Diagnosis and Management of Sarcopenia after Hip Fracture Surgery: Current Concept Review

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To date, family medicine and internal medicine fields have been responsible for defining, researching, and development of treatments for sarcopenia, focusing mainly on diabetes and metabolic diseases. Therefore, application of current guidelines for diagnosis of sarcopenia which differ according to continent to patients with hip fractures in the orthopedic field is difficult. The purpose of this review was to understand the recent consensus on the definition and diagnosis of sarcopenia and to highlight the importance of research and future research opportunities on the management of sarcopenia in patients with hip fractures by orthopedic surgeons. The global prevalence of sarcopenia in patients with hip fractures is statistically significant. Despite establishment of various therapeutic and diagnostic criteria for osteoporosis in the clinical field, there are no clear, useful diagnostic criteria for sarcopenia in the clinical field. In particular, few studies on the evaluation and treatment of sarcopenia in patients with hip fractures have been reported. In addition, the quality of life of postoperative patients with hip fractures could be significantly improved by development of precise assessment for muscle regeneration and rehabilitation in the operating room.

Key Words: Diagnosis, Management, Sarcopenia, Hip fracture

INTRODUCTION

An increase in the prevalence of sarcopenia along with the global aging trend has led to a subsequent increase in interest and research on sarcopenia[1-3]. In the USA, sarcopenia received an ICD-10-CM (M62.84) code in 2016, based on ICD-10, a global classification of diseases published by the World Health Organization (WHO)[4]. In Korea, sarcopenia received an ICD-10-CM (M62.5) code with the eighth revision of the Korean Classification of Diseases (KCD). Thus, the importance of diagnosis and treatment of sarcopenia has been emphasized in earnest.

To date, those in the fields of family medicine and internal medicine who focus mainly on diabetes and metabolic diseases have been responsible for the definition, research,

and development of treatments for sarcopenia[5,6]. Therefore, application of current guidelines for diagnosis of sarcopenia which differ according to continent to patients with hip fractures in the orthopedic field is difficult. For example, evaluation of physical performance by measurement of walking speed or sit-to-stand, part of the diagnostic guidelines, is practically impossible for patients with hip fractures.

The purpose of this review is to understand the recent consensus on the definition and diagnosis of sarcopenia, highlighting the importance of research on the management of sarcopenia in patients with hip fractures by orthopedic surgeons.

LATEST UPDATES FOR SARCOPENIA GUIDELINES

1. Definition of Sarcopenia

In 2020, in the position paper update of the Asian Working Group for Sarcopenia (AWGS), Chen et al.[6] defined sarcopenia as age-related loss of skeletal muscle mass and skeletal strength and/or decreased physical performance; for each country the definition for elderly was those aged more than 60 or 65 years.

Current definitions and diagnostic criteria for sarcopenia are the result of significant research and a long period of debate among researchers. However, for patients with hip fractures, muscle viability based on operating room findings, contractions, and fat degeneration shown by numerous computed tomography (CT) and magnetic resonance imaging (MRI) images[7] taken by orthopedic surgeons does not often match with existing criteria for diagnosis of sarcopenia (Fig. 1).

In addition, in patients with hip fractures, accurate evaluation of muscle mass using dual energy X-ray absorptiometry (DEXA) measurement-based sarcopenia diagnosis is difficult due to surgical implant metal artifacts[8]. Therefore, establishment of a new definition of sarcopenia specific to patients with hip fractures is necessary for quality management of postoperative sarcopenia.

2. Epidemiology of Sarcopenia in Patients with Hip Fractures

A review of epidemiology studies in Asian countries that used AWGS 2014 criteria reported a prevalence of sarcopenia ranging from 5.5% to 25.7%, with a male predominance (5.1%-21.0% in men vs 4.1%-16.3% in women)[6]. According to the AWGS 2014 criteria, the prevalence of sarcopenia in patients with hip fractures in Japan was 81.1% for males and 44.7% for females, while a domestic study conducted in 2016 reported a prevalence of 68.2% for males and 44.3% for females[6,9-16] (Table 1).

3. Risk Factors for Sarcopenia

In studies on major risk factors for sarcopenia conducted in Asia since 2014, demographic factors (such as old age, men, and living alone) and lifestyle habits (such as binge drinking, short sleep duration, and inadequate water intake) were leading risk factors. Other risk factors includ-
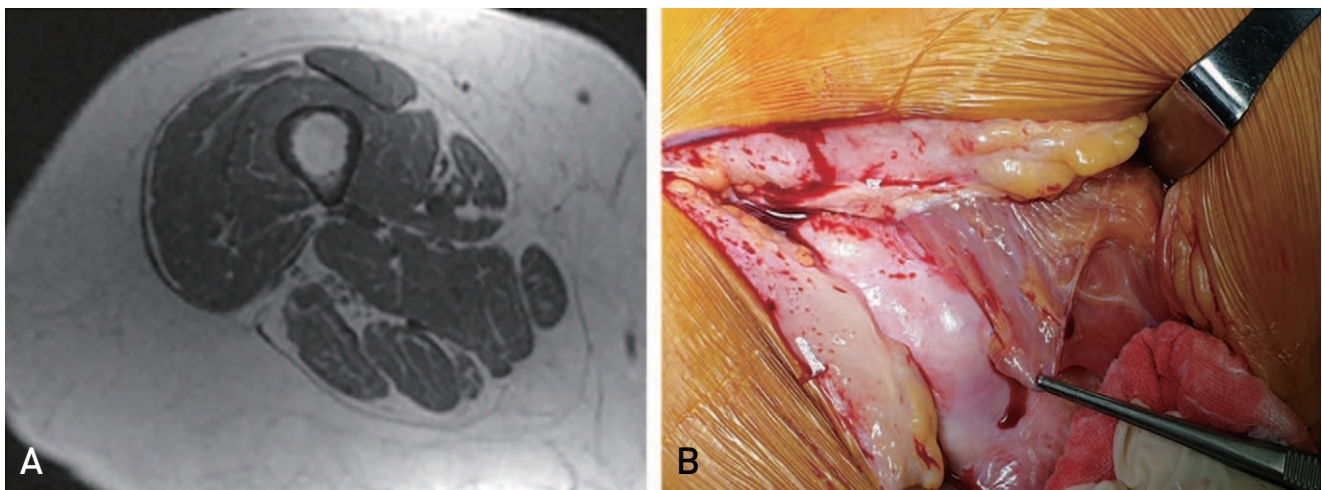

Fig. 1. (A) Thigh magnetic resonance image showing fatty degeneration change. (B) Operative room photo showing loss of muscle viability.

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Table 1. Summaries of Studies of Sarcopenia in Patients with Hip Fracture

Study	Study design	Regions	Population	Mean age (yr)	Definition	Cut-off of muscle mass (appendicular muscle kg/height^2) by DXA	Prevalence (%)
Hida et al.[14] (2013)	Case-control	Japan	357:2,511	82.7 (F), 80.3 (M)	Japanese criteria	6.87 (M), 5.46 (F)	81.1 (M), 44.7 (F)
Di Monaco et al.[15] (2012)	Case series	Italy	591	79.7	New Mexico Elder Health Survey	<2 SD in a young reference group	95 (M), 65 (F)
González-Montalvo et al.[16] (2015)	Case series	Spain	479	78.3 (F), 75.3 (M)	EWGOSP	<2 SD in a young reference group	12.4 (M), 18.3 (F)
Yoo et al.[13] (2016)	Case-control	Korea	359:1,614	78.3 (F), 75.3 (M)	AWGS EWGOSP	7.0 (M), 5.4 (F) <2 SD in a young reference group	68.2 (M), 44.3 (F) 80.5 (M), 47.1 (F)

Adapted from the article of Yoo et al. (J Korean Med Sci. 2016;31:1479-84)[13] in accordance with the Creative Commons Attribution Non-Commercial (CC BY-NC 4.0) license.
F: female, M: male, EWGOSP: European Working Group on Sarcopenia in Older people, AWGS: Asian Working Group for Sarcopenia, DXA: dual X-ray absorptiometry, SD: standard deviation.

Table 2. Risk Factors of Sarcopenia in Studies from East and Southeast Asia since 2014

Category	Risk factors
Demographic characteristics	Age, sex
Household status	Living alone or living with children, and/or grandchildren; Person's satisfaction with their perceived level of family function (family APGAR score)
Lifestyle habits	Binge drinkers with weekly or daily alcohol consumption (women); short sleep duration or having long sleep duration (women); water intake from food (g/d and cup/d) and dietary water adequacy ratio (mL)
Physical activity	Locomotive syndrome (one study for women)
Dietary pattern, dental condition and nutritional status	Lower frequency of nut consumption per week; impaired dentition status; higher dietary variety score (one study for women); lower body mass index (<18.5 kg/m^2); risk of malnutrition (MNA score)
Comorbidities	Osteoporosis; cardiovascular risk factors (including type 2 diabetes mellitus, hypertension, dyslipidemia)

Data from the article of Chen et al. (J Am Med Dir Assoc. 2014;15:95-101)[17].
APGAR: adaptability, partnership, growth, affection, and resolve, MNA: Mini Nutritional Assessment.

ed lack of physical activity, inadequate dietary nutritional intake, dental problems, osteoporosis, type 2 diabetes mellitus, hypertension, and dyslipidemia[17-19] (Table 2).

DIAGNOSTIC CRITERIA FOR SARCOPENIA

Criteria for diagnosis of sarcopenia vary among the guidelines for international associations. In general, diagnosis of sarcopenia is based on evaluation of the following three factors: muscle mass, strength, and physical performance[6]. The AWGS published revised guidelines in 2019 (Table 3). First, depending on the purpose, diagnosis of sarcopenia is largely divided into primary health care or community ser-

vice settings and acute to chronic health care or clinical research settings. Second, diagnosis of sarcopenia is based on measurement of calf thickness or a questionnaire, SARC-F, followed by evaluation of muscle mass, strength, and physical performance.

In a community setting without evaluation of muscle mass, possible sarcopenia is diagnosed by evaluation of muscle strength and physical function. However, it is recommended that patients go to a hospital for confirmation of sarcopenia (Fig. 2).

For patients with hip fractures, diagnosis of sarcopenia is based on diagnostic criteria for acute to chronic health care settings. However, evaluation of physical ability in patients

Table 3. Diagnostic Criteria for Sarcopenia according to the Different Consensus Group

	Muscle mass	Muscle strength	Physical performance
EWGSOP	ALM/height^2 (DXA) ($\leq$7.26 kg/m^2 [M], $\leq$5.5 kg/m^2 [F]) SM/height^2 (BIA) ($\leq$8.87 kg/m^2 [M], $\leq$6.42 kg/m^2 [F])	Grip strength (<30 kg [M], <20 kg [F])	SPPB$\leq$8 Gait speed<0.8 m/s
EWGSOP2	ASM/height^2 ($\leq$7.0 kg/m^2 [M], $\leq$6.0 kg/m^2 [F]) ASM (<20 kg [M], <15 kg [F])	Grip strength (<27 kg [M], <16 kg [F]) Chair stand >15 s for five rises	SPPB$\leq$8 Gait speed<0.8 m/s TUG $\geq$20 s
IWGS	ALM/height^2 (DXA) ($\leq$7.23 kg/m^2 [M], $\leq$5.67 kg/m^2 [F])		Gait speed<1.0 m/s
AWGS	ALM/height^2 (DXA) ($\leq$7.0 kg/m^2 [M], $\leq$5.4 kg/m^2 [F]) SM/height^2 (BIA) ($\leq$7.0 kg/m^2 [M], $\leq$5.7 kg/m^2 [F])	Grip strength (<26 kg [M], <18 kg [F])	Gait speed<0.8 m/s
AWGS 2019	ALM/height^2 (DXA) ($\leq$7.0 kg/m^2 [M], $\leq$5.4 kg/m^2 [F]) SM/height^2 (BIA) ($\leq$7.0 kg/m^2 [M], $\leq$5.7 kg/m^2 [F])	Grip strength (<28 kg [M], <18 kg [F])	Gait speed<1.0 m/s 5-time chair stand test$\geq$12 s SPPB$\leq$9
FNIH Sarcopenia project	ALM/BMI (DXA) ($\leq$0.789 [M], $\leq$0.512 [F])	Grip strength (<26 kg [M], <16 kg [F])	Gait speed<0.8 m/s

Data from the article of Chen et al. (J Am Med Dir Assoc. 2014;15:95-101)[17].

EWGSOP: European Working Group on Sarcopenia in Older people, ALM: appendicular lean mass, DXA: dual X-ray absorptiometry, M: male, F: female, SPPB: short physical performance battery, SM: skeletal muscle mass, BIA: body impedance analysis, ASM: appendicular skeletal muscle mass, TUG: Timed Up and Go test, IWGS: International Working Group for Sarcopenia, AWGS: Asian Working Group for Sarcopenia, FNIH: Foundation for the National Institutes of Health, BMI: body mass index (kg/m^2).
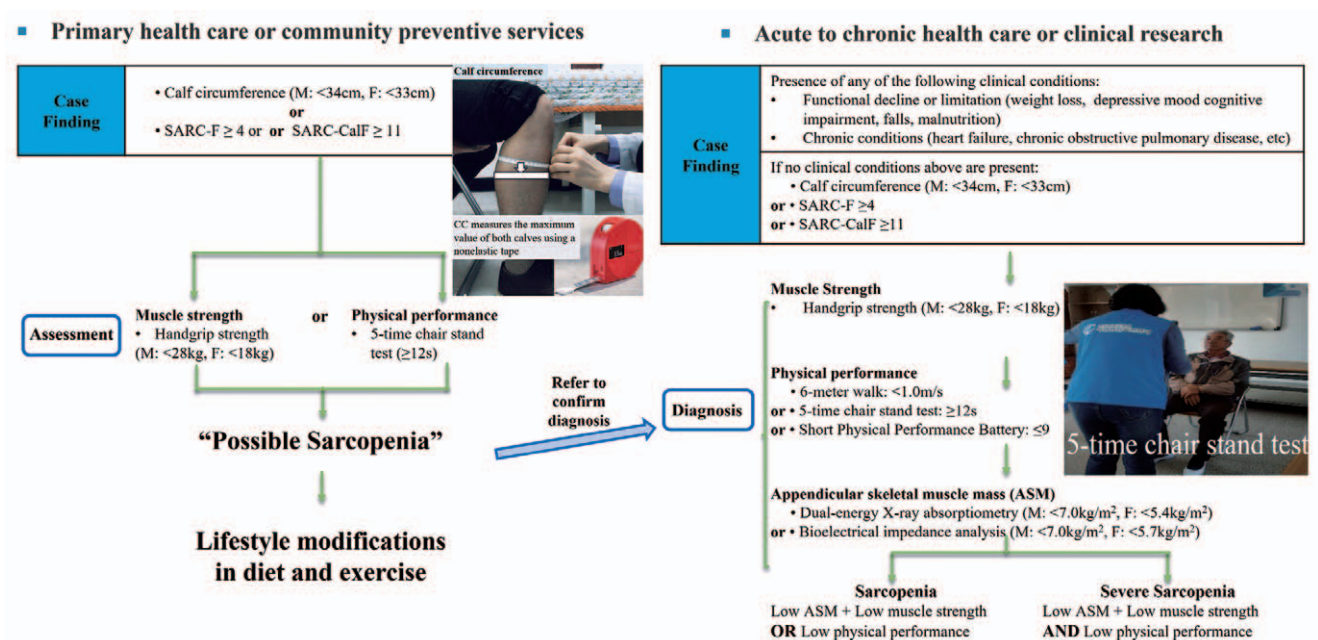

Fig. 2. Modified Asian Working Group for sarcopenia in 2019 criteria.
Revised from the article of Chen et al. (J Am Med Dir Assoc. 2020;21:300-7.e2)[6].

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with hip fractures is not possible. Only grip strength can be measured. In addition, while measurement of muscle mass is important for patients with hip fractures, whole-body DEXA imaging before surgery is difficult due to pain and anatomical abnormalities at the fracture site. Therefore, in the future, study of the cut-off point of the muscle mass using CT and MRI will be necessary. Development of a method for evaluating muscle mass that reflects the clinical significance and prognosis after surgery is also important. In addition, development of a tool for evaluating the quality of muscles based on the amount of fat and water in muscles is needed[7,20-24]. Automated segmentation studies of whole-body muscles using deep learning are currently in progress. Automated classification of these muscles will enable specific imaging tests for sarcopenia using CT and MRI[25-27] (Fig. 3).

Previous studies have reported on the usefulness of the SARC-F questionnaire for screening sarcopenia in community dwellings. Validation studies for the Korean translated version have been reported[28]. In addition, a study has reported the usefulness of the SARC-F questionnaire for patients with hip fractures in Korea with a high diagnostic sensitivity and a low diagnostic specificity[29]. Thus, more

Fig. 3. Deep neural network for automatic volumetric segmentation of whole-body computed tomography images.

research is needed for development of a screening tool with both high sensitivity and specificity.

1. Appendicular Skeletal Muscle Mass (ASM)

A measurement value called skeletal muscle index (SMI), obtained by dividing the sum of the muscle mass of the extremities by the square of the height, is currently used in diagnosis of sarcopenia according to the AWGS. According to the DEXA test, if the standard SMI is less than 7.0 kg/m^2 for men and less than 5.4 kg/m^2 for women, it can be concluded that the muscle mass is lower than the standard. Body impedance analysis (BIA) is also used as a method for measurement of muscle mass. If the muscle mass is less than 7.0 kg/m^2 for men and less than 5.7 kg/m^2 for women, it can be concluded that the muscle mass is lower than the standard[6]. However, BIA measurement using commercially available wearable devices or home equipment is not recommended. Instead, a multi-frequency BIA measurement is recommended. While ultrasound is recommended as a tool for evaluation of muscle mass, it is currently used for research purposes only. In Korea, measurement of muscle using the DEXA method has been recognized as an approach for diagnosis of sarcopenia since 2019, with a growing popularity. Because there are significant differences in measured muscle values between those of bone density, validation of instruments and standardization of measuring methods through country-based research should be conducted and re-discussed in the future. Studies on errors of muscle mass values due to measurement time and soft tissue edema at the time of measurement should also be conducted.

2. Handgrip Strength Measurement

For consistent measurement and accurate diagnosis of sarcopenia, this study adopted the method suggested by Ha et al.[30], where the subject used a Smedley-type dynamometer while in a standing position, achieving maximum grip strength three times with both hands. Since it is difficult for patients with hip fractures to remain standing, a method of measuring maximum grip strength in a sitting position with elbow at angle of 90 degrees is presented (Fig. 4).

However, it remains controversial whether measurement of grip strength alone is an effective evaluation method for the management of sarcopenia in patients with hip fractures. In addition, many patients have postoperative delirium or neurological disease, making measurement of handgrip strength difficult using current standardized protocols. Therefore, devel-
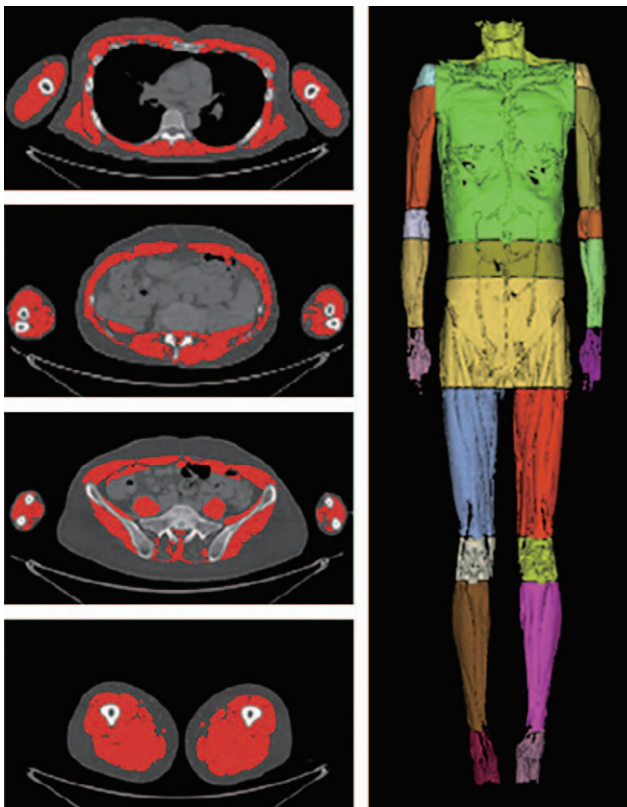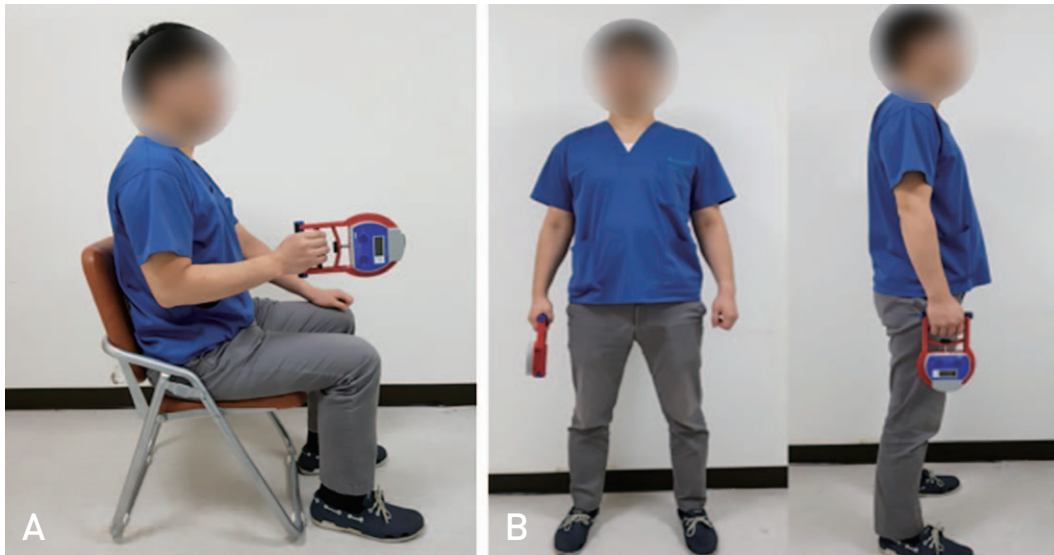
Fig. 4. Hand grip strength measurement in sitting position (**A**) and standing position (**B**).
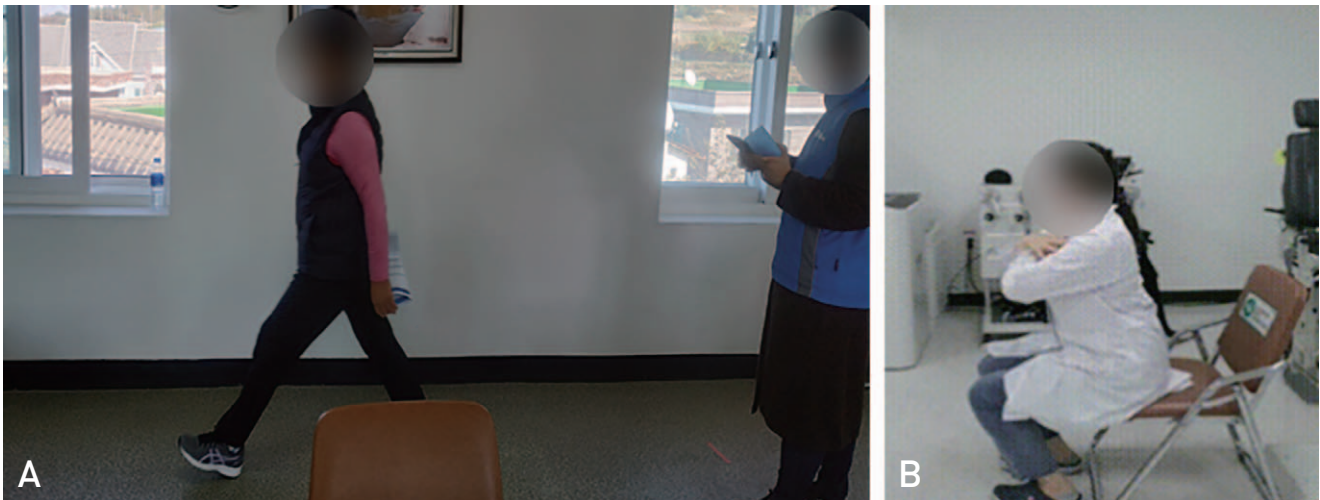

Fig. 5. Physical performance measurement using 6-meter walking time (**A**) and 5-time chair stand test (**B**).

opment of tools for assessment of muscle strength for diagnosis of sarcopenia in postoperative patients with hip fractures is needed. Although surface electromyography (sEMG) has been used for assessment of muscle strength in patients with hip fractures, a standardized protocol for assessment of muscle strength in patients with hip fractures has yet to be established[31]. A standardized method for measurement of muscle strength for treatment of sarcopenia in patients with hip fractures should be developed in the future.

3. Physical Performance Measurement

Methods such as Short physical performance ($\leq$9), 6-meter walking time (<1.0 m/s), and 5-time chair stand test ($\geq$12 seconds) are used in evaluation of physical performance in the diagnosis of sarcopenia[6] (Fig. 5). However, the Timed Up and Go test (TUG) widely used in previous studies was excluded from the revised AWGS guidelines. TUG was not recommended as a method for evaluating physical performance because other underlying diseases could not be excluded.

Application of these tools for evaluation of physical performance is also difficult in patients with hip fractures. For this purpose, non-face-to-face gait analysis studies using various types of artificial intelligence are being conducted. However, clear diagnostic criteria have not yet been established.

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4. Other Sarcopenia Assessment Tools

Evaluation of muscle mass using the D3Cr dilution method is also considered for diagnosis of sarcopenia. Briefly, assessment of systemic creatinine pool size and total body muscle mass is performed using a single oral dose of deuterated creatine (D3-creatine). The tablet enters the endogenous creatine pool of skeletal muscle and becomes absorbed and diluted[32,33]. Measurement of labeled creatinine (D3-creatinine) and unlabeled creatinine in fasting single void urine samples is performed 3 to 6 days after dose intake. These measurements are then incorporated into an algorithm that determines the total body creatine pool size and skeletal muscle mass in kilograms. Research on D3Cr is being actively conducted in the United States; however, it has not yet been implemented in Korea.

In addition, the Korean version of SARC_QOL has been recently translated into 30 languages and published on the website (http://www.sarqol.org). A validation study on the translation has already been reported[34].

5. Suggestions for the Development of a Sarcopenia Evaluation Method for Patients with Hip Fractures

Gait status and lower extremity strength cannot be properly evaluated in patients with hip fractures due to their pain and loss of walking ability at the time of injury. For evaluation of their muscle functions, our only choice is to rely on questionnaire-based methods for evaluation of gait including Koval score. In the measurement method according to the currently used sarcopenia diagnostic criteria, only evaluation of muscle mass using DEXA and BIA and grip strength using a hand dynamometer are possible and the SARC-F questionnaire test for screening can be performed. Since grip strength cannot fully reflect the strength of the lower extremities, development of a method for evaluating the strength of the lower extremities for patients with hip fractures is necessary. In addition, in the evaluation of muscle mass using DEXA, accurate evaluation is often impossible due to metal artifacts or difficulty in taking a posture. Therefore, an accurate system for evaluation of muscle mass based on CT scan is required. Although validation studies on patients with hip fractures were published, very low specificity was reported for the SARC-F questionnaire. Therefore, development of a specialized questionnaire item that can predict the decrease of muscle function in patients with hip fractures is necessary. In addition, development of an intraoperative biomarker for sarcopenia will be necessary so that future rehabilitation plans can be implemented based on the muscle findings in the operating room.

6. Rehabilitation for Sarcopenia in Patients with Hip Fractures

Oh et al.[35] applied an antigravity treadmill combined with conventional rehabilitation for 10 days after surgery in hip fracture patients with sarcopenia. Although functional scores such as Koval score and Berg Balance Scale in patients at postoperative 3-6 months showed improvement, they plateaued in the subsequent period. The authors concluded that additional rehabilitation with an antigravity treadmill was beneficial for patients with hip fractures. However, no improvement in handgrip strength was reported[35]. Lim et al.[36] operated an elaborate rehabilitation program for approximately 10 days in patients who had undergone a hip fracture surgery. Based on clinical results, the authors reported that use of this rehabilitation program resulted in improvement of ambulatory functions such as Koval score and Functional Ambulatory and Category scale of patients at up to six months after surgery regardless of the presence of sarcopenia[36]. However, no significant improvement in handgrip strength was observed in that study. Although improvement of functional score was observed in both studies, several factors should be considered for the fact that there was no change in handgrip strength, an index related to sarcopenia. First, exercise for 10 days after surgery might be too short for improvement of sarcopenia. Lim et al.[36] reported that only 61.5% to 70% of patients recovered with walking ability before fracture and treatments for hip fracture did not prevent muscle loss, even considering the complications of fractures. Muscle mass and muscle strength and body muscle function can be improved by performance of moderate to high intensity resistance exercises. More research is needed to determine the intensity and duration of exercises that can increase muscle mass in patients with hip fractures. In consideration of this, a change in the rehabilitation protocol is required. Second, the sarcopenia status of patients might have been affected by failure of social or familial support for rehabilitation after surgery. Third, there was no support for nutritional status in either study.

SUMMARY

The global prevalence of sarcopenia in patients with hip fractures is statistically significant. Although various therapeutic agents and diagnostic criteria have been established

for osteoporosis, there are no clear, useful criteria for diagnosis of sarcopenia in the clinical field. In particular, few studies on the evaluation and treatment of sarcopenia in patients with hip fractures have been reported. In addition, the quality of life of postoperative patients with hip fractures could be significantly improved by development of precise assessment for muscle regeneration and rehabilitation in the operating room.

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CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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