function, but not in terms of improvement in lumbar lordosis. This study is essential in presenting that a different exercise program is more effective than conventional exercises [17]. However, future studies with higher levels of evidence should support these results, with a particular focus on blinding assessors.

Minetama et al. compared the effectiveness of supervised and unsupervised exercise practices. LSS patients with neurogenic claudication were included in this single-center randomized controlled study. In the evaluation of the individuals at the 6th week, better results were obtained in the supervised group in terms of pain, physical performance, and quality of life. These results support the qualitative study by Peterson et al. emphasizing supervised exercise in patient beliefs and recovery [12]. The authors were emphasized that in addition to conventional exercise applications (stretching, strengthening, aerobic ergometer exercises), manual therapy was also applied [23]. In this respect, studies in which the effectiveness of manual therapy is also analyzed in the LSS may additionally support these results.

Schneider et al. obtained the effect of exercise on pain, disability, and walking capacity with 2 and 6 months of follow-up. Their study focused on the importance of finding a solution with exercise, as LSS is one of the most surgical causes. The authors were observed that spinal stenosis symptoms decreased more in 2 months of follow-up, but this situation did not remain stable in 6 months of follow-up [26]. In this respect, it will be necessary for patients to make their exercises a lifestyle and be involved in physical therapy and rehabilitation sessions every three months to maintain effectiveness in reducing symptoms.

Minetama et al. conducted recent studies published in 2020 and 2021. They reported that manual therapy applications and exercise are practical in pain, walking, claudication, quality of life and psychosocial status. Because manual therapy can only be supervised, patients' frequent visits to therapists and combining manual therapy with exercise provide advantages in many parameters. It should be noted that applications such as lumbar distraction mobilization, hip joint mobilization, lumbar/sacroiliac joint mobilization, and neural mobilization deliver the patient more clinically well in terms of relevant parameters [22, 24]. Finally, Marchand et al. and colleagues compared exercise with a control group that received no treatment. In this study, LSS patients older than 18 years of age were included. The positive effects of the combination of strengthening and aerobic exercise on pain, disability, trunk muscle strength, walking, and physical performance were emphasized [25]. With the control group not receiving any intervention, the authors put forward their hypotheses as expected.

The current systematic review has several limitations that should be addressed. To begin, only narrative synthesis could be offered due to the varied designs of the included studies. Second, several databases, such as CINAHL, were unavailable to us. Third, presenting the effectiveness of a particular type of exercise on spinal stenosis could provide more detailed practical information, however, there were limited number of studies available to include in this systematic review. Fourth, other bias risk assessment tools, rather than PEDro, could offer more data to demonstrate the quality of the studies included in the review. Finally, some studies on this topic may have been overlooked due to human mistake.

Conclusions

The review results showed that supervised exercise was more effective in LSS than self-management or home exercise. In addition, core stabilization, aqua therapy or aerobic (e.g., treadmill, cycling) exercises can be advantageous in different parameters. Manual therapy, in addition to exercise, had practical and efficient utilization. Clinicians' treatment beliefs should consider a patient-centered biopsychosocial model, along with an exercise-intensity conservative approach.

Appendix 1

Search strategy of PubMed, web of science, science direct, cochrane library, Scopus

Search ID#	Search terms	Search options
S1	spinal stenosis AND exercise AND randomized controlled trial	Boolean/Phrase
S2	spinal stenosis AND exercise AND random allocation	Boolean/Phrase
S3	spinal stenosis AND rehabilitation AND randomized controlled trial	Boolean/Phrase

Search ID#	Search terms	Search options
S4	spinal stenosis AND rehabilitation AND random allocation	Boolean/Phrase
S5	spinal stenosis AND therapy AND randomized controlled trial	Boolean/Phrase
S6	spinal stenosis AND therapy AND random allocation	Boolean/Phrase
S7	spinal stenosis AND physiotherapy AND randomized controlled trial	Boolean/Phrase
S8	spinal stenosis AND physiotherapy AND random allocation	Boolean/Phrase
S9	canal stenosis AND exercise AND randomized controlled trial	Boolean/Phrase
S10	canal stenosis AND exercise AND random allocation	Boolean/Phrase
S11	canal stenosis AND rehabilitation AND randomized controlled trial	Boolean/Phrase
S12	canal stenosis AND rehabilitation AND random allocation	Boolean/Phrase
S13	canal stenosis AND therapy AND randomized controlled trial	Boolean/Phrase
S14	canal stenosis AND therapy AND random allocation	Boolean/Phrase
S15	canal stenosis AND physiotherapy AND randomized controlled trial	Boolean/Phrase
S16	canal stenosis AND physiotherapy AND random allocation	Boolean/Phrase
S17	vertebral stenosis AND exercise AND randomized controlled trial	Boolean/Phrase
S18	vertebral stenosis AND exercise AND random allocation	Boolean/Phrase
S19	vertebral stenosis AND rehabilitation AND randomized controlled trial	Boolean/Phrase
S20	vertebral stenosis AND rehabilitation AND random allocation	Boolean/Phrase
S21	vertebral stenosis AND therapy AND randomized controlled trial	Boolean/Phrase
S22	vertebral stenosis AND therapy AND random allocation	Boolean/Phrase
S23	vertebral stenosis AND physiotherapy AND randomized controlled trial	Boolean/Phrase
S24	vertebral stenosis AND physiotherapy AND random allocation	Boolean/Phrase

Total result literature searches: $n = 3768$ references

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Availability of data and material All data generated or analyzed during this study are included in this published article.

Declarations

Conflict of interest The authors report no conflicts of interest and certify that no funding has been received for this study and/or preparation of this manuscript.

Ethical approval Not applicable.

Consent to participate Not applicable.

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