Original Paper

Comparison of Muscle Mass Indices Using Computed Tomography or Dual X-Ray Absorptiometry for Predicting Physical Performance in Hemodialysis Patients

Seok Hui Kang^a Hyun Seok Lee^b Sukyung Lee^c Ji-Hyung Cho^d Jun Chul Kim^d

^aDivision of Nephrology, Department of Internal Medicine, Yeungnam University Hospital, Daegu,

^bDepartment of Radiology, CHA Gumi Medical Center, CHA University, Gumi-si, Gyeongsangbuk-do,

^cDivision of Nephrology, Department of Internal Medicine, Semyung Christianity Hospital, Pohang-si,

Gyeongsangbuk-do, ^dDivision of Nephrology, Department of Internal Medicine, CHA Gumi Medical Center, CHA University, Gumi-si, Gyeongsangbuk-do, Republic of Korea

Key Words

Hemodialysis • Thigh muscle cross-sectional area • Appendicular muscle mass • Physical performance

Abstract

Background/Aims: Our study aims to evaluate the association between thigh muscle cross-sectional area (TMA) using computed tomography (CT), or appendicular skeletal muscle mass (ASM) using dual energy X-ray absorptiometry (DEXA), and physical performance levels in hemodialysis (HD) patients. **Methods:** Patients were included if they were on HD for ≥ 6 months ($n = 84$). ASM and TMA were adjusted to body weight (BW, kg) or height² (Ht², m²). Each participant performed a short physical performance battery test (SPPB), a sit-to-stand for 30 second test (STS30), a 6-minute walk test (6-MWT), a timed up and go test (TUG), and hand grip strength (HGS) test. **Results:** Correlation coefficients for SPPB, GS, 5STS, STS30, 6-MWT, and TUG were highest in TMA/BW. Results from partial correlation or linear regression analyses displayed similar trends to those derived from Pearson's correlation analyses. An increase in TMA/BW or TMA/Ht² was associated with a decreased odds ratio of low SPPB, GS, or HGS in multivariate analyses. Indices using DEXA were associated with a decreased odds ratio of a low HGS only in multivariate analysis. **Conclusion:** TMA indices using CT may be more valuable in predicting physical performance or strength in HD patients.

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Introduction

Chronic kidney disease, caused by various factors such as diabetes mellitus (DM), hypertension, glomerulonephritis, or age, is a well-known public health problem. Chronic

Jun Chul Kim, MD

CHA University School of Medicine, CHA Gumi Medical Center, 12 Sinsi-ro 10-gil, Gumi-si, Gyeongsangbuk-do, 39295 (Republic of Korea)
Tel. +82-54-450-9550, Fax +82-54-450-9790, E-Mail truedoc1@hanmail.net

kidney disease can progress to end-stage renal disease, which then requires renal replacement therapy. Hemodialysis (HD) is the most commonly used modality among renal replacement therapies [1, 2]. HD patients are exposed to various factors including uremic toxins, metabolic disturbances, and inflammatory agents [3]. These are associated with early ageing processes in HD patients. Therefore, HD patients have a rapid decline in muscle mass leading to low physical performance as compared to a healthy population. Previous studies show that the prevalence of sarcopenia ranges from approximately 3.6% to 31.5% in HD patients [4-6]. Sarcopenia is associated with an adverse outcome; therefore, monitoring of muscle mass through accurate measurements, is important to predict low physical performance.

Decline in muscle mass is associated with low muscle strength, which leads to poor physical performance. However, two unresolved issues remain regarding the association between muscle mass and levels of physical performance. First, previous studies have conflicting results regarding the association between muscle mass measurements and physical performance [7-12]. Second, there is no consensus regarding the optimal methods for predicting muscle mass in HD patients. Dual X-ray absorptiometry (DEXA) is the most commonly used measurement for predicting muscle mass, but HD patients have a volume overload status and insulin resistance associated with fat mass accumulation. These factors may be associated with a more limited capacity to accurately predict muscle mass in HD patients [13, 14]. Thigh muscle cross-sectional area (TMA) using computed tomography (CT) is a well-known, accurate method for predicting muscle mass. However, there are few studies regarding the comparison between TMA using CT and physical performance in HD patients. Our study aims address these issues and to evaluate the association between TMA using CT, or appendicular skeletal muscle mass (ASM) using DEXA, and physical performance levels in HD patients.

Materials and Methods

Study population

This study was conducted in CHA Gumi Medical Center, Republic of Korea, from 1st January 2015 to 30th December 2015. Patients were included if they were over 20 years-old, on dialysis for ≥6 months, with no history of hospitalization in the previous 3 months, able to ambulate without an assistive device, able to communicate with the interviewer, and able to provide informed consent. A total of 84 patients were enrolled. None of the participants were taking opioids, antihistamines, or antidepressants, which can be associated with decreased physical activity and cognitive function. This study was approved by the Institutional Review Board of CHA Gumi Medical Center (IRB number: 12-07) and all participants provided written informed consent.

Study variables

Demographic and laboratory data collected at enrollment included the following: age, sex, hemoglobin level (g/dL), Kt/Vurea, high-sensitivity C-reactive protein (hs-CRP, mg/dL), serum albumin level (g/dL), dialysis vintage, and the presence of DM. Kt/Vurea was calculated using following formula: $Kt/Vurea = -\ln(R - 0.008 \times t) + (4 - 3.5 \times R) \times UF/W$ (R: post-dialysis blood urea nitrogen/pre-dialysis blood urea nitrogen, t: dialysis duration in hours, UF: ultrafiltration volume in liters, W: post-dialysis body weight in kilograms) [15]. If a patient had a self-reported history and a medical record of DM diagnosis or medication, the patient was defined as having DM.

Assessment of muscle mass

We performed two muscle mass measurements using DEXA and CT. Two measurements were performed after the midweek HD session. DEXA was measured using a Prodigy Advance instrument and performed by a technologist while each participant was in a supine position and clothed in a light gown (GE Medical Systems Lunar, Madison, WI, USA). ASM (kg) was defined as the sum of both upper extremities and lower extremities. After the DEXA measurement, each participant underwent a multi-slice, mid-thigh

CT scan using a 320-slice CT scanner (Aquilion ONE; Toshiba Medical Systems Corp., Tokyo, Japan). An axial image was obtained at the midpoint of a line extending from the superior border of the patella to the greater trochanter (3 mm thickness, 5 slices). The images were analyzed using image analysis software (ImageJ 1.45S, National Institutes of Health, Bethesda, MD, USA). ASM and TMA were adjusted to body weight (BW, kg) or height² (Ht², m²).

Assessment of physical performance

In our study, each participant performed a short physical performance battery test (SPPB), a sit-to-stand for 30 second test (STS30), a 6-minute walk test (6-MWT), a timed up and go test (TUG), and hand grip strength (HGS) test. The SPPB test, which consisted of assessing the usual gait speed (GS), a sit-to-stand test performed 5 times (5STS), and balance tests, were calculated using previously defined methods, and scores ranged from 0 to 12 [16]. For GS, the participants were asked to walk a 4-meter distance and the time taken (in seconds) to walk the distance was recorded. For the 5STS test, each participant was seated in a chair with arms crossed and hands touching the shoulders [17]. The participants were asked to stand up and sit down 5 times as quickly as possible, and the time taken in seconds was recorded. For the STS30 test, the participants were seated in a chair with their arms crossed and hands touching the shoulders. Scores were defined as the number of stands a person could complete in 30 seconds without using their arms to stand [18]. For the 6-MWT, participants were asked to walk at their best pace for 6 minutes, and the distance they covered was recorded in meters [19]. For the TUG test, the participants were instructed to rise from an arm-chair, walk 3 meters, turn around, return, and sit down [20]. The time in seconds was recorded. For the HGS test, 3 trials were performed on the dominant hand using a manual hydraulic dynamometer (Jamar Hydraulic hand dynamometer; Sammons Preston, Chicago, USA). Over the 3 trials, maximum strength was recorded. We also defined a low physical performance group for the SPPB, GS, and HGS tests. The low SPPB group was defined as scoring ≤ 10 . The low GS group was defined as scoring ≤ 1 m/s [21]. The low HGS group was defined as scoring < 26 kg for men and < 18 kg for women [22].

Statistical analyses

The data were analyzed using the statistical software SPSS version 21 (Chicago, IL, USA). Categorical variables were expressed as both counts and percentages. Continuous variables were expressed as mean $\pm$ standard deviation (SD) or mean $\pm$ standard error (SE). For continuous variables, means were compared using the t-test. Multivariate analysis was performed using analysis of covariance. Correlation between 2 continuous variables was assessed using Pearson's or partial correlation analyses. Linear regression analysis was performed to assess the independent predictors of each physical performance. Logistic regression analyses were used to estimate the odds ratios and 95% confidence intervals (CI), which were used to determine the relationship between low physical performance groups and muscle mass indices. Multivariate analysis was adjusted for age, sex, and DM. The level of statistical significance was set at $P < 0.05$.

Results

Participants' clinical characteristics

The mean participant age was 55.6 ± 12.8 years (Table 1). The proportion of males was 52.4%. The mean value of ASM, ASM/BW, and ASM/Ht² was 17.4 ± 3.8 kg, 28.1 ± 4.5 %, 6.58 ± 0.97 kg/m², respectively. The mean value of TMA, TMA/BW, and TMA/Ht² was 97.2 ± 23.2 cm², 1.56 ± 0.25 cm²/kg, and 36.9 ± 7.04 cm²/m², respectively. The proportions of participant with low SPPB, GS, and HGS was 25 (29.8%), 55 (65.5%), and 15 (17.9%), respectively.

Table 1. Participants' clinical characteristics

	(n = 84)
Age (years)	55.6 $\pm$ 12.8
Sex (male, %)	44 (52.4%)
Diabetes mellitus (%)	44 (52.4%)
Dialysis vintage (years)	4.6 $\pm$ 5.1
Hemoglobin (mg/dL)	11.0 $\pm$ 0.6
Serum albumin (g/dL)	3.8 $\pm$ 0.3
High sensitivity C-reactive protein (mg/dL)	0.42 $\pm$ 0.60
Kt/Vurea	1.36 $\pm$ 0.31

Association between various muscle mass indices and physical performance

Pearson's correlation coefficients for SPPB, GS, 5STS, STS30, 6-MWT, and TUG were highest in TMA/BW (Table 2). The correlation coefficient values for SPPB, GS, STS5, STS30, 6-MWT, and TUG were 0.397, 0.559, -0.326, 0.497, 0.531, and -0.472, respectively. The correlation coefficient for HGS was highest in TMA ($r = 0.614$). Results from partial correlation or linear regression analyses displayed similar trends to those derived from Pearson's correlation analyses (Table 3).

An increase in TMA/BW was associated with a decreased odds ratio of low SPPB, GS, or HGS in both univariate and multivariate analyses (Table 4). An increase in TMA/Ht² was associated with a decreased odds ratio of low SPPB, GS, or HGS in multivariate analysis. Indices using DEXA were associated with a decreased odds ratio of a low HGS only in multivariate analysis.

Comparison of indices between participants with normal and poor physical performance

For the SPPB test, univariate and multivariate analyses showed that there was no significant difference in indices using DEXA between participants with normal and low SPPB scores (Table 5). TMA/BW and TMA/Ht² were greater in participants with a normal SPPB score than in those with a low SPPB. For the GS test, univariate analysis showed that all indices were greater in participants with a normal GS than in those with a low GS. However, for multivariate analysis, statistical significances were observed only in ASM/Ht² and indices

Table 2. Correlation between various muscle mass indices and physical performance. Data were expressed as correlation coefficients. Partial correlations were adjusted for age, sex, and diabetes mellitus. * $P < 0.05$. Abbreviations: ASM, appendicular skeletal muscle mass; ASM/BW, appendicular skeletal muscle mass per body weight; ASM/Ht², appendicular skeletal muscle mass per height squared; TMA, thigh muscle area; TMA/BW, thigh muscle area per body weight; TMA/Ht², thigh muscle area per height squared; SPPB, short physical performance battery; GS, gait speed; 5STS, 5 times sit to stand test; STS30, sit to stand for 30 seconds test; 6-MWT, 6 minute walk test; TUG, timed up and go test; HGS, hand grip strength

	ASM	ASM/BW	ASM/Ht ²	TMA	TMA/BW	TMA/Ht ²
Pearson correlation						
SPPB	0.074	0.191	0.112	0.203	0.397*	0.259*
GS	0.380*	0.300*	0.355*	0.517*	0.559*	0.485*
5STS	-0.088	-0.172	-0.150	-0.197	-0.326*	-0.260*
STS30	0.177	0.173	0.237*	0.393*	0.497*	0.476*
6-MWT	0.268*	0.359*	0.246*	0.359*	0.531*	0.330*
TUG	-0.177	-0.243*	-0.179	-0.324*	-0.472*	-0.333*
HGS	0.574*	0.412*	0.502*	0.614*	0.543*	0.492*
Partial correlation						
SPPB	0.035	0.144	0.166	0.173	0.347*	0.235*
GS	0.220	0.199	0.220	0.406*	0.453*	0.398*
5STS	-0.090	-0.171	-0.177	-0.199	-0.319*	-0.252*
STS30	0.007	0.037	0.147	0.317*	0.437*	0.430*
6-MWT	0.117	0.257*	0.133	0.233*	0.454*	0.235*
TUG	-0.050	-0.145	-0.097	-0.241*	-0.409*	-0.270*
HGS	0.255*	0.070	0.235*	0.386*	0.326*	0.349*

Table 3. Linear regression analyses of physical performances based on various muscle mass indices. Data were expressed as standardized $\beta \pm$ standard errors. The multivariate analyses were adjusted for age, sex, and diabetes mellitus. *P < 0.05. Abbreviations: ASM, appendicular skeletal muscle mass; ASM/BW, appendicular skeletal muscle mass per body weight; ASM/Ht², appendicular skeletal muscle mass per height squared; TMA, thigh muscle area; TMA/BW, thigh muscle area per body weight; TMA/Ht², thigh muscle area per height squared; SPPB, short physical performance battery; GS, gait speed; 5STS, 5 times sit to stand test; STS30, sit to stand for 30 seconds test; 6-MWT, 6 minute walk test; TUG, timed up and go test; HGS, hand grip strength

	ASM	ASM/BW	ASM/Ht ²	TMA	TMA/BW	TMA/Ht ²
Univariate						
SPPB	0.074 ± 0.047	0.191 ± 0.039	0.112 ± 0.184	0.203 ± 0.008*	0.397 ± 0.649*	0.259 ± 0.025*
GS	0.380 ± 0.005*	0.300 ± 0.005*	0.355 ± 0.021*	0.517 ± 0.001*	0.559 ± 0.071*	0.485 ± 0.003*
5STS	-0.088 ± 0.179	-0.172 ± 0.148	-0.150 ± 0.692	-0.197 ± 0.029	-0.326 ± 2.532*	-0.260 ± 0.093*
STS30	0.177 ± 0.164	0.173 ± 0.138	0.237 ± 0.631*	0.393 ± 0.025*	0.497 ± 2.157*	0.476 ± 0.079*
6-MWT	0.268 ± 3.171*	0.359 ± 2.580*	0.246 ± 12.446*	0.359 ± 0.502*	0.531 ± 41.646*	0.330 ± 1.673*
TUG	-0.177 ± 0.058	-0.243 ± 0.048*	-0.179 ± 0.227	-0.324 ± 0.009*	-0.472 ± 0.777*	-0.333 ± 0.030*
HGS	0.574 ± 0.176*	0.412 ± 0.164*	0.502 ± 0.724*	0.614 ± 0.028*	0.543 ± 2.691*	0.492 ± 0.101*
Multivariate						
SPPB	0.068 ± 0.067	0.168 ± 0.044	0.143 ± 0.219	0.210 ± 0.009	0.373 ± 0.717*	0.236 ± 0.025*
GS	0.264 ± 0.008	0.114 ± 0.005	0.234 ± 0.025	0.443 ± 0.001*	0.456 ± 0.080*	0.378 ± 0.003*
5STS	-0.155 ± 0.265	-0.208 ± 0.175	-0.228 ± 0.860	-0.254 ± 0.036	-0.359 ± 2.878*	-0.265 ± 0.100*
STS30	0.045 ± 0.238	0.057 ± 0.159	0.187 ± 0.772	0.386 ± 0.031*	0.472 ± 2.442*	0.433 ± 0.083*
6-MWT	0.170 ± 4.354	0.275 ± 2.838*	0.156 ± 14.279	0.262 ± 0.588*	0.453 ± 44.707*	0.221 ± 1.650*
TUG	-0.079 ± 0.079	-0.158 ± 0.053	-0.116 ± 0.259	-0.271 ± 0.011*	-0.411 ± 0.828*	-0.256 ± 0.030*
HGS	0.308 ± 0.244*	0.072 ± 0.169	0.239 ± 0.805*	0.377 ± 0.032*	0.284 ± 2.733*	0.288 ± 0.092*

Table 4. Logistic regression analyses of decreased physical performances according to various muscle mass indices. Data were expressed as odds ratio (95% confidence interval) and odds ratios were defined as increase in one unit of each indices. The multivariate analyses were adjusted for age, sex, and diabetes mellitus. Abbreviations: ASM, appendicular skeletal muscle mass; ASM/BW, appendicular skeletal muscle mass per body weight; ASM/Ht², appendicular skeletal muscle mass per height squared; TMA, thigh muscle area; TMA/BW, thigh muscle area per body weight; TMA/Ht², thigh muscle area per height squared; SPPB, short physical performance battery; GS, gait speed; HGS, hand grip strength

	ASM	ASM/BW	ASM/Ht ²	TMA	TMA/BW	TMA/Ht ²
Univariate						
Low SPPB	0.98 (0.87-1.12) P = 0.803	0.94 (0.84-1.04) P = 0.227	0.90 (0.55-1.46) P = 0.659	0.99 (0.97-1.01) P = 0.425	0.03 (0.00-0.38) P = 0.006	0.96 (0.90-1.03) P = 0.273
Low GS	0.78 (0.68-0.91) P = 0.001	0.87 (0.78-0.97) P = 0.011	0.37 (0.21-0.66) P = 0.001	0.98 (0.95-1.00) P = 0.069	0.04 (0.00-0.58) P = 0.018	0.93 (0.86-1.01) P = 0.100
Low HGS	0.78 (0.64-0.94) P = 0.011	0.86 (0.74-0.99) P = 0.045	0.37 (0.18-0.75) P = 0.006	0.98 (0.96-1.00) P = 0.097	0.02 (0.00-0.22) P = 0.002	0.92 (0.85-0.99) P = 0.036
Multivariate						
Low SPPB	1.00 (0.82-1.21) P = 0.988	0.94 (0.82-1.09) P = 0.403	0.86 (0.44-1.65) P = 0.642	0.98 (0.95-1.01) P = 0.111	0.01 (0.00-0.26) P = 0.005	0.91 (0.83-0.99) P = 0.045
Low GS	0.87 (0.71-1.07) P = 0.193	0.95 (0.84-1.09) P = 0.483	0.51 (0.25-1.03) P = 0.062	0.96 (0.93-0.99) P = 0.015	0.04 (0.00-0.45) P = 0.010	0.89 (0.81-0.97) P = 0.007
Low HGS	0.53 (0.36-0.77) P = 0.001	0.81 (0.67-0.98) P = 0.030	0.17 (0.06-0.50) P = 0.001	0.91 (0.86-0.96) P = 0.001	0.01 (0.00-0.22) P = 0.005	0.82 (0.72-0.94) P = 0.003

using TMA. For the HGS test, there were significant differences in all indices between participants with normal and low HGS scores on both univariate and multivariate analyses.

Discussion

In univariate and multivariate analyses, our study showed a consistent superiority in predicting physical performance or strength indicators of TMA indices using CT, compared

Table 5. Changes in muscle mass indices according to physical performance status. Data were expressed as mean $\pm$ standard deviations for univariate analysis and mean $\pm$ standard errors for multivariate analysis. Univariate analysis and multivariate analysis were performed using t-test and analysis of covariance, respectively. Multivariate analyses were adjusted for age, sex, and diabetes mellitus. Abbreviations: ASM, appendicular skeletal muscle mass; ASM/BW, appendicular skeletal muscle mass per body weight; ASM/Ht², appendicular skeletal muscle mass per height squared; TMA, thigh muscle area; TMA/BW, thigh muscle area per body weight; TMA/Ht², thigh muscle area per height squared; SPPB, short physical performance battery; GS, gait speed; HGS, hand grip strength

	SPPB			GS			HGS		
	Low	Normal	P-value	Low	Normal	P-value	Low	Normal	P-value
Univariate									
ASM	17.3 $\pm$ 4.2	17.5 $\pm$ 3.7	0.806	16.3 $\pm$ 3.1	19.4 $\pm$ 4.2	<0.001	15.1 $\pm$ 3.0	17.9 $\pm$ 3.8	0.008
ASM/BW	27.2 $\pm$ 4.4	28.5 $\pm$ 4.5	0.228	27.1 $\pm$ 4.2	29.9 $\pm$ 4.7	0.008	25.9 $\pm$ 3.7	28.6 $\pm$ 4.6	0.039
ASM/Ht ²	6.51 $\pm$ 0.99	6.61 $\pm$ 0.97	0.663	6.30 $\pm$ 0.82	7.11 $\pm$ 1.03	<0.001	5.93 $\pm$ 0.78	6.72 $\pm$ 0.96	0.004
TMA	90.7 $\pm$ 24.3	100.0 $\pm$ 22.4	0.094	89.4 $\pm$ 18.6	112.0 $\pm$ 24.1	<0.001	80.4 $\pm$ 12.5	100.9 $\pm$ 23.4	0.002
TMA/BW	1.42 $\pm$ 0.19	1.62 $\pm$ 0.25	0.001	1.48 $\pm$ 0.22	1.72 $\pm$ 0.24	<0.001	1.39 $\pm$ 0.15	1.60 $\pm$ 0.26	0.002
TMA/Ht ²	34.3 $\pm$ 6.5	37.9 $\pm$ 7.0	0.031	34.6 $\pm$ 6.2	41.2 $\pm$ 6.7	<0.001	31.9 $\pm$ 4.7	38.0 $\pm$ 7.0	0.002
Multivariate									
ASM	17.4 $\pm$ 0.5	17.4 $\pm$ 0.3	0.967	17.1 $\pm$ 0.4	18.0 $\pm$ 0.5	0.150	15.1 $\pm$ 0.6	17.9 $\pm$ 0.3	<0.001
ASM/BW	27.5 $\pm$ 0.8	28.3 $\pm$ 0.5	0.421	27.9 $\pm$ 0.5	28.5 $\pm$ 0.8	0.478	26.2 $\pm$ 1.0	28.5 $\pm$ 0.4	0.032
ASM/Ht ²	6.52 $\pm$ 0.16	6.61 $\pm$ 0.10	0.637	6.45 $\pm$ 0.11	6.83 $\pm$ 0.15	0.046	5.93 $\pm$ 0.19	6.72 $\pm$ 0.09	<0.001
TMA	91.9 $\pm$ 3.8	99.5 $\pm$ 2.4	0.105	92.9 $\pm$ 2.5	105.3 $\pm$ 3.5	0.007	81.5 $\pm$ 4.4	100.6 $\pm$ 2.0	<0.001
TMA/BW	1.45 $\pm$ 0.04	1.61 $\pm$ 0.03	0.003	1.51 $\pm$ 0.03	1.67 $\pm$ 0.04	0.004	1.41 $\pm$ 0.06	1.60 $\pm$ 0.03	0.003
TMA/Ht ²	34.5 $\pm$ 1.3	37.9 $\pm$ 0.9	0.045	35.2 $\pm$ 0.9	40.1 $\pm$ 1.2	0.002	32.2 $\pm$ 1.6	37.9 $\pm$ 0.8	0.002

with ASM indices using DEXA, in HD patients. These results suggest that TMA indices using CT would be valuable for predicting physical performance in HD patients.

HD patients have higher insulin resistance and prevalence of DM than the general population, resulting in changes in body composition [23-25]. In HD patients, various factors including inflammation lead to insulin resistance, which is associated with increased catabolism and decreased anabolism in the muscles [26, 27]. These lead to sarcopenia or protein-energy wasting. Previous studies showed that prevalence of protein-energy wasting was higher in HD patients with insulin resistance or DM than in those without insulin resistance or DM [26-28]. Fat mass is associated with development of insulin resistance or DM. However, the association between insulin resistance and change in fat mass is complex. Patients with insulin resistance or DM have decreased lipolysis and increased adipogenesis, but HD patients are prone to low energy intake and increased catabolism [26, 27, 29]. Although HD patients with adequate or high energy intake have increased fat mass, most HD patients have decreased or stable fat mass when on dialysis [30-32].

End-stage renal disease is associated with a rapid decline in muscle mass, which leads to high mortality and low quality of life [3, 4, 33, 34]. Therefore, early detection of decline in muscle mass and accurate measurement of muscle mass is important to improve the prognosis of dialysis patients. In non-dialysis patients, muscle mass is measured using various methods such as DEXA, bioimpedance analysis, CT, or creatinine-based equations. DEXA is a useful method for predicting muscle mass in the general population. However, compared with non-dialysis patients, HD patients are prone to overhydration [35]. Overhydration in HD patients can lead to overestimation of lean mass. Formica et al. investigated fat-free mass before and after ultrafiltration in HD patients. That study showed that gravimetric weight loss almost always consists of a decrease in lean mass [36]. Although measurements using DEXA are performed after an HD session, inappropriate dry weight is associated with inaccurate measurement of muscle mass. In addition, because lean mass measurement using DEXA is calculated after subtracting bone mass and fat mass from total mass, lean mass from DEXA includes skin and fat-free components of adipose tissue [37]. Levine et al. showed an approximately 6% to 13% overestimate for muscle mass using CT. This is associated with an inherent overestimation of muscle mass calculation using DEXA [37].

Although there are few studies regarding the comparison between DEXA and CT in the measurement of muscle mass according to volume overload, CT would be less likely overestimate muscle mass estimation compared with DEXA due to the division of total volume overload into subcutaneous tissue and intramuscular tissue. Kalima et al. investigated volume distribution in chronic venous insufficiency patients, clinically similar to overhydrated HD patients [38]. They showed that volume overload of HD patients was distributed into the subcutaneous tissue in 25% and into the intramuscular tissue in 65%. These results reveal that measurement using CT would reduce overestimation of muscle mass by volume overload compared with using DEXA. In addition, TMA using CT can exclude skin mass.

There are conflicting results regarding the association between muscle mass and physical performance. Although some studies have shown that the association between muscle mass and physical performance has a linear association, other studies have demonstrated a weak association between the two variables [8-11, 39]. These heterogeneous results indicate the need of studies to use specified population groups, for example various diseased populations or ethnicities. To the best of our knowledge, the present study is the first study that compares muscle mass measurements using CT and DEXA for predicting physical performance in HD patients. We also considered body size and analyzed data adjusted for body weight or height squared. Our study shows that muscle strength using HGS is associated with both TMA indices using CT and with ASM indices using DEXA. TMA measured the lower extremity only, but a decrease of muscle mass in pathologic conditions such as in HD patients is likely to develop in both upper and lower extremities at the same time. Therefore, muscle mass in the lower extremity would correlate highly with muscle mass or strength in the upper extremity in HD patients. In addition, our results reveal a higher association of TMA indices using CT with HGS than ASM indices using DEXA. TMA indices using CT were superior to ASM indices using DEXA for predicting physical performance. Better estimation of muscle mass using CT may be associated with superiority in the prediction of HGS or physical performance. Adjusted data was a better predictor of physical performance than raw muscle mass, but there was no difference in prediction of physical performance among adjusted variables.

The limitations of the present study should be considered. Our study was performed in a single center and included a small number of patients. We did not calculate sample size to confirm statistical significance. We included all participants who provide informed consent. In addition, our study did not include data regarding volume status and muscle mass using standardized reference methods (e.g., total body potassium or nitrogen). A large prospective study, including additional parameters such as volume status and reference measurement methods for muscle mass, is warranted to overcome these limitations.

In conclusion, the present study demonstrates that TMA indices using CT may be more valuable in predicting physical performance or strength in HD patients. Our results can provide information regarding optimal muscle mass measurements for predicting physical performance or strength, which may be more closely associated with improved quality of life or prognosis.

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Disclosure Statement

The authors declare that they have no Disclosure Statement.

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