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ORIGINAL ARTICLE

Analysis of skeletal muscle mass in women over 40 with degenerative lumbar scoliosis

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Abstract

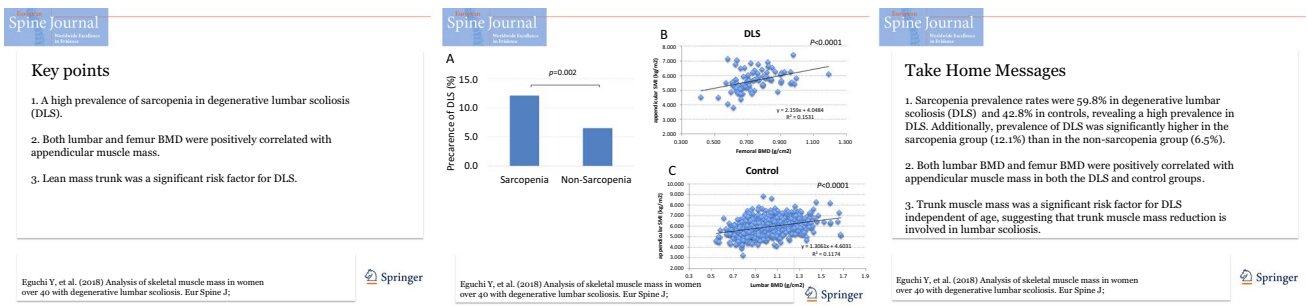
Purpose We investigated the involvement of sarcopenia in middle-aged and elderly women with degenerative lumbar scoliosis (DLS).

Methods A total of 971 women (mean age 70.4 years) were included in our study. These included 87 cases of DLS (mean 73.8 years) and 884 controls (69.8). Lumbar and femur BMD was measured for all participants using dual-energy X-ray absorptiometry. We used a bioelectrical impedance analyzer to analyze body composition, including appendicular skeletal muscle mass index (SMI; appendicular lean mass (kg)/(height (m))^2. We determined bone density and skeletal muscle mass in both groups and determined the prevalence of sarcopenia. We examined the correlation between bone density and appendicular muscle mass in both groups. We also examined factors related to scoliosis using logistic regression analysis.

Results The DLS group showed significantly higher lumbar BMD, lower femur BMD, lower lean mass arm, and lower lean mass leg, and lower lean mass trunk ($p < 0.05$). Sarcopenia prevalence (SMI < 5.75) was 59.8% in DLS subjects and 42.8% in controls, revealing a high prevalence in DLS ($p < 0.05$). In both groups, lumbar and femur BMD were positively correlated with appendicular muscle mass. By logistic regression analysis, trunk muscle mass was detected as a risk factor for DLS independent of age ($p < 0.05$).

Conclusions In middle-aged and elderly women, prevalence of sarcopenia was 59.8% in DLS cases and 42.8% in controls, which revealed a high prevalence in DLS. A decrease in trunk muscle was a significant risk factor for DLS that was independent of age.

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



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Extended author information available on the last page of the article

Keywords Degenerative lumbar scoliosis · Sarcopenia · Skeletal muscle mass · Bioelectrical impedance analyzer

Introduction

With an aging society, there is an increasing number of patients who have trouble in their daily lives due to scoliosis. Takemitsu et al. have reported that lumbar scoliosis causes low back pain and disrupts activities of daily living (ADLs). As a result of spinal deformities, back pain, low back pain, gait disturbances due to truncal balance failure, reflux esophagitis, and various cosmetic psychological problems, among others become problematic for ADLs [1–6]. Causes of degenerative lumbar scoliosis (DLS) including sex, age, osteoporotic vertebral fractures, kyphoscoliosis accompanying deformation, and factors accompanying spinal surgery have been reported, but the pathophysiological mechanism is not clear [1–6]. Spinal musculature is important as a mechanism for spinal support. Although spinal muscle degeneration has been implicated in spinal deformity, there are no reports on the relationship between trunk and appendicular skeletal muscle and spinal deformity.

Sarcopenia is a syndrome characterized by progressive, systemic decline in skeletal muscle mass and skeletal muscle strength. The risk of becoming bedridden following a fall is high, and physical and economic losses are high in an aging society [7–10]. The cause of sarcopenia is thought to be inactivity, but this mechanism has not been fully elucidated. The fact that back strength decreases due to sarcopenia is thought to be a causal agent for degeneration and deformation of the natural spinal curvature; nevertheless, there are few studies that have explored the involvement of sarcopenia in the development of DLS. Eguchi et al. have previously reported that trunk and appendicular skeletal muscle mass were both lower in DLS and that low back pain was associated with decreased appendicular skeletal muscle mass. Regarding the relationship between skeletal muscle mass and spinal alignment, appendicular skeletal muscle was related to posterior pelvic tilt, while trunk muscle affected stooped posture, posterior pelvic tilt, lumbar scoliosis. These results indicate that sarcopenia may be involved in causing spinal deformities; the loss of trunk muscle and appendicular muscle, which form structures instrumental in truncal stabilization, is thought to be one of the causes of progressive deformation of the spine and of low back pain [11]. Nevertheless, with this study a small number of subjects, including only 40 elderly women, were investigated, requiring confirmation of our findings in a larger population.

Accordingly, in the present research, we investigated sarcopenia in both degenerative lumbar scoliosis (DLS) and healthy subjects among 1179 middle-aged and elderly female patients age 40 years or older who visited our outpatient clinic.

Methods

Participants

Informed consent was obtained from all participants before the study began. The study protocol was approved by the ethical review committee (No. of IRB: H26′-6).

The subjects all visited the outpatient clinic in our hospital between April 2015 and December 2016.

A total of 1179 middle-aged and elderly women over 40 (mean age 72.0 years, range 40–96) underwent standing lumbar x-ray with measurement of body composition and bone density. After excluding 198 due to vertebral body compression fracture, 971 women (70.4, 40–94) were included. From a plain x-ray front and lateral view, degenerative lumbar scoliosis Criteria for DLS were lumbar scoliosis > 10°, and a sagittal vertical axis (SVA) of > 50 mm^2 [2]. Using this definition, 87 subjects were identified as having DLS (73.8, 40–93), and there were 884 controls without degenerative scoliosis (69.8, 40–94) (Table 1). Exclusion criteria included vertebral body compression fracture, any signs of idiopathic scoliosis, history of spinal surgery, secondary osteoporosis, and Parkinson disease or any other neuromuscular disorder.

DXA

Bone mineral density (BMD) of the left proximal femur and lumbar spine (L2–L4) was measured using dual-energy X-ray absorptiometry (DXA) (Lunar Prodigy, GE Healthcare, WI, USA).

Radiographic analysis

The frontal view of the lumbar spine and the lateral view were photographed in a standing position. Radiographic measurements were made of lumbar scoliosis (LS), sagittal vertical axis (SVA), lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI), and sacral slope (SS). The LS was measured as the angle between the lower end plate of L1 and the lower end plate of L5 on frontal radiographs. The

Table 1 Summary of subjects

	DLS	Control	Total
Sarcopenia	52	378	430
Non-sacropenia	35	506	541
Total	87	884	971

SVA was measured as the distance from the C7 plumb line to a perpendicular line drawn from the superior posterior end plate of the S1 vertebral body on lateral radiographs. The LL was measured from the lower end plate of T12 to the upper end plate of S1. The PT was measured as the angle between the vertical line and the line joining the hip axis to the center of the superior end plate of S1. The PI was measured as the angle subtended by a perpendicular line from the upper end plate of S1 and a line connecting the center of the femoral head to the center of the cephalad end plate of S1. The SS was measured as the angle between the superior end plate of S1 and a horizontal line.

Analysis of skeletal muscle mass

A multifrequency bioelectrical impedance analyzer (BIA), the InBody 720 Biospace device (Biospace Co, Korea), was used according to the manufacturer's guidelines. BIA estimates body composition using the difference in conductivity of the various tissues which are due to differences in their biological characteristics. Conductivity is proportional to water content (more specifically to electrolytes): adipose tissue contains relatively little water compared with other tissues like muscle; therefore, conductivity decreases as body fat increases with relatively high impedance. The volume of body water and fat mass can be calculated by measuring the impedance. In practice, electrodes are placed at 8 precise tactile-points of the body to achieve a multisegmental frequency analysis. A total of 30 impedance measurements were obtained using 6 different frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz, 1000 kHz) for the following 5 segments of the body: right and left arms, trunk, right and left legs.

Appendicular skeletal muscle mass was calculated as the sum of skeletal muscle mass in the arms and legs, assuming that mass of lean soft tissue is effectively equivalent to skeletal muscle mass. Appendicular skeletal mass index (SMI) was determined as the sum of arm and leg lean mass (kg)/(height (m))^2. The diagnosis of sarcopenia among women was defined as appendicular SMI value < 5.75 kg/m^2, determined using sarcopenia normative data [12].

The prevalence of sarcopenia was examined in both groups in conjunction with age; weight; body mass index (BMI) (kg/m^2); fat mass (kg); bone mineral density of the lumbar vertebrae and femur (g/cm^2); and skeletal mass indices including lean mass arm (kg), lean mass leg (kg), and lean mass trunk (kg). In both groups, we examined the correlation between bone densities of the lumbar vertebrae and femur with appendicular SMI. In addition, we used logistic regression analysis to examine the associations of factors related to scoliosis.

Statistical analysis

Statistical analyses were performed with Stat View software (version 5.0). For each parameter, differences between both groups were evaluated using the unpaired t test. Differences in the prevalence of sarcopenia between both groups were evaluated using a Chi square test.

Pearson correlation coefficients were calculated to determine the correlation between appendicular SMI and lumbar or femoral BMD in both groups. To determine loss of skeletal muscle mass or sarcopenia as an independent variable in predicting occurrence of scoliosis, we performed logistic regression, using DLS as a dependent variable with skeletal muscle mass. Other covariates included in these multivariate analyses were age, weight, and femoral BMD, which were considered significant between both groups.

All data are expressed as the mean ± standard deviation (SD). A threshold of $p < 0.05$ was considered significant.

Results

Radiographical alignment in the DLS group revealed LS: 29.1° ± 13.5°, SVA: 113.0 ± 57.8 mm, LL: 19.2° ± 10.9°, PI: 53.5° ± 9.1°, PT: 33.1° ± 6.9°, SS: 19.9° ± 6.1°. In the control group, LS: 1.2° ± 1.4°, SVA: 27.1 ± 26.4 mm, LL: 46.6° ± 9.8°, PI: 49.6° ± 8.1°, PT: 15.7° ± 5.2°, SS: 32.1° ± 5.8°. SVA ($p < 0.05$), and LS ($p < 0.05$), PT ($p < 0.05$) were significantly higher, and LL ($p < 0.05$) and SS ($p < 0.05$) was significantly lower for the DLS group compared with controls.

Regarding physical examination, weight (kg) was 48.0 ± 8.6 for DLS and 51.7 ± 9.1 for controls ($p = 0.0006$); BMI (kg/m^2) was 21.4 ± 3.5 for DLS and 22.2 ± 3.8 for controls ($p = 0.085$); fat mass (kg) was 14.7 ± 6.3 for DLS and 16.5 ± 6.6 for controls ($p = 0.015$). Weight and fat mass was significantly lower in DLS than in controls (Table 2).

Lumbar BMD (g/cm^2) was 1.042 ± 0.173 for DLS and 0.993 ± 0.182 for controls ($p = 0.0232$). Femur BMD (g/cm^2) was 0.746 ± 0.120 for DLS and 0.768 ± 0.121 for controls ($p = 0.0251$). Lumbar BMD was significantly higher in DLS; femur BMD was significantly lower in DLS (Table 2).

Regarding skeletal muscle mass indices: lean arm mass (kg) was 2.9 ± 0.5 for DLS and 3.2 ± 0.6 for controls ($p = 0.0002$); lean mass leg (kg) was 9.7 ± 1.8 for DLS and 10.5 ± 1.7 for controls ($p = 0.0004$); lean mass trunk (kg) was 14.1 ± 2.3 for DLS and 15.7 ± 7.1 for controls ($p = 0.0449$). Lean mass arm, lean mass leg and lean mass trunk were significantly lower for DLS (Table 2).

If all 971 subjects are divided into sarcopenia (SMI < 5.75) and non-sarcopenia (SMI > 5.75) groups, there were 430 subjects with sarcopenia (72.1, 40–93) and 541 subjects without sarcopenia (69.2, 40–94); the overall

Table 2 Physical examination, BMD, and skeletal muscle mass in patients with degenerative lumbar scoliosis and healthy volunteers

	DLS	Normal	*p*
Physical examinations			
No. of subjects	87	884	
Age (y)	73.8 ± 9.5	69.8 ± 10.1	0.0008
Weight (kg)	48.0 ± 8.6	51.7 ± 9.1	0.0006
BMI (kg/cm^2)	21.4 ± 3.5	22.2 ± 3.8	0.085
Fat mass (kg)	14.7 ± 6.3	16.5 ± 6.6	0.015
BMD			
Lumbar (g/cm^2)	1.042 ± 0.173	0.993 ± 0.182	0.0232
Femoral (g/cm^2)	0.736 ± 0.120	0.768 ± 0.121	0.0251
Skeletal muscle			
Lean mass arm (kg)	2.9 ± 0.5	3.2 ± 0.6	0.0002
Lean mass leg (kg)	9.7 ± 1.8	10.5 ± 1.7	0.0004
Lean mass trunk (kg)	14.1 ± 2.3	15.7 ± 7.1	0.0449
Sarcopenia prevalence (%)	59.8	42.8	0.002

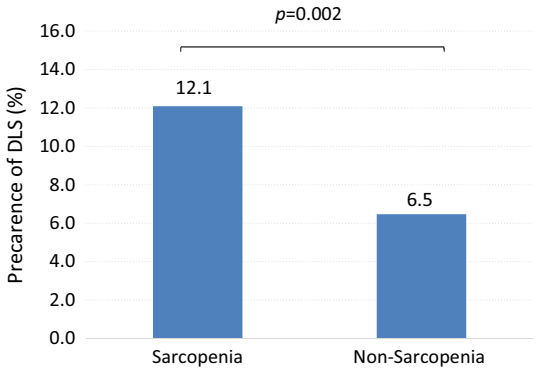

Fig. 1 Prevalence of degenerative lumbar scoliosis in 430 subjects with sarcopenia and 541 subjects without sarcopenia. DLS was significantly higher in the sarcopenia group: 12.1% (52/430), versus the group without sarcopenia: 6.5% (35/541) ($p = 0.002$)

prevalence of sarcopenia in our sample was 44.3% (430/971) (Table 1). Comparing across groups, the prevalence of sarcopenia was significantly higher in the DLS group (52/87, 59.8%) compared to controls (378/884, 42.8%) ($p = 0.002$) (Table 2).

Additionally, prevalence of DLS was significantly higher in the sarcopenia group (52/430, 12.1%) than in the non-sarcopenia group (35/541, 6.5%) ($p = 0.002$) (Fig. 1).

Regarding the correlation of appendicular SMI with bone density, in both groups, lumbar and femur BMD showed a positive correlation with appendicular muscle mass (in the DLS group, lumbar BMD ($r = 0.31$, $p = 0.003$), femur BMD ($r = 0.42$, $p < 0.0001$); in the control group, lumbar BMD ($r = 0.34$, $p < 0.0001$), femur BMD ($r = 0.4$, $p < 0.0001$)). In DLS, femur BMD showed a stronger correlation than lumbar BMD (Fig. 2).

Based on logistic regression analysis, trunk muscle mass was identified as a risk factor for DLS independent of age ($p = 0.0016$) (Table 3).

Discussion

The result of this study revealed a high prevalence of sarcopenia in DLS in middle-aged and elderly women. A decrease in trunk muscle was a significant risk factor for DLS that was independent of age. To the best of our knowledge, there has been no previous large-scale study on the skeletal muscle mass in patients with degenerative lumbar scoliosis.

Reports have been published on research using MRI to assess paraspinal muscles in spinal deformities. Yagi et al. [13] reported that multifidus and iliopsoas muscle cross sections were smaller in spinal deformation, and that this correlated with sagittal alignment. A report found fatty degeneration of multifidus muscle on the concave side of degenerative scoliosis [14], while hypertrophy of the multifidus muscle and iliopsoas muscle have been reported on the convex side of degenerative scoliosis [15]. Furthermore, when Enomoto et al. [16] took surface electromyograms of paravertebral muscle activity, they found that, compared to lumbar spinal canal stenosis (LSS), patients with degenerative lumbar scoliosis (DLS) had higher paravertebral muscle activity. Yagi et al. [13] measured appendicular skeletal muscle mass in patients with DLS and LSCS by dual-energy X-ray absorptiometry (DXA) and reported that there was no significant difference between the two groups. Nevertheless, postoperative measurements were only taken for appendicular weight, and height-corrected SMI values were not considered. Muscle assessment in adult spinal deformity had previously been limited to localized evaluation of appendicular and trunk muscle mass using MRI. How these might relate to sarcopenia has never been investigated until this time.

On the other hand, the research using computed tomography revealed that individuals with symptomatic degenerative lumbar spinal stenosis (LSS) manifested greater paraspinal muscles density and cross-sectional area for the erector spinae compared to the control group, suggesting that the paraspinal muscles work to compensate for instability in symptomatic LSS individuals, thus resulting in thicker and denser muscles [17].

Sarcopenia is defined as the age-associated loss of skeletal muscle mass and function with a risk of adverse outcomes such as physical disability and poor quality of life [7, 8]. Sarcopenia is very common in older individuals, with a reported prevalence in 60- to 70-year-olds of 5–13% [9]. Baumgartner et al. [18] reported that prevalence of sarcopenia in community-dwelling women was 33–36% in those

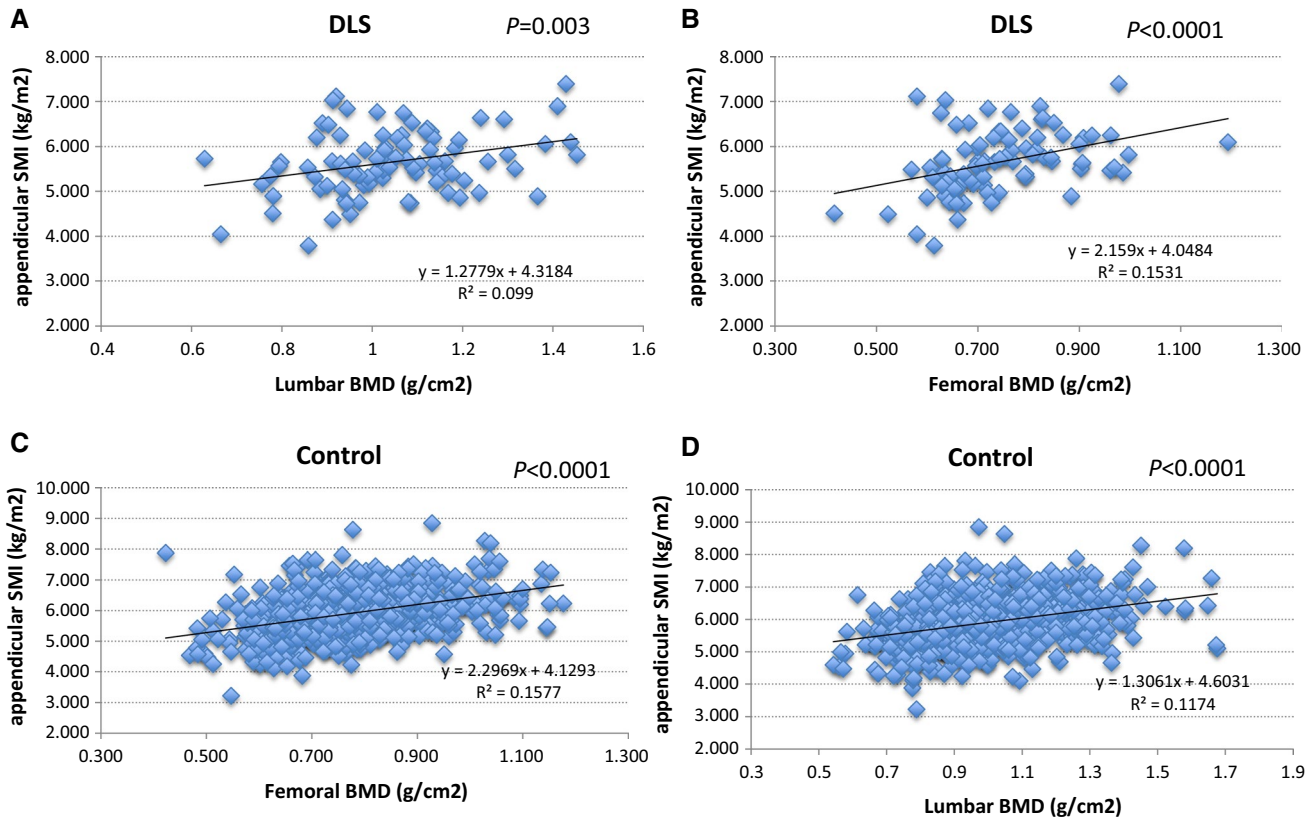

Fig. 2 Correlation between bone density and appendicular SMI. In DLS: **a** lumbar BMD ($r=0.31$, $p=0.003$); **b** femur BMD ($r=0.42$, $p<0.0001$). In controls: **c** lumbar BMD ($r=0.34$, $p<0.0001$); (D) femur BMD ($r=0.40$, $p<0.0001$). Both lumbar and femur BMD were positively correlated with appendicular muscle mass in both groups

Table 3 Logistic regression analysis: factors associated with the occurrence of scoliosis

	B	χ^2 value	*p*
Age (year)	0.013	0.715	0.3977
Weight (kg)	−0.017	0.465	0.4952
Femoral BMD (g/cm^2)	−0.198	0.029	0.864
Lean mass arm (kg)	2.412	5.212	0.0224
Lean mass leg (kg)	0.129	0.825	0.3638
Lean mass trunk (kg)	−0.998	9.952	0.0016

at least 70 years old and 23–24% in those < 70 years old, according to the New Mexico Elder Health Survey.

In reports on sarcopenia and spinal disease, Miyakoshi et al. [19] report that in Japanese people with osteoporosis, the prevalence of sarcopenia is 20%, compared to 10% in healthy individuals. Nevertheless, few studies have elucidated this relationship between sarcopenia and spinal deformity. We previously reported that sarcopenia complications were noted in 16% of patients with lumbar canal stenosis and a much higher 46.6% of patients with DLS and that both appendicular and trunk skeletal muscle mass was lower in DLS, suggesting sarcopenia may be involved in causing spinal deformities [11].

In the present study, the overall prevalence of sarcopenia was 44.3%, which was somewhat higher than has been previously reported. In this research, the average age is 72 years, and there were many elderly patients included. About half (485/971, 49.9%) of our subjects were taking medications for osteoporosis at the time of our study. It is possible that many osteoporotic patients with comparatively low muscle mass were included. Nevertheless, the prevalence of sarcopenia was significantly higher in DLS subjects (59.8%), compared to controls (42.8%).

This study does not consider that it may be the presence of the degenerative scoliosis which has led to a decrease in the muscle mass. Several studies showed that sagittal malalignment tended to originate in the pelvis in females on the other hand the cervical alignment in males [20, 21]. It was possible that deterioration of global sagittal alignment in females whose skeletal muscle mass were smaller than males originated from the pelvis. However, why spinal deformity originates from the pelvis in females and cervical spine in males remains unclear. The longitudinal study is needed to solve this issue.

We recently reported that the relationship between psoas major morphology and the course of lumbar nerve tracts using diffusion tensor imaging (DTI) in patients with DLS [22]. Compared with controls, the patients with DLS showed a significant anterior shift of lumbar nerves at each intervertebral level. A rising psoas sign was seen in all patients in the DLS group, with an anterior shift of lumbar nerves together with the psoas muscle. Furthermore, on the convex side, the psoas major was relaxed and the nerve was shifted posteriorly. Maybe that disfunction of muscle and neural steering is responsible for development of DLS as well.

Advanced glycation end products (AGEs) such as pentosidine are active biomolecules formed by the non-enzymatic covalent binding of sugars with proteins and other molecules. AGEs have been associated with increased muscle stiffness and reduced whole muscle function. Recent study has reported that serum pentosidine levels were significantly higher in the patients with DLS than in controls. High serum pentosidine levels are associated with severity of coronal and sagittal malalignment in older women, suggesting that high levels of AGEs are a potential biomarker for a progression of lumbar scoliosis and kyphotic deformity [23].

Regarding bone mineral density, femur BMD was significantly lower in DLS, but lumbar BMD was significantly higher. Liu et al. [24] have demonstrated that lumbar spinal osteophyte formation and bone density are positively correlated. In scoliosis, it is possible that lumbar BMD increases due to osteophyte formation. On the other hand, in both the DLS and control groups, both lumbar BMD and femur BMD were positively correlated with appendicular muscle mass. Sjöblom et al. [25] have shown that clinical sarcopenia is strongly associated with osteoporosis. The pathogenesis of osteoporosis involves aging, the involvement of diabetes mellitus [26] and arteriosclerosis, reduction in mechanical loading, and vitamin D deficiency [27, 28], among other risk factors. These may also be deeply involved in the pathogenesis of sarcopenia.

We also previously reported that decreases in appendicular skeletal muscle mass were associated with posterior pelvic tilt and low back pain, while decreases in trunk muscle mass were associated with stooping posture, posterior pelvic tilt, and lumbar scoliosis [11]. We also found in the present study that trunk muscle mass decrease was a significant risk factor for lumbar scoliosis. Based on our results, we believe that treatment of degenerative scoliosis in the elderly may entail effective conservative treatment that promotes skeletal muscle maintenance or enhancement, such as exercise therapy (i.e., resistance training [29]) or nutrient supplementation (i.e., essential amino acids, vitamin D [30]. Further longitudinal research is required in the future.

Our study has several limitations: (1) The study is cross-sectional and not longitudinal; (2) We did not conduct comprehensive measurements of whole spine alignment. Further studies are needed to clarify the association between global alignment or the spinopelvic alignment and sarcopenia; (3) DXA appears to be the most reliable tool to evaluate body composition and is considered the gold standard in clinical practice. BIA may represent a simpler, portable, and less expensive alternative. BIA has a tendency to overestimate muscle mass compared with DXA, but agreement between DXA and BIA is high for lean mass arm and for axial lean mass [31]; and (4) We evaluated only slim Japanese women with relatively low BMI; therefore, the amount of truncal fat is much less likely to affect calculations than it might in a typical western population.

Conclusion

We examined the involvement of sarcopenia in degenerative lumbar scoliosis patients and healthy subjects among 971 middle-aged and elderly female patients over 40 years old. Sarcopenia prevalence rates were 59.8% in DLS and 42.8% in controls, revealing a high prevalence in DLS. Trunk muscle mass was a significant risk factor for DLS independent of age. It is suggested from the present study that trunk muscle mass reduction is involved in lumbar scoliosis.

Authors' contributions YE conducted data collection and data entry, performed the statistical analysis, and wrote the manuscript. TT developed data collection and participated in the design of the study and performed the statistical analysis. All authors contributed to and approved the final manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests. We did not receive grants or external funding in support of our research or preparation of this manuscript. We did not receive payments or other benefits or a commitment or agreement to provide such benefits from any commercial entities.

Human and animal rights statement We declare that all protocols involving humans have been performed in accordance with the ethical standards of the institutional committee laid down in the 1964 Declaration of Helsinki and its later amendments. We declare that all participants provided written informed consent before their inclusion in this study.

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