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EFFECTIVENESS OF EXERCISE PROGRAMS FOR SYMPTOMATIC LUMBAR SPINAL STENOSIS: A SYSTEMATIC REVIEW

UČINKI VADBENIH PROGRAMOV PRI BOLNIKIH S SIMPTOMI LEDVENE SPINALNE STENOZE: SISTEMATIČNI PREGLED LITERATURE

ABSTRACT

Patients with lumbar spinal stenosis (LSS) have significant disability and functional limitations of walking. They commonly report problems with balance, sensory loss, and weakness of the muscles of the lower extremities. The prevalence and economic burden associated with LSS are expected to increase dramatically because of the aging population. Recently, physical exercise and walking programs have been presented as possible interventions to improve daily life in patients with lumbar spinal stenosis (LSS). To date, there is a lack of clear descriptions of non-surgical treatment protocols and how combinig these interventions affect daily life of the patients and help to prolong the time to surgery. The aim of this systematic review is to provide a comprehensive and updated summary to the reader addresing exercise programs which can help reduce symptoms of lumbar spinal stenosis. Two electronic databases were searched for randomized controlled studies of physical exercise or walking programs and other non-surgical treatment that examined effects on physical abilities/performance in daily life. Four articles were included. All included studies used physical exercise as an intervention, with one study also including medical care (tablet-based with the option of epidural steroid injections). Two studies included manual therapy and two studies offered individually supervised exercise sessions. As a control group, two included a home-based intervention and one was comparing three different conservative treatments included manual therapy/individualized exercise. A significant intervention effect was observed in all studies compared with the control groups, except in study, where the primary outcomes were between-group differences. The present systematic review on non-operative treatment included patients diagnosed for lumbar spinal stenosis with neurogenic claudication concluded that there is moderate-quality evidence and limiting the ability to make conclusions about their effectiveness. Further trials are needed.

Keywords: degenerative spinal disease, neurogenic claudication, physical performance, individualized exercise, training program, walking

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IZVLEČEK

Bolniki z ledveno spinalno stenozo (LSS) imajo znatno invalidnost in funkcionalne omejitve pri hoji. Pogosto poročajo o težavah z ravnotežjem, izgubi občutkov in šibkosti v mišicah spodnjih okončin. Pričakuje se, da se bosta razširjenost in gospodarsko breme, povezano z LSS močno povečala zaradi staranja prebivalstva. Pred kratkim so bili programi telesne vadbe in hoje predstavljeni kot načini konservativnega zdravljenja, ki lahko izboljšajo vsakdanje življenje pri bolnikih z ledveno spinalno stenozo (LSS). Do danes primanjkuje jasnih opisov nekirurških protokolov zdravljenja in kako kombiniranje teh vpliva na vsakdanje življenje pacientov in pomaga podaljšati čas do operacije. Cilj tega sistematičnega pregleda je bralcu zagotoviti izčrpen in posodobljen povzetek, ki obravnava vadbene programe, ki lahko pomagajo zmanjšati simptome ledvene spinalne stenoze. V dveh elektronskih zbirkah podatkov smo iskali randomizirane kontrolirane študije programov telesne vadbe ali hoje in drugega nekirurškega zdravljenja, ki je preučevalo učinke na telesne sposobnosti/zmogljivosti v vsakdanjem življenju. Vključeni so štirje članki. Vse vključene študije so kot intervencijo uporabile telesno vadbo, pri čemer je ena študija vključevala tudi medicinsko oskrbo (na osnovi tablet z možnostjo epiduralnih injekcij steroidov). Dve študiji sta vključevali manualno terapijo, dve pa sta ponujali individualno vadbo. Dve sta v kontrolno skupino vključevali intervencijo vadbenega programa, ki so ga udeleženci raziskave izvajali sami doma, ena raziskava pa je primerjala tri različne konservativne načine zdravljenja, vključno z manualno terapijo in individualnimi vajami. V vseh študijah so opazili pomemben učinek intervencije v primerjavi s kontrolnimi skupinami, razen v eni študiji, ki je primerjala razlike med različnimi intervencijami. Zadnji sistematični pregled nekirurškega zdravljenja je vključeval bolnike z diagnozo ledvene spinalne stenoze z nevrogeno klavdikacijo. Zaključili so, da obstajajo dokazi zmerne kakovosti, ki omejujejo sklepanja o njihovi učinkovitosti.

Ključne besede: degenerativna bolezen hrbtenice, nevrogena klavdikacija, telesna zmogljivost, individualna vadba, program treninga, hoja

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INTRODUCTION

Lumbar spinal stenosis (LSS) is a leading degenerative condition of the spine with dramatic rise in spine surgery rates because of the aging population (Schneider et al., 2019). Also the prevalence and economic burden associated with LSS are expected to increase dramatically due to the same reason (Bussières et al., 2021). The disease is associated with significant disability, functional limitations and pain which has a profound impact on person's daily life.

Symptoms called neurogenic claudication typically present with gluteal and/or leg pain, numbness, weakness or fatigue when standing or walking, with relief of symptoms when sitting down or bending forward (Anderson et al., 2019; Lurie & Tomkins-Lane, 2016). That's why most people with symptomatic LSS have limited walking capacity, they may require walking aids and may even avoid walking. As a result, these patients are less physically active which has consequences on overall health and physical performance (Lurie & Tomkins-Lane, 2016).

Impaired walking includes aspects of being physically restricted, isolated and emotionally unstable and that can lead to increased levels of depression, anxiety, and hopelessness (Knutsson et al., 2021). Therefore, LSS affects not only quality of life but also increases the risk for developing chronic diseases (Minetama et al., 2019).

A systematic review concluded that manual therapy and exercise give important short-term improvement in symptoms and function compared with medical care or community-based group exercise. It was found that comprehensive care demonstrates important improvements in walking distance compared with self-directed home exercise (Bussières et al., 2021).

In a recent studies all exercise interventions lasted 6 weeks, 2-3 times per week. Exercise intensity level was individually tailored and progressively modified to avoid pain. In one study all patients in both groups were asked to take a daily walk and write a walking diary (Minetama et al., 2019). Not even one study included a structured walking program. Two studies also included a cognitive behavioral approach with instructions on self-management strategies, including education regarding their condition and how to manage symptoms (Ammendolia et al., 2018; Chow et al., 2019). The main role of physical exercises may be to improve patients function with LSS rather than improve the LSS itself. Although physical exercises are commonly recomended in clinical practice for patients with mild to moderate LSS, there is still not enough studies that examined the effect of individual exercise programs or walking interventions that improve patients function. The aim of this systematic review is to provide a

comprehensive and updated summary to the reader addresing exercise programs which can help reduce symptoms of lumbar spinal stenosis.

METHODS

The review methods and reporting were performed according to the preferred reporting items in systematic review and meta-analyses (PRISMA) guidelines.

Eligibility criteria

The PICOS search tool (participant, intervention, comparison, outcome, and study design) was used to determine keywords (Table 1).

Studies were included in the systematic review if they met the following criteria: (a) randomized controlled trials, (b) published in academic journals, (c) written in English, (d) with participants older than 65 years, diagnosed with degenerative LSS, (e) studies that included physical exercise or walking programe as an interventions with (f) outcome of physical ability/performance. All other studies were excluded.

Table 1. »PICOS« items used to select keywords.

PICOS item	Detail
Participants	Patients with LSS
Interventions	Physical exercise training or/and walking program
Comparisons	Active or inactive control group
Outcomes	Physical ability/performance
Study designs	RCTs

Note. RCT, randomized controlled trial.

Search strategy

To identify potentially relevant studies, we performed a comprehensive literature search in electronic databases PubMed and MEDLINE from the database's inception to the final update in October 2022. Medical subject heading (mesh) terms were used, if available, for a qualitative search of potential studies. Search strategies utilized a combination of key words to represent definitions of lumbar spinal stenosis, neurogenic claudication, physical activity interventions and walking programs. Terms were combined using the »AND« and »OR«. Combination of search phrases and terms was: »lumbar spinal stenosis AND neurogenic claudication AND

(physical performance OR exercise OR training program OR sport OR physical activity OR bodily performance) AND (walking test OR 6-min walk test OR six minute walking test OR 6-min walking test OR walk test)« and we search only for randomized controlled trials between years 2017-2022. A flow diagram of the search is presented in Figure 1.

Figure 1. PRISMA flow diagram.

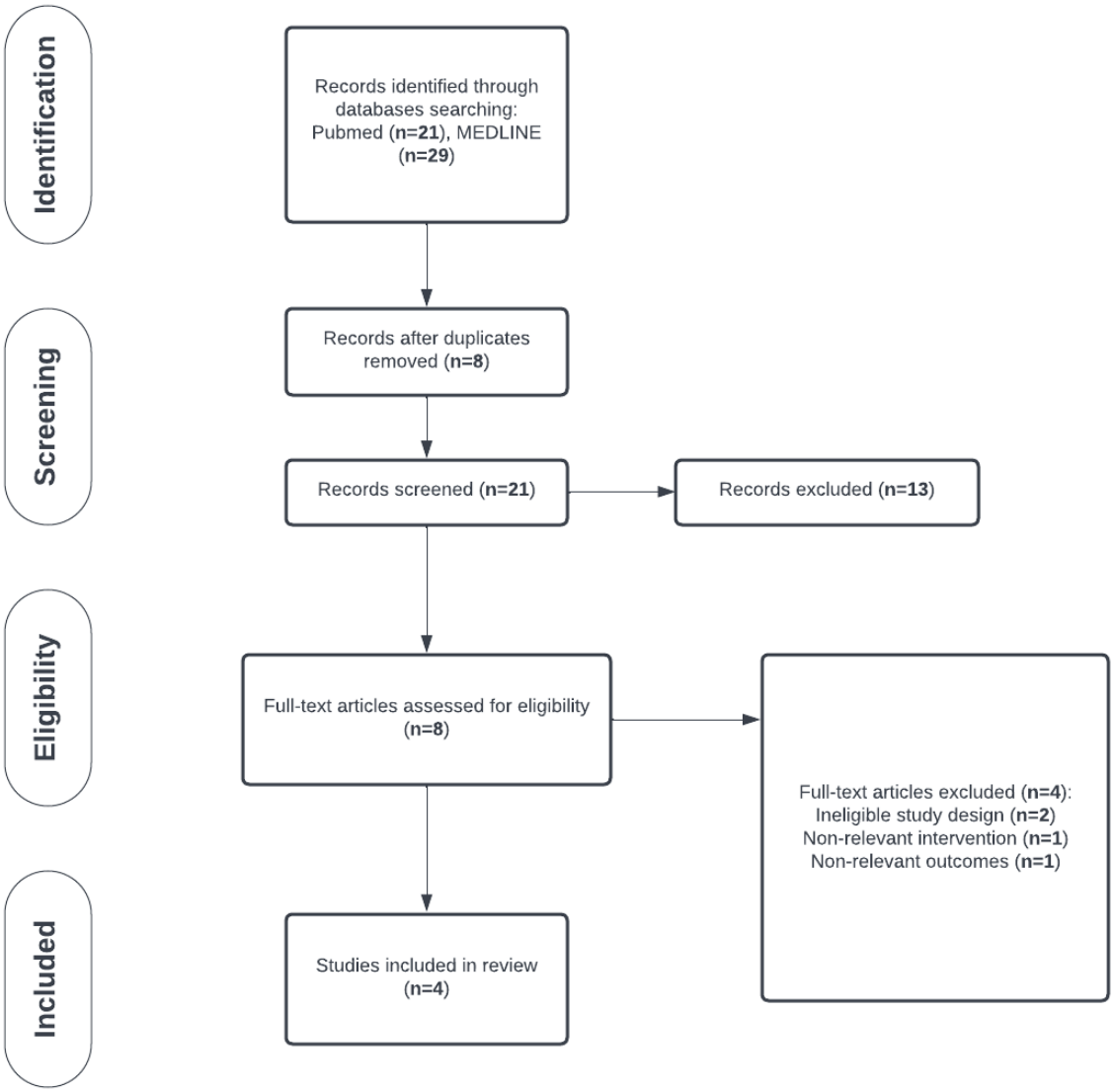


Figure 1 represents search strategy where we included articles that match all our inclusion criteria. Between screening proces we also excluded all articles which compare preoperative programes or presurgery physiotherapy with outcome of the surgery (Hebert et al., 2019; Kitano CP et al., 2020; Kitano et al., 2021; Lindbäck et al., 2018; Perruccio et al., 2021). In systematic review we did not include any other detected degenerative or chronical disease in patients with LSS. We assumed that it can have a high impact on results of exercise programes because our

population of LSS patients is older than 65 years (Booth et al., 2017; Norden et al., 2017; Vanti et al., 2021). We also try not to include any medical accessory to help improve ability to walk and overall physical performance as belt (Ammendolia et al., 2019) or tens (Ammendolia et al., 2016; Martins et al., 2021) and other kind of physiotherapy (Zhu et al., 2021).

Risk of bias assessment

The quality of the included studies was evaluated using the revised Cochrane Collaboration's risk of bias tool (*Cochrane Handbook for Systematic Reviews of Interventions | Cochrane Training*, n.d.). The following biases were evaluated: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, bias in selection of the reported result and overall bias. Risk of bias was assessed as low, some concerns or high for each domain and for overall bias.

RESULTS

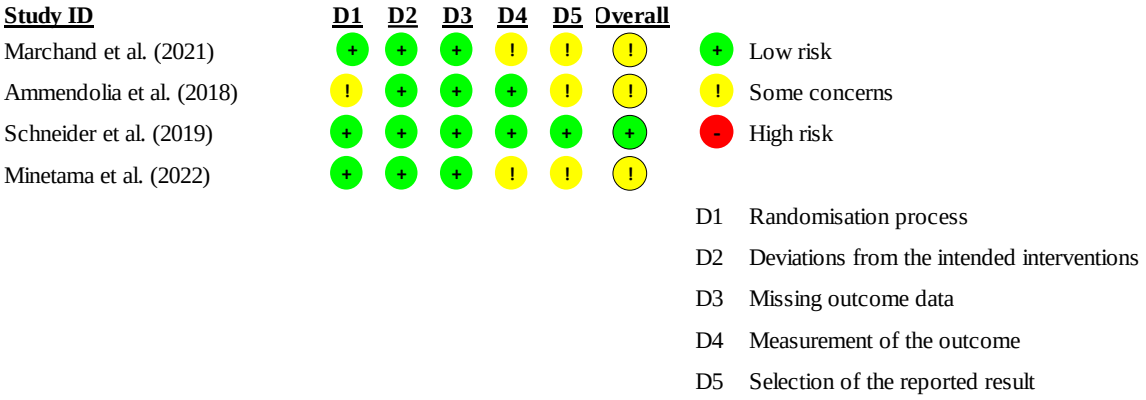
Study selection

The flow of studies through the review process is reported in Figure 1. Automation tools used in databases were language (English), study type (randomized controlled trial) and year (2017 to 2022). Duplicate records were removed once the search strategy outputs were combined. All potentially eligible articles were screened, using a standardized Exel spreadsheet. In phase one screening, titles and abstracts were classified as relevant, possibly relevant, or irrelevant according to the eligibility criteria. Then during phase two screening, the full text of possibly relevant articles were read to see whether full inclusion criteria were met. All studies that met inclusion criteria were again screened to determined eligibility for the systematic literature review.

Quality assessment

The bias risks are presented using a risk of bias summary in Figure 2. In the aspects of measurement of the outcome, two of the studies were assessed with some concerns, in the aspects of randomization process one out of the four included studies was assessed with some concerns. Three of all included studies were assessed with some concerns on selection of the reported result and all domains and overall.

Figure 2. Risk of bias summary.



Study characteristics

All included studies were published between 2017 and 2022. They included a total of 517 patients with LSS. One study was conducted in USA, one in Japan, one in Canada and for one, the location is not described. Two hundred sixteen patients received a supervised physical exercise intervention. Two studies compared self-directed/home exercise program with an individual exercise intervention. One study compared between group exercise, medical care and manual therapy/individualized exercise and one study aims to evaluate the effectiveness of a preoperative exercise-based intervention program with usual care. The average age of participants in the included studies ranged from 66.2 to 73.2 years. The youngest patients were in the exercise group of the study by Marchand et al. (2021), and the oldest were in the control group of the study by Minetama et al. (2019). All studies reported frequency of exercise. The exercises were performed two to three times per week. The duration of the interventions was 6 weeks. The characteristics of the included studies are shown in Table 2.

In each study the follow up was different. In Table 2 we showed results for clinical outcome measures first follow up after intervention. In two studies it was right after the intervention, at 6-weeks, in one at 8-weeks, and in one the first follow up was at two months. We mostly showed the primary outcomes which are important for our systematic review.

One included study examined the effect of an intervention on walking distance as a primary measure using the Self-Paced Walk Test (SPWT). The experimental group demonstrated statistically significant and clinically important improvement in the SPWT compared to the self-directed group at each follow up period (8 weeks, 3 months, 6 months and 12 months). As

a secondary measures two studies also measured the difference in walking distance. In one study has been shown that Oswestry disability index (ODI) is highly correlated (r= 0.83) with the SPWT. In all studies the minimally clinically important difference was the proportion of participants who achieved at least a 30% improvement. Two studies included Zürich Claudication Questionnaire (ZCQ), which includes subscales for symptoms (scores 1-5, with higher scores indicating worse symptoms) and physical function (scores 1-4, with higher scores indicating worse function). In two studies the primary outcome was measured by Oswestry disability index (ODI) which is a reliable and valid measure of back-related disability, where 0 represents no disability and 100 represents the worst possible disability. Three studies indicated current low back and leg pain using a 11- point Numerical Rating Scale (NRS) which is a global measure of pain intensity ranging from 0 (no pain) to 10 (pain as bad as it could be). There were statistically significant and clinically important improvements in disability, ZCQ symptom severity, ZCQ physical function, walking distance on the SPWT, leg pain on the NRS and number of daily steps. Both studies which included a home-based intervention in control group showed greater improvements favoring the comprehensive program/supervized exercises. In study where they analyzed between-group differences, all groups showed some level of improvement on all outcome measures at 2- and 6-month follow-ups. Group exercise had greater improvement in mean daily physical activity compared with medical care. All groups showed within-group improvements in walking distance at 2 months, which was sustained up to 6 months. The mean (SD) walking distance had increased from 433.4 (421.2)- 482.2 (529.1) meters to a range of 683.3 (723.5). No between-group differences in physical activity (secondary outcome) responder rates were found at 2 months, and there were no differences found at 6 months for any of the 3 outcome. In the study of an exercise-based prehabilitation program for patients awaiting surgery, they identified between-group differences for low back extensor endurance (modified Sorensen test; +47.8 s=267.0% increase) and total ambulation time (+85.4 s=58.4% increase).

Types of physical activity mostly included treadmill or outdoor walking and stationary or outdoor cycling as a warm-up procedure. Both activities was also recommended as part of the daily home exercise routine. Individualized supervized program consisted of fall risk prevention exercises, spinal stabilization exercises, and stretching. In one study, same exercise instructions and self-management strategies was received also in control group, but without personalized education or instruction. Manual therapy included lumbar flexion-distraction mobilization, hip joint mobilization, side posture lumbar/sacroiliac joint mobilization, and

neural mobilization. Individually tailored muscle exercises included those for the trunk and lower extremities with concentric and/or isometric phases.

Table 2. Characteristics of included studies.

Study	Sample size	Age (mean+/- SD)	Intervention	Duration	Measures	Outcomes
Marchand et al. (2021)	EX= 35 CON= 33	EX= 66.2+/-9.6 CON= 71.6+/-7.6	EX= preoperative exercise- based program CON= usual care	3 times per week 6 weeks	11-point Numerical Rating Scale (NRS) ODI Walking ability (time to first symptoms and total ambulation time Lumbar extensors endurance (modified Sorensen test)	Back pain intensity: EX=4.5+/-2.2, CON=5.0+/-2.7, p=0.91 (group x time interaction) Leg pain intensity: EX= 5.5+/-2.3, CON= 6.5+/-2.4, p= 0.04 (group x time interaction) LSS disability: EX=35.0+/-7.9, CON=37.5+/-6.5, p= 0.04 (group x time interaction) Walking capacities-s: EX=Time to 1st symptoms (158.8+/- 102.4), CON= Time to 1st symptoms (79.4+/- 87.4), p=0.08 (group x time interaction); EX= Total ambulation time (231.7+/- 92.2), CON=Total ambulation time (146.3+/- 104.7), p=0.02 (group x time interaction) Lumbar extensors endurance: EX=65.7+/-65.6, CON=17.9+/-35.8, p=0.002 (group x time interaction)
Ammendolia et al. (2018)	EX= 51 CON= 53	EX= 69.4+/-7.7 CON= 71.7+/-9.5	EX= comprehensive training program; one-on-one sessions, self-management strategies, manual therapy, instructional video and workbook, pedometer (Pedusa PE-771) CON= self-directed training program	2 times 15- to 20- minute treatment sessions per week 6 weeks	SPWT ZCQs ZCQf ODI ODI walk NRS back NRS leg	SPWT: EX= 501.8+/-610, CON= 210.8+/- 401, p=0.0005 ZCQs: EX=-0.47+/-0.55, CON= -0.24+/-0.46, p=0.033 ZCQf: EX=-0.43+/-0.55, CON= -0.37+/-0.54, p=0.81 ODI: EX=-0.1+/-0.10, CON=-0.1+/-0.10, p=0.3 ODI walk: EX=-0.6+/-0.70, CON=-0.3+/-0.90, p=0.14 NRS back: EX=-2.0+/-2.7, CON=-0.8+/-2.1, p=0.002 NRS leg: EX=-2.1+/-2.1, CON=-1.2+/-2.2, p=0.094
Schneider et al. (2019)	MC= 88 GE= 84 MTE= 87	MC= 72.0+/-7.4 GE=72.9+/-8.1 MTE=72.1+/-8.1	EX= 1) Medical care, 2) Group exercise, 3) Manual therapy/Individualized exercise No control group	MC= 3 visits to a physical medicine physician GE= two exercise classes per week MTE= 2 times per week	Swiss Spinal Stenosis questionnaire SPWT	MTE vs. MC: -2.0; 95% CI, -3.6 to -0.4 or GE: -2.4; 95% CI, -4.1 to -0.8, less than a 10% improvement from baseline is not likely to be clinically important SPWT: MC=616.6 (620.8), GE=651.5 (639.7), MTE=698.6 (662.7), p=0.26
Minetama et al. (2019)	PT=42 HE=42	PT=72.3+/-6.9 HE=73.2 +/-8.2	PT= supervised physical therapy HE= home exercise program	Twice per week 6 weeks	ZCQs ZCQf NRS back NRS leg SPWT (m)	Mean change at 6 weeks (95% CI): ZCQs: PT=-0.6 (-0.7 to -0.4), HE=-0.2 (-0.3 to 0) ZCQf: PT=-0.5 (-0.7 to -0.3), HE=-0.1 (-0.3 to 0) NRS back: PT=-1.3 (-2.3 to -0.4), HE=-0.2 (-0.9 to 0.5) NRS leg: PT=-2.0 (-2.8 to -1.3), HE= -0.6 (-1.5 to 0.2) SPWT: PT=525.8 (384.8-666.8), HE=69.9 (24.4-115.5)

Note. EX = experimental group; CON = control group; NRS = Numerical Rating Scale; ODI = Oswestry Disability Index; ZCQs = Zurich Claudication Questionnaire Symptom severity; ZCQf = Zurich Claudication Questionnaire Physical function; SPWT = Self-Paced Walking Test; MC = Medical Care; GE = Group Exercise; MTE = Manual therapy/Individualized exercise; PT = Physical Therapy; HE = Home exercise; CI = confidence interval; p = statistical significance

DISCUSSION

This systematic review explored the current state of scientific knowledge regarding the associations between physical exercise interventions or walking programes and physical function and walking ability in patients with LSS. In addition, we presented and described which tests were used in the included studies. The results of a limited number of studies show that physical exercise may significantly improve walking ability, low back and/or leg symptoms and overall health-related quality of life. Furthermore, there is insufficient evidence to conclude that supervised individual exercise-based and walking program can attenuate long-term effects in symptom severity, physical function, walking distance, pain, disability and physical activity.

This is the first systematic review to demonstrate the effect of physical exercise and walking program in LSS patients. It also provides insight into the instruments used to measure walking ability and physical performance. These results from a small number of studies suggest that physical exercise training can have a positive effect on symptoms related to LSS, function, disability and walking distance in those patients. Further work should be more focused in multimodal approach (Bagley et al., 2019; Lurie & Tomkins-Lane, 2016; Whitman et al., 2006). Management strategies of psychological factors should be taken more seriously as LSS patients are mostly older. In those patients there is usually lack of motivation for changing lifestyle and daily routines. With tests as Hospital Anxiety and Depression Scale (HADS), Pain Catastrophizing Scale (PCS), Pain Anxiety Symptoms Scale (PASS-20) and Tampa Scale for Kinesiophobia (TSK-11) which were used in one study, we can also reduce follow up drop. In two studies participants received instructions on how to manage symptoms using a cognitive behavioral approach. There is lack of evidence reported on the association between psychological factors and disability, pain or walking ability in patients with LSS (Houle et al., 2021). The correlation between daily step count and TSK, HADS or PCS was found as non significant (Minetama et al., 2022). Before we start working on improving someone's health behavioural change, it's really important to know an individual's capability (Bearne et al., 2019). Many studies on walking ability, have been published, not only with LSS patients, and they all suggest pain-free exercise, which induces changes in walking distance (Manfredini et al., 2022). The proper combination of intensity, duration and frequency of the training bouts to maintain a pain-free exercise is the possible key to help those patients with their pain and disability level. Exercises should be individually tailored and comfortable done with as many instructions patients need to understand why and what they are doing (Tew et al., 2015).

CONCLUSION

The wide range of questionnaires used to assess the same outcome could led to some conflicting conclusions. There is also lack of functional tests described in all studies included in systematic review. We suggest in further research to describe measurements of functional limitations caused by LSS. The low number of studies that provided a direct evaluation with combination of structured exercise and walking program is for sure the biggest limitation of our systematic review. Only studies published in English were considered for this scoping review. We cannot rule-out that additional relevant evidence may have been published in other languages.

With only four articles included in this systematic review we can see that there is really high need for further research to be done. The present systematic review on non-operative treatment included patients diagnosed for lumbar spinal stenosis with neurogenic claudication concluded that there is moderate-quality evidence and limiting the ability to make conclusions about their effectiveness. Further trials are needed.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Ammendolia, C., Côté, P., Rampersaud, Y. R., Southerst, D., Budgell, B., Bombardier, C., & Hawker, G. (2016). Effect of TENS Versus Placebo on Walking Capacity in Patients With Lumbar Spinal Stenosis: A Protocol for a Randomized Controlled Trial. *Journal of Chiropractic Medicine*, *15*(3), 197–203. https://doi.org/10.1016/j.jcm.2016.04.001

Ammendolia, C., Côté, P., Southerst, D., Schneider, M., Budgell, B., Bombardier, C., Hawker, G., & Rampersaud, Y. R. (2018). Comprehensive Nonsurgical Treatment Versus Self-directed Care to Improve Walking Ability in Lumbar Spinal Stenosis: A Randomized Trial. *Archives of Physical Medicine and Rehabilitation*, *99*(12), 2408-2419.e2. https://doi.org/10.1016/j.apmr.2018.05.014

Ammendolia, C., Rampersaud, Y. R., Southerst, D., Ahmed, A., Schneider, M., Hawker, G., Bombardier, C., & Côté, P. (2019). Effect of a prototype lumbar spinal stenosis belt versus a lumbar support on walking capacity in lumbar spinal stenosis: a randomized controlled trial. *The Spine Journal : Official Journal of the North American Spine Society*, *19*(3), 386–394. https://doi.org/10.1016/J.SPINEE.2018.07.012

Anderson, D. B., Mathieson, S., Eyles, J., Maher, C. G., Van Gelder, J. M., Tomkins-Lane, C. C., Ammendolia, C., Bella, V., & Ferreira, M. L. (2019). Measurement properties of walking outcome measures for neurogenic claudication: a systematic review and meta analysis. *Spine Journal*, *19*(8), 1378–1396. https://doi.org/10.1016/j.spinee.2019.04.004

Bagley, C., Macallister, M., Dosselman, L., Moreno, J., Aoun, S., & Ahmadieh, T. El. (2019). Current concepts and recent advances in understanding and managing lumbar spine stenosis [version 1; referees: 3 approved]. *F1000Research*, *8*, 1–9. https://doi.org/10.12688/f1000research.16082.1

Bearne, L., Galea Holmes, M., Bieles, J., Eddy, S., Fisher, G., Modarai, B., Patel, S., Peacock, J. L., Sackley, C., Volkmer, B., & Weinman, J. (2019). Motivating Structured walking Activity in people with Intermittent Claudication (MOSAIC): Protocol for a randomised controlled trial of a physiotherapist-led, behavioural change intervention versus usual care in adults with intermittent claudication. *BMJ Open*, *9*(8), 1–12. https://doi.org/10.1136/bmjopen-2019-030002

Booth, F. W., Roberts, C. K., Thyfault, J. P., Ruegsegger, G. N., & Toedebusch, R. G. (2017). Role of inactivity in chronic diseases: Evolutionary insight and pathophysiological mechanisms. *Physiological Reviews*, *97*(4), 1351–1402. https://doi.org/10.1152/physrev.00019.2016

Bussières, A., Cancelliere, C., Ammendolia, C., Comer, C. M., Zoubi, F. Al, Châtillon, C. E., Chernish, G., Cox, J. M., Gliedt, J. A., Haskett, D., Jensen, R. K., Marchand, A. A., Tomkins-Lane, C., O'Shaughnessy, J., Passmore, S., Schneider, M. J., Shipka, P., Stewart, G., Stuber, K., … Ornelas, J. (2021). Non-Surgical Interventions for Lumbar Spinal Stenosis Leading To Neurogenic Claudication: A Clinical Practice Guideline. *Journal of Pain*, *22*(9), 1015–1039. https://doi.org/10.1016/j.jpain.2021.03.147

Chow, N. W., Southerst, D., Wong, J. J., Kopansky-Giles, D., & Ammendolia, C. (2019). Clinical Outcomes in Neurogenic Claudication Using a Multimodal Program for Lumbar Spinal Stenosis: A Study of 49 Patients With Prospective Long-term Follow-up. *Journal of Manipulative and Physiological Therapeutics*, *42*(3), 203–209. https://doi.org/10.1016/j.jmpt.2018.11.004

Cochrane Handbook for Systematic Reviews of Interventions | Cochrane Training. (n.d.). Retrieved October 27, 2022, from https://training.cochrane.org/handbook

Hebert, J. J., Abraham, E., Wedderkopp, N., Bigney, E., Richardson, E., Darling, M., Hall, H., Fisher, C. G., Raja Rampersaud, Y., Thomas, K. C., Jacobs, B., Johnson, M., Paquet, J., Attabib, N., Jarzem, P., Wai, E. K., Rasoulinejad, P., Ahn, H., Nataraj, A., … Manson, N. (2019). Patients undergoing surgery for lumbar spinal stenosis experience unique courses of pain and disability: A group-based trajectory analysis. *PLoS ONE*, *14*(11), 1–14. https://doi.org/10.1371/journal.pone.0224200

Houle, M., Bonneau, J. D., Marchand, A. A., & Descarreaux, M. (2021). Physical and Psychological Factors Associated With Walking Capacity in Patients With Lumbar Spinal Stenosis With Neurogenic Claudication: A Systematic Scoping Review. *Frontiers in Neurology*, *12*. https://doi.org/10.3389/FNEUR.2021.720662

Kitano CP, T., Kawakami, M., Fukui, D., Ishimoto, Y., Nagata, K., Yamada, H., & Nakagawa, Y. (2020). Preoperative psychological factors affecting surgical satisfaction of elderly patients with lumbar spinal stenosis. *Journal of Orthopaedic Science*, *25*(5), 751–756. https://doi.org/10.1016/j.jos.2019.10.005

Kitano, T., Kawakami, M., Ishimoto, Y., Teraguchi, M., Fukui, D., Matsuoka, T., & Nakagawa, Y. (2021). Psychological Distress Associated with Patient-Reported Outcomes in Preoperative Patients with Lumbar Spinal Stenosis. *Asian Spine Journal*, *15*(4), 533–538. https://doi.org/10.31616/asj.2020.0093

Knutsson, B., Jong, M., Sayed-Noor, A., Sjödén, G., & Augutis, M. (2021). Waiting for lumbar spinal stenosis surgery: suffering and a possibility to discover coping abilities. *Orthopedic Reviews*, *14*(1), 1–7. https://doi.org/10.52965/001C.30716

Lindbäck, Y., Tropp, H., Enthoven, P., Abbott, A., & Öberg, B. (2018). PREPARE: presurgery physiotherapy for patients with degenerative lumbar spine disorder: a randomized controlled trial. *Spine Journal*, *18*(8), 1347–1355. https://doi.org/10.1016/j.spinee.2017.12.009

Lurie, J., & Tomkins-Lane, C. (2016). Management of lumbar spinal stenosis. *BMJ (Online)*, *352*. https://doi.org/10.1136/bmj.h6234

Manfredini, F., Traina, L., Gasbarro, V., Straudi, S., Caruso, L., Fabbian, F., Zamboni, P., Manfredini, R., & Lamberti, N. (2022). Structured pain-free exercise progressively improves ankle-brachial index and walking ability in patients with claudication and compressible arteries: an observational study. *Internal and Emergency Medicine*, *17*(2), 439–449. https://doi.org/10.1007/s11739-021-02827-4

Marchand, A. A., Houle, M., O'Shaughnessy, J., Châtillon, C. É., Cantin, V., & Descarreaux, M. (2021). Effectiveness of an exercise-based prehabilitation program for patients awaiting surgery for lumbar spinal stenosis: a randomized clinical trial. *Scientific Reports*, *11*(1), 1–13. https://doi.org/10.1038/s41598-021-90537-4

Martins, Â., Gouveia, D., Cardoso, A., Gamboa, Ó., Millis, D., & Ferreira, A. (2021). Nervous system modulation through electrical stimulation in companion animals. *Acta Veterinaria Scandinavica*, *63*(1). https://doi.org/10.1186/s13028-021-00585-z

Minetama, M., Kawakami, M., Teraguchi, M., Kagotani, R., Mera, Y., Sumiya, T., Nakagawa, M., Yamamoto, Y., Matsuo, S., Koike, Y., Sakon, N., Nakatani, T., Kitano, T., & Nakagawa, Y. (2019). Supervised physical therapy vs. home exercise for patients with lumbar spinal stenosis: a randomized controlled trial. *Spine Journal*, *19*(8), 1310–1318. https://doi.org/10.1016/j.spinee.2019.04.009

Minetama, M., Kawakami, M., Teraguchi, M., Kagotani, R., Mera, Y., Sumiya, T., Nakagawa, M., Yamamoto, Y., Matsuo, S., Sakon, N., Nakatani, T., Kitano, T., & Nakagawa, Y. (2022). Associations between psychological factors and daily step count in patients with lumbar spinal stenosis. *Physiotherapy Theory and Practice*, *38*(10). https://doi.org/10.1080/09593985.2020.1855685

Norden, J., Smuck, M., Sinha, A., Hu, R., & Tomkins-Lane, C. (2017). Objective measurement of free-living physical activity (performance) in lumbar spinal stenosis: are physical activity guidelines being met? *Spine Journal*, *17*(1), 26–33. https://doi.org/10.1016/j.spinee.2016.10.016

Perruccio, A. V., Power, J. D., Yip, C., Badley, E. M., Canizares, M., & Rampersaud, Y. R. (2021). The impact of multijoint symptoms on patient-reported disability following surgery for lumbar spine osteoarthritis. *Spine Journal*, *21*(1), 80–89. https://doi.org/10.1016/j.spinee.2020.08.005

Schneider, M. J., Ammendolia, C., Murphy, D. R., Glick, R. M., Hile, E., Tudorascu, D. L., Morton, S. C., Smith, C., Patterson, C. G., & Piva, S. R. (2019). Comparative Clinical Effectiveness of Nonsurgical Treatment Methods in Patients With Lumbar Spinal Stenosis: A Randomized Clinical Trial. *JAMA Network Open*, *2*(1), e186828. https://doi.org/10.1001/jamanetworkopen.2018.6828

Tew, G. A., Humphreys, L., Crank, H., Hewitt, C., Nawaz, S., Al-Jundi, W., Trender, H., Michaels, J., & Gorely, T. (2015). The development and pilot randomised controlled trial of a group education programme for promoting walking in people with intermittent claudication. *Vascular Medicine (United Kingdom)*, *20*(4), 348–357. https://doi.org/10.1177/1358863X15577857

Vanti, C., Ferrari, S., Guccione, A. A., & Pillastrini, P. (2021). Lumbar spondylolisthesis: STATE of the art on assessment and conservative treatment. *Archives of Physiotherapy*, *11*(1), 19. https://doi.org/10.1186/s40945-021-00113-2

Whitman, J. M., Flynn, T. W., Childs, J. D., Wainner, R. S., Gill, H. E., Ryder, M. G., Garber, M. B., Bennett, A. C., & Fritz, J. M. (2006). A comparison between two physical therapy teratment programs for patients with lumbar spinal stenosis. *Number*, *31*(22), 2541–2549.

Zhu, Y., Wu, T., Wang, W., Cai, C., Zhu, B., Lin, W., Xu, H., Liang, Q., & Wang, Y. (2021). Artificial Intelligence Algorithm-Based Lumbar and Spinal MRI for Evaluation of Efficacy of Chinkuei Shin Chewan Decoction on Lumbar Spinal Stenosis. *Contrast Media and Molecular Imaging*, *2021*. https://doi.org/10.1155/2021/2700452