Development and validation of equations for predicting appendicular skeletal muscle mass in male patients with head and neck cancer with normal hydration status

Running title: Prediction equations for appendicular skeletal muscle mass

Miyu Kubo R.D., M.Sc.[a]; Sonoko Yasui-Yamada R.D., Ph.D.[a,*]; Haruka Hayashi R.D., M.Sc.[a]; Midori Kitao R.D., M.Sc.[a]; Kyoko Wada R.D., M.Sc.[a]; Ayaka Yamanaka R.D., M.Sc.[a]; Nao Ohmae R.D.[a]; Momoyo Matsuoka M.D.[b]; Seiichiro Kamimura M.D., Ph.D.[b]; Aki Shimada M.D., Ph.D.[b]; Yoshiaki Kitamura M.D., Ph.D.[b]; Yasuhiro Hamada M.D., Ph.D.[a]

[a]Department of Therapeutic Nutrition, Institute of Biomedical Sciences, Tokushima University Graduate School, 3-18-15, Tokushima 770-8503, Japan

[b]Department of Otolaryngology, Institute of Biomedical Sciences, Tokushima University Graduate School, 3-18-15, Tokushima 770-8503, Japan

*Corresponding author: Sonoko Yasui-Yamada

Department of Therapeutic Nutrition, Institute of Biomedical Sciences, Tokushima University Graduate School, 3-18-15 Kuramoto-Cho, Tokushima 770-8503, Japan. Tel.: +81-88-633-9124; Fax: +81-88-633-9574. E-mail: yamada.sonoko@tokushima-u.ac.jp

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Author Contributions

Miyu Kubo: Data curation, formal analysis, investigation, visualization, and writing-original draft.

Sonoko Yasui-Yamada: Conceptualization, data curation, formal analysis, funding acquisition, investigation, project administration, supervision, visualization, and writing-original draft.

Haruka Hayashi: Data curation and investigation.

Midori Kitao: Data curation and investigation.

Kyoko Wada: Data curation and investigation.

Ayaka Yamanaka: Data curation and investigation.

Nao Ohmae: Data curation and investigation.

Momoyo Matsuoka: Investigation and resources.

Seiichiro Kamimura: Investigation and resources.

Aki Shimada: Investigation and resources.

Yoshiaki Kitamura: Resources and writing - review & editing.

Yasuhiro Hamada: Writing - review & editing.

Conflict of Interest

The authors declare no conflict of interest.

Abstract

Objective: Muscle mass is typically assessed by abdominal computed tomography, magnetic resonance imaging, and dual-energy X-ray absorptiometry. However, these tests are not routinely performed in patients with head and neck cancer (HNC), making sarcopenia assessment difficult. This study aimed to develop and validate equations for predicting appendicular skeletal muscle (ASM) from data obtained in daily medical practice, with bioelectrical impedance analysis (BIA)-measured ASM (BIA-ASM) as a reference.

Research Methods & Procedures: This cross-sectional study included 103 male patients with HNC and randomly divided them into development and validation groups. The prediction equations for BIA-ASM were developed by multiple regression analysis and validated by Bland–Altman analyses. The estimated skeletal muscle mass index (eSMI) was also statistically evaluated to discriminate the cutoff value for BIA-measured SMI according to Asian Working Groups for Sarcopenia.

Results: Two practical equations, which include 24-hour urinary creatinine excretion volume (24hUCrV), handgrip strength (HGS), body weight (BW), and body height (BHt), were developed: ASM (kg) = −39.46 + (3.557 × 24hUCrV[g]) + (0.08872 × HGS[kg]) + (0.1263 × BW[kg]) + (0.2661 × BHt[cm]) if available for 24hUCrV (adjusted R^2 = 0.8905), and ASM (kg) = −42.60 + (0.1643 × HGS[kg]) + (0.1589 × BW[kg]) + (0.2807 × BHt[cm]) if not (adjusted R^2 = 0.8589). ASM estimated by these two equations showed a significantly strong correlation with BIA-ASM (R > 0.900). Bland–Altman analyses showed a good agreement, and eSMI accuracy was high (>80%) in both equations.

Conclusions: These two equations are a valid option for estimating ASM and diagnosing sarcopenia in patients with HNC in all facilities without special equipment.

Key Words: Appendicular skeletal muscle mass, Bioelectrical impedance analysis, Estimation equation, Head and neck cancer, Sarcopenia, Skeletal muscle mass index

27

28 **Abbreviations**[1]

29

[1] ASM, appendicular skeletal muscle mass; AWGS, Asian Working Group for Sarcopenia; BIA, bioelectrical impedance analysis; BIA-ASM, bioelectrical impedance analysis-measured appendicular skeletal muscle mass; BIA-SMI, bioelectrical impedance analysis-measured skeletal muscle mass index; BHt, body height; BMI, body mass index; BW, body weight; CRT, chemoradiotherapy; CT, computed tomography; CCr, creatinine clearance; DXA, dual-energy X-ray absorptiometry; ECW, extracellular water; Eq, equation; eASM, estimated appendicular skeletal muscle mass; eSMI, estimated skeletal muscle mass index; HGS, handgrip strength; HNC, head and neck cancer; MRI, magnetic resonance imaging; NPV, negative predictive value; PPV, positive predictive value; SMM, skeletal muscle mass; SMI, skeletal muscle mass index; SD, standard deviation; SE, standard error; C3, third cervical; L3, third lumbar; TBW, total body water; 24hUCrV, 24-hour urinary creatinine excretion volume; VIF, variance inflation factor.

Introduction

Sarcopenia is common among patients with head and neck cancer (HNC) (reported global prevalence rates: 24.4%–42.0%) [1,2]. Low skeletal muscle mass (SMM) prior to treatment is associated with worse outcomes, such as increased chemotherapy toxicity [3,4], early termination of planned treatment [5,6], and poor survival [5,7,8]. Therefore, SMM must be assessed before treatment. Dual-energy X-ray absorptiometry (DXA), computed tomography (CT), magnetic resonance imaging (MRI), and bioelectrical impedance analysis (BIA) can be used to evaluate SMM in patients with HNC [9]. However, these tools have limitations in terms of invasiveness, cost, and convenience in day-to-day practice [9]. Although DXA is the gold standard for determining body composition, its routine use for SMM assessment can be difficult because of its cost and radiation exposure in patients with HNC. MRI and CT are also gold standards for muscle mass assessment [10, 11]. However, these tools are not commonly used in HNC management. CT images of the third lumbar (L3) are usually performed for diagnostic purpose before treatment, especially in abdominal cancer [12], and the cross-sectional area of L3 highly correlates with the whole-body muscle mass [13]. Unfortunately, CT imaging of L3 is not routinely performed for HNC management. Thus, third cervical (C3) CT imaging, which is routinely performed, has recently been reported as an alternative method [14]. However, the validity of C3 imaging for assessing the whole-body SMM remains uncertain. Moreover, the cutoff points for low muscle mass are not yet well defined for MRI and CT. In sarcopenia diagnosis, the European Working Group on Sarcopenia in Older People and Asian Working Group for Sarcopenia (AWGS) have suggested the cutoff values for BIA-measured skeletal muscle mass index (BIA-SMI) [10,15]. SMI is the index of appendicular skeletal muscle mass (ASM) adjusted by body height (BHt). BIA has been widely used because it is simple, noninvasive, and relatively inexpensive than other techniques such as DXA, CT, and MRI. However, BIA is not available at all hospitals because it is not inexpensive enough to be purchased by all facilities.

Therefore, we examined the possibility of estimating ASM from data obtained in daily medical

practice that could be applicable in any hospital. We focused on 24-hour urinary creatinine excretion volume (24hUCrV), handgrip strength (HGS), and anthropometries such as body weight (BW) and BHt. The 24hUCrV, which is the classical method for assessing SMM, can be easily obtained by 24-hour urine collection test, which is often scheduled before chemotherapy to assess renal function and determine anticancer drug doses for HNC treatment. HGS and anthropometric measurements are applicable to all hospitals conducting HNC treatment because they are easy, simple, and inexpensive. In this study, we aimed to develop and validate equations for predicting ASM from data obtained in daily medical practice, with BIA-measured ASM (BIA-ASM) used as a reference.

Materials & Methods

Patients and study design

This was a cross-sectional study using data from our previous study [16] on patients with HNC treated with chemotherapy or chemoradiotherapy (CRT) at the Department of Otolaryngology in Tokushima University Hospital, Japan, between January 2015 and July 2021. In total, 155 patients who had pretreatment data on BIA, 24hUCrV, HGS, and anthropometric measurements were enrolled. However, we excluded 33 females because patients with HNC were predominantly male and we could not gather enough number of female patients. We also excluded 19 patients with BIA-derived extracellular water/total body water ratio (ECW/TBW) ≥ 0.400 because the accuracy of measuring SMM by BIA methods depends on the hydration status [17,18]. Ultimately, 103 patients were analyzed. This study conformed to the guidelines of the Declaration of Helsinki and obtained approval from the ethical committee of Tokushima University Hospital (No. 2161-3). All patients provided informed consent to participate in this study.

Data collection

We collected data on age, sex, BHt, cancer site, cancer stage, 24-hour urine collection data, serum creatinine level, and dietary intake from electronic medical records. Before chemotherapy or CRT, our hospital performed 24-hour urine collection for 3 days to assess renal function and determine anticancer drug doses. We used these data to calculate creatinine clearance (CCr) and 24hUCrV. CCr was determined using the Cockcroft–Gault formula described in a previous report [19]. To calculate 24hUCrV, we used the following equation: 24hUCrV (g) = urine volume (L) × urinary creatinine concentration (g/L). For accuracy, 3-day data of 24hUCrV were averaged. To consider the effect of protein intake during the urine collection period on 24hUCrV, we calculated the protein intake during 24-hour urine collection. Data on food intake percentage were collected from the electronic medical records, and the amount of meals provided by the hospital was multiplied by the food intake percentage. In addition, we asked patients about the amount of food

93 they ate other than the hospital meals and added it.

94

95 *Direct segmental multifrequency BIA*

96 While wearing light clothing with no shoes, patients were weighed for BW measurement using a
97 scale (TANITA, Tokyo, Japan) to the nearest 0.1 kg. In addition, SMM was assessed via direct
98 segmental multifrequency BIA using InBodyS10® (InBody Co., Ltd., Seoul, Korea). Patients were
99 required to fast for at least 4 hours before SMM measurement, which was performed in the supine
100 position within the 24-hour urine collection period. InBodyS10® measures impedance with six
101 frequencies (1, 5, 50, 250, 500, and 1,000 kHz) and reactance (Xc) with three frequencies (5, 50,
102 and 250 kHz) at each of the five segments (right arm, left arm, trunk, right leg, and left leg), using
103 an eight-point tactile electrode. Moreover, body composition parameters, including SMM, were
104 calculated using formulas in the inner software based on BHt and 30 impedances measured using
105 six frequencies. InBodyS10® automatically displays SMM, ASM, and ECW/TBW. We calculated
106 body mass index (BMI) as BW/BHt^2 (kg/m^2) and SMI as ASM/BHt^2 (kg/m^2). We used the cutoff
107 point of low SMI according to the AWGS, that is, 7.0 kg/m^2 in males [15].

108

109 *HGS*

110 Using a dynamometer (Takei Scientific Instruments, Niigata, Japan), we measured patients' HGS
111 in both hands while they were standing. These tests were repeated twice for each hand, and the
112 highest value for each hand was included in the overall mean.

113

114 *Statistical analysis*

115 Of the 103 participants, 52 were randomly allocated as the development group to establish the
116 equation used for predicting BIA-ASM. The 51 remaining participants were the validation group.

117 In the development group, we used Spearman's correlation coefficient to determine the
118 correlation between BIA-ASM and indexes such as age, BHt, BW, HGS, 24hUCrV, CCr, serum

creatinine level, and protein intake during the 24-hour urine collection period. Next, multiple regression analysis was performed using variables that showed a strong or moderate correlation with BIA-ASM as candidate independent variables predicting BIA-ASM. Variables were entered in order of their Spearman's correlation coefficients. Additionally, the coefficient of determination (adjusted R^2) and standard error (SE) were used to compare different models and determine the most accurate model for prediction. The estimated formulas with adjusted $R^2 \geq 0.8$ were employed for further investigation.

To validate the estimated ASM (eASM), we determined the correlation between BIA-ASM and eASM by using Spearman's correlation coefficient in the development group, validation group, and all participants. We calculated the estimated SMI (eSMI) as eASM/BHt^2 (kg/m^2). Spearman's correlation coefficient was also used to test the correlation between eSMI and BIA-SMI. Furthermore, the eSMI's sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy to discriminate SMI < 7.0 kg/m^2 were calculated. The Kappa coefficient was also calculated to evaluate the consistency between BIA-SMI and eSMI. The mean difference between BIA-ASM and eASM was tested using the paired t-test. The accuracy of eASM was also evaluated by Bland–Altman analysis of the BIA-ASM and eASM.

Non-normally distributed continuous variables are expressed as medians and interquartile ranges. We compared two groups (development and validation groups) by using Wilcoxon's rank-sum test for the continuous variables and chi-squared test for the categorical variables. Statistical data were analyzed using the JMP version 13.0 software (SAS Institute, Cary, NC, USA). A P-value < 0.05 was considered statistically significant. The sample size was calculated using the G-Power software. For development analysis, after factoring an alpha rate of 5%, a power of 80%, a large effect size ($f^2 = 0.35$), and four independent variables, a minimum sample size of 40 was required for multiple regression analysis. For validation analysis, we considered that the sample size was appropriate because 51 was above the minimum sample size calculated by G-Power with a 5% alpha rate, 80% power, and moderate effect size (d = 0.5) for a paired t-test.

Results

Patient characteristics

Overall, 103 patients were analyzed, with 52 in the development group and 51 in the validation group. Table 1 shows patients' characteristics and comparison of data between the two groups. None of the variables differed significantly between such groups.

Table 1. Patient characteristics

	All participants n = 103	Development group n = 52	Validation group n = 51	P-value
Age (years)	67 (61–71)	67 (63–71)	67 (59–71)	0.468
Cancer site				0.726
Nasopharynx	9 (8.7)	5 (9.6)	4 (7.8)	
Oropharynx	19 (18.4)	10 (19.2)	9 (17.6)	
Hypopharynx	27 (26.2)	16 (30.8)	11 (21.6)	
Larynx	21 (20.4)	10 (19.2)	11 (21.6)	
Others	27 (26.2)	11 (21.2)	16 (31.4)	
Cancer stage				0.146
I	2 (1.9)	2 (3.8)	0 (0.0)	
II	17 (16.5)	8 (15.4)	9 (17.6)	
III	20 (19.4)	14 (26.9)	6 (11.8)	
IV	59 (57.3)	25 (48.1)	34 (66.7)	
Unknown	5 (4.9)	3 (5.8)	2 (3.9)	
BHt (cm)	166.9 (162.4–170.5)	166.8 (162.4–169.8)	167.7 (161.0–172.0)	0.553
BW (kg)	60.5 (53.9–68.8)	60.8 (54.5–67.4)	60.0 (53.8–70.8)	0.976
BMI (kg/m^2)	21.7 (19.8–24.4)	21.8 (19.8–24.6)	21.5 (20.1–24.1)	0.971

24hUCrV (g)	1.07 (0.87–1.28)	1.07 (0.93–1.23)	1.06 (0.83–1.29)	0.623
Serum creatinine (mg/dL)	0.85 (0.75–0.96)	0.87 (0.78–0.97)	0.83 (0.70–0.96)	0.159
CCr (mL/min)	95.2 (75.8–107.1)	95.5 (76.0–105.6)	94.9 (75.8–111.5)	0.767
Protein intakes during 24-hour urine collection (g)	64.4 (52.6–70.5)	66.1 (56.2–70.5)	60.7 (47.0–70.1)	0.387
HGS (kg)	33.9 (29.2–38.0)	33.4 (29.6–37.8)	33.9 (28.7–38.9)	0.974
BIA-ASM (kg)	19.3 (16.8–21.7)	19.1 (17.3–21.2)	19.6 (16.7–21.9)	0.861
BIA-SMI (kg/m^2)	7.03 (6.30–7.68)	7.01 (6.27–7.68)	7.03 (6.30–7.68)	1.000
BIA-SMI (kg/m^2) as categorical data				0.921
<7.0	51 (49.5)	26 (50.0)	25 (49.0)	
≥7.0	52 (50.5)	26 (50.0)	26 (51.0)	

BHt, body height; BIA-ASM, bioelectrical impedance analysis-measured appendicular skeletal muscle mass; BIA-SMI, bioelectrical impedance analysis-measured skeletal muscle mass index; BMI, body mass index; BW, body weight; CCr, creatinine clearance; HGS, handgrip strength; 24hUCrV, 24-hour urinary creatinine excretion volume.

Development of new equations to estimate BIA-ASM

Table 2 shows the correlations between BIA-ASM and other variables in the development group. In the correlation with BIA-ASM, we noted a significantly weak negative correlation in age, a significantly strong positive correlation in 24hUCrV and HGS, a significantly moderate positive correlation in BW and BHt, and a significantly weak positive correlation in CCr. Serum creatinine and protein intake during 24-hour urine collection did not show any significant correlation with

164 BIA-ASM.

165

166 Table 2. Correlation coefficients between BIA-ASM and other variables in the development group

Variables	Spearman's correlation coefficient	P-value
Age (years)	−0.3154	**0.023**
BHt (cm)	0.6488	**<0.001**
BW (kg)	0.6785	**<0.001**
HGS (kg)	0.7284	**<0.001**
24hUCrV (g)	0.7639	**<0.001**
Serum creatinine (mg/dL)	0.1917	0.052
CCr (mL/min)	0.3129	**0.024**
Protein intake during 24-hour urine collection (g)	0.2218	0.114

167 BHt, body height; BIA-ASM, bioelectrical impedance analysis-measured appendicular skeletal
168 muscle mass; BW, body weight; CCr, creatinine clearance; HGS, handgrip strength; 24hUCrV, 24-
169 hour urinary creatinine excretion volume. $P < 0.05$ is shown in bold.

170

171 In the regression model, we used variables that had a strong or moderate correlation with BIA-
172 ASM according to the results shown in Table 2. Table 3 shows the several prediction equations
173 derived by using 24hUCrV, HGS, BW, and BHt in the descending order of correlation coefficient.
174 Among equations 1–4, Equation 4 was most applicable to estimate BIA-ASM (adjusted R^2 =
175 0.8905, $P < 0.001$). Considering that 24hUCrV is not always measured in all facilities, we created a
176 prediction formula that excluded 24hUCrV for easy use in the clinical setting (Equation 5).
177 Equation 5 also showed high adjusted R^2 (adjusted $R^2 = 0.8589$, $P < 0.001$). All variables of
178 equations 4 and 5 were significant, with no multicollinearity. Finally, we obtained the following two
179 formulas (Equation 4, which was more accurate, and Equation 5, which was easier to use

clinically), as shown below:

Equation 4

eASM (kg) = −39.46 + (3.557 × 24hUCrV[g]) + (0.08872 × HGS[kg]) + (0.1263 × BW[kg]) + (0.2661 × BHt[cm])

Equation 5

eASM (kg) = −42.60 + (0.1643 × HGS[kg]) + (0.1589 × BW[kg]) + (0.2807 × BHt[cm])

Table 3. Prediction equations to estimate BIA-ASM in the development group

		Variables						
		Intercept	24hUCrV (g)	HGS (kg)	BW (kg)	BHt (cm)	Adjusted R^2	P-value
Eq1	β	8.441	10.12				0.5783	**<0.001**
	SE	1.333	1.201					
	VIF		1					
Eq2	β	5.170	7.554	0.1780			0.6198	**<0.001**
	SE	1.805	1.522	0.07006				
	VIF		1.782	1.782				
Eq3	β	0.5269	4.439	0.1525	0.1453		0.7400	**<0.001**
	SE	1.772	1.412	0.05817	0.02987			
	VIF		2.243	1.797	1.584			
Eq4	β	−39.46	3.557	0.08872	0.1263	0.2661	0.8905	**<0.001**
	SE	5.020	0.9230	0.03855	0.01952	0.03252		
	VIF		2.274	1.873	1.607	1.264		
Eq5	β	−42.60		0.1643	0.1589	0.2807	0.8589	**<0.001**
	SE	5.623		0.03767	0.01997	0.03666		
	VIF			1.388	1.305	1.247		

BHt, body height; BIA-ASM, bioelectrical impedance analysis-measured appendicular skeletal

muscle mass; BW, body weight; Eq, equation; HGS, handgrip strength; SE, standard error; 24hUCrV, 24-hour urinary creatinine excretion volume; VIF, variance inflation factor. $P < 0.05$ is shown in bold.

Validation of new equations

Figure 1 presents the correlation between BIA-ASM and eASM. ASM estimated by equations 4 and 5 showed a significantly strong correlation ($R > 0.9$) with BIA-ASM in the development group, validation group, and all participants. Figure 2 shows the correlation between BIA-SMI and eSMI. SMI estimated by equations 4 and 5 also showed a significantly strong correlation with BIA-SMI in the development group, validation group, and all participants. Table 4 summarizes the statistical evaluation of eSMI by both equations to discriminate the cutoff points of low SMI according to the AWGS (SMI < 7.0 kg/m^2). For both equations 4 and 5, the sensitivity, specificity, PPV, NPV, and accuracy were higher than 80% in the development group, validation group, and all participants. Kappa coefficients showed substantial agreement (>0.60) between BIA-SMI and eSMI in both equations 4 and 5. Moreover, Figure 3 shows the Bland–Altman plot of BIA-ASM and eASM by equations 4 and 5. The mean differences between BIA-ASM and eASM were not significant. For example, the result of equation 4 in the development group (upper left of Figure 3) shows a mean difference of −0.004, implying that the difference between the measured and estimated values by equation 4 was almost zero, suggesting a low bias. All results showed a good agreement between BIA-ASM and eASM values.

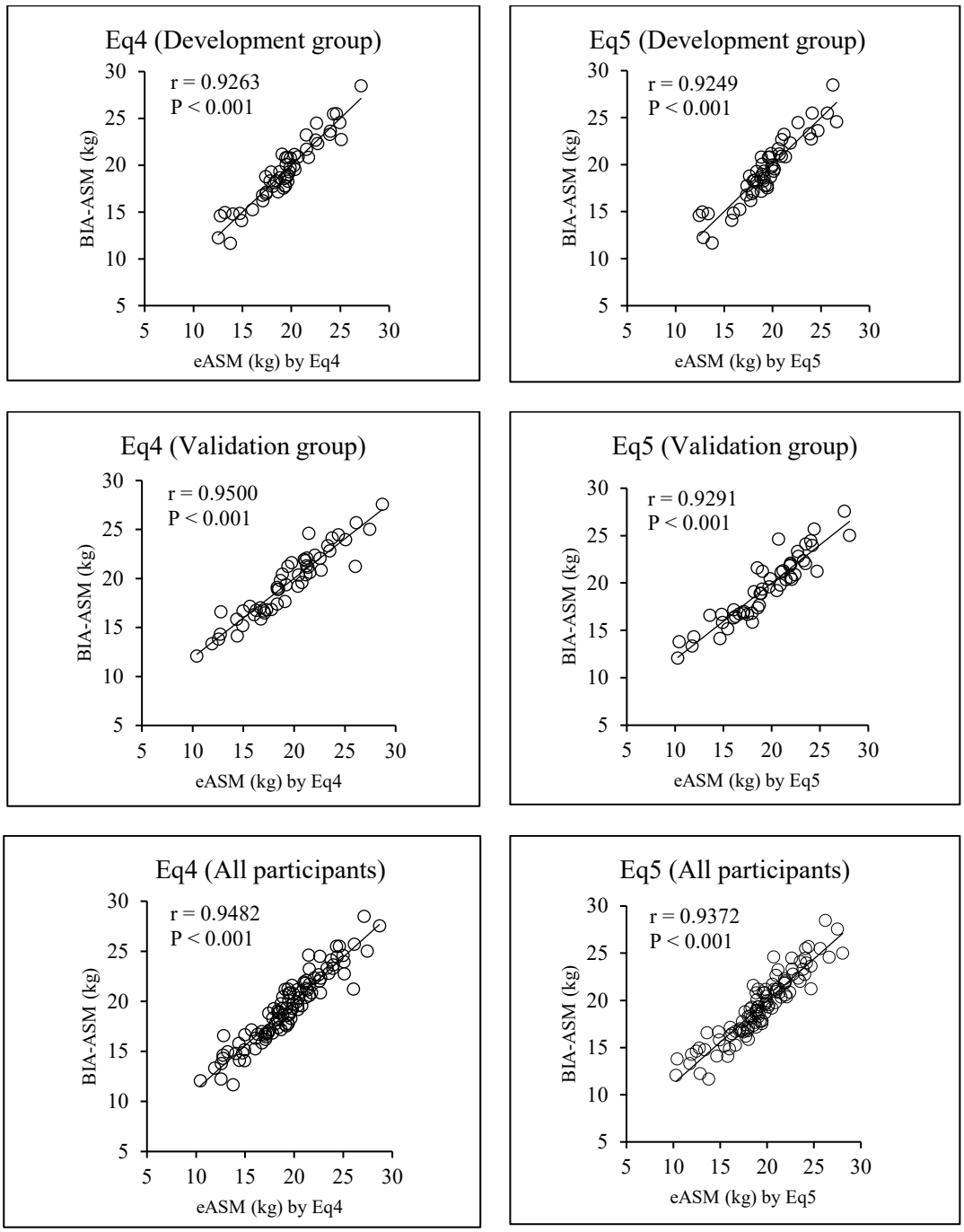

Figure 1. Correlation coefficients between BIA-ASM and eASM by equations 4 and 5 in the development group (above), validation group (middle), and all participants (below).
BIA-ASM, bioelectrical impedance analysis-measured appendicular skeletal muscle mass; Eq, equation; eASM, estimated appendicular skeletal muscle mass.

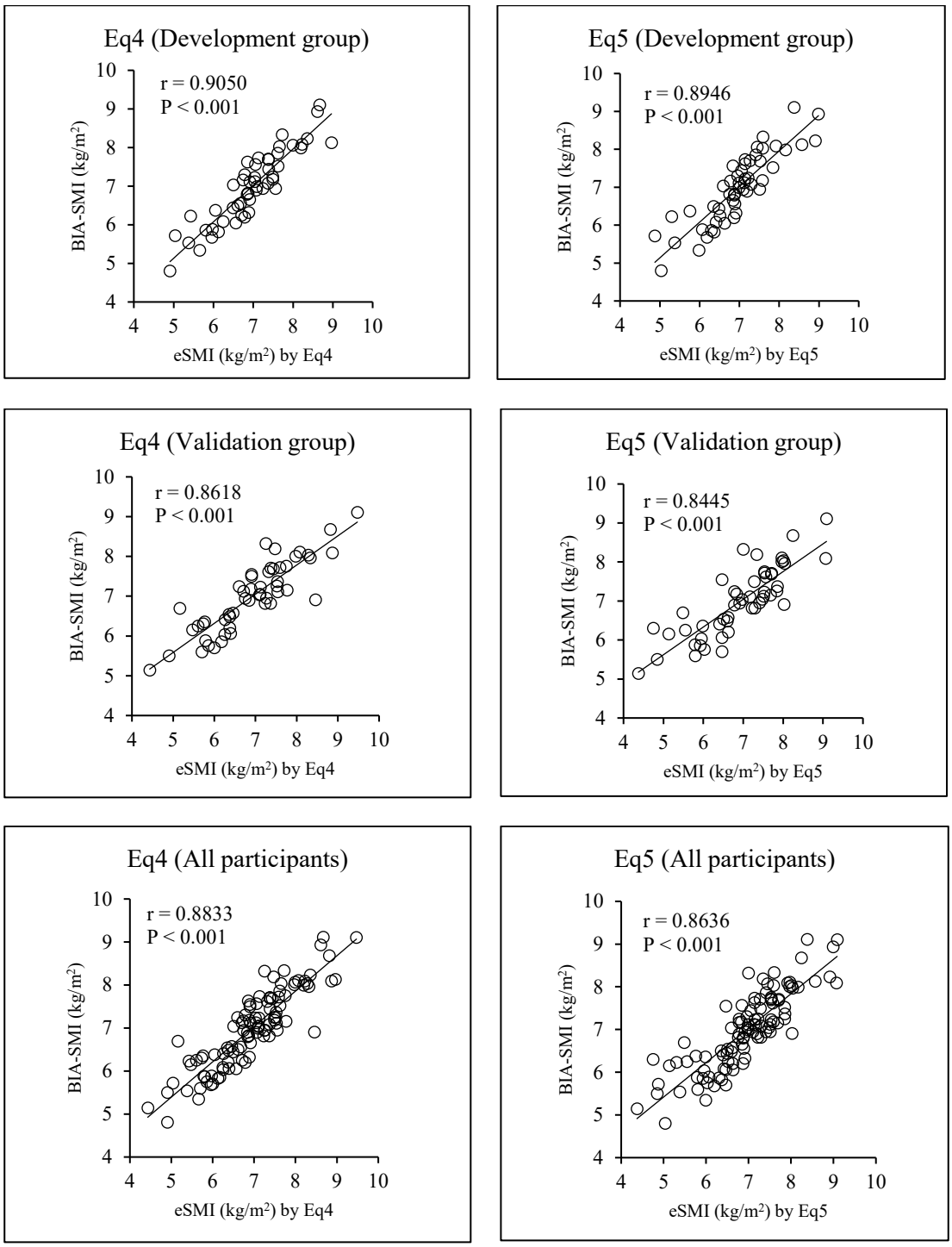

Figure 2. Correlation coefficients between BIA-SMI and eSMI by equations 4 and 5 in the development group (above), validation group (middle), and all participants (below). BIA-SMI, bioelectrical impedance analysis-measured skeletal muscle mass index; Eq, equation; eSMI, estimated skeletal muscle mass index.

Table 4. Statistical evaluations of eSMI by equations 4 and 5 to discriminate the cutoff value for

the BIA-SMI according to AWGS*

		Development group		Validation group		All participants	
		BIA-SMI		BIA-SMI		BIA-SMI	
		Low	Normal	Low	Normal	Low	Normal
eSMI by Eq4	Low	22	5	21	5	43	10
	Normal	4	21	4	21	8	42
	Sensitivity	85%		84%		84%	
	Specificity	81%		81%		81%	
	PPV	81%		81%		81%	
	NPV	84%		84%		84%	
	Accuracy	83%		82%		83%	
	Prevalence	50%		49%		50%	
	Kappa	0.65		0.65		0.65	
		Low	Normal	Low	Normal	Low	Normal
eSMI by Eq5	Low	23	5	21	5	44	10
	Normal	3	21	4	21	7	42
	Sensitivity	88%		84%		86%	
	Specificity	81%		81%		81%	
	PPV	82%		81%		81%	
	NPV	88%		84%		86%	
	Accuracy	85%		82%		83%	
	Prevalence	50%		49%		50%	
	Kappa	0.69		0.65		0.67	

AWGS, Asian Working Group for Sarcopenia; BIA-SMI, bioelectrical impedance analysis-measured skeletal muscle mass index; Eq, equation; eSMI, estimated skeletal muscle mass index;

NPV, negative predictive value; PPV, positive predictive value. *SMI < 7.0 kg/m^2 in males.

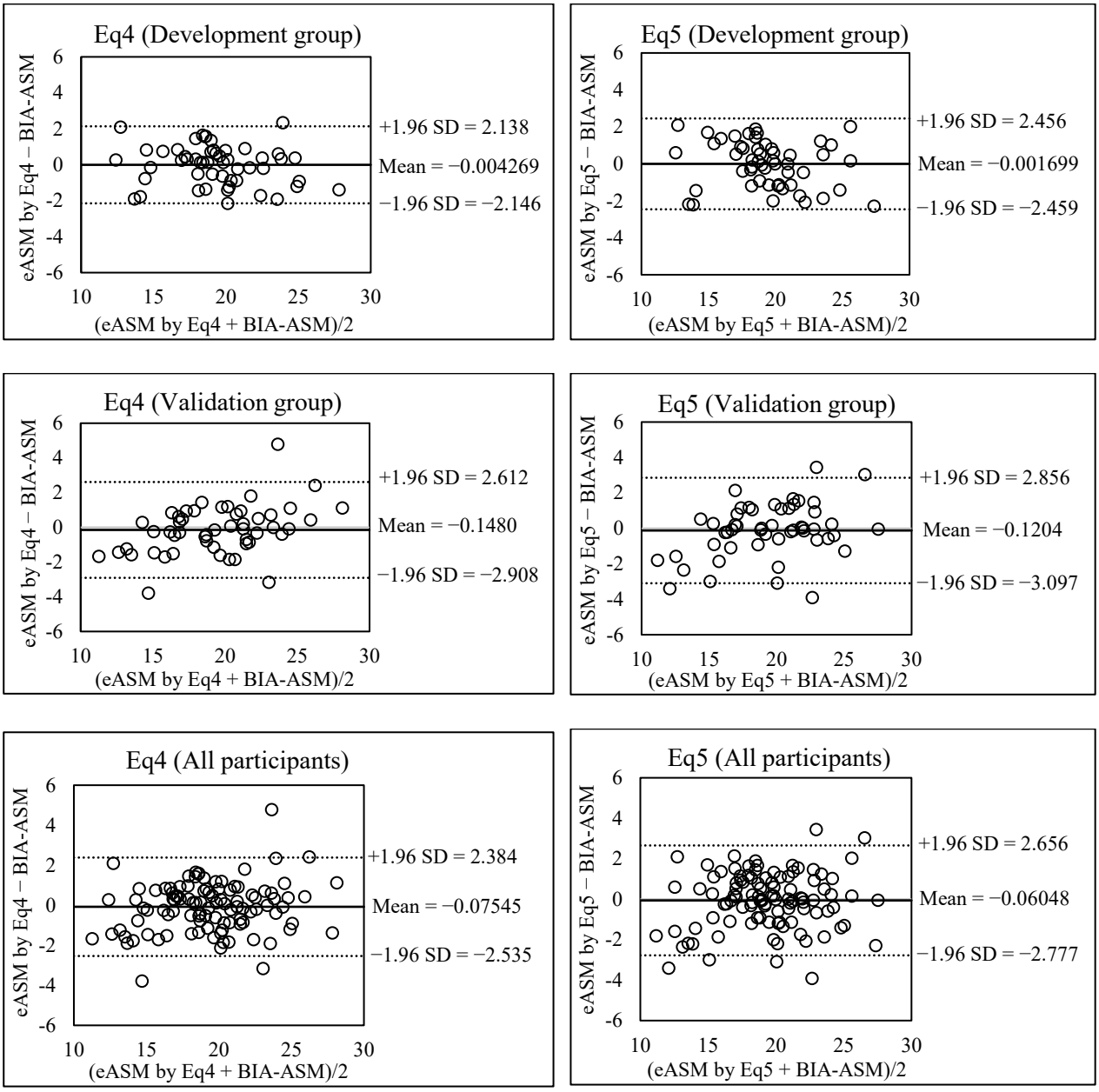

Figure 3. Bland–Altman analysis of measured BIA-ASM and eASM by equations 4 and 5 in the development group (above), validation group (middle), and all participants (below).
BIA-ASM, bioelectrical impedance analysis-measured appendicular skeletal muscle mass; Eq, equation; eASM, estimated appendicular skeletal muscle mass; SD, standard deviation.

Discussion

This study developed and validated two simple equations for predicting BIA-ASM, using the data obtained in daily medical practice that would be applicable in patients with HNC. Equation 4, which uses 24hUCrV, HGS, BW, and BHt, is more accurate, and Equation 5, which uses HGS, BW, and BHt, is the simpler one. The validation group confirmed a strong correlation between the BIA-ASM and eASM calculated by these two equations; BIA-SMI and eSMI also showed a strong correlation. In addition, the accuracy rate of using eSMI to discriminate the sarcopenia cutoff value < 7.0 kg/m^2 was high, indicating that these estimation equations can be clinically used for diagnosing sarcopenia.

In this study, eASM by equations 4 and 5 strongly correlated with BIA-ASM in patients with HNC. Other studies have reported estimating equations for ASM using sex, BW, waist circumference, calf circumference, and BHt in healthy participants [20] and TBW, BW, sex, and age in patients undergoing hemodialysis [21]. Although these previous studies have large sample sizes and appropriate methodologies, the former study recruited healthy volunteers, implying a population with a small number of sarcopenia; thus, applying their equation directly to patients with HNC with a high percentage of sarcopenia would be unsuitable. In the latter study, patients undergoing hemodialysis were included; this type of patients tends to be overhydrated, indicating a different population from patients with HNC. Additionally, the use of a BIA-measured variable as a predictor of ASM is not applicable in several facilities. Therefore, the present study focused on 24hUCrV, which could be obtained from routine practice in patients with HNC. The 24hUCrV is a classical method used for evaluating muscle mass and has shown a strong correlation ($R = 0.92$) with SMM by CT [22]. However, several factors, such as renal function and protein intake, should also be considered. In fact, although data were not shown, 24hUCrV moderate correlated with CCr ($R = 0.59$) and weakly correlated with protein intake ($R = 0.35$). Table 1 shows that serum creatinine level and CCr were normal or mildly impaired in our participants, suggesting that renal function slightly influences 24hUCrV. Regarding the effect of protein intake, 24hUCrV reportedly

increases by 13% after ingestion of a meal containing cooked meat (225 g) in healthy people [23]. According to a Japanese report, a meat diet intake of <100 g in healthy participants has no significant effect on 24hUCrV [24]. The daily amount of meat provided in the hospital diet is <100 g, indicating a slight influence on 24hUCrV. Thus, 24hUCrV can be used to estimate whole-body SMM in this study. HGS also positively correlates with lean body mass in older Asian adults [25], supporting our results that incorporated HGS into the equation for estimating muscle mass.

Furthermore, when using eSMI, the accuracy rate was high to discriminate the cutoff value < 7.0 kg/m^2. Sarcopenia reduces the strength of swallowing-related muscles, leading to impaired swallowing function (i.e., sarcopenic dysphagia) [26]. Sarcopenia is also associated with poor overall survival in patients with HNC [27]. Therefore, sarcopenia assessment has a potential prognostic value in patients with HNC, and it could be used to tailor treatment [28]. Through early identification of sarcopenia with low tolerance to treatment, we can also modify the treatment early [29]. While BIA is recommended when available because of its relatively low cost and simplicity, we believe that our estimation formulas will be useful for estimating muscle mass and diagnosing sarcopenia in patients with HNC in all facilities that do not have special equipment.

The strength of this study is that the estimation equations can be used at any facility and by anyone without special training, because they were developed using data that are easily obtained from routine medical care without the need for special equipment or techniques. However, this study had some limitations. First, the study has a small sample size, and it was conducted in a single center. Larger multicenter studies are required to confirm whether the equations retain its validity when applied in other populations. Second, this study excluded patients with ECW/TBW ≥ 0.400 because the accuracy of BIA-ASM depends on hydration status; therefore, the estimation equations were developed and validated in only populations with normal hydration status. Thus, the validity of this regression equation in a population with ECW/TBW ≥ 0.4 is unknown. Third, given that patients with HNC are predominantly male, only males were included in this study. Further research is required to develop and validate estimation formulas for females.

Conclusion

This study established and validated the following simple equations for ASM estimation: if available for 24hUCrV, ASM (kg) = −39.46 + (3.557 × 24hUCrV[g]) + (0.08872 × HGS[kg]) + (0.1263 × BW[kg]) + (0.2661 × BHt[cm]), and if not available for 24hUCrV, ASM (kg) = −42.60 + (0.1643 × HGS[kg]) + (0.1589 × BW[kg]) + (0.2807 × BHt[cm]). These formulas may be useful for estimating muscle mass and diagnosing sarcopenia in patients with HNC in all facilities without the requirement of special equipment. However, the validity of these equations still needs to be confirmed in other populations.

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