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HEALTH SERVICES RESEARCH

Clinical Features of Sarcopenia in Patients With Lumbar Spinal Stenosis

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Study Design. Cross-sectional design.

Objective. To investigate the prevalence of sarcopenia and identify factors associated with sarcopenia in patients with lumbar spinal stenosis (LSS).

Summary of Background Data. Patients with LSS have a higher prevalence of sarcopenia compared with healthy older adults. However, the clinical features of sarcopenia in patients with LSS are poorly understood and the factors affecting sarcopenia in patients with LSS remain unclear.

Methods. Patients diagnosed with LSS based on clinical examination and magnetic resonance imaging findings, and referred to physical therapy, were enrolled. Muscle mass was measured using bioelectrical impedance using InBody S10. We collected a numerical rating scale (NRS) for back pain, the 36-Item Short-Form Survey (SF-36), the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), bone mineral density (BMD), and radiographic measurements of spinal alignment. Sarcopenia was defined according to the Asian Working Group for Sarcopenia guidelines and patients were classified into sarcopenia or nonsarcopenia groups.

Results A total of 178 patients were enrolled: 35 in the sarcopenia group and 143 in the nonsarcopenia group. The prevalence of sarcopenia was 19.7%. The average percent of slip (% slip) among patients in the sarcopenia group was significantly higher compared with those in the nonsarcopenia group ($P < 0.05$). Body mass index (BMI), BMD, physical function as assessed by the SF-36, and gait disturbance as assessed by the JOABPEQ were significantly lower in the sarcopenia group compared with those in the nonsarcopenia group ($P < 0.05$). A trend was observed toward between-group differences in back pain on the NRS ($P < 0.1$). In the logistic regression analysis, significant associations were seen between sarcopenia and % slip (odds ratio 1.15, 95% CI 1.01–1.30).

Conclusion. Patients with LSS and sarcopenia have a higher degree of slippage and lower BMI, BMD, and physical function, and reported more severe low back pain, compared with those without sarcopenia.

Key words: % slip, bone mineral density, degree of slippage, Japanese Orthopaedic Association Back Pain Evaluation Questionnaire, low back pain, lumbar spinal stenosis, muscle mass, physical function, sarcopenia, SF-36, spinal alignment.

Level of Evidence: 4

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The term "sarcopenia" is used to indicate progressive low muscle mass, low muscle strength, and low function that affect older adults.[1] The cause of sarcopenia is generally thought to be multifactorial, with decreased physical activity, poor nutrition, disease triggers, inflammatory pathway activation, loss of neuromuscular junctions, mitochondrial abnormalities, reduced satellite cell numbers, and hormonal changes all potential contributors.[2] Sarcopenia is also associated with adverse outcomes such as physical disability and immobility, potentially leading to a loss of independence, increased frailty, poor quality of life, increased healthcare costs, and ultimately death.[1]

Lumbar spinal stenosis (LSS) is one of the most commonly diagnosed and treated musculoskeletal conditions and is the most common reason for spinal surgery among older adults.[3,4] LSS is a clinical syndrome presenting with pain in the buttocks or lower extremities, with or without low back pain. It is associated with reduced space available for the neural and vascular elements of the lumbar spine. The condition is often exacerbated by standing, walking, or lumbar extension.[5] Patients with LSS avoid walking and exhibit sedentary behavior because of neurogenic claudication.[6]

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Some studies investigated the prevalence of sarcopenia in patients with LSS.[7,8] Of these, one study showed that the impact of sarcopenia on disability, quality of life, and physical performance is more pronounced in patients with LSS compared with matched controls from the normal population.[7] Sarcopenia has also been reported to be related to osteoporosis.[9–11] Hida *et al*[9] reported that patients with hip fractures had a higher prevalence of sarcopenia and more reduced leg muscle mass and whole-body bone mineral density (BMD) compared with patients without hip fractures. To date, studies have evaluated the relationships between sarcopenia, osteoporosis, pain, physical function, and quality of life in patients with LSS.[8] However, the clinical features of sarcopenia in patients with LSS are poorly understood, and the factors affecting sarcopenia in patients with LSS remain unclear. The purposes of this study were to investigate the prevalence of sarcopenia and identify factors associated with sarcopenia in patients with LSS, using multimodal assessments.

MATERIALS AND METHODS

Study Sample

This cross-sectional study was conducted at the Spine Care Center of Wakayama Medical University Kihoku Hospital from September 2017 to August 2018. The study was approved by the Institutional Review Board at Wakayama Medical University (No. 2378). All participants provided written informed consent before enrollment. The inclusion criteria were presence of neurogenic intermittent claudication and pain and/or numbness in the lower extremities with or without low back pain, magnetic resonance imaging (MRI) findings consistent with degenerative LSS, and referral to physical therapy. Patients 50 years of age and older were included in this study, because it is well known that muscle mass decreases 1% to 2% per year after the age of 50-year-old and degenerative LSS is a common condition in person over 50 years old.[12,13] The exclusion criteria were device contraindications such as the presence of an electronic implant (*i.e.*, heart pacemaker, brain stimulator), prostheses or metal implant; cognitive impairment; or history of psychiatric illness. We enrolled consecutive patients who met the inclusion and exclusion criteria and who agreed to participate in the study.

Measurements

We collected demographic data including age, sex, height, body weight, body mass index (BMI), radiographic measurements (including sagittal vertical axis [SVA], thoracic kyphosis, lumbar lordosis [LL], pelvic tilt [PT], pelvic incidence [PI], sacral slope [SS] percent of slip [% slip], number of vertebral fractures, and BMD),[14] appendicular and trunk skeletal muscle mass, hand grip strength, gait speed, numerical rating scale (NRS) of low back pain, leg pain and numbness,[15,16] the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ),[17] and the 36-Item Short-Form Survey (SF-36).[18,19]

Muscle mass was measured by bioelectrical impedance analysis (BIA) using InBody S10 (InBody Co. Ltd, Seoul, Korea). After height and weight were measured, four electrodes were attached to both upper and lower extremities in the supine position. Appendicular and trunk muscle mass and skeletal muscle index (SMI) were obtained. SMI was calculated by dividing the appendicular muscle mass by squared height in meters.[20] Although dual-energy X-ray (DXA) is considered the gold standard for body composition measurement, BIA and DXA have been reported as strongly correlated.[21,22]

Handgrip strength was measured using a T.K.K.5001 dynamometer (Takei, Niigata City, Japan) in the standing position with shoulder adducted and neutrally rotated, and elbow in full extension. The device handle was adjusted to accommodate each patient's hand size such that the index finger of each hand was at 90° flexion between the proximal and middle phalangeal joint. Two measurements were taken with each hand and the maximum score for each hand was recorded.

The 5-m walk test[23] was used to assess maximal gait speed. Patients were instructed to walk as quickly as possible over a total distance of 10 m, with time recorded with a stopwatch during the middle 5 m to minimize the effects of acceleration and deceleration.

The JOABPEQ is a self-report questionnaire designed to evaluate the common symptom of "back pain" and is not designed to evaluate disease-specific patient conditions. The 25-item instrument is divided into five domains (pain-related disorders, lumbar dysfunction, gait disturbance, social life dysfunction, and psychological disorders). Scores for each domain range from 0 to 100, with higher scores indicating a better condition.[17]

The SF-36 is a 36-item scale constructed to assess health status and quality of life across eight multi-item scales (physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health). The scores for each domain range from 0 to 100, with higher scores indicating a better condition.[18,19]

Definition of Sarcopenia

Sarcopenia was defined according to the Asian Working Group for Sarcopenia (AWGS) guidelines: hand grip strength less than 26 kg for men and less than 18 kg for women and/or gait speed less than 0.8 m/s, and SMI less than 7.0 kg/m^2 for men and less than 5.7 kg/m^2 for women.[24]

Statistical Analysis

Patients were classified into sarcopenia and nonsarcopenia groups based on the definition above and clinical outcomes were compared between groups. The Pearson's chi-square test was used to compare categorical data. Between-group comparisons were made using Student *t* test for parametric variables and the Mann–Whitney *U* test for nonparametric variables. Multivariate logistic regression analysis was performed to examine the relationships between sarcopenia and outcome measures. Variables which *P*-values <0.01 in

the univariate analyses were entered as independent variables into the regression analysis. *P*-values < 0.05 were considered statistically significant. Statistical analyses were performed using JMP Pro (version 14; SAS Institute, Cary, NC).

RESULTS

A total of n = 178 patients (average age: 75.8 yr; 77 men, 101 women) were enrolled, 35 of whom (average age: 79.0 yr; 11 men, 24 women) were in the sarcopenia group and 143 (average age: 72.6 yr; 66 men, 77 women) were in the nonsarcopenia group. The prevalence of sarcopenia was 19.7%. The average age (sarcopenia group, 79.0 yr *vs.* nonsarcopenia group, 72.6 yr) and % slip (17.8 *vs.* 13.6) of patients in the sarcopenia group were significantly higher than those in the nonsarcopenia group ($P < 0.05$; Tables 1 and 2). Height (151.6 *vs.* 159.0), BMI (21.7 *vs.* 24.0), BMD lumbar (0.953 *vs.* 1.096), BMD right femoral (0.748 *vs.* 0.863), BMD left femoral (0.743 *vs.* 0.857), and physical function (48.4 *vs.* 58.9) on the SF-36 were significantly lower in the sarcopenia group than those in the nonsarcopenia group ($P < 0.05$; Tables 1 and 2). A trend was

TABLE 1. Clinical Characteristics of the Sarcopenia and Nonsarcopenia Groups

	Sarcopenia Group (n = 35)	Nonsarcopenia Group (n = 143)	*P*
Age, yr	79.0 ± 1.2	72.6 ± 0.6	0.001*
Sex	Female: 24	Female: 77	0.116†
	Male: 11	Male: 66	
Height, cm	151.6 ± 8.1	159.0 ± 8.9	0.001*
Weight, kg	49.9 ± 1.7	60.8 ± 0.8	0.001‡
BMI, kg/m^2	21.7 ± 0.5	24.0 ± 0.3	0.001*
Muscle mass			
Right arm, kg	1.6 ± 0.4	2.2 ± 0.6	0.001‡
Left arm, kg	1.6 ± 0.5	2.1 ± 0.6	0.001‡
Trunk, kg	15.1 ± 2.9	18.8 ± 3.8	0.001‡
Right leg, kg	4.8 ± 1.0	6.6 ± 1.5	0.001‡
Left leg, kg	4.8 ± 1.1	6.6 ± 1.4	0.001‡
SMI, kg/m^2	5.5 ± 0.7	6.9 ± 1.0	0.001‡
Physical function			
Right grip strength, kg	19.1 ± 1.4	28.1 ± 9.0	0.001‡
Left grip strength, kg	18.0 ± 1.4	27.1 ± 0.7	0.001‡
Gait speed, m/s	0.82 ± 0.04	1.06 ± 0.02	0.001‡
NRS			
Low back pain	5.4 ± 2.9	4.4 ± 2.6	0.075‡
Leg pain	4.5 ± 2.9	5.0 ± 2.7	0.266‡
Leg numbness	4.6 ± 2.9	4.3 ± 2.9	0.686‡
SF-36			
Physical functioning	48.4 ± 18.3	58.9 ± 22.5	0.008‡
Role physical	41.5 ± 23.0	52.2 ± 29.4	0.055‡
Bodily pain	39.7 ± 19.6	42.8 ± 20.4	0.384‡
General health	47.0 ± 17.6	52.5 ± 16.5	0.132‡
Vitality	47.8 ± 19.1	50.1 ± 22.2	0.686*
Social functioning	58.9 ± 30.7	64.4 ± 27.5	0.381‡
Role emotional	53.8 ± 32.4	57.0 ± 31.3	0.684‡
Mental health	61.3 ± 24.0	60.8 ± 20.6	0.893‡
JOABPEQ			
Pain-related disorders	44.9 ± 34.1	52.6 ± 33.8	0.308‡
Lumbar spine dysfunction	54.9 ± 31.7	60.4 ± 28.1	0.473‡
Gait disturbance	31.2 ± 25.3	46.2 ± 29.6	0.021‡
Social life disturbance	41.4 ± 19.7	43.5 ± 21.9	0.684‡
Psychological disorders	46.8 ± 17.2	49.3 ± 17.2	0.645*

Values are mean ± SD.

**Student t test.*

†Pearson chi-square test.

‡Mann–Whitney U test.

JOABPEQ indicates Japanese Orthopaedic Association Back Pain Evaluation Questionnaire; NRS, Numerical Rating Scale; SF-36, Medical Outcomes Study 36-Item Short-Form General Health Survey.

TABLE 2. Radiographic Measurements from Sarcopenia and Nonsarcopenia Groups

	Sarcopenia Group (n = 35)	Nonsarcopenia Group (n = 143)	*P*
BMD			
Lumbar, g/cm^2	0.953 ± 0.19	1.096 ± 0.25	0.006*
Right femoral, g/cm^2	0.748 ± 0.13	0.863 ± 0.14	0.001*
Left femoral, g/cm^2	0.743 ± 0.14	0.857 ± 0.14	0.001*
Spinal alignment			
SVA, °	73.6 ± 45.1	56.5 ± 46.9	0.199‡
TK, °	29.1 ± 14.8	29.0 ± 12.9	0.708‡
LL, °	27.8 ± 19.0	33.0 ± 16.0	0.277*
PI, °	61.5 ± 6.4	56.1 ± 11.3	0.088*
PT, °	36.0 ± 8.3	31.6 ± 10.4	0.072*
PI–LL, °	33.8 ± 18.7	22.9 ± 15.7	0.060*
SS, °	25.5 ± 9.3	24.5 ± 9.9	0.881‡
Number of vertebral fractures	1.2 ± 1.3	1.2 ± 1.6	0.784‡
Presence of slippage (n)	11	52	0.759†
% slip (%)	17.8 ± 5.4	13.6 ± 6.8	0.002‡

Values are mean ± SD.

**Mann–Whitney U test.*

†Pearson chi-square test.

‡Student t test.

BMD indicates bone mineral density; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis; TK, thoracic kyphosis.

observed toward between-group differences in low back pain on the NRS (5.4 *vs.* 4.4), PI (61.5 *vs.* 56.1), PT (36.0 *vs.* 31.6), and PI–LL (33.8 *vs.* 22.9) ($P < 0.1$; Tables 1 and 2).

Age, BMI, BMD, physical function on the SF-36 and % slip, which *P*-values < 0.01 in the univariate analyses were entered as independent variables into the regression analysis. Only BMD right femoral was entered as independent variable, because the *P*-values of BMD right femoral were smaller than those of BMD lumbar and left femoral. Logistic regression analysis showed a significant association between sarcopenia and % slip (odds ratio 1.15, 95% CI 1.01–1.30) (Table 3).

DISCUSSION

This cross-sectional observational study, which investigated the incidence of sarcopenia in accordance with AWGS guidelines, identified factors associated with sarcopenia in patients with LSS using multimodal assessments. Findings show that the prevalence of sarcopenia in patients with LSS (average age: 75.8 yr) was 19.7%. In 1000 older adult participants from Japanese population-based cohorts, the prevalence rates of sarcopenia, using the European Working Group on Sarcopenia in Older People definition, were 13.8% in men (average age: 75.7 yr) and 12.4% in women (average age: 74.4 yr).[25] Park *et al*[7] reported that sarcopenia, defined by hand-grip strength (low hand-grip strength <26 kg for men and <18 kg for women), is more prevalent in patients with LSS (average age: 67.9 yr, sarcopenia prevalence rate: 24%) compared with age- and sex-matched controls (average age: 68.2 yr, sarcopenia prevalence rate: 12%). Eguchi *et al*[8] reported that sarcopenia prevalence rates, defined as appendicular SMI of less than 5.46 kg/m^2, were 16% in women patients with LSS (average age: 72.9 yr) and 46.6% in women patients with degenerative lumbar scoliosis (average age: 74.8 yr). Although definitions of sarcopenia differ among studies, our present work shows that sarcopenia is more prevalent in patients with LSS

TABLE 3. Multivariate Logistic Regression Analysis

Baseline Factor	Odds Ratio (OR)	95% CI for OR		*P*
		Lower	Upper	
Age	1.05	0.95	1.17	0.299
BMI	0.85	0.63	1.15	0.287
SF-36 PF	1.00	0.96	1.04	0.997
BMD right femoral	0.72	0.00	191.56	0.907
% slip	1.15	1.01	1.30	0.023

Independent variables entered into model: age, body mass index (BMI), physical function assessed by the 36-Item Short-Form General Health Survey (SF-36), bone mineral density (BMD) right femoral, % slip.

Nagelkerke's R-squared: 0.17.

compared with community-dwelling elderly, consistent with previous studies investigating the prevalence of sarcopenia in patients with LSS.

Our study also demonstrates that a sarcopenia group has a higher degree of slippage in the lumbar spine compared with a nonsarcopenia group, and that the degree of slippage is associated with sarcopenia in the multiple regression analysis. Regarding the association between trunk muscles and spondylolisthesis, Zhu *et al*[26] demonstrated that reduced force of back muscles causes an obvious change in the shear force of the lower region of the lumbar spine *in vitro* in a finite element study. That group concluded that reducing the force of global back muscles might lead to, or aggravate, degenerative spondylolisthesis with forward slipping, from a biomechanical point of view. In their *in vivo* study, Shadani *et al*[27] found that patients with spondylolisthesis had smaller abdominal and lumbar multifidus muscle thicknesses, as assessed by ultrasonography at rest and during contraction, compared with a healthy group. Herein, the sarcopenia group not only had lower appendicular muscle mass, they also had a lower trunk muscle mass than the nonsarcopenia group. Therefore, it is possible that trunk muscle atrophy aggravates degenerative spondylolisthesis in patients with LSS and sarcopenia.

In this study, the sarcopenia group had more severe low back pain and worse spinopelvic alignments on PT, PI, and PI–LL compared with the nonsarcopenia group, although there were no significant between-group differences ($P < 0.1$). Several studies have investigated differences in paraspinal muscle morphology between patients with low back pain and control patients.[28–31] A systematic review investigating the association between paraspinal muscle morphology and low back pain revealed that paraspinal muscles are significantly smaller in patients with chronic low back pain than in control patients.[32] Tanishima *et al*[33] reported the mean visual analogue scale ratings of low back pain were highest in the sarcopenia group, although there were no significant differences among the sarcopenia group, presarcopenia group, and normal group from the general population. However, Oswestry Disability Index scores were significantly higher in the sarcopenia group compared with the other groups. Katsu *et al*[34] investigated the relationship between paraspinal musculature and spinopelvic alignment in patients with adult spinal deformity. They found that the relative cross-sectional paraspinal muscle area, evaluated with MRI, was negatively correlated with Oswestry Disability Index score, PT, and SS, and concluded that multifidus and erector muscles significantly influence maintenance of pelvic alignment. Therefore, trunk muscle atrophy may influence low back pain, low back pain-related disability, and spinal malalignment in patients with LSS.

Our study indicated there is high prevalence of sarcopenia among LSS, and patients with LSS and sarcopenia have a higher degree of slippage in the lumbar spine and worse spinopelvic alignments and higher self-reported severe low back pain compared with those without sarcopenia. In recent years, several studies have revealed the impact of the loss of skeletal muscle mass on clinical outcomes in spinal disorders. Hori *et al*[35] demonstrated that trunk muscle mass was significantly associated with visual analogue scale score for back pain, Oswestry Disability Index, EuroQol 5 Dimension score, and SVA in patients with spinal disorders. Sarcopenia also has been reported to predict postoperative outcomes including mortality, morbidity, in-hospital length of stay, and discharge disposition in adult spine surgery.[36] Therefore, there is the possibility that assessment of sarcopenia plays a crucial role in managing patients with LSS. Our study suggested that to assess muscle mass using BIA, which is a simple and noninvasive method is useful method in assessing sarcopenia among patients with LSS. Future studies should confirm whether the treatment of sarcopenia can help to improve clinical outcomes such as low back pain, spinopelvic alignments, quality of life, and postoperative outcomes in patients with LSS.

This study was not without limitations. First, a cross-sectional design limits causal inference. Thus, longitudinal studies are needed to clarify whether LSS causes sarcopenia by sedentary behavior because of neurogenic claudication, or *vice versa*. Second, a control group of participants without LSS was not included. Thus, future studies should compare those with sarcopenia with and without LSS, to identify factors associated with LSS among those with sarcopenia. Finally, we did not assess physical activity and nutrition status, which are considered primary causes of sarcopenia. The etiology of sarcopenia is generally thought to be multifactorial, with decreased physical activity, poor nutrition, disease triggers, and other factors. Assessments of physical activity and nutrition status may therefore help to identify the effects of LSS on sarcopenia, and to improve treatment of sarcopenia in patients with LSS.

In conclusion, patients with LSS and sarcopenia have lower BMD, muscle mass and strength, physical performance, and physical function; a higher degree of slippage in the lumbar spine; and higher self-reported severe low back pain compared with those without sarcopenia. Multiple regression analysis revealed that the degree of slippage was the primary factor associated with sarcopenia in patients with LSS. Thus, sarcopenia may adversely affect low back pain in patients with LSS.

➢ Key Points

- ❑ Sarcopenia patients have LSS at a prevalence rate of 19.7%.
- ❑ Patients with LSS and sarcopenia have lower bone mineral density, muscle mass and strength, physical performance, and physical function, and they have a higher degree of slippage in the lumbar spine than those without sarcopenia.
- ❑ Although not statistically significant, patients with LSS and sarcopenia report more severe low back pain and have worse spinopelvic alignments than those without sarcopenia.

- ❑ Multiple regression analysis reveals that the degree of slippage is associated with sarcopenia in patients with LSS.
- ❑ Sarcopenia may adversely affect low back pain in patients with LSS.

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