



# Sarcopenia and Back Muscle Degeneration as Risk Factors for Back Pain: A Comparative Study

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**Study Design:** Case-control study.

**Purpose:** To investigate the independent associations of back pain with sarcopenia and with back muscle degeneration, and to introduce a new risk index for back muscle degeneration.

**Overview of Literature:** The Asian Working Group for Sarcopenia recommends diagnosis using handgrip strength, gait speed, and skeletal muscle mass. However, these criteria do not strongly reflect back muscle degeneration.

**Methods:** Patients who completed a questionnaire on back-pain between October 2016 and October 2017 were enrolled in this study. Appendicular skeletal muscle index (ASMI), cross-sectional area (CSA) index, fatty infiltration (FI) rate of the paraspinal muscles, and lumbar extensor strength index (LESI) were measured and compared between no back-pain and back-pain group. Correlations between LESI and ASMI, CSA index, and FI rate were analyzed. The back-pain group was further divided according to ASMI into sarcopenia and non-sarcopenia subgroups and by our newly developed back muscle degeneration risk index based on correlation coefficients between LESI and CSA index, FI rate. Differences in ASMI, CSA index, FI rate, LESI, and Visual Analog Scale (VAS) score between subgroups were analyzed.

**Results:** The ASMI, CSA index, FI rate, and LESI differed significantly between back-pain and pain-free groups. The LESI demonstrated the strongest correlation with FI rate. There were no significant differences in VAS score and back muscle degeneration index in the back-pain group when divided according to the presence of sarcopenia. However, there was a significant difference in VAS score between back-pain patients when classified according to high and low back muscle degeneration risk index.

**Conclusions:** We suggest that the degree of back pain is more strongly associated with back muscle degeneration than with sarcopenia. This back muscle degeneration risk index, reflecting both back muscle morphology and function, could be a useful parameter for evaluation of back pain and muscle degeneration.

**Keywords:** Back pain; Sarcopenia; Back muscle degeneration; Cross-sectional area; Fatty infiltration

## Introduction

Interest in the pathogenesis and clinical manifestations

of sarcopenia has grown rapidly since the first description by Rosenberg [1]. Sarcopenia decreases muscle mass and function, thereby limiting patient activity, physical

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performance, and quality of life [2]. The recent upsurge in research and interest in sarcopenia is attributed to its recognition as an independent condition by the International Classification of Diseases, 10th revision, clinical modification [3]. Age-related sarcopenia is a common health problem, so evaluation and measurement of sarcopenia are important for clinical research and treatment strategies [2,4]. Back pain is one of the most common musculoskeletal symptoms of many diseases, including sarcopenia [5]. Potential causes of back pain include degeneration of the intervertebral disk, hypertrophy of the facet joint, and segmental instability [6]. Studies have explored the relationship between sarcopenia and degenerative spinal disease, including back pain [7,8], and some suggest that back muscle degeneration is another cause of back pain [9,10]. However, these studies focused only on muscle atrophy and fatty infiltration (FI), and excluded functional measures. Back muscle degeneration can be classified according to morphological change or functional decrease [2], the former using cross-sectional area (CSA) and FI rate, and the latter by lumbar extensor strength testing [11]. Lumbar extensor strength, measured using a lumbar extension dynamometer, is an important parameter in patients with back pain and functional disability [11-13]. Furthermore, muscle strength and function are better predictors of adverse outcomes than muscle mass [14].

The recently proposed diagnostic criteria of the Asian Working Group for Sarcopenia (AWGS) include calculating handgrip strength, gait speed, and skeletal muscle mass as indices of muscle strength, physical activity, and performance level [15]. However, sarcopenia according to these criteria does not necessarily reflect back muscle degeneration, so sarcopenia and back muscle degeneration may be independent factors that can induce back pain.

To the best of our knowledge, no studies have focused on indicators that reflect both morphological change and functional decrease due to back muscle degeneration. Studies evaluating factors relevant to back pain in patients with sarcopenia and (or) back muscle degeneration are also rare. Therefore, this study aimed to analyze the association between sarcopenia and back muscle degeneration and to verify the effects of sarcopenia and back muscle degeneration on back-pain severity. Additionally, we aimed to establish a risk index of back muscle degeneration using the quantified data.

## Materials and Methods

### 1. Subjects

We conducted a prospective data-based case-control study of patients receiving bioimpedance analysis (BIA) using the Inbody720 (Inbody720; InBody Corp., Seoul, Korea), abdominopelvic computed tomography (CT, SOMATOM Definition AS+; Siemens, Munich, Germany), and lumbar extensor strength measurement using a lumbar extension dynamometer (SYSTEM 3 PRO; Biodex Medical Systems, Shirley, NY, USA) during regular health checkups at Eulji University Hospital from October 2016 to October 2017. All participants provided written informed consent, and the Institutional Review Board of Eulji University Hospital approved this study (EUH IRB file no., 2016-03-003). Subjects examined for lumbar extensor strength were requested to answer the question "Have you felt back pain enough in your daily life to take pain medications in the last 12 months?" from the modified Nordic questionnaire for musculoskeletal symptoms [16]. Those who answered "Yes" were included as back-pain subjects. All participants who complained of back pain were also asked to rate pain on a 100-mm horizontal Visual Analog Scale (VAS). Patients were excluded in cases of recent trauma (within the past 1 month), tumors, and infections. Patients answering "No" were enrolled as the control group. A total of 212 subjects (100 controls and 112 with back pain) were included in this study. Neither mean age nor sex ratio (male/female) differed between control and back-pain groups (mean age,  $56.6 \pm 15.2$  years [range, 28-74 years] versus  $57.8 \pm 17.6$  years [range, 18-77 years];  $p=0.63$ ; sex ratio, 58:42 versus 50:62;  $p=0.12$ ).

### 2. Measurement of appendicular skeletal muscle mass

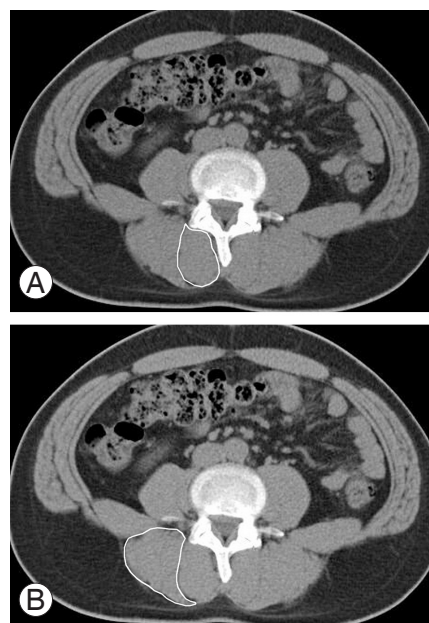
Appendicular skeletal muscle mass index (ASMI) was determined as the sum of arm and leg lean mass (kg) using the InBody720 BIA method and divided by the square of height ( $m^2$ ) for normalization across subjects (Fig. 1). Male subjects were classified into the sarcopenia group according to  $ASMI < 7.0 \text{ kg}/m^2$  (sarcopenia) and females according to  $ASMI < 5.7 \text{ kg}/m^2$  based on AWGS recommendations, while participants with higher values were classified into corresponding non-sarcopenia groups [15].



**Fig. 1.** Appendicular skeletal muscle mass measurement using InBody 720 (InBody Corp., Seoul, Korea) bioelectrical impedance analysis.

### 3. Measurement of cross-sectional area and fatty infiltration of paraspinal muscles

Abdominopelvic CT was used to measure the CSA ( $\text{cm}^2$ ) and FI rate (%) of the paraspinal muscles (multifidus and erector spinae) at intervertebral disk levels L2–3, L3–4, and L4–5, the levels where the paraspinal muscles have highest stretching force and thus where exact muscle size can be measured [17,18]. All measurements were averaged and standardized. Images were acquired using a 120 kV CARE Dose 4D CT device with axial section thickness of 0.6 mm, and reconstructed to 0.3 mm thickness by the measured values of muscle and fat selected in the ‘Standard Algorithm 131 medium Smooth.’ The CSA was measured using the Marosis PACS system (Marotech Inc., Seoul, Korea) region of interest function by tracing the fascial boundary of the multifidus and erector spinae (Fig. 2). The measured value was normalized across subjects by dividing by the square of subject height to obtain the CSA index ( $\text{cm}^2/\text{m}^2$ ). FI rate was measured by muscle attenuation in Hounsfield units (HUs), where FI rate equals the area with fat-specific HU divided by the whole back muscle area with variable HU. Intra- and inter-observer correlation coefficients were also calculated for CSA and FI rate of the paraspinal muscles [19] and results revealed high reliabilities for measurements of both multifidus and erector spinae muscles (0.84–0.92 and 0.81–0.93, respectively).



**Fig. 2.** Cross-sectional area and fatty infiltration rate measurements of multifidus (A) and erector spinae (B) muscles using axial images from abdominopelvic computed tomography at the L2–3, L3–4, and L4–5 intervertebral disk levels.

### 4. Measurement of lumbar extensor strength

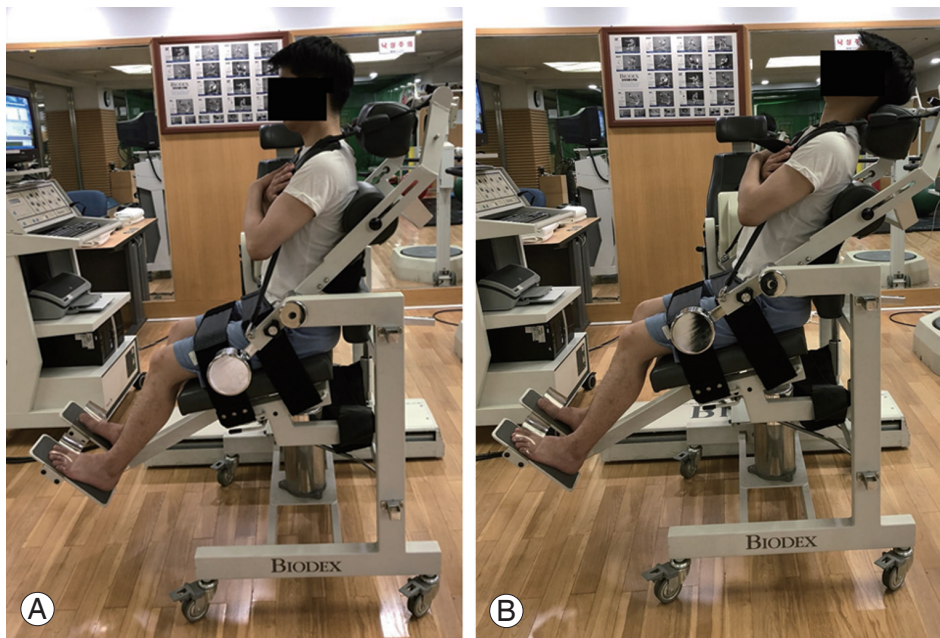
Lumbar extensor strength was measured using a lumbar extension dynamometer in the sitting position with stable pelvis. Warm-up trials and stretching exercises were conducted for 5 minutes before measurements. The testing device was set to an angular velocity of  $60^\circ$  per second, and lumbar extensor strength was measured 5 times and recorded as peak torque (Nm) (Fig. 3). The lumbar extensor strength index (LESI, Nm/kg) was obtained by dividing the measured peak torque value by body weight (kg).

### 5. Relationship between sarcopenia and back muscle degeneration

The relationship between sarcopenia and back muscle degeneration was assessed by dividing all subjects into sarcopenia and non-sarcopenia groups based on ASMI (above). These groups then compared for differences in CSA index, FI rate, and LESI by independent samples Student *t*-test.

### 6. Back muscle degeneration risk index

To develop a single risk index reflecting both functional and morphological aspects of back muscle degeneration,



**Fig. 3. (A, B)** Lumbar extensor strength measurement using the SYSTEM 3 PRO (Biodex Medical Systems, Shirley, NY, USA) lumbar extension restraint system dynamometer.

we conducted Pearson correlation analysis of the association between LESI and CSA index and between LESI and FI rate. The correlation coefficient between LESI, reflecting back muscle function, and CSA index, reflecting back muscle morphological degeneration, was multiplied by the CSA index. Similarly, the correlation coefficient between LESI and FI rate was multiplied by the FI rate. The sum of these two products was defined as the back muscle degeneration risk index (risk index=coefficient of LESI and CSA index×CSA index+coefficient of LESI and FI rate×FI rate). The FI rate was expressed as a percentage to prevent the absolute value from becoming too small.

### 7. Comparison of back-pain severity between sarcopenia/non-sarcopenia and high/low back muscle degeneration groups

The back-pain group was classified into ASMI-based sarcopenia and non-sarcopenia groups, and CSA index, FI rate, LESI, and VAS scores compared. Back-pain patients were subsequently divided into high-risk and low-risk back muscle degeneration groups using the median cutoff risk index as a threshold, and ASMI, CSA index, FI rate, LESI, and VAS scores compared by Student *t*-test or Mann-Whitney *U*-test. Through these comparisons, the effects of sarcopenia and back muscle degeneration on back-pain severity were revealed.

### 8. Statistical analyses

All data are expressed as mean±standard deviation. Differences in demographic characteristics, sarcopenia prevalence, back muscle degeneration indices, and VAS scores were examined using Student *t*-test or Mann-Whitney *U*-test. Pearson correlation coefficients for LESI versus ASMI, LESI versus CSA index, and LESI versus FI rate were also calculated. A  $p < 0.05$  (two-tailed) was considered significant for all tests. Statistical analyzes were performed using IBM SPSS ver. 22.0 software (IBM Corp., Armonk, NY, USA).

## Results

### 1. Comparison of sarcopenia prevalence and back muscle degeneration characteristics between patients with and without back pain

Body mass index did not differ between the back pain-free group (group A) and the back-pain group (group B; mean VAS score,  $6.32 \pm 1.88$ ;  $24.23 \pm 5.14$  kg/m<sup>2</sup> versus  $25.63 \pm 4.70$  kg/m<sup>2</sup>,  $p = 0.07$ ), while sarcopenia prevalence was significantly higher in group B than group A (26.8% [n=30] versus 8.0% [n=8],  $p < 0.01$ ) (Table 1).

There were no significant differences in demographic variables between pain-free and back-pain groups; how-

ever, there were significant group differences in indicators of both sarcopenia and back muscle degeneration. Average ASMI, which was used as an indicator for sarcopenia, was significantly lower in the back-pain group. In addition, CSA index and FI rate differed significantly between groups, and we found that back muscle degeneration tended to progress further in the back-pain group (Table 1).

## 2. Relationship between sarcopenia and back muscle degeneration

Average age did not differ between the total sarcopenia and non-sarcopenia groups ( $57.6 \pm 13.3$  years versus  $55.5 \pm 13.5$  years,  $p=0.45$ ). Similarly, there were no significant differences in the indicators of back muscle degeneration CSA index, FI rate, and LESI between sarcopenia groups (Table 2), indicating that the presence of sarco-

penia alone does not predict progression of back muscle degeneration.

## 3. Pearson correlation coefficients used to develop a back muscle degeneration risk index

Pearson correlation coefficient for the associations between LESI and ASMI, LESI and CSA index, and LESI and FI rate were all significant within group B (LESI versus ASMI,  $r=0.493$ ; LESI versus CSA index,  $r=0.557$ ; LESI versus FI rate,  $r=-0.741$ ) (Table 3).

## 4. The back muscle degeneration risk index but not sarcopenia presence alone predicted more severe back pain

There were no significant differences in CSA index, FI rate, and LESI between the sarcopenia and non-

**Table 1.** Comparison of sarcopenia and back muscle degeneration characteristics between group A and B

Characteristic	Group A (n=100)	Group B (n=112)	p-value
Age (yr)	56.6±15.2	57.8±17.6	0.63
Sex			0.12
Male	58	50	
Female	42	62	
Body mass index (kg/m <sup>2</sup> )	24.23±5.14	25.63±4.70	0.07
Prevalence of sarcopenia	8 (8.0)	30 (26.8)	<0.01*
Appendicular skeletal muscle index (kg/m <sup>2</sup> )	7.35±1.01	6.75±1.18	<0.01*
Cross-sectional area index (cm <sup>2</sup> /m <sup>2</sup> )	10.13±1.95	6.40±1.25	<0.01*
Fatty infiltration rate (%)	8.10±1.74	18.33±3.40	<0.01*
Lumbar extensor strength index (Nm/kg)	1.64±0.21	0.76±0.12	<0.01*

Values are presented as mean±standard deviation, number, or number (%).

\* $p<0.05$  was defined as statistically significant.

**Table 2.** Comparison between sarcopenia and non-sarcopenia group in all subjects

Variable	Sarcopenia group (n=38)	Non-sarcopenia group (n=174)	p-value
Age (yr)	57.6±13.3	55.5±13.5	0.45
Sex			0.21
Male	18	90	
Female	20	84	
Appendicular skeletal muscle index (kg/m <sup>2</sup> )	6.11±0.72	7.47±1.03	<0.001*
Cross-sectional area index (cm <sup>2</sup> /m <sup>2</sup> )	8.99±2.11	8.65±1.81	0.63
Fatty infiltration rate (%)	12.21±2.92	13.32±2.73	0.90
Lumbar extensor strength index (Nm/kg)	1.12±0.64	1.35±0.63	0.14

Values are presented as mean±standard deviation or number.

\* $p<0.05$  was defined as statistically significant.

sarcopenia patients of group B. The degree of back pain as measured by VAS score also did not differ significantly between sarcopenia and non-sarcopenia groups ( $p=0.067$ ) (Fig. 4). However, LESI was significantly lower in the high-risk muscle degeneration subgroup of group B, defined as those patients with back muscle degeneration index value above the median, compared to the low-

risk group (below the median value) ( $p=0.015$ ). Similarly, VAS score was significantly greater in the high-risk group ( $p<0.05$ ) (Fig. 5). The specific cutoff values for the high-risk group were ASMI  $<5.87 \text{ kg/m}^2$ , CSA index  $<6.78 \text{ cm}^2/\text{m}^2$ , FI rate  $>24.89\%$ , and LESI  $<0.58 \text{ Nm/kg}$  (Table 4).

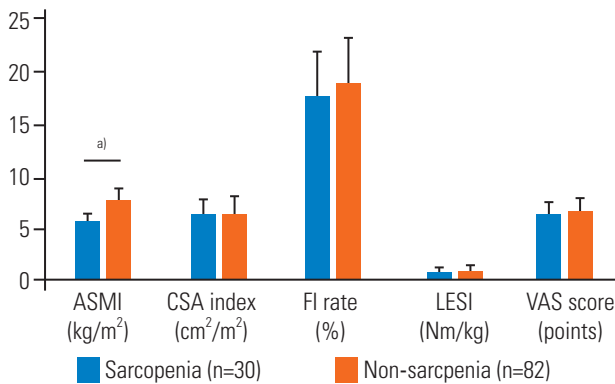
### Discussion

The central findings of this study are that back-pain severity is more strongly related to back muscle degeneration than to sarcopenia, and that back muscle degeneration is only weakly related to sarcopenia. Thus, sarcopenia and back muscle degeneration are mainly independent factors influencing back pain. Here ASMI was assessed as an index of sarcopenia, and CSA, FI rate, and LESI as indices of back muscle degeneration. As sarcopenia indicates the co-occurrence of skeletal muscle mass and strength loss [4], we used CSA index and FI rate to reflect back muscle morphology (quantity and quality) and LESI to indicate

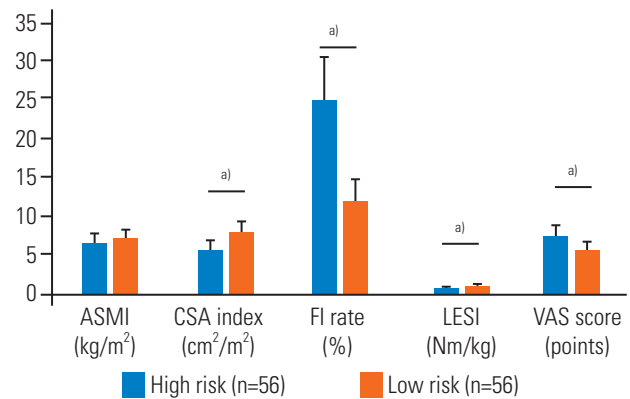
**Table 3.** Results of correlation analysis between LESI and ASMI, CSA index, FI rate in group B

Factor	Correlation with LESI (n=112)	
	Coefficient	p-value
ASMI ( $\text{kg/m}^2$ )	0.493	$<0.01^*$
CSA index ( $\text{cm}^2/\text{m}^2$ )	0.557	$<0.01^*$
FI rate (%)	-0.741	$<0.01^*$

LESI, lumbar extensor strength index; ASMI, appendicular skeletal muscle index; CSA, cross-sectional area; FI, fatty infiltration. \* $p<0.05$  was defined as statistically significant.



**Fig. 4.** Comparisons of ASMI, CSA index, FI rate, and VAS scores between sarcopenia and non-sarcopenia groups of back-pain patients (group B) stratified by ASMI score (group B). ASMI, appendicular skeletal muscle index; CSA, cross-sectional area; FI, fatty infiltration; VAS, Visual Analog Scale. <sup>a)</sup>Means difference with statistical significance.



**Fig. 5.** Comparisons of ASMI, CSA index, FI rate, LESI, and VAS scores between high-risk and low-risk muscle degeneration groups of back-pain patients stratified by the median value of the back muscle degeneration risk index. ASMI, appendicular skeletal muscle index; CSA, cross-sectional area; FI, fatty infiltration; LESI, lumbar extensor strength index; VAS, Visual Analog Scale. <sup>a)</sup>Means difference with statistical significance.

**Table 4.** Comparison and value ratio of high risk group to group A

Variable	High risk group (n=56)	Group A (n=100)	Value ratio of high risk group to group A (%)	p-value
Appendicular skeletal muscle index ( $\text{kg/m}^2$ )	5.87±1.00	7.35±1.01	79.9	$<0.01$
Cross-sectional area index ( $\text{cm}^2/\text{m}^2$ )	6.78±1.56	10.13±1.95	66.9	$<0.01$
Fatty infiltration rate (%)	24.89±5.52	8.10±1.74	307.3	$<0.01$
Lumbar extensor strength index (Nm/kg)	0.58±0.34	1.64±0.21	35.4	$<0.01$

Values are presented as mean±standard deviation, unless otherwise stated.

back muscle function (strength). The prevalence of sarcopenia as well as ASMI, CSA index, FI rate, and LESI scores differed significantly between control pain-free and back-pain groups, suggesting that both sarcopenia and back muscle degeneration contribute to back pain. Sarcopenia prevalence varies from 5%–13% in people >60 years, and is as high as 50% in those >80 years old [20]. In this study, sarcopenia prevalence was approximately 18%, which is unexpectedly high considering the participants' average age (<60 years). Moreover, 53% of all participants had back pain that interfered with daily activity, suggesting reduced muscle mass and strength, which may have elevated sarcopenia prevalence. The CSA index, FI rate, and LESI did not differ between sarcopenia and non-sarcopenia groups stratified by ASMI score, suggesting that sarcopenia is not directly related to back muscle degeneration. Thus, sarcopenia and back muscle degeneration should be considered separate factors influencing back pain.

Lumbar extensor muscles are important for controlling gait in patients with back pain [21], and lumbar extensor strengthening exercises can substantially improve clinical outcome in patients with chronic back pain plus deconditioning [22]. Additionally, lumbar extensor muscles are critical for the dynamic control of spinal segments [23]. The clinical significance of lumbar extensor strength has been widely reported. Moreover, the isokinetic lumbar extensor dynamometer is widely used and its reliability well established [11,24]. Here, we also confirmed high reliability in a retest of 30 subjects (intraclass correlation coefficient=0.862).

Among ASMI, CSA index, and FI rate, the latter was most strongly correlated with LESI, suggesting a close relation between back muscle function and FI rate. This may be because the back muscle is replaced by fat concomitant with aging and degeneration, while the CSA itself may not change [9]. Thus, FI rate and lumbar extensor strength are important factors reflecting back muscle degeneration.

There was no significant difference in CSA index or FI rate between the general sarcopenia and non-sarcopenia groups or the sarcopenia and non-sarcopenia subgroups of back-pain patients. Among back-pain patients, in fact, FI rate was even higher in the non-sarcopenia group, although the difference did not reach statistical significance. This result further supports the independent influences of sarcopenia and back muscle degeneration on back pain, and validates our initial purpose of analyzing the relationship between sarcopenia and back muscle degen-

eration. Moreover, no significant difference in VAS score was found between the sarcopenia and non-sarcopenia groups, suggesting that sarcopenia is only weakly associated with the severity of back pain (Fig. 4).

We analyzed the correlations between LESI and CSA index and between LESI and FI rate to establish a risk index that can quantify both morphological and functional aspects of back muscle degeneration. The correlation coefficients were multiplied by the CSA index and FI rate, respectively, and added to obtain the risk index, which was then used to classify patients into high-risk and low-risk back muscle degeneration groups. There was a significant difference in VAS score between these groups, but not between sarcopenia groups, indicating a close association between back muscle degeneration and back-pain severity. Average index values of 79.9% of ASMI, 66.9% of CSA index, 307.3% of FI rate, and 35.4% of LESI define the high-risk group and so may be used as clinical references to assess back muscle degeneration (Table 4). Collectively, these findings suggest that patients at high-risk of back muscle degeneration according to this index should be carefully managed in clinical practice.

This study has several limitations. First, although the data was collected prospectively, the study design was cross-sectional. Further longitudinal studies with follow-up assessments of sarcopenia and back muscle degeneration over time should be conducted. Recent studies have shown that the multifidus muscle affects back pain more strongly than the erector spinae muscle, whereas the erector spinae muscle shows wider and earlier fatty degeneration than the multifidus [25,26]. This indicates a relationship between stress loading and back muscle degeneration, and suggests that the multifidus and erector spinae muscles may contribute differently to back muscle degeneration. In our study, however, paraspinal muscle was considered the sum of the multifidus and erector spinae muscles. In addition, only ASMI was used to evaluate sarcopenia based on AWGS guidelines [15]. However, the complete AWGS algorithm using grip strength and gait speed was not employed for two reasons. First, measurements using BIA are equally objective and valid under the same conditions [27] and second, the grip strength may vary depending on patient cooperation, as patients with back pain demonstrate deteriorated physical performance not just from muscle weakness or wasting but from pain. We also did not investigate the causes of back pain in patients without sarcopenia or back muscle degeneration,

such as disk degeneration, hypertrophy of facet joints, instability between the segments [28], or myofasciitis, a systemic acquired inflammatory muscle disease with perifascicular cellular infiltration [29]. Myofasciitis patients often complain of diffuse myalgia and various types of pain, such as aching and cramps. The lower extremities are mainly involved, but there are also reported cases with back muscle involvement [30]. The etiology of back pain is so variable that it is difficult to know exactly whether a given condition such as myofasciitis alone contributes to back pain. It is critical therefore to validate this muscle degeneration index on patients with known back-pain etiology. However, the effect of sarcopenia and back muscle degeneration on back pain was compared at the same time, and the back muscle degeneration risk index was set to reflect both CSA and FI rate of the back muscle. This index may therefore facilitate future studies on back pain, sarcopenia, and back muscle degeneration.

### Conclusions

Back muscle degeneration is more strongly associated with back pain than with sarcopenia. Lumbar extensor strength in particular was closely related to back muscle degeneration and so may be an important indicator of back muscle function and the root cause of back pain. We also developed and validated a risk index reflecting both muscle morphology and function for assessing back muscle degeneration. This value may be a useful clinical reference for determining the degree of back muscle degeneration and a helpful treatment guide.

### Conflict of Interest

No potential conflict of interest relevant to this article was reported.

### Acknowledgments

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