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ORIGINAL ARTICLE

The prevalence and impact of frailty in patients with symptomatic lumbar spinal stenosis

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Abstract

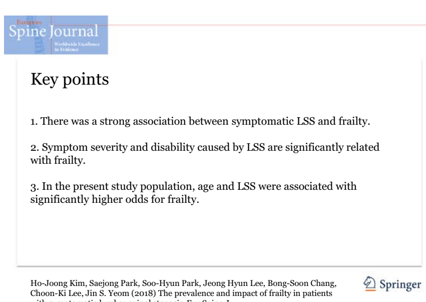
Purpose To investigate the prevalence of frailty in patients with symptomatic lumbar spinal stenosis (LSS) and a propensity score-matched control group, and to analyze the association between symptomatic LSS and frailty.

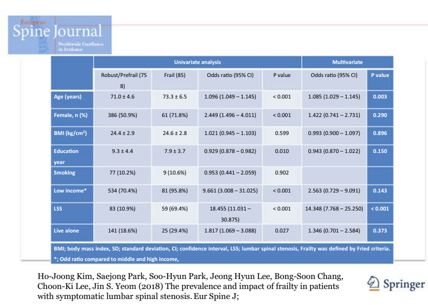
Methods This study included 2 groups: 1 consisting of patients with symptomatic LSS (LSS group) and the other including healthy elderly subjects without degenerative spinal disease (control group). Baseline sociodemographic data, variables regarding frailty assessment, and clinical outcomes were collected. The frailty was assessed with Fried criteria. Between the LSS and control groups, the prevalence of frailty was compared. Among all participants, risk factors for frailty were identified using multivariate logistic regression.

Results Totally, 843 subjects participated (142 in LSS group and 701 in control group) in this study. After the propensity score matching (142 in each group), the LSS group had significantly higher prevalence of frail than the control group ($P < 0.001$): 59 (41.5%) participants in the LSS group were frail, whereas 10 (7.0%) participants in the control group were frail. Within LSS group analysis showed that participants with frailty had significantly higher disability and lower quality of life compared to those in a robust state. Among all participants, LSS and age were found to be significant risk factors for frail in multivariate logistic regression model.

Conclusions The present study highlights a strong association between symptomatic LSS and frailty. Furthermore, symptom severity and disability caused by LSS are significantly related to frailty. Therefore, early detection and appropriate treatment for frailty in patients with LSS is important.

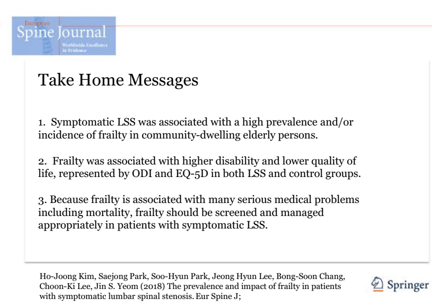
Graphical abstract These slides can be retrieved under Electronic Supplementary Material.





	Univariate analysis				Multivariate	
	Robust/Prefrail (758)	Frail (85)	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Age (years)	71.0 ± 4.6	73.3 ± 6.5	1.096 (1.049 – 1.145)	< 0.001	1.085 (1.029 – 1.145)	0.003
Female, n (%)	386 (50.9%)	61 (71.8%)	2.449 (1.496 – 4.011)	< 0.001	1.422 (0.741 – 2.731)	0.290
BMI (kg/cm²)	24.4 ± 2.9	24.6 ± 2.8	1.021 (0.945 – 1.103)	0.599	0.993 (0.900 – 1.097)	0.896
Education year	9.3 ± 4.4	7.9 ± 3.7	0.929 (0.878 – 0.982)	0.010	0.943 (0.870 – 1.022)	0.150
Smoking	77 (10.2%)	9 (10.6%)	0.953 (0.441 – 2.059)	0.902		
Low income*	534 (70.4%)	81 (95.8%)	9.661 (3.008 – 31.025)	< 0.001	2.563 (0.729 – 9.091)	0.143
LSS	83 (10.9%)	59 (69.4%)	18.455 (11.031 – 30.875)	< 0.001	14.348 (7.768 – 25.250)	< 0.001
Live alone	141 (18.6%)	25 (29.4%)	1.817 (1.069 – 3.088)	0.027	1.346 (0.701 – 2.584)	0.373

BMI; body mass index, SD; standard deviation, CI; confidence interval, LSS; lumbar spinal stenosis, Frailty was defined by Fried criteria.
*; Odd ratio compared to middle and high income,



Keywords Frailty · Lumbar spinal stenosis · Fried frailty criteria · Propensity score matching

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Extended author information available on the last page of the article

Introduction

Owing to the acceleration of aging in populations worldwide, "aging well" should be a global priority [1]. Frailty is a serious public health issue with an increasing prevalence, and it represents an increased vulnerability to poor resolution of homoeostasis after a stressor event resulting from aging-related decline of physical, psychological, and social functioning [2, 3]. Thus, frailty eventually results in the increased risk of adverse outcomes, including falls, delirium, disability, and mortality [1–3].

Degenerative lumbar spinal stenosis (LSS) is a prevalent condition in the elderly and causes severe back and leg pain, decreased physical activity, and impaired quality of life [4–6]. Neurological deficit in both legs due to nerve impingement and ischemia leads to weakness and atrophy of the muscles in the legs [6, 7], eventually causing walking intolerance and limiting physical activity. These clinical manifestations of LSS are closely associated with sarcopenia [8].

Considering that frailty and LSS are related to decreased physical functioning, there might be an association between frailty and LSS, especially in the elderly population. However, to our knowledge, no study has thus far examined this association. Therefore, in this study, we aimed to investigate the prevalence of frailty in patients with symptomatic LSS and a propensity score-matched control group and to analyze the association between symptomatic LSS and frailty. We hypothesized that LSS and frailty would be associated with each other in elderly patients.

Materials and methods

Study design and study population

This propensity score matching, case–control study was performed within the framework of a prospective study designed to develop criterion-referenced health-related fitness standards for the National Fitness Award [8]. This study was approved by the institutional review boards of a hospital where this study was conducted and the Institutional Review Board of the Korea Institute of Sport Science. All participants provided written informed consent before enrollment in the study.

The study included two groups: the LSS group, comprising patients with LSS, and the control group, comprising *community-dwelling elderly population without low back or related leg pain*. The inclusion criteria for the LSS group were age, 65–85 years; the presence of LSS *diagnosed by a spine surgeon* by a radiological stenotic lesion in the lumbar spine observed on magnetic resonance imaging, a corresponding neurogenic intermittent claudication, and one or more of the corresponding symptoms: pain, numbness, neurological deficits in the legs and buttocks and/or bladder/bowel dysfunction [9, 10]. The inclusion criteria of the control group were *elderly people not in an institution*, aged 65–85 years; the absence of low back or leg pain; and no history of degenerative lumbar spinal disease. The exclusion criteria for both groups were severe pain in the hip, knee, or ankle joints impeding walking; peripheral vascular disease; any cervical disease causing gait disturbance; cerebral vascular disease; any serious uncontrolled medical comorbidity such as sepsis and malignancy that would cause disability or worsen the patient's general health condition; and the inability to complete the questionnaires on frailty and disability. All participants in the LSS groups were enrolled in the spinal center of a tertiary-care teaching hospital, and *the control group was enrolled in National Fitness Award program centers or elderly community centers*, between August 2014 and February 2017.

Data collection

Baseline data for gender; age; height; weight; body mass index (BMI); variables regarding frailty assessment; medical history; and clinical outcomes including the Oswestry Disability Index (ODI) scores, and the EuroQol 5-dimension questionnaire (EQ-5D) were collected by blinded research assistants [11–13].

Frailty measurement

Frailty was defined according to the following five criteria reported by Fried et al. (Table 1): weight loss, exhaustion, physical inactivity, slowness, and handgrip strength [14–17]. Participants meeting none of the below-mentioned criteria for frailty were considered robust, those meeting one to two criteria were considered pre-frail, and those meeting three or more criteria were considered frail (Table 1).

Clinical outcome variables

The ODI is a self-administered questionnaire that measures back-specific function on a 10-item scale with six response categories for each item. Each item is scored from 0 to 5, and the summation of scores for each item is converted into a 0–100 scale [11]. The EQ-5D is a 5-dimensional health-state classification [13]. The 5 dimensions are mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. An EQ-5D health state is defined by selecting one level from each dimension. The EQ-5D preference-based measure can

Table 1 Frailty-defining criteria in this study

	Definition and cutoff criteria			
Weight loss	Weight loss was defined as a loss of more than 5 kg in the last year (approximately 5% weight loss)			
Exhaustion	Self-report of either of: (a) I felt that everything I did was an effort; (b) I could not get going. If answered yes, the following question was asked: "How often in the last week did you feel this way?" The scoring ranged from 0 to 3: 0 indicated rarely or none of the time (1 day), 1 indicated some of the time (1–2 days), 2 indicated a moderate amount of the time (3–4 days), and 3 indicated most of the time. Subjects answering 2 or 3 to either of these questions were categorized as frail as per the exhaustion criterion			
Physical inactivity	The participants were asked about the amount of time they spent engaged in physical activity in the past 7 days. The lowest gender-specific 20% of study population (IPAQ score)			
Slowness	5-m walk at one's usual pace: lowest gender-specific 20% of study population			
	BMI (kg/cm^2)	Handgrip strength for male (kg)	BMI (kg/cm^2)	Handgrip strength for female (kg)
Handgrip strength—cutoff values indicating weak grip strength in relation with BMI	≤ 24	≤ 29	≤ 23	≤ 17
	24–28	≤ 30	23–26	≤ 17.3
			26–29	≤ 18
	> 28	≤ 32	> 29	≤ 21

BMI body mass index; *IPAQ* International Physical Activity Questionnaire; for the handgrip strength measure, participants were asked to squeeze a handgrip dynamometer (GRIP-D5101; Takei, Niigata, Japan) as hard as possible; this exercise was repeated thrice (once with each hand and then with the strongest hand), and the maximum value was recorded; participants meeting none of the abovementioned criteria for frailty were considered robust, those meeting one to two criteria were considered pre-frail, and those meeting three or more criteria were considered frail

be regarded as a continuous outcome scored on a scale of 0–1.00, with 1.00 indicating full health and 0 representing death [13].

Statistical analysis

Unadjusted continuous and categorical variables were analyzed by using the Student's *t* test and Chi-square test, respectively. To minimize differences in baseline characteristics and influential variables for frailty, a propensity score matching algorithm was used. Propensity score matching allows for an improved estimate of the effect of group difference by balancing observed covariates simultaneously between groups [18]. Thus, a logistic regression model for deriving propensity scores was created. The matching algorithm used for this study was 1:1, with nearest neighbor matching without replacement, in which each case in the control group was matched to a unique case in the LSS group based on the nearest propensity scores. For propensity score matching, factors such as age, sex, BMI, educational level, and income that are associated with frailty were included in the logistic regression model as expected confounding variables for frailty [3, 17, 19, 20]. This procedure produced 142 well-matched pairs in the LSS and control groups, respectively. The logistic regression model was validated by comparing the significance and standardized mean difference of propensity scores between the pre- and post-matched samples.

The baseline demographic data and clinical outcomes were analyzed using Student's *t* test and Chi-square test for continuous variables and categorical variables, respectively, between the well-matched both groups. The adjusted prevalence of frailty was compared between the LSS and control groups. Within each LSS and control group, the clinical outcome and other variables were compared according to the frailty status using the Kruskal–Wallis test with post hoc Bonferroni-corrected Mann–Whitney tests. Analysis of covariance (ANCOVA) was used for adjustment of age and sex. Given the difference in the prevalence of frailty between the two groups, the post hoc power was also calculated.

In addition, among all participants, univariate analyses were performed for all expected variables related to frailty. The variables that were significantly associated with frailty at $P < 0.10$ in univariate analysis were entered into the multivariate model, along with potentially important variables such as age, BMI, and gender, regardless of statistical significance. For the multivariate models, we anticipated a potential issue of collinearity between the variables and set an a priori rule to exclude variables with correlation coefficients of ≥ 0.50. All statistical analyses were performed using the SPSS 20.0.0 statistics package (SPSS, Inc., Chicago, IL, USA). The alpha level of significance was set at 0.05.

Results

Unadjusted case–control group

Totally, 843 subjects participated in this study, of which 142 and 701 participants were enrolled in the LSS and control groups, respectively (Fig. 1). Table 2 shows baseline characteristics of participants in both groups. There were significant differences in gender distribution, BMI, and income ($P<0.001$, $P=0.013$, and $P<0.001$, respectively). As expected, clinical outcomes including ODI and EQ-5D were significantly worse in the LSS group, compared to the control group ($P<0.001$ for both variables). Furthermore, the frail and pre-frail percent ratio was significantly higher in the LSS group than in the control group ($P<0.001$).

Propensity score-matched case–control group

Propensity score matching yielded 142 well-matched LSS and control pairs (Fig. 1). The mean standard differences in the propensity scores before and after the matching procedure were 0.093 and 0.012, respectively. After propensity score matching of the two groups based on potentially confusing variables of frailty, including age, sex, BMI, educational level, and income, none of the variables were significantly different with exception of clinical outcomes such as ODI and EQ-5D (Table 3). The LSS group demonstrated significantly higher disability (ODI) and lower quality of life (EQ-5D) ($P<0.001$ for both variables).

The LSS group had a significantly higher prevalence of frailty than the control group ($P<0.001$): 59 (41.5%) and 66 (46.5%) participants in the LSS group were frail and pre-frail, respectively, whereas 10 (7.0%) and 56 (39.4%) participants in the control group were frail and pre-frail, respectively (Table 3). The post hoc power analysis confirmed this difference in the ratio of frail versus pre-frail and robust participants, with an alpha value of 0.05 and a statistical power of 100.0%.

Among the frailty criteria, weight loss was not different between the both groups, whereas other criteria were significantly different between the both groups (Table 3).

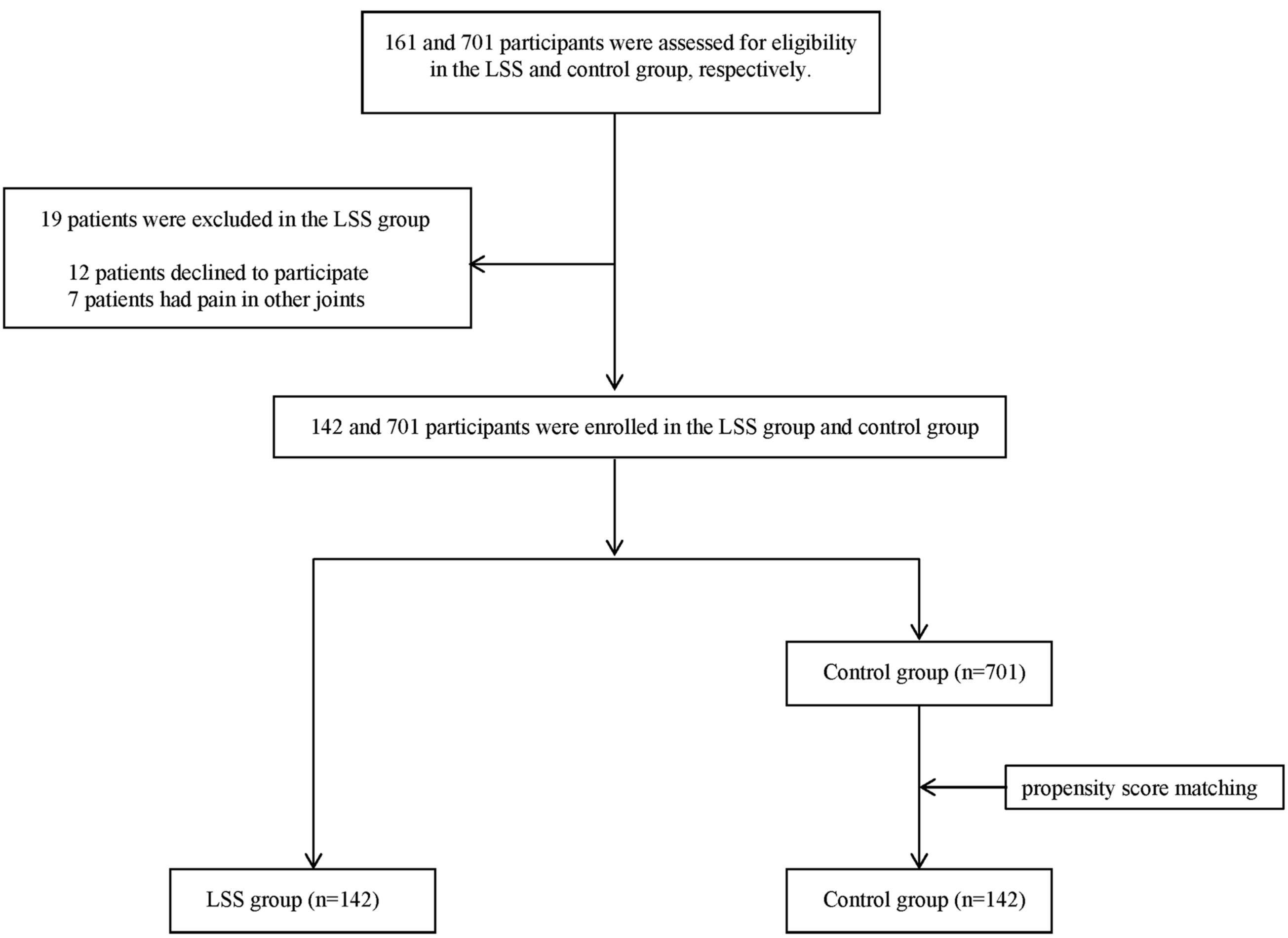

Fig. 1 Enrollment, group assignment, and propensity score matching

Table 2 Descriptive statistics of the subjects in the unadjusted population

	LSS group (142)	Control group (701)	*P* value
Age (years)	72.1 ± 6.9	71.0 ± 4.3	0.060
Male/female	42:100	354:347	< 0.001
BMI (kg/cm^2)	25.0 ± 2.9	24.3 ± 2.9	0.013
ODI	36.9 ± 13.4	9.6 ± 11.9	< 0.001
EQ-5D	0.523 ± 0.229	0.834 ± 0.151	< 0.001
Level of education [*n* (%)]			
Nothing	8 (5.6)	42 (6.0)	0.955
Elementary school	50 (35.2)	221 (31.5)	
Middle school	29 (20.4)	140 (20.0)	
High school	37 (26.1)	194 (27.7)	
University	18 (12.7)	104 (14.8)	
Education (year)	9.4 ± 3.8	9.1 ± 4.5	0.478
Income [*n* (%)]			< 0.001
Low	136 (95.8)	480 (68.5)	
Middle	6 (4.2)	184 (26.2)	
High	0	37 (5.3)	
Living condition [*n* (%)]			0.382
Live alone	32 (22.6)	134 (19.1)	
Live with someone	110 (77.4)	567 (80.9)	
Smoking [*n* (%)]			0.870
None or past smoker	129 (90.8)	628 (89.6)	
Current smoker or ex-smoker within 1 year	13 (9.2)	73 (10.4)	
Chronic disease [*n* (%)]			
Hypertension	57 (40.1)	297 (42.4)	0.624
Diabetes	20 (14.1)	118 (16.8)	0.420
Stroke	2 (1.4)	30 (4.3)	0.145
Myocardial infarction	3 (2.1)	21 (3.0)	0.783
Lung disease	4 (2.8)	34 (4.9)	0.377
Musculoskeletal	23 (16.2)	136 (19.4)	0.374
Frailty [*n* (%)]			
Robust	17 (12.0)	372 (53.1)	< 0.001
Pre-frail	66 (46.5)	303 (43.2)	
Frail	59 (41.5)	26 (3.7)	

Values are mean ± SD or numbers (%)

LSS lumbar spinal stenosis, *BMI* body mass index, *SD* standard deviation, *ODI* Oswestry Disability Index, *EQ* Euro-Qol, frailty was defined by Fried criteria

Within-group analysis for relation between frail and clinical outcome

Within the LSS group, participants with frailty had significantly higher disability and lower quality of life compared to those in a robust state ($P < 0.001$ for ODI and EQ-5D) (Fig. 2) (Table 4). Post hoc analysis with Bonferroni correction for ODI and EQ-5D scores showed significant differences between the frail and pre-frail patients ($P = 0.019$ and 0.007, respectively) and between the frail and robust patients ($P < 0.001$ and $P = 0.002$, respectively) in the LSS group. A similar trend was observed in the control group (Table 4). After adjustment for age and sex, ODI and EQ-5D were significantly different with regard to the frailty status in the both groups (Fig. 2).

Odds ratio of variables for frailty among all participants

The univariate analysis demonstrated age, sex, educational attainment, low income status, living alone, and lumbar spinal stenosis were associated with a higher odds for frailty (Table 5). Based on the result of univariate analysis, age, sex, BMI, education level (year), living alone, low income,

Table 3 Descriptive statistics of the subjects in the propensity score-matched case–control group

	Propensity-matched LSS group (142)	Propensity-matched control group (142)	*P* value
Age (years)	72.1 ± 6.9	72.0 ± 4.6	0.840
Male/female	42:100	54:88	0.167
BMI (kg/cm^2)	25.0 ± 2.9	25.0 ± 3.1	0.988
ODI	36.9 ± 13.4	11.3 ± 13.5	< 0.001
EQ-5D	0.523 ± 0.229	0.822 ± 0.155	< 0.001
Level of education [*n* (%)]			
Nothing	8 (5.6)	9 (6.3)	0.804
Elementary school	50 (35.2)	40 (28.2)	
Middle school	29 (20.4)	35 (24.6)	
High school	37 (26.1)	41 (28.9)	
University	18 (12.7)	17 (12.0)	
Education (year)	9.4 ± 3.8	8.8 ± 4.2	0.198
Income [*n* (%)]			
Low	136 (95.8)	131 (92.3)	0.211
Middle	6 (4.2)	11 (7.7)	
High	0	0	
Living condition [*n* (%)]			0.675
Live alone	32 (22.6)	35 (24.6)	
Live with someone	110 (77.4)	107 (75.4)	
Smoking [*n* (%)]			1.000
None or past smoker	129 (90.8)	129 (90.8)	
Current smoker or ex-smoker within 1 year	13 (9.2)	13 (90.8)	
Chronic disease [*n* (%)]			
Hypertension	57 (40.1)	56 (39.4)	0.904
Diabetes	20 (14.1)	29 (20.4)	0.158
Stroke	2 (1.4)	6 (4.2)	0.151
Ischemic heart disease	3 (2.1)	5 (3.5)	0.473
Lung disease	4 (2.8)	11 (7.7)	0.063
Musculoskeletal	23 (16.2)	30 (21.1)	0.286
Frailty [*n* (%)]			
Robust	17 (12.0)	76 (53.5)	
Pre-frail	66 (46.5)	56 (39.4)	
Frail	59 (41.5)	10 (7.0)	< 0.001
Frailty criteria [*n* (%)]			
Weight loss	33 (23.2)	24 (16.9)	0.202
Exhaustion	65 (45.8)	11 (7.7)	< 0.001
Physical inactivity	52 (36.6)	23 (16.2)	< 0.001
Slowness	80 (56.3)	19 (13.4)	< 0.001
Handgrip strength	53 (37.3)	22 (15.5)	< 0.001

Values are mean ± SD or numbers (%)

LSS lumbar spinal stenosis, *BMI* body mass index, *SD* standard deviation, *ODI* Oswestry Disability Index, *EQ* Euro-Qol, frailty was defined by Fried criteria

and LSS were included in the multivariate logistic regression model (Table 5). The multivariate analysis revealed that only age ($P = 0.003$; odds ratio [OR] 1.085; 95% confidence interval [CI] 1.029–1.145) and LSS ($P < 0.001$; OR 14.348; 95% CI 7.768–25.250) were significantly associated with a higher odds of frailty (Table 5).

Discussion

In this case–control study, symptomatic LSS was associated with a high prevalence and/or incidence of frailty in community-dwelling elderly persons. In addition, frailty was associated with higher disability and lower quality of life,

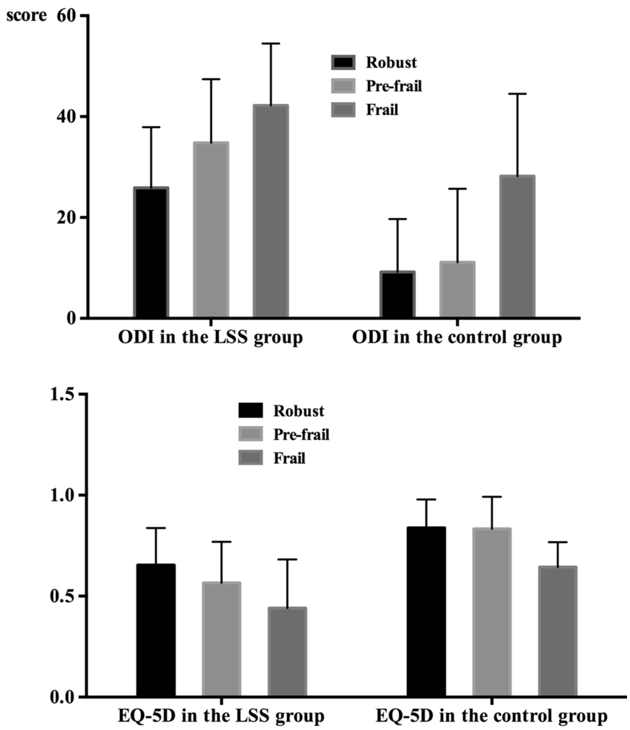

Fig. 2 Comparison of clinical outcomes according to frailty status in each group (ODI score in the LSS and control group, $P<0.001$ for both; EQ-5D in the LSS and control group, $P=0.002$ and $P=0.001$, respectively; P values were adjusted for age and sex with analysis of covariance)

represented by ODI and EQ-5D in both LSS and control groups.

After propensity score matching for potentially confounding variables such as sociodemographic and health-related variables, a strong association between symptomatic LSS and frailty was observed. Although, to our knowledge, this is the first study to examine the relation between symptomatic LSS and frailty, recent studies found a high prevalence of frailty in patients with degenerative osteoarthritis at the knee or hip joints [21–23]. Considering that both knee and/or hip osteoarthritis and symptomatic LSS lead to walking intolerance and physical inactivity, the underlying potential mechanism of LSS for frailty might be similar to that of the osteoarthritis at knee and/or hip joints [21–23]. Therefore, the strong association between LSS and frail can be explained by the fact that physical inactivity due to LSS contributes to loss of muscle mass and strength, leading to frailty. Walking intolerance caused by back and leg pain due to symptomatic LSS may lead to decreased physical activity, which might subsequently worsen age-related muscle weakness and frailty [23]. This generalized muscle weakness in the patient with symptomatic LSS was supported by the finding that the ratio of weak handgrip strength among the frailty criteria was significantly different between the both groups in this study. Even though other criteria for frailty including physical inactivity, slowness, and even exhaustion could be influenced directly by deteriorated nerve function of the lower extremities and pain in LSS, handgrip strength is not directly affected by compromised nerves of lower extremities in LSS. A recent study is in line with these results that patients with LSS demonstrate a high prevalence of sarcopenia [8], which has overlapping clinical manifestations with frailty, such as low physical capacity [1]. The findings of our within-group analysis support this mechanism: Frailty had a stronger relation with more severe symptoms and higher disability by LSS. Multivariate logistic regression analysis also showed that age and LSS were associated with significantly higher odds for frailty.

However, as the present cross-sectional design could not reveal a causal relationship between LSS and frailty, it is also plausible that frailty aggravates symptom severity and disability in patients with LSS. Even though pathology of frailty is not related to anatomical stenosis of spinal canal [3], frailty might aggravate disability and physical function because frailty is associated with increased disability and physical dysfunction, in itself [24]. A previous study has shown that the presence of frailty was related to incident or worsening disability [24].

Because a causal relationship between LSS and frailty was not determined in this study, we only suggest possible implications depending on the causality. Given that the high prevalence of frailty in patients with symptomatic LSS and that frailty is associated with many serious medical

Table 4 Clinical outcome variable according to frailty status in each group

		LSS group (142)		Control group (142)	
ODI scores	Robust	25.9 ± 12.0	P < 0.001 (P < 0.001)*	9.2 ± 10.5	P < 0.001 (P < 0.001)*
	Pre-frail	34.8 ± 12.6		11.1 ± 14.6	
	Frail	42.2 ± 12.3		28.2 ± 16.3	
EQ-5D	Robust	0.654 ± 0.183	$P=0.004$ ($P=0.002$)*	0.838 ± 0.141	$P=0.003$ ($P=0.001$)*
	Pre-frail	0.566 ± 0.203		0.833 ± 0.159	
	Frail	0.441 ± 0.241		0.644 ± 0.123	

LSS lumbar spinal stenosis, *SD* standard deviation, *ODI* Oswestry Disability Index, *EQ* Euro-Qol

**P* value adjusted for age and sex with ANCOVA (analysis of covariance)

Table 5 Univariate and multivariate analysis for the risk factors for frail

	Univariate analysis				Multivariate	
	Robust/pre-frail (758)	Frail (85)	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
Age (years)	71.0 ± 4.6	73.3 ± 6.5	1.096 (1.049–1.145)	< 0.001	1.085 (1.029–1.145)	0.003
Female [*n* (%)]	386 (50.9%)	61 (71.8%)	2.449 (1.496–4.011)	< 0.001	1.422 (0.741–2.731)	0.290
BMI (kg/cm^2)	24.4 ± 2.9	24.6 ± 2.8	1.021 (0.945–1.103)	0.599	0.993 (0.900–1.097)	0.896
Education year	9.3 ± 4.4	7.9 ± 3.7	0.929 (0.878–0.982)	0.010	0.943 (0.870–1.022)	0.150
Smoking	77 (10.2%)	9 (10.6%)	0.953 (0.441–2.059)	0.902		
Low income*	534 (70.4%)	81 (95.8%)	9.661 (3.008–31.025)	< 0.001	2.563 (0.729–9.091)	0.143
LSS	83 (10.9%)	59 (69.4%)	18.455 (11.031–30.875)	< 0.001	14.348 (7.768–25.250)	< 0.001
Live alone	141 (18.6%)	25 (29.4%)	1.817 (1.069–3.088)	0.027	1.346 (0.701–2.584)	0.373

BMI body mass index, *SD* standard deviation, *CI* confidence interval, *LSS* lumbar spinal stenosis, frailty was defined by Fried criteria

*Odd ratio compared to middle and high income

problems, proper attention to screening frailty should be necessary in elderly patients with symptomatic LSS. In addition, both early detection and proper treatment for frailty would also be important for the management of the patients who have both frailty and LSS. To aggregate, the present study supports early detection of frailty and appropriate treatment for LSS in the patients with both frailty and LSS. In addition, this study can serve as the basis for further prospective studies on the prevention of frailty.

This study has a few limitations. First, we could not examine the causal relationship between LSS and frailty. Because LSS is caused by obvious mechanical stenosis of the spinal canal and an ischemic condition of the nerve root, frailty is not a direct causative factor of LSS. However, it should be noted that frailty can aggravate the severity of symptoms and disability in patients with LSS. Therefore, a future longitudinal evaluation can provide more information about the association between frailty and LSS. Second, although 843 participants were enrolled in this study and post hoc power was 100%, only 142 patients were included in the LSS group. Therefore, there might be a selection bias owing to the relatively limited number of patients in the LSS group. However, demographic and clinical outcomes in the LSS group were comparable to those in other studies on LSS [8, 25, 26]. Third, propensity score matching was used for control of well-known factors related to frailty, which were age, sex, BMI, educational level, and income. However, it might be possible that unknown bias for frailty was missed in the propensity score-matched case–control group. Fourth, in order to estimate the specific effect of LSS in comparison with low back pain and sciatica, another low back pain group without LSS and sciatica group should have been added. This would allow for a view of the full picture of the association between spinal conditions and frailty.

In conclusion, the present study highlights a strong association between two common geriatric conditions—symptomatic LSS and frailty—both of which carry a substantial risk for adverse outcomes. Furthermore, symptom severity and disability caused by LSS are significantly related to frailty. Because frailty is associated with many serious medical problems including mortality, frailty should be screened and managed appropriately in patients with symptomatic LSS.

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Compliance with ethical standards

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

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