European Spine Journal (2020) 29:2143–2163
https://doi.org/10.1007/s00586-020-06339-1

REVIEW ARTICLE

Prevalence of lumbar spinal stenosis in general and clinical populations: a systematic review and meta-analysis

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Received: 4 November 2019 / Revised: 27 January 2020 / Accepted: 9 February 2020 / Published online: 24 February 2020

Abstract

Purpose To estimate the prevalence of degenerative lumbar spinal stenosis (LSS) in adults, identified by clinical symptoms and/or radiological criteria.

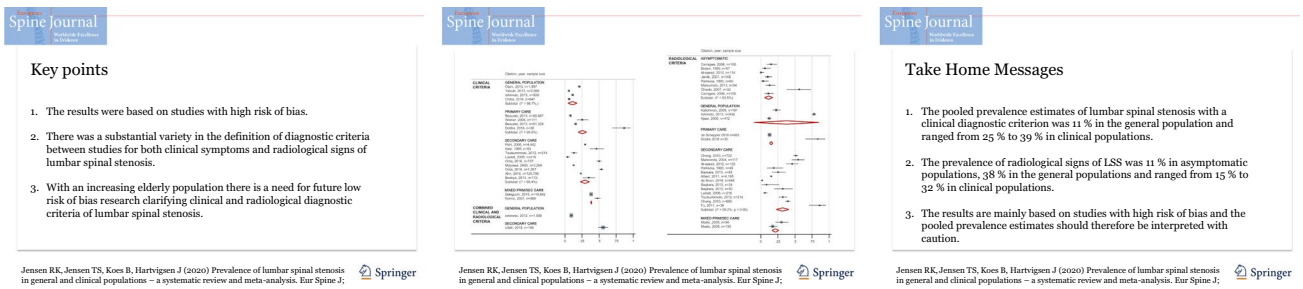
Methods Systematic review of the literature. Pooled prevalence estimates by care setting and clinical or radiological diagnostic criteria were calculated and plotted [PROSPERO ID: CRD42018109640].

Results In total, 41 papers reporting on 55 study samples were included. The overall risk of bias was considered high in two-thirds of the papers. The mean prevalence, based on a clinical diagnosis of LSS in the general population, was 11% (95% CI 4–18%), 25% (95% CI 19–32%) in patients from primary care, 29% (95% CI 22–36%) in patients from secondary care and 39% (95% CI 39–39%) in patients from mixed primary and secondary care. Evaluating the presence of LSS based on radiological diagnosis, the pooled prevalence was 11% (95% CI 5–18%) in the asymptomatic population, 38% (95% CI − 10 to 85%) in the general population, 15% (95% CI 13–18%) in patients from primary care, 32% (95% CI 22–41%) in patients from secondary care and 21% (95% CI 16–26%) in a mixed population from primary and secondary care.

Conclusions The mean prevalence estimates based on clinical diagnoses vary between 11 and 39%, and the estimates based on radiological diagnoses similarly vary between 11 and 38%. The results are based on studies with high risk of bias, and the pooled prevalence estimates should therefore be interpreted with caution. With an growing elderly population, there is a need for future low risk-of-bias research clarifying clinical and radiological diagnostic criteria of lumbar spinal stenosis.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.



Keywords Lumbar spinal stenosis · Neurogenic claudication · Prevalence · MRI · Review · Meta-analysis

Background

Degenerative lumbar spinal stenosis (LSS) refers to narrowing of the spinal canal due to age-related changes in facet joints, discs and ligamentum flavum. The reduced space around the neurovascular structures can lead to neurogenic

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00586-020-06339-1) contains supplementary material, which is available to authorized users.

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claudication, which is the main symptom of LSS. Clinical symptoms related to LSS range from numbness and fatigue to actual pain in the buttocks and/or legs that increase with activities such as walking and standing (neurogenic claudication). Patients often find relief from symptoms when sitting or flexing the spine [1]. Because of the aggravation of symptoms with walking and standing, individuals with LSS often experience reduced self-efficacy and physical function [2].

Currently, there is uncertainty about the clinical diagnostic criteria for LSS. In 2016, Tomkins-Lane et al. [3] published an international Delphi study (2016) that aimed at reaching an expert consensus on which factors were most important in the clinical diagnosis of LSS. The working group proposed seven case history items useful in understanding the clinical presentation of people with LSS: (1) leg or buttock pain while walking, (2) flex forward to relieve symptoms, (3) feel relief when using a shopping cart or bicycle, (4) motor or sensory disturbance while walking, (5) normal and symmetric foot pulses, (6) lower extremity weakness and (7) low back pain [3]. In 2018, Genevay et al. [4] suggested a set of clinical classification criteria including case history items and physical findings aimed at identifying people with LSS. The study identified six items that predicted LSS. These criteria have, however, not yet been validated in an independent dataset, and they have not been widely implemented in research or daily practice.

Magnetic resonance imaging (MRI) is often used to assess radiological signs of LSS as it gives information on the presence and extent of degenerative changes in the lumbar spine and the size of the spinal canal [5]. However, there are no detailed classification criteria to describe LSS using MRI. In fact, pronounced variability in both quantitative, semiquantitative and qualitative definitions have been described [6, 7]. As a consequence by means of consensus, Andreisek and colleagues [8] suggested a set of core items to be assessed in a structured imaging report on LSS. However, there seems to be only a poor correlation between spinal morphology assessed by MRI and clinical symptoms [9].

The prevalence of LSS increases with age due to the degenerative pathogenesis of the condition and is rarely seen in persons below 50 years of age [10–12]. Although, abnormalities in the postnatal development can cause congenital stenosis resulting in an early symptom onset, this is an uncommon condition [13]. With an increasing elderly dependency ratio, the number of people with pain and disability due to LSS will continue to increase and thereby the health care costs as well. However, there is a large range in the reported prevalence of LSS ranging between 6 and 47% depending on diagnostic criteria and the study population [14, 15] and therefore a need for clarity.

This systematic literature review was performed in order to identify studies on prevalence of LSS and to critically appraise and synthesise the evidence.

Objectives

The objective of this study was to estimate the prevalence of LSS in the general and occupational population, and in primary and secondary care, identified by (1) clinical criteria of LSS or (2) by radiological criteria of LSS or (3) a combination of a clinical and radiological criteria of LSS.

Methods

The study protocol for this systematic review was registered on PROSPERO [16] (PROSPERO ID: CRD42018109640) [17]. The review was conducted and reported according to the Meta-analyses Of Observational Studies in Epidemiology (MOOSE) [18] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses PRISMA [19].

Search strategy

A search strategy for electronic databases was developed and assisted by a research librarian. The databases MEDLINE, EMBASE and CINAHL were searched for articles in any language using relevant words in MeSH terms and/or as free text: ‘spinal stenosis’ and ‘lumbar spine’. The search period was not limited, and the searches were conducted on 14 July 2019. See Supplementary file 1 for full search strategy. Also, reference lists from eligible studies and reviews were hand searched for additional references.

Types of studies

Studies with observational study design (cross-sectional, cohort or case–control) or RCTs were considered if the prevalence of LSS was reported in asymptomatic, occupational, general or clinical populations from primary and/or secondary care settings.

Inclusion and exclusion criteria

Two investigators assessed all titles and abstracts independently. In case of disagreement, consensus was reached through discussion. Articles were considered for inclusion if they were original articles from peer-reviewed scientific journals reporting the prevalence of LSS in human adults (above age 18). Studies in all languages were considered. Articles were excluded in the case of: (1) including populations with symptoms or diagnosis mimicking LSS such as

vascular claudication, (2) including populations with competing disease clouding the LSS symptoms such as Parkinson's disease or traumatic spinal cord injury, (3) papers reporting exclusively on prevalence of congenital LSS and (4) studies investigating cadavers.

Data extraction

Data were extracted from the full text papers independently by two of the authors in pairs using a predefined form. If disagreement occurred, consensus was reached through discussion. If data were reported by age and/or sex, both the stratified and total data were extracted.

Case definitions were split onto two groups: (1) Clinical diagnosis of LSS (based on neurogenic claudication: reduced waking distance due to leg pain relieved when sitting or flexing the spine) and (2) radiological diagnosis of LSS (based on a description of narrowing of the central, lateral (recess) or foraminal canal as seen on MRI or CT).

The following descriptive items were extracted: country; year of publication; study design; population (primary care, secondary care, general, asymptomatic or occupational); sample size; age; sex; denominator (number of cases at risk); numerator (number of cases with LSS); diagnostic tool for each of the two case definitions together with all items from the risk-of-bias tool.

Risk-of-bias assessment

Two authors in pairs assessed the risk of bias for each included study using a tool developed to assess the risk-of-bias studies reporting prevalence of low back pain developed by Hoy et al. [20]. The original tool is comprised of 10 questions rated with either high or low risk of bias. We added a descriptive text for each of the LSS case definitions. We modified three questions for the aim of this study. The question in item 1 was rephrased to "Was the study population representative of the target population?" instead of the national population as our study included both general and clinical populations. The original item 5 was left out as both clinical and imaging information could only have been collected directly from the subjects. The original item 9 concerning the length of the shortest prevalence period was considered irrelevant if the case definition was imaging. The modified tool thus became a 9-item checklist addressing internal and external validity (Table 1). Each question could be answered as "yes" or "no", and an overall assessment of risk of bias was rated low, moderate or high. Any disagreement was resolved by discussion between the authors. The full risk-of-bias tool is shown in Supplementary file 2.

Data management and analysis

EndNote X8' (Clarivate Analytics, Philadelphia, USA) was used for management of included references and removal of duplicates. Covidence (Covidence systematic review software, 2013, Veritas Health Innovation, Melbourne, Australia) was used for further management during the inclusion and exclusion process.

If the severity of LSS was assessed and reported, the prevalence of the categories moderate and severe was merged and included as the overall prevalence. If the location of LSS was described (foraminal, recess and central), the combined prevalence was included and if combining the three was not possible the prevalence of central stenosis was chosen. If more studies reported on the same data source, only the original study was included in the meta-analysis.

Data were extracted from each individual study population if the studies included more than one study population or used more than one case definition. The prevalence was calculated by extracting the number of people diagnosed with LSS (numerator) divided by the sample size (denominator).

Data extraction was done in Microsoft Excel 2010 database (Microsoft Corporation, Redmond, WA, USA), and the extracted data were presented in tabular form with summarising tables.

Table 1 Risk-of-bias assessment tool [20]

Items	Risk-of-Bias tool modified from Hoy et al. [20]
1.	Was the study population representative of the target population?
2.	Was the sampling frame a true or close representation of the target population?
3.	Was some form of random selection used to select the sample, OR, was a census undertaken?
4.	Was the likelihood of non-response bias minimal?
5.	Was an acceptable case definition used in the study?
6.	Was the study instrument that measured the parameter of interest (e.g. prevalence of LSS) shown to have reliability and validity (if necessary)?
7.	Was the same mode of data collection used for all subjects?
8.	Was the length of the shortest prevalence period for the parameter of interest appropriate?
9.	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?

The mean prevalence for each subpopulation was calculated, and descriptive data were tabulated and displayed.

Pooled prevalence estimates were calculated and grouped first by case definition (clinical or radiological) and then by setting (asymptomatic, general and occupational populations, primary care, secondary care or mixed primary and secondary care) using a random-effects model (to account for heterogeneity). Separate meta-analyses were carried out for the different subgroups to avoid dependence problems and a pooled prevalence figure was calculated with 95% CI showing the relative study weights assigned. Two studies reporting a prevalence of 0% were artificially given a numerator of 0.001.

Even though subgroups were formed, some heterogeneity was expected within the subgroups due to differences in clinical populations and case definitions. The heterogeneity was statistically assessed by calculating I^2.

The distribution of prevalence estimates by risk of bias was assessed by a graphical display.

Data management and statistical analysis were performed using Stata version 15 (StataCorp, College Station, Texas, USA).

Results

After excluding duplicates, the electronic search provided 1813 papers of potential interest. Additionally, four papers were identified through reference list and one from contact with an expert with a final of 1817 papers. After screening titles and abstracts, 105 full text papers were retrieved. A total of 41 (reporting on 52 study populations) papers were included in the review. Figure 1 displays the flow of the inclusion. For three of the 52 populations, prevalence of LSS was reported for both the clinical and the radiological case definitions. Therefore, the final number of study samples reporting prevalence figures was 55.

Characteristics of studies

Of the 55 study samples reporting prevalence estimates, 22 used a clinical case definition of LSS, 30 a radiological case definition and three used a combination. In three study samples, CT was used to diagnose LSS. One used either MRI or CT, one used fluoroscopically guided diagnostic injections and advanced imaging techniques and the remaining

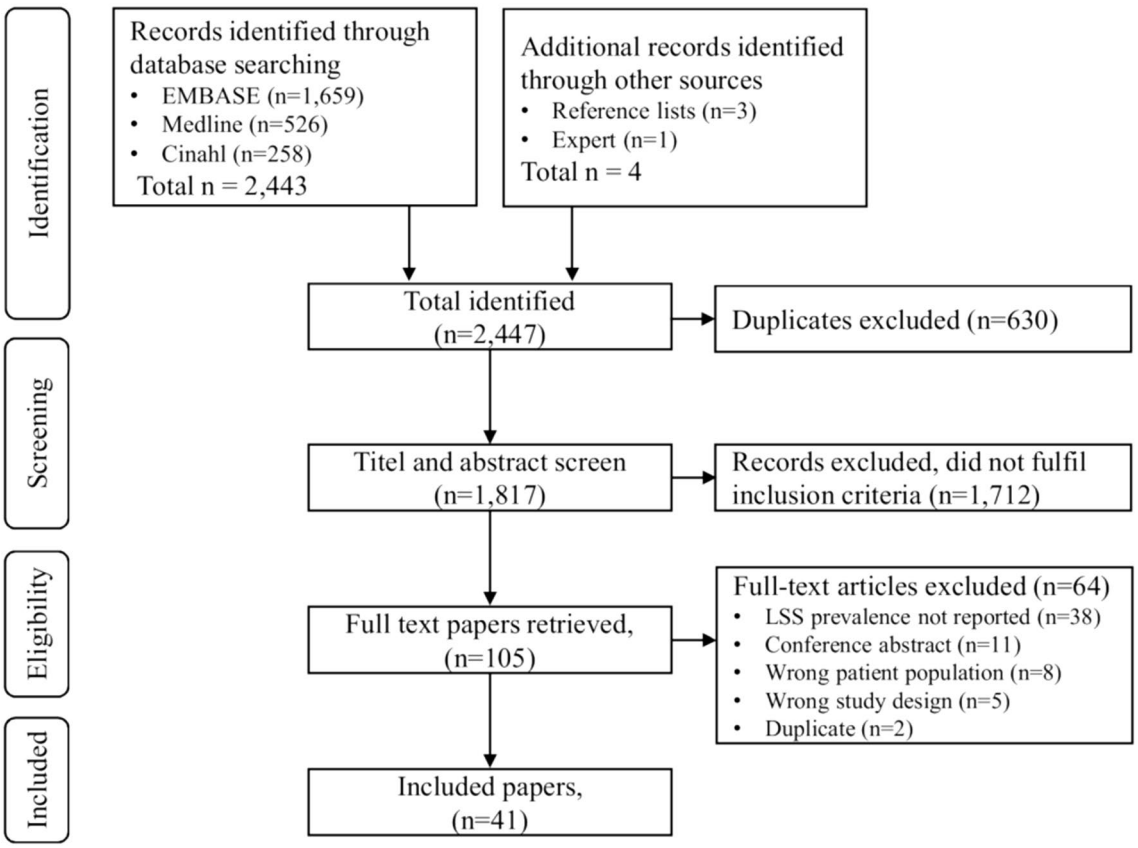

Fig. 1 PRISMA flowchart of search and exclusion process for papers of the prevalence of LSS PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis

25 study samples used MRI. LSS was identified by expert opinion in 13 study samples, by ICD-9 or -10 codes in 4, by questionnaire in 4 and one study used a single clinical test. Three studies used a combination of expert opinion and MRI. Nine estimates of prevalence were extracted from an asymptomatic population, 11 from the general population, six from primary care, 23 from secondary care and six from a mixed primary and secondary care setting. None of the study samples were from an occupational care setting. Most study samples were from Japan ($n=18$) and USA ($n=16$), followed by Canada ($n=4$), Turkey ($n=3$), Denmark, Finland, UK, Kuwait ($n=2$), and Italy, France, Korea, Netherlands, Pakistan, Togo ($n=1$). The sample size ranged from 24 to 699,723 people with a median of 216 (IQR 100-938). Table 2 shows the study characteristics of all included populations.

Risk of bias

Of the 41 included papers, eight had low risk of bias, five had moderate risk of bias and 28 (68%) had high risk of bias. The main reason for high risk of bias was item one (28 negative ratings) and two (29 negative ratings) addressing the repetitiveness of the study populations and the sampling frame, respectively. The full risk-of-bias assessment is shown in Table 3. As shown in Figs. 2 and 3, studies with high risk of bias in general had higher prevalence estimates than studies with moderate or low risk of bias.

Prevalence estimates

The pooled prevalence estimates for each subpopulation are shown in Fig. 4.

Clinical case definition

The pooled prevalence of clinical symptoms of LSS in the general population was 11% (95% CI 4–18%) (4 study samples [10, 12, 14, 21], $n=6108$, mean age 62, age range 19–93, 56% female), 25% (95% CI 19–32%) in patient populations from primary care (4 study samples from 3 papers [22–24], $n=171{,}157$, mean age 69, age range 18–80, 55% female), 29% (95% CI 22–36%) in patient populations from secondary care (9 study samples from 8 papers [25–32], $n=135{,}881$, mean age 58, age range 17–94, 51% female) and 39% (95% CI 39–39%) in patients in a mixed patient population from both primary and secondary care (2 study samples [33, 34], $n=19{,}110$, mean age 65, age range 20–96, 55% female).

Radiological case definition

When evaluating the presence of LSS based on radiological diagnosis, the pooled prevalence was 11% (95% CI 5–18%) in an asymptomatic population (8 study samples from 7 papers [35–41], $n=715$, mean age 45, age range 20–80, 37% female), 38% (95% CI − 10 to 85%) in the general population (3 study samples [13, 21, 42], $n=1541$, mean age 53, age range 32–93, 60% female), 15% (95% CI 13–18%) in a patient population from primary care (2 study samples [24, 43], $n=713$, mean age 57, age range 19–80, 46% female), 32% (95% CI 22–41%) in a patient population from secondary care (13 study samples from 10 papers [31, 32, 35, 37, 44–49], $n=7133$, mean age 52, age range 18–95, 50% females) and 21% (95% CI 16–26%) in a mixed patient population from primary and secondary care (2 study samples from 1 paper [50], $n=246$, mean age 43, age range 18–65, 58% female).

Mixed clinical and radiological definition

One study [11] investigated the prevalence of LSS in the general population ($n=1009$, mean age 66, age range 21–97, 67% female) using a clinical diagnosis based on expert opinion combined with the presence of LSS on MRI and found a prevalence of 9% (95% CI 8–11%). Another study [51] used the same diagnostic criteria (expert opinion + MRI) in a patient population from secondary care ($n=186$, mean age 40, age range 20–60, 43% female) and found a prevalence of 56% (95% CI 48–63%).

Classification of severity and radiological anatomical location of LSS

The distributions of LSS by classification of severity was reported in 13 study populations. Details are shown in Table 4. Some papers did not describe how severity was classified while others used different definitions and cut-off points. However, except for two study populations [24, 49], all the results showed that LSS classified as severe was less prevalent than classifications of mild/moderate LSS.

Of the 33 study samples including imaging in the diagnosis of LSS, 17 reported if the case definition included central, recess/lateral or foraminal stenosis. The description of spinal stenosis on imaging ranged from very detailed radiological definitions to only mentioning the anatomical location. The prevalence of LSS by anatomical site was reported in four study samples using different radiological definitions and a comparison was therefore not possible.

Table 2 Characteristics of included studies

Citation	Year of publication	Country	Type of study	Sample size	Study population	Symptoms	Setting	Mean age (SD)	Age range	Sex (% female)	Case definition (clinical or radiological)	Prevalence	Risk of bias
Clinical diagnosis													
General population													
Chiba et al. [14]	2016	Japan	Cross-sectional	647	General	NA	NA	58 (11)	20–89	38%	Questionnaire (LSS-DST)	6%	High
Yabuki et al. [10]	2013	Japan	Cross-sectional	2666	General	NA	Community-based cohort	60 (10.9)	40–79	53%	Questionnaire (LSS-DST)	6%	Low
Yamada et al. [54][d]	2018	Japan	Cross-sectional	868	General	NA	Community-based cohort	NR	NA	NR	Expert opinion	9%	High
Ishimoto et al. [21]	2013	Japan	Cohort	938	General	NA	NA	67 (12.4)	40–93	67%	Expert opinion	11%	Low
Otani et al. [12]	2013	Japan	Cross-sectional	1857	General	NA	Community-based cohort	NR	19–93	63%	Questionnaire (LSS-DST)	21%	High
Primary care population													
Beaudet et al. [23]	2013	Canada	Cohort	89,687	Clinical	LBP	Primary care	NR	18–80+	NR	ICD-9	8%	High
Beaudet et al. [23]	2013	Canada	Cohort	81,329	Clinical	LBP	Primary care	NR	18–80+	NR	ICD-9	16%	High
Weiner et al. [22]	2006	USA	Cross-sectional	111	Clinical	LBP	Primary care	75 (6.3)	NR	59%	Expert opinion	25%	High
Dobbs et al. [24]	2016	UK	Cross-sectional	30	Clinical	LBP + leg pain	Primary care	64 (6.9)	≥50	43%	One clinical test	87%	Moderate

Table 2 (continued)

Citation	Year of publication	Country	Type of study	Sample size	Study population	Symptoms	Setting	Mean age (SD)	Age range	Sex (% female)	Case definition (clinical or radiological)	Prevalence	Risk of bias
Secondary care population													
Laslett et al. [31]	2005	USA	Cross-sectional	216	Clinical	LBP	Secondary care	44 (13.1)	20–77	57%	Expert opinion	4%	High
Ahn et al. [25]	2016	Korea	Cross-sectional	125,796	Clinical	Lumbar disorder	Secondary care	NR	20–70+[c]	NR	ICD-10	23%	Moderate
Mijiyawa et al. [27]	2000	Togo	Cross-sectional	3204	Clinical	LBP	Secondary care	45 (14.4)	17–94	58%	Expert opinion	13%	High
Tsutsumimoto et al. [32]	2012	Japan	Cross-sectional	214	Clinical	Cervical myelopathy ± LSS	Secondary care	63	29–85	29%	Expert opinion	13%	High
Pahl et al. [28]	2006	USA	Cross-sectional	4442	Clinical	LBP ± leg pain	Secondary care	NR	NR	46%	Expert opinion	30%	High
Boakye et al. [30]	2013	USA	Cross-sectional	112	Clinical	LBP or neurogenic weakness	Secondary care	60[a] (3.2)	NR	4%	Expert opinion	35%	High
Katz et al. [29]	1995	USA	Cross-sectional	93	Clinical	LBP	Secondary care	65	40–91	31%	Expert opinion	46%	High
Orita et al. [26]	2016	Japan	Cross-sectional	737	Clinical	Neuropathic pain	Secondary care	66 (11.6)	20–79	53%	Expert opinion	50%	High
Orita et al. [26]	2016	Japan	Cross-sectional	1067	Clinical	Nociceptive pain	Secondary care	63 (13.7)	20–79	52%	Expert opinion	53%	High
Mixed primary & secondary care population													
Kuboyama et al. [53] [d]	2016	Japan	Cross-sectional	699,723	Clinical	Beneficiaries of health insurance	Community-based cohort	NR	0–85[c]	55%	ICD-10	7%	High
Sekiguchi [33]	2015	Japan	Cross-sectional	18,642	Clinical	Care-seeking for any reason	Secondary care	NR	58–80+	55%	Questionnaire (LSS-DST)	38%	High

Table 2 (continued)

Citation	Year of publication	Country	Type of study	Sample size	Study population	Symptoms	Setting	Mean age (SD)	Age range	Sex (% female)	Case definition (clinical or radiological)	Prevalence	Risk of bias
Sugioka et al. [15]	2008	Japan	Cross-sectional	468	General	NA		65 (13.7)	20–96	46%	Expert opinion	47%	High
Konno et al. [34]	2007	Japan	Cross-sectional	468	Clinical	LBP or leg symptoms	Secondary care	64 (13.7)	20–96	54%	Expert opinion	47%	High
Radiological diagnosis													
Asymptomatic population													
Al-Saeed et al. [35]	2012	Kuwait	Case–control	114	Healthy volunteers	No LBP	NR	NR	23–29	NR	MRI	0%	High
Parkkola et al. [37]	1993	Finland	Case–control	60	Healthy volunteers	No LBP or chronic disease	Population register National Insurance	NR	30–47	45%	MRI	3%	High
Boden et al. [36]	1990	USA	Cross-sectional	67	Volunteers	No LBP, sciatica or LSS symptoms	Advertising in newspapers	42	20–80	55%	MRI	6%	Moderate
Jarvik et al. [38]	2001	USA	Cross-sectional	148	Patients from General Internal Medicine, Dental, Dermatology and Women's clinics	No LBP or sciatica	Veterans Affairs Puget Sound Health Care System	54	36–71	12%	MRI	10%	Low
Carragee et al. [39]	2006	USA	Cohort	100	Patients with chronic nonlumbar pain	No LBP	Secondary care	38	NR	38%	MRI	11%	High

Table 2 (continued)

Citation	Year of publication	Country	Type of study	Sample size	Study population	Symptoms	Setting	Mean age (SD)	Age range	Sex (% female)	Case definition (clinical or radiological)	Prevalence	Risk of bias
Matsumoto et al. [41]	2013	Japan	Cross-sectional	94	Healthy volunteers	No spinal pain	Advertising	48 (13.4)	NR	49%	MRI	13%	High
Carragee et al. [39]	2006	USA	Cohort	100	Patients with cervical pain	None or only mild LBP	Secondary care	41	NR	43%	MRI	15%	High
Yamada et al. [54][d]	2018	Japan	Cross-sectional	787	General population	No clinical symptoms of LSS	Community-based cohort	67 (12.4)	NR	12%	MRI	28%	High
Chiodo et al. [40]	2007	USA	Cross-sectional	32	Healthy volunteers	No LBP or LSS symptoms	Community-based cohort	NR	55–80	NR	MRI	56%	High
General population													
Kalichman et al. [52][d]	2009	USA	Cross-sectional	187	General	NA	Community-based cohort	53 (10.8)	NR	44%	CT	8%	Low
Kjaer et al. [42]	2005	Denmark	Cross-sectional	412	General	NA	County of Funen	40	40	52%	MRI	12%	Low
Kalichman et al. (SpineJr) [13]	2009	USA	Cross-sectional	191	General	NA	Community-based cohort	53 (10.8)	32–79	46%	CT	23%	Low
Ishimoto et al. [21]	2013	Japan	Cohort	938	General	NA	NA	67 (12.4)	40–93	67%	MRI	78%	Low
Primary care population													
de Schepper et al. [43]	2016	Netherlands	Cross-sectional	683	Clinical	LBP	Primary care	50 (12.5)	19–80	47%	MRI	13%	Moderate
Dobbs [24]	2016	UK	Cross-sectional	30	Clinical	LBP + leg pain	Primary care	64 (6.9)	≥50	43%	MRI	83%	Moderate
Secondary care population													
de Bruin et al. [47]	2018	France	Cohort	648	Clinical	LBP/Suspicion of SpA	Secondary care	34 (8.6)	NR	47%	MRI	2%	High
Parkkola et al. [37]	1993	Finland	Case–control	48	Clinical	LBP	Secondary care	NR	30–47	50%	MRI	19%	High

Table 2 (continued)

Citation	Year of publication	Country	Type of study	Sample size	Study population	Symptoms	Setting	Mean age (SD)	Age range	Sex (% female)	Case definition (clinical or radiological)	Prevalence	Risk of bias
Laslett et al. [31]	2005	USA	Cross-sectional	216	Clinical	LBP	Secondary care	44 (13.1)	20–77	57%	Injections and advanced imaging techniques	6%	High
Baykara et al. [44]	2013	Turkey	Cross-sectional	24	Clinical	RA	Secondary care	48[b] (11.1)	NR	87%	MRI	8%	High
Albert et al. [45]	2011	Denmark	Cross-sectional	4195	Clinical	LBP	Secondary care	46 (13.5)	18–92	51%	MRI	16%	Moderate
Baykara et al. [44]	2013	Turkey	Cross-sectional	83	Clinical	LBP	Secondary care	46[b] (12.1)	NR	75%	MRI	25%	High
Baykara et al. [44]	2013	Turkey	Cross-sectional	50	Clinical	RA + LBP	Secondary care	49.6[b] (12.3)	NR	93%	MRI	32%	High
Tsutsumimoto et al. [32]	2012	Japan	Cross-sectional	214	Clinical	Cervical myelopathy	Secondary care	63	29–85	29%	CT	32%	
Cheng et al. [46]	2010	Canada	Cross-sectional	690	Clinical (non-surgical)	LBP	Secondary care	52 (14.2)	18–95	47%	MRI	40%	High
Al-Saeed et al. [35]	2012	Kuwait	Case–control	122	Clinical	LBP ± leg pain	Secondary care	NR	23–29	NR	MRI	46%	High
Cheng et al. [46]	2010	Canada	Cross-sectional	722	Clinical (surgical)	LBP	Secondary care	57 (15.5)	18–95	48%	MRI	51%	High
Mariconda et al. [48]	2004	Italy	Cross-sectional	117	Clinical	LBP ± leg pain	Secondary care	60 (10.5)	40–70+	56%	MRI	55%	High
Fu et al. [49]	2011	USA	Cross-sectional	36	Clinical	LBP + degen. scoliosis	Secondary care	69 (9.2)	51–85	64%	MRI or CT	86%	High

Table 2 (continued)

Citation	Year of publication	Country	Type of study	Sample size	Study population	Symptoms	Setting	Mean age (SD)	Age range	Sex (% female)	Case definition (clinical or radiological)	Prevalence	Risk of bias
Mixed primary & secondary care population													
Modic et al. [50]	2005	USA	RCT	96	Clinical	Leg pain	Mixed prim/sec	44 (10.6)	18–65	55%	MRI	30%	High
Modic et al. [50]	2005	USA	RCT	150	Clinical	LBP	Mixed prim/sec	43 (10.1)	18–65	59%	MRI	17%	High
Combined clinical and radiological diagnosis													
General population													
Ishimoto et al. [11]	2012	Japan	Cohort	1009	General	NA	NA	66 (13.6)	21.97	67%	Expert opinion & MRI	9%	Low
Ishimoto et al. [55][d]	2017	Japan	Cohort	938	General	NA	NA	67 (12.4)	40–93	67%	Expert opinion & MRI	9%	Low
Secondary care population													
Ullah et al. [51]	2018	Pakistan	Cross-sectional	186	Clinical	LBP	Secondary care	40 (10.6)	20–60	43%	Expert opinion & MRI	56%	High

[a]Median age; [b]Mean age of the total population before the included subpopulation was extracted; [c]Extracted from information on age groups and therefore actual lower and upper age are uncertain; [d]Excluded from meta-analysis due to double population on the study sample

Table 3 Summary of risk-of-bias assessment

	1. Was the study population representative of the target population?	2. Was the sampling frame a true or close representation of the target population?	3. Was some form of random selection used to select the sample, OR, was a census undertaken?	4. Was the likelihood of non-response bias minimal?	5. Was an acceptable case definition of LSS used in the study?	6. Was the study instrument that measured the parameter of interest (e.g. prevalence of LSS) shown to have reliability and validity?	7. Was the same mode of data collection used for all subjects?	8. Was the length of the shortest prevalence period for the parameter of interest appropriate?	9. Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	10. Summary item on the overall risk of bias
Ahn et al. [25]	+	+	+	+	−	−	+	−	+	Moderate
Albert et al. [45]	−	−	+	+	−	+	+	NA	+	Moderate
Al-Saeed et al. [35]	−	−	+	+	−	−	+	NA	−	High
Baykara et al. [44]	−	−	+	−	−	−	+	NA	−	High
Beaudet et al. [23]	+	+	+	+	−	−	+	+	−	High
Boakye et al. [30]	−	−	+	+	−	−	+	−	−	High
Boden et al. [36]	−	−	−	+	+	+	+	NA	+	Moderate
Carragee et al. [39]	−	−	−	+	−	−	+	NA	−	High
Cheng et al. [46]	−	−	+	+	−	−	+	NA	−	High
Chiba et al. [14]	−	−	−	+	+	+	+	−	+	High
Chiodo et al. [40]	−	−	−	+	−	−	+	NA	−	High
de Bruin et al. [47]	−	−	−	+	+	+	+	+	+	High
de Schepper et al. [43]	+	+	+	+	−	−	+	NA	+	Moderate
Dobbs et al. [24]	+	−	−	+	+	+	+	+	+	Moderate
Fu et al. [49]	−	−	−	−	+	−	−	NA	−	High
Ishimoto et al. [11]	+	+	+	+	+	+	+	−	+	Low
Ishimoto et al. [21]	+	+	+	+	+	+	+	−	+	Low

Table 3 (continued)

	1. Was the study population representative of the target population?	2. Was the sampling frame a true or close representation of the target population?	3. Was some form of random selection used to select the sample, OR, was a census undertaken?	4. Was the likelihood of non-response bias minimal?	5. Was an acceptable case definition of LSS used in the study?	6. Was the study instrument that measured the parameter of interest (e.g. prevalence of LSS) shown to have reliability and validity?	7. Was the same mode of data collection used for all subjects?	8. Was the length of the shortest prevalence period for the parameter of interest appropriate?	9. Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	10. Summary item on the overall risk of bias
Ishimoto et al. [55]	+	+	+	+	+	+	+	−	+	Low
Jarvik et al. [38]	+	+	+	+	+	+	+	NA	+	Low
Kalichman et al. [52]	+	+	+	+	+	+	+	+	+	Low
Kalichman et al. [13]	+	+	+	+	+	+	+	+	+	Low
Katz et al. [29]	−	−	−	−	+	+	+	−	−	High
Kjaer et al. [42]	+	+	+	−	+	+	+	NA	+	Low
Konno et al. [34]	−	−	+	−	−	+	+	−	+	High
Kuboyama et al. [53]	+	+	−	−	−	−	+	−	+	High
Laslett et al. [31]	−	−	−	−	+	−	+	−	+	High
Mariconda et al. [48]	−	−	−	−	+	+	+	NA	+	High
Matsumoto et al. [41]	−	−	−	−	+	−	+	NA	+	High
Mijiyawa et al. [27]	−	−	+	+	+	−	−	−	+	High
Modic et al. [50]	−	−	−	−	+	+	+	NA	−	High
Orita et al. [26]	−	−	−	−	−	−	−	−	+	High
Otani et al. [12]	−	−	−	−	+	+	+	−	−	High
Pahl et al. [28]	−	−	−	−	−	−	+	−	−	High
Parkkola et al. [37]	−	−	−	−	−	+	+	NA	−	High
Sekiguchi et al. [33]	−	−	−	−	+	+	+	−	+	High

Table 3 (continued)

	1. Was the study population representative of the target population?	2. Was the sampling frame a true or close representation of the target population?	3. Was some form of random selection used to select the sample, OR, was a census undertaken?	4. Was the likelihood of non-response bias minimal?	5. Was an acceptable case definition of LSS used in the study?	6. Was the study instrument that measured the parameter of interest (e.g. prevalence of LSS) shown to have reliability and validity?	7. Was the same mode of data collection used for all subjects?	8. Was the length of the shortest prevalence period for the parameter of interest appropriate?	9. Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	10. Summary item on the overall risk of bias
Sugioka et al. [15]	−	−	+	−	−	+	+	−	+	High
Tsutsumimoto et al. [32]	−	−	−	−	+	−	+	NA	+	High
Ullah et al. [51]	−	−	−	−	−	−	+	−	−	High
Weiner et al. [22]	−	−	−	−	+	−	+	−	+	High
Yabuki et al. [10]	+	+	+	−	+	−	+	+	+	Low
Yamada et al. [54]	−	−	−	−	+	−	−	−	−	High

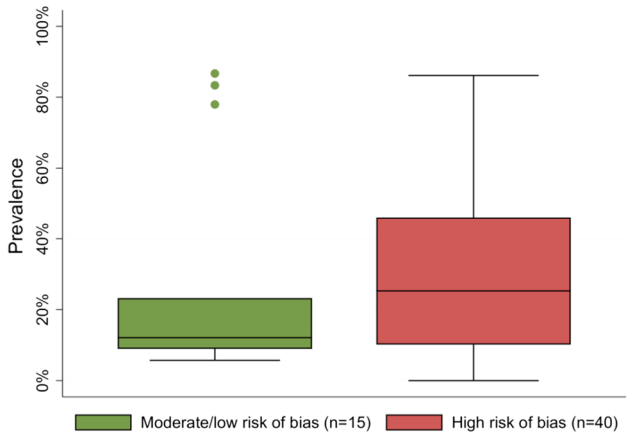

Fig. 2 Box plot of prevalence estimates of LSS: moderate or low (green) versus high (red) risk of bias

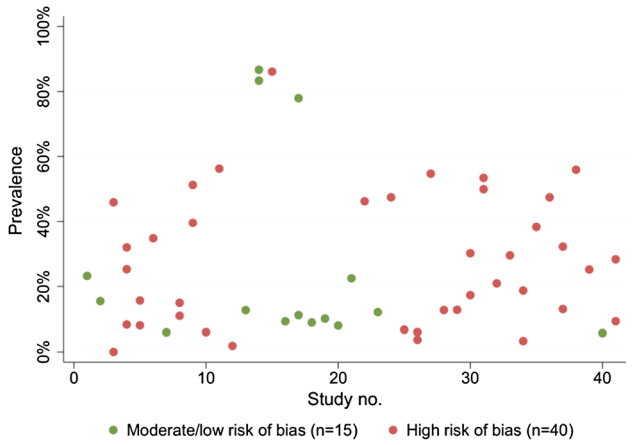

Fig. 3 Scatter plot of prevalence estimates of LSS by moderate or low (green) versus high (red) risk of bias

Age groups

Data on the prevalence of LSS in age groups was extracted from 11 papers (12 study samples) and showed an increase in prevalence by age for both clinical diagnosis of LSS (five study samples [10, 12, 25, 32, 33]) and radiological diagnosis (seven study samples [11, 15, 32, 36, 38, 41, 45]) as shown in Fig. 5. The graphs indicate that the increase in prevalence happens earlier using a radiological diagnosis (around 40 years) compared to a clinical diagnosis (around 50 years). Additionally, four studies reported an increasing prevalence by age groups but with a graphical display only [13, 21, 52, 53].

Discussion

Overall, there was a wide range in prevalence estimates among the 55 included study samples. When defining LSS by a clinical diagnostic criterion, the pooled prevalence estimates were 11% in the general population, 25% in populations from primary care and 29% from secondary care populations. Radiological signs of LSS was 11% in asymptomatic people, 38% in the general populations, 15% in populations from primary care and 32% from secondary care. Severe radiological signs of LSS were less prevalent than moderate or mild LSS. There was a pattern of increasing prevalence by age and that the increase happened around a decade earlier when using a radiological diagnosis of LSS compared to using a clinical diagnosis. The majority of studies (68%) had high risk of bias and in general, these studies reported a higher prevalence than studies with moderate or low risk of bias.

To our knowledge, this is the first systematic review on the prevalence of LSS, and therefore, we are not able to make a comparison with other studies.

Single studies investigating the prevalence of LSS are limited by choice of the population and diagnostic criteria used. In that aspect doing a systematic review including different definitions of LSS and a variety of populations is superior.

The strengths of this review include a predefined protocol registered in PROSPERO and no limitations on search criteria addressing time and language. We were able to include a wide range of studies enabling a subdivision into relevant case definitions (clinical or radiological) and further into different populations. Also, all studies reporting a prevalence estimate of LSS were considered and not only those with an aim to investigate the prevalence LSS, which of course also affected the risk-of-bias assessment.

The ratio of true heterogeneity to total observed variation (I^2) showed a very high variance between studies even after subdividing them into relevant subgroups. There could be several reasons for this diversity all related to the high variety of definitions of LSS by both clinical and radiological criteria.

Studies reporting the prevalence of LSS by radiological diagnosis used various definitions and cut-off points of severity introducing heterogeneity which is why we chose to include the prevalence for both moderate and severe LSS if reported. Additionally, some studies reported solely on central LSS, others included lateral/recess or foraminal stenosis and some studies did not report how LSS was defined. Also, the difference in imaging modality (MRI/CT) and imaging techniques could have influenced the prevalence.

Studies reporting the prevalence of LSS by a clinical diagnosis also used a wide range of definitions and measures

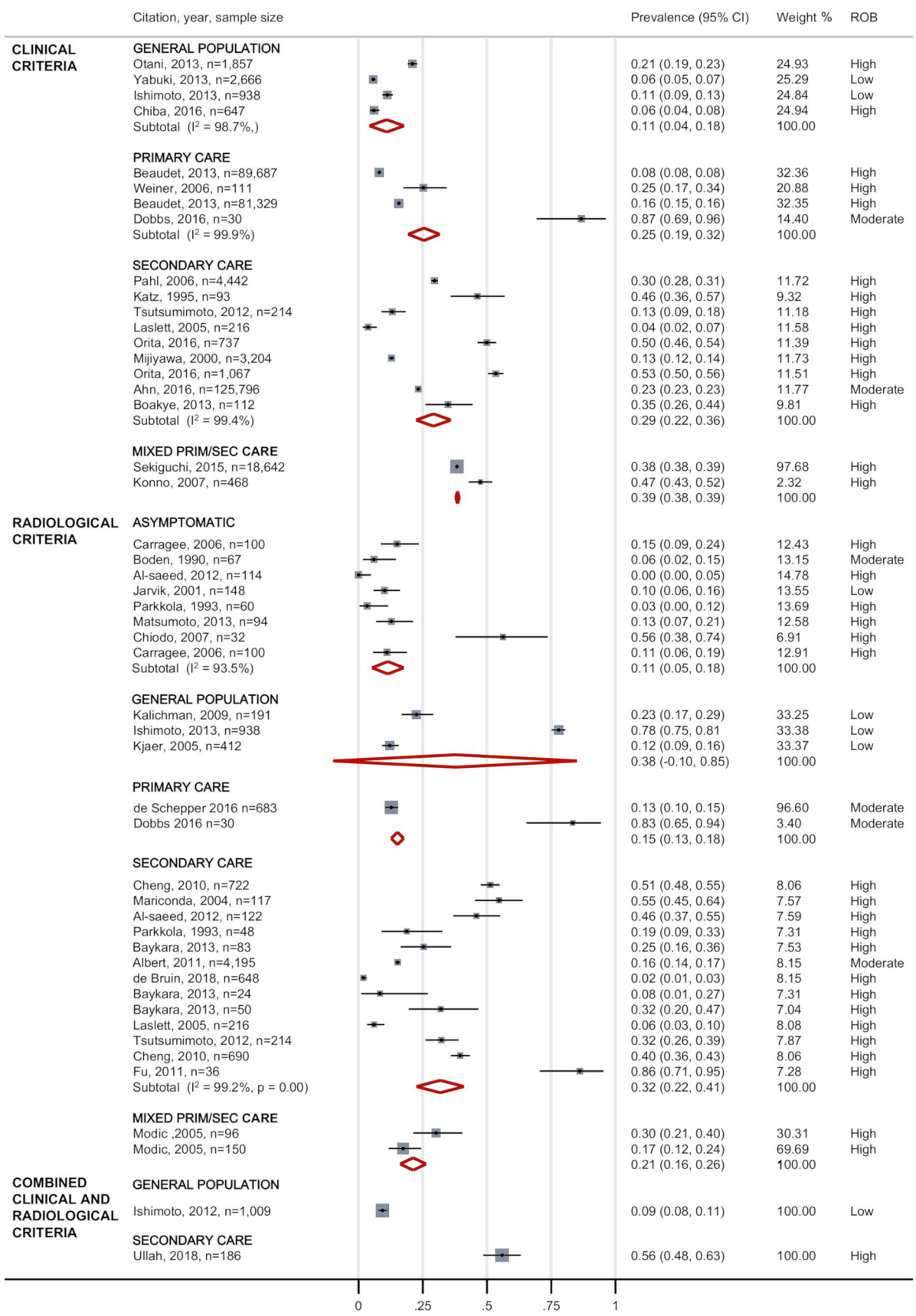

Fig. 4 Prevalence of LSS in different populations by clinical diagnosis and radiological signs

Table 4 Prevalence of radiological lumbar spinal stenosis classifications

Citation	Population	*N*	Classification			
			No LSS	Mild	Moderate	Severe
Carragee et al. [39]	Asymptomatic (Chronic nonlumbar pain)	*n* = 100	89%		11%	
Carragee et al. [39]	Asymptomatic (No pain)	*n* = 100	85%		15%	
Cheng et al. [46]	Secondary care (Surgical)	*n* = 675	52%	29%		19%
Cheng et al. [46]	Secondary care (Non-surgical)	*n* = 647	64%	29%		7%
Chiodo et al. [40]	Asymptomatic (No LBP or LSS symptoms)	*n* = 32	44%	25%	28%	3%
Dobbs et al. [24]	Primary care (LBP + leg pain)	*n* = 30	17%	3%	37%	43%
Fu et al. [49]	Secondary care (LBP + degenerative scoliosis)	*n* = 36	14%	6%	36%	44%
Ishimoto et al. [21]	General					
Central stenosis		*n* = 938	1%	21%	48%	30%
Lateral stenosis		*n* = 938	1%	22%	41%	37%
Foraminal stenosis		*n* = 938	9%	51%	33%	7%
Jarvik et al. [38]	Asymptomatic (No LBP or sciatica)	*n* = 148	–	–		10%
Kalichman et al. (SpJr) [13]	General	*n* = 191	67%	23%		7%[a]
Kjaer et al. [42]	General					
Central stenosis		*n* = 412	87.9%	10.7%		1.5%
Foraminal stenosis		*n* = 412	73.5%	22.1%		4.1%
Modic et al. [50]	Mixed primary/secondary (Leg pain)	*n* = 150	83%		17%	
Modic et al. [50]	Mixed primary/secondary (LBP)	*n* = 96	70%		30%	

[a]CT definition: ≤ 12 mm ('relative' stenosis) and ≤ 10 mm ('absolute' stenosis). Absolute stenosis is therefore also included in the 'relative' stenosis group

of prevalence which could question the comparability. Some used ICD codes collected in registries (prevalence ranging from 7 to 23%), some used expert opinions (prevalence 4–53%) and others used questionnaires collected from patients (prevalence 6–38%). Even though expert opinions are the gold standard of diagnosing LSS in everyday clinical work, the reproducibility may be limited and therefore hardly comparable.

Due to the degenerative nature of the condition, the prevalence of LSS is associated with age and the age range of the study sample will therefore be likely to influence the prevalence. As an example, Ishimoto et al. [21] investigated a population with an age range from 40 to 93 years (mean age 67, prevalence 78%) while a study by Kjaer et al. [42] only included people who were 40 years old (prevalence 12%).

Even though we subdivided the study samples into study populations (asymptomatic, general, primary care, secondary care and a mixed primary/secondary care), there were still differences within each study population. For example, clinical populations from secondary care were included from departments of surgery, rheumatology or general internal medicine while others were from specialised spine clinics. Asymptomatic populations included study samples of participants with no clinical symptoms of LSS, participants with no LBP but pain in other regions such as neck pain or participants from, e.g. dental or dermatology clinics. Also, in 28 of the 41 studies there was a high risk of bias that the study sample was not representative of the target population and combined with the heterogenicity of the study samples the pooled prevalence estimates should be interpreted with caution.

The majority of studies were from Europe, North America or Japan (90%); therefore, the results are only considered applicable to those regions.

By using both a clinical criterion (clinical symptoms of LSS) and a radiological criterion (LSS present on MRI or CT), we aimed to visualise a possible difference between the two criteria. We expected to find the lowest prevalence

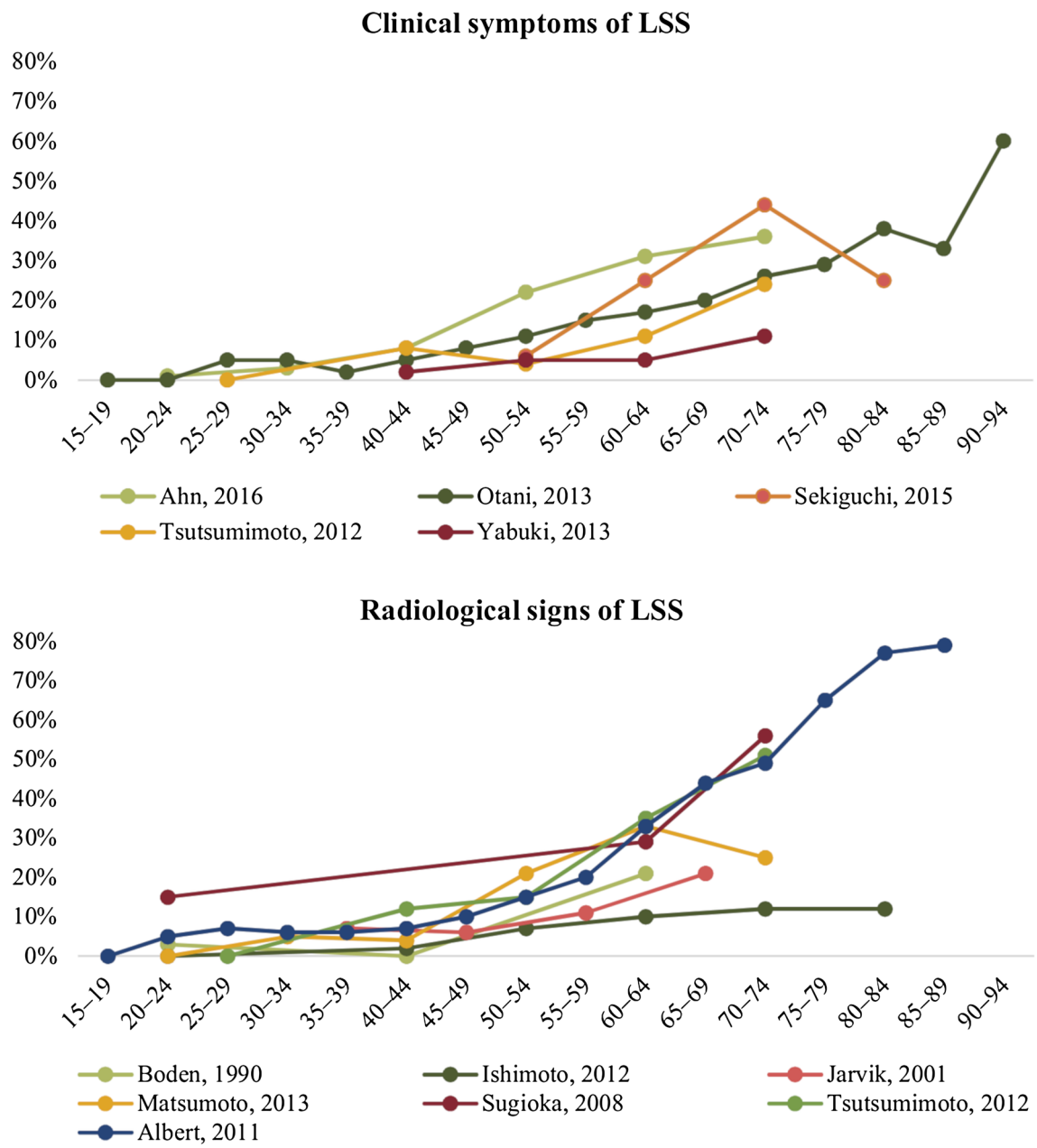

Fig. 5 Prevalence of LSS in age groups by clinical diagnosis and radiological signs

estimates when investigating clinical symptoms compared to using a radiological criterion. However, the wide range in prevalence made it impossible to draw such conclusions although it remains the most logical expectation. There was a trend for both clinical and radiological criterion that the prevalence was lowest in asymptomatic and general populations and increased in the clinical populations, the only exception being the radiological criteria in the general populations although this could be explained by the cut-off point of LSS used in the study by Ishimoto et al. [21]. The variety in reported prevalence estimates found in this study should make clinicians carefully consider the clinical implications of both clinical and especially radiological evidence of LSS.

The topic is of highly clinical importance due to the growing elderly population and thereby a possible rise in prevalence of the disease.

We need better definitions of both clinical symptoms and radiological signs to be able to compare studies, and it is obvious that we need more studies with low risk of bias investigating the prevalence of LSS and especially in the clinical populations. We found no studies with low risk of bias investigating the prevalence in either primary

or secondary care populations. Also, we were not able to identify any studies on occupational populations investigating the prevalence of LSS. In addition, a research focus on the association between clinical symptoms and the presence of LSS on imaging would be highly relevant from a clinical point of view.

Conclusions

The pooled prevalence estimates of LSS with a clinical diagnostic criterion were 11% in the general population and ranged from 25 to 39% in clinical populations. The prevalence of radiological signs of LSS was 11% in asymptomatic populations, 38% in the general populations and ranged from 15 to 32% in clinical populations. The results are based on studies with high risk of bias, and there was a substantial variety in the definition of diagnostic criteria between studies for both clinical symptoms and radiological signs of LSS and cautious interpretation of the results is therefore required.

Funding The authors did not receive funding for this study.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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