Osteoporosis and Sarcopenia 6 (2020) 88–93

Contents lists available at ScienceDirect

Osteoporosis and Sarcopenia

journal homepage: http://www.elsevier.com/locate/afos

Original article

Muscle mass measurements in hip fracture patients and control general population depending on dual-energy X-ray absorptiometry device used: The General Electric Lunar and Hologic systems

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ARTICLE INFO

Article history:
Received 22 November 2019
Received in revised form
23 February 2020
Accepted 9 May 2020
Available online 23 May 2020

Keywords:
Sarcopenia
Muscle mass
Dual-energy X-ray absorptiometry
Hip fracture

ABSTRACT

Objectives: The prevalence of sarcopenia, an independent risk factor for fragility fractures, is high in geriatric hip fracture patients. We aim to compare patients with hip fractures to the general population using different dual-energy X-ray absorptiometry (DXA) devices – General Electric (GE) Lunar and Hologic.

Methods: We retrospectively reviewed data of patients diagnosed with osteoporotic hip fractures. At our institute, 252 patients with hip fractures were measured with the GE Lunar DXA. The control group included 252 matched individuals from a general population dataset whose data were measured with the Hologic DXA; controls were selected using nearest-neighbor propensity score matching. Measurements included appendicular lean mass (ALM), bone mineral density, and subsequent rates of sarcopenia and osteoporosis.

Results: The BMD T-score was significantly lower in patients with hip fractures than in matched controls (−2.7 vs. −2.1, respectively; $P < 0.001$). However, mean lean body mass of the arm was significantly greater in the hip fractures group compared to the matched control groups (4.092 kg vs. 3.869 kg, respectively; $P = 0.024$). Additionally, mean lean body mass of the leg was similar between groups (11.565 kg vs. 11.986 kg, respectively; $P = 0.084$). ALM/height^2 and subsequent sarcopenia rates were not different between groups (hip fractures and 6.257 kg/m^2 and 38.5%; matched controls, 6.198 kg/m^2 and 33.7%).

Conclusions: Despite experiencing hip fractures, muscle mass measurements and sarcopenia prevalence were similar between the groups. Muscle mass measurements for evaluating sarcopenia present significant discrepancies according to the DXA used.

1. Introduction

Sarcopenia is a degenerative decrease of skeletal muscle mass (0.5%–1.0% loss per year after the age of 50) that has recently gained attention and is being investigated in diverse areas [1]. Sarcopenia, especially in peripheral skeletal muscle, correlates with functional impairment in daily life, inducing difficulties in walking, climbing up stair, and moving slowly, which, in turn, increases the risk of falls and results in fracture [2]. Sarcopenia independently appears to be a risk factor for fragility fractures leading to a condition known as sarco-osteoporosis, regardless of bone density [3]. With respect to proximal femur fractures, also recognized as hip fractures, there have been many studies regarding the prevalence of sarcopenia. Although the prevalence of sarcopenia in patients with hip fractures ranges from 17% to 74% depending on the population and definition of sarcopenia, the prevalence of sarcopenia was very high in geriatric patients with hip fractures [4–7].

Muscle mass is one of diagnostic component for sarcopenia. Several tools are available for the measurement of muscle mass,

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Peer review under responsibility of The Korean Society of Osteoporosis.

https://doi.org/10.1016/j.afos.2020.05.002

including dual-energy X-ray absorptiometry (DXA), bioelectrical impedance analysis, magnetic resonance imaging, and computed tomography [8,9]. DXA allows for body composition assessment using whole body or regional imaging by separating body mass into bone parameters and fat and lean body mass (fat-free soft tissue [10,11]. The DXA has several advantages of its noninvasive nature and whole-body assessment feature, DXA is commonly used to assess muscle mass in practical settings [3,8,10].

Of many commercial manufacturers of DXA, Hologic, Inc. (Bedford, MA, USA) and General Electric (GE) Healthcare, Ltd. (Madison, WI, USA) are highly validated and dominant instruments [12,13]. Nevertheless, measurement differences between them, and even within the same brand, have been noted in several studies [12–16].

Therefore, we aimed to compare the muscle mass measurements using the 2 DXA devices between patients with hip fractures and the general population. Despite different measurement tools, we predicted lower bone mineral density (BMD) and muscle mass in patients with hip fractures compared to the general population.

2. Methods

We retrospectively reviewed the data of patients diagnosed with hip fracture, intertrochanter and femur neck fractures, under the approval of the Institutional Review Board (IRB) (CHAMC 2017-11-003). All participants gave their informed consent. We identified 282 patients with hip fractures who underwent appendicular lean mass (ALM) and BMD assessments via DXA (Lunar Prodigy Advance; GE Healthcare, Ltd., Madison, WI, USA) between January 2015 and December 2017. The ALM and BMD measurement were conducted after hip fracture with average 9.0 days ranging from 0 to 20 days. The ALM is the sum of the lean soft tissue masses of the arms and legs. The ALM was measured for the upper and lower extremities separately. BMD was measured at both the lumbar spine and unaffected proximal femoral area. We also obtained data on medical conditions influencing on sarcopenia, including stroke, hypertension, angina or myocardial infarction, asthma or chronic obstructive pulmonary disease, diabetes, thyroid disease, dyslipidemia, renal failure, hepatic failure, rheumatoid arthritis, cancer diagnosis, and current smoking status [2,17–19].

The patients' hip fractures were properly treated based on current standards. To isolate the role of sarcopenia in hip fractures, we focused on fragility fractures. Inclusion criteria were age over 50 years and fracture caused from low-energy trauma including a fall from a standing height or low height of less than 1 m. Multiple fractures and fracture from high energy trauma were excluded. We excluded patients with insufficient assessments (i.e., femoral BMD in a patient with a history of bilateral total hip replacement). As a result, 252 patients were included in the hip fractures group.

For the control group, we utilized general population data from the Korea National Health and Nutrition Examination Surveys (KNHANES) from 2008 to 2011 [20]. During this period, the KNHANES, led by the Korea Centers for Disease Control, measured ALM and BMD under their own IRB approval, and some of the data has been released for medical research. The whole-body DXA examinations were conducted using a QDR Discovery (formerly the QDR 4500A) fan beam densitometer (Hologic, Inc.), according to the manufacturer's instructions. From this data, we could access information on the general population, including age, sex, height, weight, medical history, fracture history, ALM, and BMD. We identified available data from 21, 303 individuals assessed between 2008 and 2011. We excluded individuals with any fracture history and those aged younger than 50 years. Patients with insufficient information were also excluded. Eventually, 4314 potential individuals were acquired before propensity score matching with the patients with hip fractures (unmatched control group) (Fig. 1).

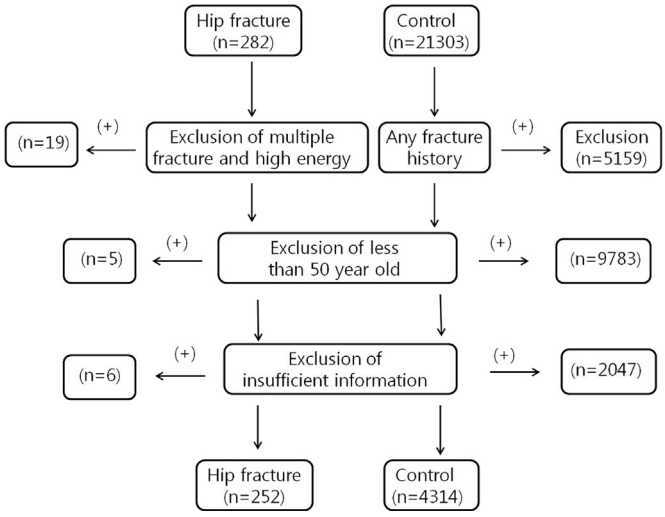

Fig. 1. Patient selection flow chart for those with hip fractures and controls.

In order to generate a comparable control group (matched control group), Nearest-neighbor propensity score matching was utilized. The matching variables of sex, age, weight, height, body mass index, and medical conditions including hypertension, dyslipidemia, stroke, angina or myocardial infarction, rheumatoid arthritis, asthma, chronic obstructive pulmonary disease, thyroid disease, renal failure, liver cirrhosis, cancer, and current smoking were inserted into a propensity score matching algorithm between the groups. Finally, we obtained an equal number of individuals for the hip fractures and control groups, resulting in the enrollment of 252 patients with hip fractures and 252 controls.

We initially analyzed the demographic factors between the hip fractures and control groups using unmatched and matched comparisons (Table 1). Relative ALM was defined as ALM divided by height squared, and a relative ALM below respective sex-based thresholds (males, <7.00 kg/m^2; females, <5.40 kg/m^2) was regarded as sarcopenia based on the Asian sarcopenia guideline [11,21]. Osteoporosis was diagnosed using the lowest measured T-score, according to World Health Organization criteria – osteopenia, T-score between −2.5 and −1.5; osteoporosis, T-score ≤ −2.5 [22].

Propensity score matching was used to select the control group. The Student t-test for continuous variables and Pearson chi-square test or Fisher exact test for categorical variables were used for the between-group comparisons. Before the Student t-test was performed, a normality test (Shapiro-Wilk test) was applied to the continuous variables. A $P < 0.05$ was considered statistically significant. With software R (ver. 3.1.0; The R Foundation, Vienna, Austria), the statistical evaluation was conducted.

3. Results

Table 2 presents study outcomes for the matched comparisons of ALM and BMD.

3.1. Matched comparison: BMD

The hip fractures group presented with significantly lower BMD compared to the control group, indicating similar outcomes as the unmatched comparisons. Mean lumbar spine T-score was significantly lower in the hip fractures group compared to the control group (−2.1 vs. −1.6, respectively, $P < 0.001$). Femoral T-score of the hip fractures group was also lower than that of the control group (−2.3 vs. −1.9, respectively, $P < 0.001$). In the final T-score

Table 1
Descriptive statistics by group.

Variable	Unmatched cohort			Propensity-matched cohort			Absolute standardized diff in means
	Control (n = 4314)	Hip fracture (n = 252)	P-value	Control (n = 252)	Hip fracture (n = 252)	P-value	
Sex			<0.001			0.181	0.0657
Male	2095 (48.6)	73 (29.0)		88 (34.9)	73 (29.0)		
Female	2219 (51.4)	179 (71.0)		164 (65.1)	179 (71.0)		
Age, yr	63.4 ± 9.3	75.9 ± 9.7	<0.001	75.0 ± 8.7	75.9 ± 9.7	0.242	0.1043
Height, cm	159.6 ± 8.8	158.1 ± 8.2	0.009	159.1 ± 9.0	158.1 ± 8.2	0.200	0.1142
Weight, kg	61.1 ± 10.3	56.9 ± 10.9	<0.001	57.8 ± 10.0	56.9 ± 10.9	0.371	0.0798
BMI, kg/m^2	23.9 ± 3.1	22.8 ± 4.1	<0.001	22.8 ± 3.1	22.8 ± 4.1	0.960	0.0044
Medical history							
Hypertension			<0.001			0.281	0.0503
0	2769 (64.2)	103 (40.9)		116 (46.0)	103 (40.9)		
1	1545 (35.8)	149 (59.1)		136 (54.0)	149 (59.1)		
Dyslipidemia			<0.001			0.770	0.0825
0	3786 (87.8)	247 (98.0)		245 (97.2)	247 (98.0)		
1	528 (12.2)	5 (2.0)		7 (2.8)	5 (2.0)		
Stroke			<0.001			0.471	0.0598
0	4149 (96.2)	222 (88.1)		228 (90.5)	222 (88.1)		
1	165 (3.8)	30 (11.9)		24 (9.5)	30 (11.9)		
Angina or myocardial infarction			<0.001			0.102	0.1073
0	4156 (96.3)	208 (82.5)		222 (88.1)	208 (82.5)		
1	158 (3.7)	44 (17.5)		30 (11.9)	44 (17.5)		
Rheumatoid arthritis			0.020			0.447	0.2223
0	4149 (96.2)	250 (99.2)		247 (98.0)	250 (99.2)		
1	165 (3.8)	2 (0.8)		5 (2.0)	2 (0.8)		
Asthma			0.282			1.000	0.0262
0	4064 (94.2)	242 (96.0)		243 (96.4)	242 (96.0)		
1	250 (5.8)	10 (4.0)		9 (3.6)	10 (4.0)		
COPD			0.189			1.000	0.0
0	4249 (98.5)	245 (97.2)		245 (97.2)	245 (97.2)		
1	65 (1.5)	7 (2.8)		7 (2.8)	7 (2.8)		
Diabetes			<0.001			0.427	0.0425
0	3715 (86.1)	177 (70.2)		186 (73.8)	177 (70.2)		
1	599 (13.9)	75 (29.8)		66 (26.2)	75 (29.8)		
Thyroid disease			0.276			1.000	0.0187
0	4158 (96.4)	239 (94.8)		238 (94.4)	239 (94.8)		
1	156 (3.6)	13 (5.2)		14 (5.6)	13 (5.2)		
Renal failure			<0.001			0.031	0.2127
0	4289 (99.4)	229 (90.9)		242 (96.0)	229 (90.9)		
1	25 (0.6)	23 (9.1)		10 (4.0)	23 (9.1)		
Liver cirrhosis			0.550			1.000	0.0
0	4299 (99.7)	250 (99.2)		250 (99.2)	250 (99.2)		
1	15 (0.3)	2 (0.8)		2 (0.8)	2 (0.8)		
Cancer			<0.001			0.238	0.1106
0	4189 (97.1)	229 (90.9)		237 (94.0)	229 (90.9)		
1	125 (2.9)	23 (9.1)		15 (6.0)	23 (9.1)		
Current smoking			<0.001			0.640	0.0792
0	3485 (80.8)	241 (95.6)		244 (96.8)	241 (95.6)		
1	829 (19.2)	11 (4.4)		8 (3.2)	11 (4.4)		

Values are presented as number (%) or mean ± standard deviation.
BMI, body mass index; COPD, chronic obstructive pulmonary disease.

comparison, the hip fractures group presented with significantly lower T-scores compared to the control group (−2.7 vs. −2.1, respectively, P < 0.001) (Fig. 2). The proportion of patients with osteoporosis was also significantly different between the hip fractures and control groups (151 [59.9%] vs. 108 [42.9%], respectively, P < 0.001).

3.2. Matched comparison: ALM

In contrast to the unmatched comparison, mean lean soft tissue mass of the arm was significantly greater in the hip fractures group compared to the control groups (4.092 kg vs. 3.869 kg, respectively, P = 0.024). Additionally, mean lean body mass of the leg was similar between groups (hip fractures group, 11.565 kg; control group, 11.986 kg; P = 0.084). Moreover, relative ALM was not significantly different between groups (hip fractures group, 6.217 kg/m^2; control group, 6.198 kg/m^2; P = 0.841) (Fig. 3). Lastly, the incidence beyond diagnostic value of sarcopenia is similar between the hip fractures and control groups (97 [38.5%] vs. 85 [33.7%], P = 0.308).

4. Discussion

Authors compared the bone density and muscle mass measurements using the 2 DXA devices between hip fracture patients and matched normal population. We found low bone density in hip fracture patients, but muscle mass outcome was similar to control group.

Skeletal muscle mass reduction is described using various terms depending on the suspected etiology: sarcopenia [23], sarcopenic obesity [24], dynapenia [25], myosteatosis [26], myopenia [27], and sarco-osteopenia [28]. The use of these differing terminologies implies that skeletal muscle mass reduction is not yet well-defined. Nevertheless, in October 2016, sarcopenia was recognized as an independent condition with an International Classification of

Table 2
Comparison of bone mineral density and body composite.

Variable	Propensity-matched cohort		P-value
	Control (n = 252)	Hip fracture (n = 252)	
T-score			
Spine	−1.6 ± 1.5	−2.1 ± 1.5	<0.001
Femur	−1.9 ± 1.2	−2.3 ± 1.4	<0.001
Final score	−2.1 ± 1.2	−2.7 ± 1.3	<0.001
Osteoporosis			<0.001
None	44 (17.5)	22 (8.7)	
Osteopenia	100 (39.7)	79 (31.3)	
Osteoporosis	108 (42.9)	151 (59.9)	
ALM			
Arm, kg	3.869 ± 1.044	4.092 ± 1.160	0.024
Leg, kg	11.986 ± 2.630	11.565 ± 2.829	0.084
ALM/height^2	6.198 ± 0.877	6.217 ± 1.178	0.841
Sarcopenia			0.308
None	167 (66.3)	155 (61.5)	
Sarcopenia	85 (33.7)	97 (38.5)	

Values are presented as mean ± standard deviation or number (%).
Final score is lower score of patient between spine and femoral score.
ALM, appendicular lean mass.

Disease Code of M62.84 [29].

There have been efforts to define sarcopenia in consensus groups, and the European Working Group on Sarcopenia in Older People refined the definition as follows: low muscle mass (over 2 standard deviations below), low gait speed, and low muscle strength [17].

In publications, DXA was the most frequent used device (43.6%) for muscle mass assessment [19], particularly ALM [11]. Furthermore, relative ALM was proposed as an index of relative muscle mass, with a cutoff value of 2 standard deviations from the average, however different thresholds were suggested depending on sex, men (<7.26 kg/m^2) and women (<5.45 kg/m^2) [17,30]. Considering that Asians typically present with less muscle mass, adjusted criteria were employed to diagnose sarcopenia in the Asian population (males, <7.00 kg/m^2; females, <5.40 kg/m^2) [21].

The aging process is a definite cause of sarcopenia. However, there were other reasons reported for sarcopenia, including reduced mobility, inadequate nutrition, neurodegenerative diseases, malignancy, chronic renal and endocrine disorders (mainly diabetes; abnormal thyroid function; and low levels of vitamin D, sex steroids, growth hormone, and insulin-like growth factor-1), and cardiometabolic disease [2,17–19]. The present study attempted to identify and adjust for these confounding factors, especially chronic diseases that could affect the study outcome.

Similar to previous literature and the authors' assumption, patients with hip fractures presented with low BMD T-score and subsequent higher osteoporosis rate compared to the matched control group (hip fractures group: T-score, −2.7 and osteoporosis prevalence, 151 [59.9%]; control group: T-score, −2.1 and osteoporosis incidence, 108 [42.9%]). However, with respect to the muscle mass comparison, patients with hip fractures did not exhibit ALM inferiority (hip fractures group, 6.217 kg/m^2; control group, 6.198 kg/m^2) or subsequent sarcopenia rate increase. Rather, patients with hip fractures had significantly higher upper arm lean mass than the control group (4.092 kg/m^2 vs. 3.869 kg/m^2, respectively). This finding may be from the different boundaries used for the same anatomic region measurement between the DXA systems.

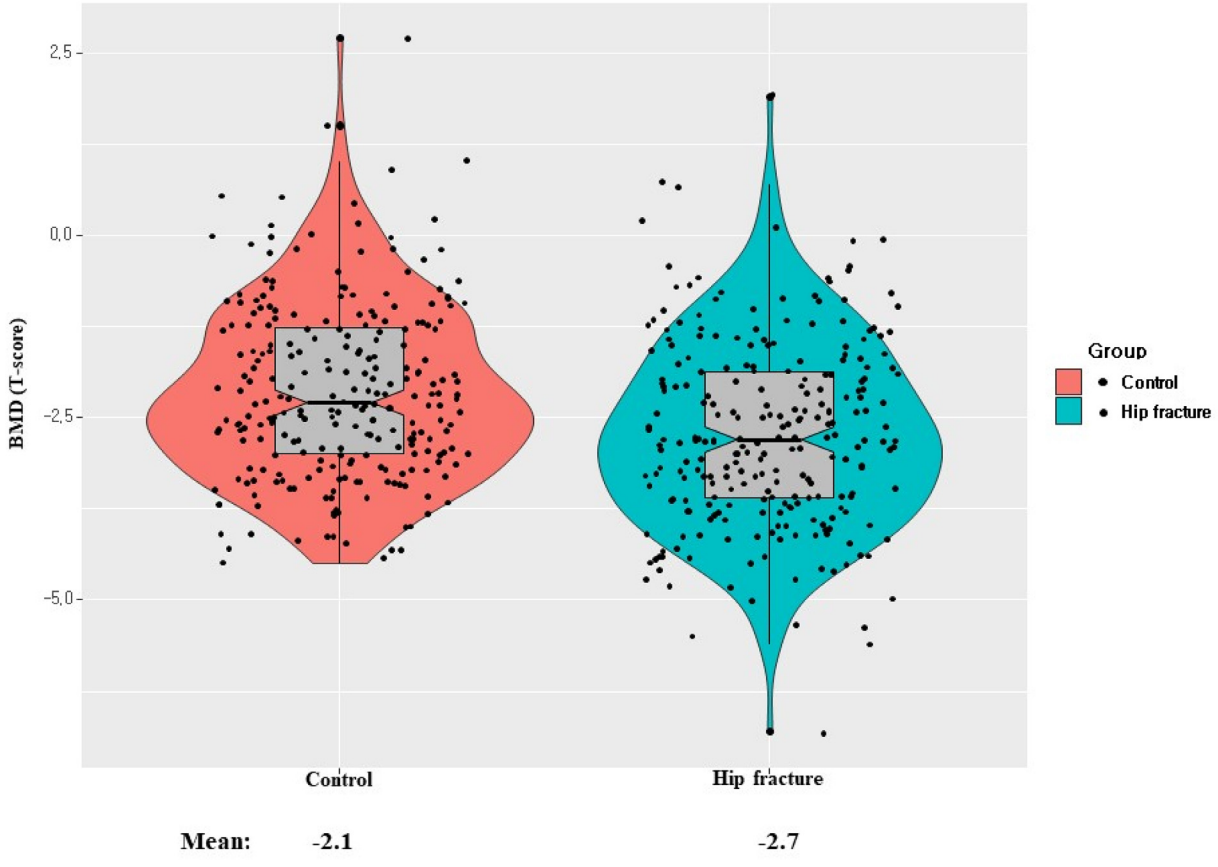

Fig. 2. Comparison of bone mineral density (BMD). BMD was significantly different between groups (P < 0.001).

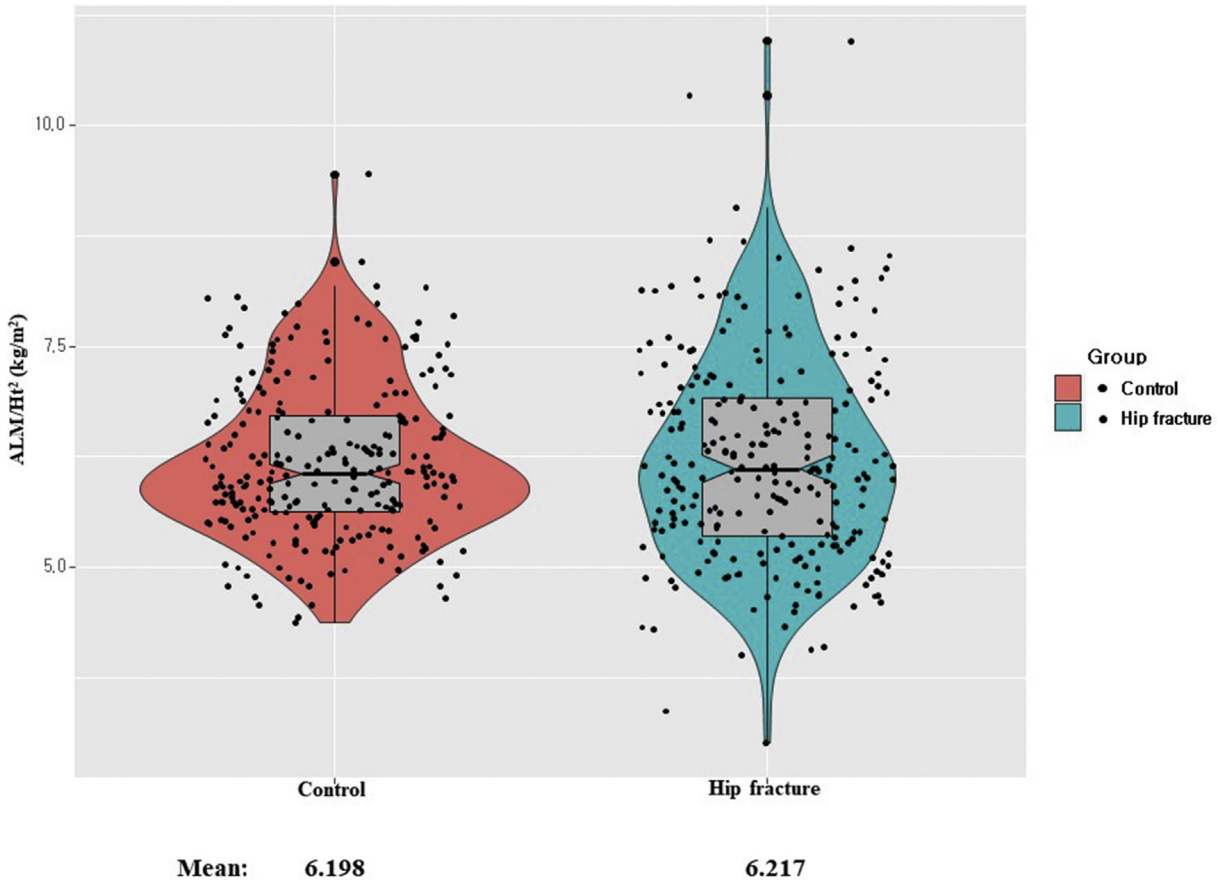

Fig. 3. Comparison of appendicular lean mass (ALM) divided by height squared. ALM divided by height squared was similar between groups (P = 0.841).

In the muscle mass assessment, the DXA technology is similar between the manufacturers. However, BMD can have substantially different values; for example, Hologic spine BMD is typically 11.7% lower than GE Lunar spine BMD [12]. In order to solve this problem, the International Committee for Standards in Bone Measurements published universal BMD standardization equations to convert spine and hip BMD results from different systems into a standardized BMD [15]. Although the application of DXA has expanded into detecting body composition changes in obesity, osteoporosis, Crohn disease, neuromuscular diseases, and other clinical conditions, there are a few studies evaluating instrument discrepancies from different commercial systems aside from BMD assessments [13,14,16]. Xu et al. [13] evaluated the agreement between the Hologic Discovery and GE iDXA systems in 96 subjects in order to determine conversion equations for body composition and bone mineral measurements. They reported significant discrepancies between 2 DXA instruments in body composition depending on body regions. Nevertheless, there was a high correlation between the 2 systems and the authors suggested possible calibration equations for body composition assessments using DXA.

Authors have attempted to investigate discrepancies in different DXA systems in the practical field, particularly comparisons between patients with osteoporotic hip fracture and matched controls. In contrast to the current study's hypothesis, patients with hip fractures who were measured with GE Lunar tended to exhibit higher ALM than the matched general population control group measured using Hologic. This finding was interesting considering previous reports of high sarcopenia prevalence in those with hip fractures. Shepherd et al. [16] reported and appendicular lean soft tissue mass using the GE Lunar system (15,715.9 g) than the Hologic system (16,176.1 g) underestimating mean ALM values with GE system measurement. With calibration, they suggested universal standardization equation of DXA between the GE Lunar and Hologic DXA systems; ALM Hologic = 818.24 + 0.989 ALM GE. However, in our study, the mean ALM of hip fracture measured with GE Lunar system was 15,657 g compared with 15,855 g of general population measured with Hologic system. If we applied this equation, the ALM of hip fracture, measured with GE, comes to 16,303 g which is beyond general population of 15,855 g measured with Hologic system. This finding contracts previous studies reporting frequent sarcopenia in hip fracture patients. Different measurement year, ethics, and version of commercial could be one explanation. Secondary, opposite finding may be affected by the Shepherd study performing calculations targeting the general pediatric and adult populations.

There were limitations to our study. BMD and body composition measurements were carried out at different institutions with different instruments. Since we did not exam the same individuals with different devices, we could not calculate the value of difference depending on the DXA system. Regardless, we could not determine which system was closer to the true value. In future studies, researchers should identify the adjustment value for muscle mass assessments based on the DXA device. Therefore, effort should be made to identify standardization equations between these dominant systems, especially in compromised patients. Additionally, international cutoff values for sarcopenia should be applied differently according to the DXA device used. Otherwise, sarcopenia diagnosis can be different depending on the commercial DXA.

5. Conclusions

Despite of low bone density in hip fracture patients, muscle mass measurements and sarcopenia prevalence were similar between groups examined by different DXA systems. Muscle mass measurements for evaluating sarcopenia could present significant discrepancies according to the DXA used.

Conflicts of interest

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

CRediT author statement

Jun-Ku Lee: Writing - original draft, Validation. **Seong-Eun Byun:** Conceptualization, Writing - review & editing. **Minki Lee:** Software, Validation. **Gotak Kim:** Data curation, Investigation. **Eugene Baek:** Data curation, Investigation. **Soo-Hong Han:** Conceptualization, Writing - original draft, Supervision, Writing - review & editing.

Acknowledgments

The authors would like to thank the Korea Centers for Disease Control and Prevention for providing the Korea National Health and Nutrition Examination Survey database. **ORCID** Jun-Ku Lee: 0000-0003-4640-9357. Seong-Eun Byun: 0000-0002-2182-9614. Minki Lee: 0000-0002-9674-9838. Gotak Kim: 0000-0002-6188-4343. Eugene Baek: 0000-0003-2672-961X. Soo-Hong Han: 0000-0002-8951-650X.

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