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ORIGINAL ARTICLE

The association of back muscle strength and sarcopenia-related parameters in the patients with spinal disorders

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Abstract

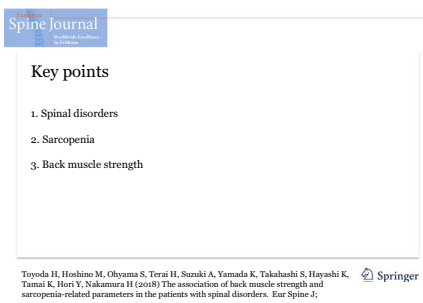
Purpose To evaluate the correlations between back muscle strength, trunk muscle mass, and sarcopenia-related parameters in patients with spinal disorders.

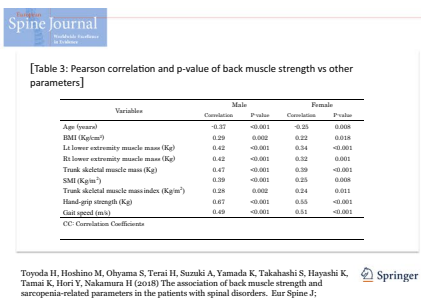
Methods This cross-sectional observational study included 230 consecutive patients with spinal disorders who visited our outpatient clinic (age range 65–92 years). We measured back muscle strength, handgrip strength, gait speed, and appendicular and trunk skeletal muscle mass using bioimpedance analysis. We classified the subjects into the sarcopenia, dynapenia, or normal stages in accordance with the guidelines set by the European Working Group on Sarcopenia in Older People, and used the cutoff values reported in the guidelines set by the Asian Working Group for Sarcopenia.

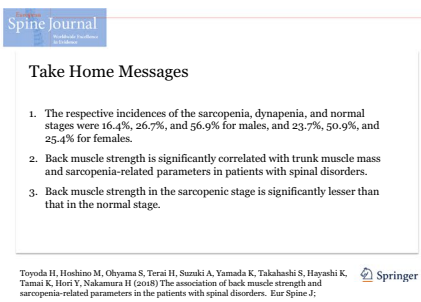
Results Back muscle strength was significantly correlated with trunk muscle mass (males: $r=0.47$, $P<0.001$; females: $r=0.39$, $P<0.001$), handgrip strength (males: $r=0.67$, $P<0.001$; females: $r=0.59$, $P<0.001$), and gait speed (males: $r=0.49$, $P<0.001$; females: $r=0.51$, $P<0.001$). The respective incidences of the sarcopenia, dynapenia, and normal stages were 16.4%, 26.7%, and 56.9% for males, and 23.7%, 50.9%, and 25.4% for females. Dynapenia was significantly more prevalent in females than in males. Back muscle strength in the normal group was significantly greater than that in the sarcopenic and dynapenic groups.

Conclusion Back muscle strength is significantly correlated with trunk muscle mass and sarcopenia-related parameters in patients with spinal disorders. Back muscle strength in the sarcopenic stage is significantly lesser than that in the normal stage. Although sarcopenia is a multifaceted geriatric syndrome, spinal disorders might be one of the risk factors for disease-related sarcopenia.

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







Keywords Sarcopenia · Dynapenia · Back muscle strength · Skeletal muscle · Spinal disorders

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Extended author information available on the last page of the article

Introduction

In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP) proposed measurements of muscle mass, muscle strength, and physical performance for the diagnosis of sarcopenia [1]. Moreover, the EWGSOP advocated conceptual staging of sarcopenia as "presarcopenia," "sarcopenia," and "severe sarcopenia." The presarcopenia stage is characterized by low muscle mass without impact on muscle strength or physical performance. The sarcopenia stage is characterized by low muscle mass, plus low muscle strength or low physical performance. Severe sarcopenia is characterized by the presence of all three criteria (low muscle mass, low muscle strength, and low physical performance). The relationship between strength and mass is reportedly not linear; therefore, defining sarcopenia only in terms of muscle mass is thought to be of limited clinical value. The term dynapenia may be better suited to describe age-associated loss of muscle strength and function [2].

The Asian Working Group for Sarcopenia (AWGS) developed a method for sarcopenia diagnosis based on evidence derived from Asian populations, as the cutoff values for these measurements may differ in Asian versus Caucasian populations [3]. The EWGSOP and AWGS recommended an algorithm for sarcopenia case finding in older individuals based on measurements of gait speed, grip strength, and muscle mass. The AWGS suggested cutoff values of < 26 kg for males and < 18 kg for females for low handgrip strength, and 0.8 m/s for slow gait speed. The AWGS recommends using height-adjusted skeletal muscle mass assessed via dual-energy X-ray absorptiometry (DXA), with suggested cutoff values of 7.0 kg/m^2 for males and 5.4 kg/m^2 for females. Using bioimpedance analysis (BIA), the suggested cutoff values for appendicular skeletal muscle mass/height^2 are 7.0 kg/m^2 for males and 5.7 kg/m^2 for females. These cutoff values and algorithms can be used to categorize each subject into the appropriate sarcopenia stage.

Measurement of appendicular skeletal muscle mass is essential for sarcopenia diagnosis; the age-related decline in muscle strength involves both the upper and lower extremities, as well as the trunk. Back muscle strength also declines with age and influences the lumbar kyphosis angle and quality of life in older adults [4–8]. Trunk skeletal mass and back muscle strength are important parameters in the treatment of aging spinal disorders; however, the associations between back muscle strength, trunk muscle mass, and sarcopenia-related parameters in patients with spinal disorders have not been well studied. Furthermore, although several studies have investigated the prevalence of sarcopenia in healthy subjects [8–15], no detailed data regarding sarcopenia as defined by the AWGS have been reported for patients with spinal disorders. The present study aimed to investigate the incidences of severe sarcopenia, sarcopenia, presarcopenia, and dynapenia in patients with spinal disorders, and to investigate the relationships between sarcopenia-related parameters and trunk muscle mass and back muscle strength.

Methods

Study population

A total of 230 consecutive outpatients being treated at our spine clinic were eligible to participate in the present cross-sectional observational study, which was carried out from August 2015 to July 2016. The study was approved by the institutional review board of our hospital (approval no. 3170), and all participants provided written informed consent prior to enrollment. The inclusion criteria were age > 65 years, diagnosis of a spinal disorder, and the ability to ambulate. Patients with a metal device or internal electrical device inserted in the body were excluded; as such, devices might affect BIA measurement of muscle mass.

Measurements

Baseline data included age, sex, height, weight, body mass index (BMI), spinal disease, medical history, appendicular and trunk skeletal muscle mass, handgrip strength, back muscle strength, and gait speed. All measurements were taken by blinded clinical research assistants.

Muscle mass evaluation

Whole-body and segmental body compositions were assessed by BIA using the Tanita MC-980A Body Composition Analyzer (Tanita, Tokyo, Japan). The muscle mass obtained by the BIA method reportedly shows a high correlation with the muscle mass obtained by the DXA method [16–18]. The BIA method requires participants to step onto a platform similar to a bathroom scale, and remain in standing position for approximately 30 s. Muscle mass index was calculated by dividing the weight by the height in meters squared (kg/m^2).

Handgrip strength

Handgrip strength was measured using a T.K.K.5401 dynamometer (Takei, Niigata City, Japan). Each participant squeezed the dynamometer twice with each hand, with a brief rest between attempts. The best performance was used for the analysis.

Gait speed

Five-meter gait tests were recorded only during the middle 5 m (i.e., between the 2- and 7-m marks). The first and last 2 m were excluded to eliminate periods of acceleration and deceleration.

Back muscle strength

Back muscle strength was determined from the maximal isometric strength of the trunk muscles in a standing posture with 30° of lumbar flexion using a digital back muscle strength meter (T.K.K.5402, Takei Co., Japan) [4]. The average force from two trials was recorded.

Definition of sarcopenia

Participants were classified as having sarcopenia based on muscle mass, muscle strength, and physical performance. In accordance with the AWGS guidelines, the cutoff values for low skeletal muscle index were <7.0 kg/m^2 for males and <5.7 kg/m^2 for females, those for low handgrip strength were <26 kg for males and <18 kg for females, and the cutoff value for low gait speed was <0.8 m/s [3]. In accordance with the EWGSOP consensus [1], presarcopenia was defined as low skeletal muscle index without low handgrip strength and low walking speed; sarcopenia was defined as low skeletal muscle index, plus low handgrip strength or low walking speed; severe sarcopenia was defined as low skeletal muscle index, plus low handgrip strength and low walking speed. Furthermore, we defined dynapenia as low handgrip strength or low walking speed without low skeletal muscle index [2].

Statistical analysis

All data are shown as the mean ± standard deviation. Statistical analyses were performed with SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). For each parameter, differences between groups were evaluated by the *t* test. Differences were considered significant at $P<0.05$. Correlations between variables were analyzed using Pearson's correlation coefficient and simple regression analysis. The strength of the correlation was classified as very weak (<0.20), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), or very strong (≥ 0.80) [19].

Results

Characteristics of the participants

Table 1 shows the baseline characteristics of the 230 patients, including age, BMI, diagnosis, and sarcopenia-related parameters. The average age was 75.8 ± 63.5 years, and more than 80% of patients underwent surgery. BMI, muscle mass, handgrip strength, and back muscle strength were significantly lower in females than in males; however, gait speed did not significantly differ between sexes.

Prevalence of sarcopenia

Table 1 and Fig. 1 show the prevalence of sarcopenia in patients with spinal disorders in accordance with the AWGS guidelines. The respective incidences of the sarcopenia, dynapenia, and normal stages were 16.4%, 26.7%, and 56.9% in males, and 23.7%, 50.9%, and 25.4% in females. The incidence of dynapenia was significantly greater in females than in males.

Back muscle strength

Back muscle strength in each sarcopenia stage is presented in Fig. 2. The respective back muscle strength values in the sarcopenia, dynapenia, and normal stages in males were 45.8 ± 13.6, 54.2 ± 19.3, and 78.5 ± 23.8 kg; the respective values in females were 26.4 ± 7.7, 28.7 ± 8.1, and 41.5 ± 11.2 kg. Back muscle strength in the sarcopenia and dynapenia groups was significantly lesser than that in the normal group for both sexes.

Relationships between back muscle strength and sarcopenia-related parameters

The correlations between back muscle strength and age, trunk muscle mass, handgrip strength, and gait speed are shown in Table 2 and Fig. 3. There was a weak negative correlation between back muscle strength and age. Handgrip strength was significantly strongly positively correlated with back muscle strength in males. Lower extremity muscle mass, trunk muscle mass, and gait speed were significantly moderately positively correlated with back muscle strength in males. Lower extremity muscle mass and trunk muscle mass were significantly weakly correlated with back muscle strength in females. Handgrip strength and gait speed were significantly moderately correlated with back muscle strength in females.

Discussion

The present cross-sectional observational study investigated the incidences of sarcopenia and dynapenia in accordance with the AWGS guidelines, and the associations between back muscle strength and sarcopenia-related parameters in patients with spinal disorders. Few previous studies have evaluated sarcopenia as muscle mass plus muscle strength/

Table 1 Baseline characteristics of the included patients

Variables	All	Males	Females	*P* value
Numbers (%)	230 (100)	116 (50.4)	114 (49.6)	
Age (years)	75.8 (6.5)	75.9 (6.6)	75.7 (6.4)	0.77
Body mass index (kg/cm^2)	23.1 (3.4)	24.0 (3.1)	22.0 (3.4)	< 0.001
Left lower extremity muscle mass (kg)	6.7 (1.7)	8.0 (1.4)	5.4 (0.7)	< 0.001
Right lower extremity muscle mass (kg)	6.8 (1.8)	8.2 (1.4)	5.4 (0.8)	< 0.001
Trunk skeletal muscle mass (kg)	21.4 (3.9)	24.5 (2.7)	18.3 (1.8)	< 0.001
SMI (kg/m^2)	7.0 (1.2)	7.9 (1.0)	6.1 (0.7)	< 0.001
Trunk SMI (kg/m^2)	8.7 (0.9)	9.3 (0.8)	8.1 (0.6)	< 0.001
Handgrip strength (kg)	21.8 (8.6)	27.7 (7.4)	15.7 (4.6)	< 0.001
Back muscle strength (kg)	49.5 (26.6)	67.1 (25.5)	31.5 (11.0)	< 0.001
Gait speed (m/s)	0.94 (0.27)	0.98 (0.28)	0.90 (0.26)	0.02
Diagnosis				0.46
Cervical spinal disorders (%)	48 (20.9)	26 (11.3)	22 (9.6)	
Cervical spondylotic myelopathy, *n*	42	22	20	
Intradural extramedullary tumor, *n*	4	2	2	
Ossification of the posterior longitudinal ligament, *n*	2	2	0	
Lumbar spinal disorders (%)	161 (70.0)	82 (35.7)	79 (34.3)	
Lumbar spinal stenosis, *n*	129	69	60	
Degenerative lumbar spondylolisthesis, *n*	13	5	8	
Lumbar disk herniation, *n*	6	2	4	
Previous osteoporotic vertebral fracture, *n*	6	3	3	
Degenerative lumbar scoliosis, *n*	4	1	3	
Intradural extramedullary tumor, *n*	2	1	1	
Ossification of the yellow ligament, *n*	1	1	0	
Others (%)	21 (9.1)	8 (3.5)	13 (5.7)	
Adult spinal deformity, *n*	8	2	6	
Previous osteoporotic vertebral fracture, *n*	8	3	5	
Diffuse idiopathic skeletal hyperostosis, *n*	2	1	1	
Intradural extramedullary tumor, *n*	2	1	1	
Ossification of the yellow ligament, *n*	1	1	0	
Neurologic problem, yes (%)	212 (92.2)	110 (94.8)	102 (89.5)	0.15
Surgery, yes (%)	186 (80.9)	99 (85.3)	87 (76.3)	0.10
Stage of sarcopenia				
Sarcopenia (%)	46 (20.0)	19 (16.4)	27 (23.7)	0.19
Severe sarcopenia (%)	20 (8.7)	7 (6.0)	13 (11.4)	0.17
Presarcopenia (%)	10 (4.3)	3 (2.6)	7 (6.1)	0.21
Dynapenia (%)	89 (38.7)	31 (26.7)	58 (50.9)	< 0.001
Normal (%)	95 (41.3)	66 (56.9)	29 (25.4)	< 0.001
Low handgrip strength and low gait speed (%)	35 (15.2)	11 (9.5)	24 (21.1)	0.02
Only low handgrip strength (%)	29 (12.6)	9 (7.8)	20 (17.5)	0.03
Only low gait speed (%)	14 (6.1)	8 (6.9)	7 (6.1)	1.00

Values are given as the mean (standard deviation) unless otherwise specified

SMI skeletal muscle mass index

physical performance. We measured muscle mass, handgrip strength, and gait speed in patients with spinal disorders, and reported respective incidences of the sarcopenia, dynapenia, and normal stages of 16.4%, 26.7%, and 56.9% in males, and 23.7%, 50.9%, and 25.4% in females. Back muscle strength was significantly associated with sarcopenia-related parameters, and back muscle strength in the normal group was significantly greater than that in the sarcopenia and dynapenia groups. Our findings suggest that those in the sarcopenia stage have low back muscle mass and strength.

The incidence of sarcopenia depends substantially on the ethnicity of the reference population and the screening

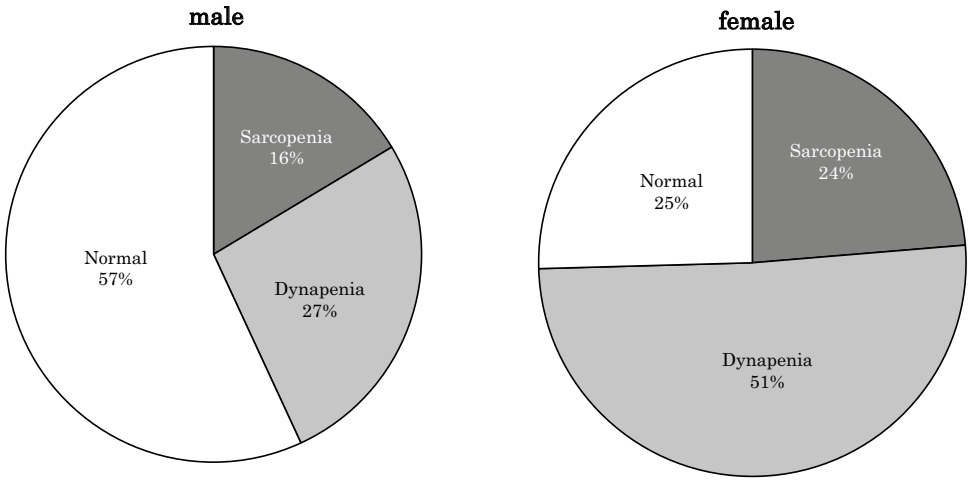

Fig. 1 Prevalence of sarcopenia in the patients with spinal disorders

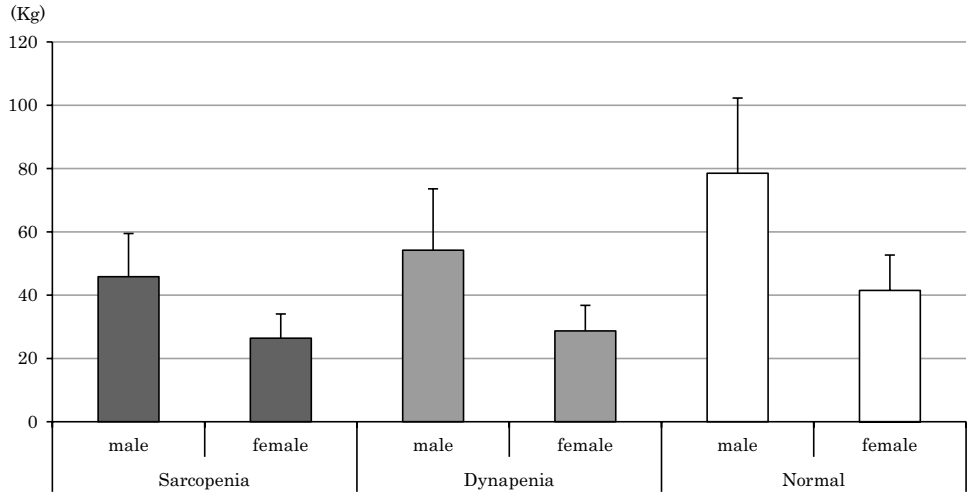

Fig. 2 Back muscle strength in each sarcopenia stage

Table 2 Pearson correlation and *P* value of back muscle strength versus other parameters

Variables	Male		Female	
	Correlation	*P* value	Correlation	*P* value
Age (years)	−0.37	< 0.001	−0.25	0.008
BMI (kg/cm^2)	0.29	0.002	0.22	0.018
Lt lower extremity muscle mass (kg)	0.42	< 0.001	0.34	< 0.001
Rt lower extremity muscle mass (kg)	0.42	< 0.001	0.32	0.001
Trunk skeletal muscle mass (kg)	0.47	< 0.001	0.39	< 0.001
SMI (kg/m^2)	0.39	< 0.001	0.25	0.008
Trunk skeletal muscle mass index (kg/m^2)	0.28	0.002	0.24	0.011
Handgrip strength (kg)	0.67	< 0.001	0.55	< 0.001
Gait speed (m/s)	0.49	< 0.001	0.51	< 0.001

CC correlation coefficients

methods used to assess muscle mass, muscle strength, and physical performance. The incidence of sarcopenia using the EWGSOP guidelines is reportedly 1–29% in community-dwelling populations, 14–33% in long-term care populations, and 10% in the only acute hospital care population examined [9]. The incidence of sarcopenia is also reportedly 6–12% in studies with large sample sizes of more than 1000 participants [10–12] and 7.5–8.2% in a Japanese population-based cross-sectional survey [11, 13]. These recent epidemiological data suggest that the overall prevalence of

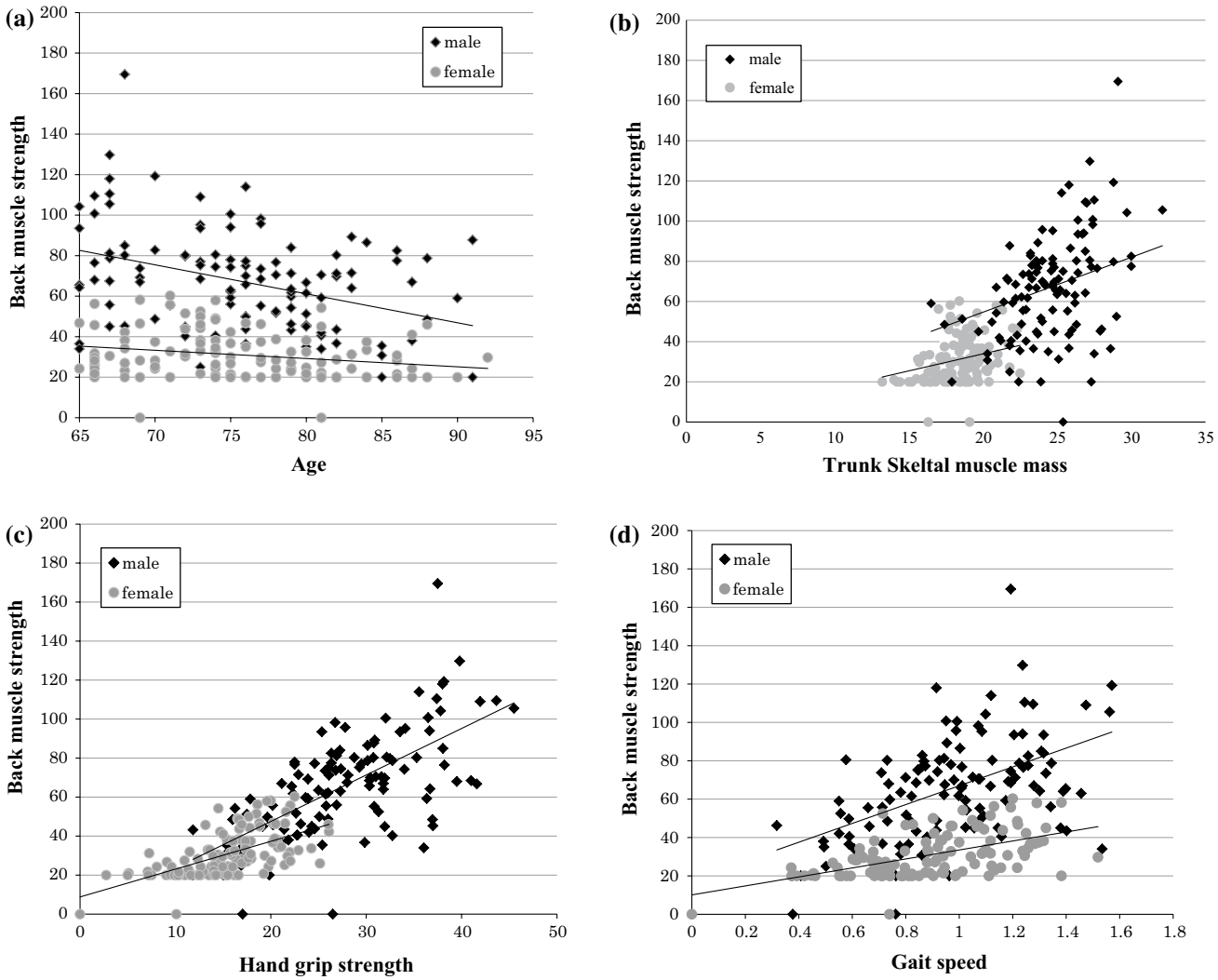

Fig. 3 Correlation of back muscle strength **a** age, **b** trunk muscle mass, **c** handgrip strength, and **d** gait speed

sarcopenia based on the EWGSOP criteria is 6–12%. In the current study, the prevalence of sarcopenia in patients with spinal disease was 20% in all subjects, 16.4% in males, and 23.7% in females. The relatively greater incidences of sarcopenia in our study indicate that spinal disease might be a risk factor for disease-related sarcopenia, as assessed using the EWGSOP criteria.

The EWGSOP divided sarcopenia into categories and proposed the terms primary and secondary sarcopenia [1]. However, there are few reports on the association between sarcopenia and spinal disorders [20]. Eguchi et al. [20] reported that sarcopenia was present in 16% of patients with lumbar spinal stenosis (LSS) compared with 46.6% of patients with degenerative lumbar scoliosis. They also reported that sarcopenia may cause spinal deformities and losses of the trunk and appendicular muscles that form the truncal stabilization structure, which may cause progressive deformation of the spine and low back pain [20]. Park et al. [21] reported that sarcopenia was more prevalent in patients with LSS compared with matched controls, and concluded that the impacts of sarcopenia on disability, quality of life, and physical performance were more pronounced in patients with LSS. In many older adults, the etiology of sarcopenia is multifactorial, so it may not be possible to characterize each individual as having exclusively primary or secondary sarcopenia. However, it is possible that physical inactivity due to spinal disorders causes an accelerated decline in appendicular and trunk skeletal muscle mass, muscle strength, and functional capacity compared with controls.

In the current study, we characterized the dynapenia stage as low handgrip strength or low walking speed without low skeletal muscle index. Dynapenia is the age-associated loss of muscle strength that is not caused by neurologic or muscular diseases; however, it is difficult to distinguish

the age-related changes in spinal neurophysiologic properties from neurologic disease caused by age-related spinal diseases such as LSS and cervical myelopathy. The strong predictors of decreased activities of daily living, sarcopenia, or dynapenia are still controversial [8, 22, 23]. In the current study, dynapenia was present in 26.7% of males and 50.9% of females with spinal disorders. Hence, dynapenia was more prevalent than sarcopenia in patients with spinal disorders. Spinal disorders are often associated with deteriorated nerve function of the upper and lower extremities, which directly influences physical performance and/or muscle mass. We thought that the quantity of muscle would contribute to the diminishment of muscle strength, physical function, and health indicators associated with walking speed and muscle strength, but not with skeletal muscle mass. Therefore, we consider it important to evaluate the prevalence of dynapenia, rather than sarcopenia. Furthermore, handgrip strength and gait speed might also be appropriate indicators for assessing the physical function of older adult patients with spinal disorders, and the consensus definitions are immensely helpful in providing clear treatment goals.

One reason that appendicular skeletal muscle mass is considered more important than trunk muscle mass is that type II muscle fiber atrophy is an important contributing factor in the development of muscle weakness during aging [24]. Trunk muscles such as the multifidus, longissimus, and iliocostalis reportedly comprise more than 60% type I muscle fibers [25]. This proportion is greater than many limb muscles, such as the flexor digitorum profundus (36%), brachioradialis (46%), and vastus lateralis (48%), and therefore, the skeletal muscles of the extremities may become the key indicators of sarcopenia [25]. However, the age-related decline in muscle strength involves not only the upper and lower extremities, but also the lumbar extensors. Trunk muscle weakness is a risk factor for low back pain, lumbar kyphosis, and locomotive syndrome in older adults [4–7]. Locomotive syndrome was proposed by the Japanese Orthopedic Association in 2007 as a concept to describe people at high risk of developing a musculoskeletal ambulation disability attributed to locomotor organs [26]. The decline in muscle mass, which is most prominent in the lower limbs, is accompanied by a 30–40% decrease in the number of muscle fibers between the ages of 20–80 years [27]. Back muscle strength also reportedly reduces by 50% between the ages of 30–60 years [28], and the cross-sectional areas of the paraspinal muscles decrease as the fat infiltration rate increases with age [29]. The present study demonstrated that back muscle strength was significantly correlated with trunk muscle mass and sarcopenia-related parameters in patients with spinal disorders. Back muscle strength in the sarcopenic and dynapenic groups was significantly lesser than that in the normal group. These results suggest that sarcopenia is a risk factor for chronic low back pain, lumbar kyphosis, and locomotive syndrome in older adults.

The present study had several limitations. First, the severity of spinal disorders was not considered. However, the included patients were all consecutive ambulatory outpatients in stable condition who were candidates for spinal surgery. Second, as the present study was a cross-sectional study and did not include data from healthy subjects, we only compared our data with previous reports. The present results do not establish cause–effect relationships between sarcopenia/dynapenia and spinal disorders. However, theoretically, certain types of morbidity caused by spinal disorders could produce sarcopenia that would result in functional impairment and disability. Third, we used a digital back muscle strength meter to measure the trunk muscle strength. Although this strength meter measures the strength of the back muscles plus the legs and chest, this method is simple and widely used. Fourth, the sample size was not sufficient for generalizability.

Conclusion

We investigated the prevalence of sarcopenia and dynapenia in accordance with the AWGS guidelines and the EWGSOP consensus, and investigated the correlations between back muscle strength, trunk muscle mass, and sarcopenia-related parameters in patients with spinal disorders. There was a high prevalence of sarcopenia and dynapenia in patients with spinal disorders, and back muscle strength was significantly correlated with trunk muscle mass and sarcopenia-related parameters. Although multiple, interrelated factors contribute to the development of sarcopenia, spinal disorders might be a risk factor for disease-related sarcopenia.

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Compliance with ethical standards

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

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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