Estimating fat-free mass in overweight and obese older adults using bioelectrical impedance analysis

Designing an equation that accurately estimates the fat-free mass in overweight and obese older adults (55+) based on measured resistance with bioelectrical impedance analysis

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Preface

This article was commissioned by the Nutrition and Exercise Research Group of the Amsterdam University of Applied Sciences and Nutritional Assessment. In this paper, a new equation is developed to estimate the FFM of overweight and obese older adults. In addition, this equation was evaluated together with current equations for estimating FFM in adults.

In addition to writing the article, we both participated in the Prointens research from September 2021 to January 2022. This research was conducted in 5 hospitals in Amsterdam and in patients their homes.

The data used to develop the equation came from 3 different studies conducted by the Nutrition and Exercise Research Group, at the Amsterdam Nutrition Assessment Centre (ANAC).

We would both like to thank our lecturer Amely Verreijen for her guidance and valuable advice. In addition, we would like to thank Carliene van Dronkelaar for her guidance during the ProIntens research. And finally, we would like to thank Hinke Kruizenga for making the assignment possible and for her valuable advice.

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Gijs Meijer and Simone van Beek

Table of contents

Abstract 6
Introduction 7
Methods 8
Subjects 8
Measurements 8
BIA and BodPod 8
Current equations 9
Statistical analyses 9
Results 11
Subjects 11
New equation 11
Validity of current equations compared to new equation 11
Cross-validation 17
Discussion 18
Conclusion 20
Recommendations 21
References 22
Appendix A 24
Appendix B 25

Abstract

Background & aims: Overweight and obesity can cause several health risks, and weight loss can help reduce them. However, weight loss in older adults is associated with loss of muscle mass and bone mineral density. To prevent this, it is important to monitor changes in FFM. Bioelectrical impedance analysis (BIA) is mostly used in dietetic practice to measure body composition. The use of BIA requires an equation to estimate the FMM. Since there is no equation for overweight and obese older adults, this study aimed to develop an equation to estimate the FFM for this population.

Methods: Data from 275 overweight and obese older adults (55+) were used to develop a new equation for estimating FFM using resistance data of BIA measurements with air displacement plethysmography (ADP) as a reference. Baseline data of 3 lifestyle interventions at the Amsterdam Nutritional Assessment Center (The Netherlands) were used. Multiple linear regression analysis was used to develop a predictive model. The equation was evaluated by analyzing the percentage under-, accurate and overestimates, bias, absolute mean error, SEE, and limits of agreement.

Results: A new equation was developed: Predicted FFM (kg) = -21.649 + (7.075 * Sex) – (0.100 * Age) + (0.484 * Height in cm) + (0.164 * Body weight) – (0.038 * Resistance). The percentage of accurate predictions of the new equation was low, at 34%, but compared to the current equations this was the highest percentage. The bias of the FFM with the new equation compared to ADP, was 0.3 ± 3.8 kg, and the mean absolute error was 3.1 ± 2.3 kg. This shows that the new equation can accurately measure FFM in groups, but per person the FMM can differ from the measured FFM by 3.1 kg.

Conclusion: In conclusion, the newly developed Beijer_hva equation does not accurately estimate the FFM. For individual estimation of the FFM the Beijer_hva equation is not suitable, but the equation can be used for estimating FFM in groups of older adults (55+) with overweight and obesity.

Keywords: overweight, obesity, fat free mass, bioelectrical impedance analysis, older adults.

Introduction

Older adults are globally the fastest growing population. By 2035, more than 25% of Europeans will be 65 years and older (1). The prevalence of obesity in this age group is around 20% (2). Trends indicate that the prevalence of obesity in this age group will continue to increase (1, 3). Obesity in older adults is a major problem. In addition to metabolic risk factors for diabetes and cardiovascular disease, it also has a significant role in nonfatal physical disability in older adults (2). This can lead to a lower quality of life (4). With age, fat mass (FM) increases while fat-free mass (FFM) decreases (2, 5). Studies favor maintaining weight for those who become obese after the age of 65, because weight loss in older adults with obesity is associated with loss of muscle mass and bone mineral density (5). This could accelerate the development of sarcopenia (6). However, intervention studies show clinically significant health benefits of voluntary weight loss (7). To prevent loss of FFM during weight loss, it is important to monitor changes in FFM. Therefore, accurate assessments of FFM are important for assessing the health and nutritional status of older adults (8).

Making accurate assessments becomes more difficult as the amount of fat in and around the muscles increases with age (2). Individuals aged 70 years and older with a BMI of 30 kg/m2 or more have a greater amount of intramuscular fat (2). Besides a greater amount of intramuscular fat, a greater amount of ectopic fat is also observed (9). BIA assumes that water is evenly distributed and that the body is composed of 5 cylinders of uniform cross-section. However, in people with dehydration and edema, water is not constantly distributed (10), and the bodies of people with obesity are less clearly composed of these 5 cylinders (10). In addition, BIA is sensitive to the chemical composition of the FFM, which may change with growth, aging, and disease (11). This could affect the impedance measured by BIA and thus the estimated body water and FFM.

There are several methods for determining body composition. Dual-energy X-ray absorptiometry (DXA) and air displacement plethysmography (BodPod) are considered reliable methods (11, 12). Another method is bioelectrical impedance analysis (BIA), which is mostly used in dietetic practice because it is feasible (11). However, for estimating FFM, BIA is less accurate than DXA and BodPod (13). The precision of BIA devices is usually very good, but for individual assessment of particularly ill and overweight people, the accuracy varies. In these individuals, the measurement error for FFM ranges from 3.5-6% (10). For estimating the FFM with BIA an equation is required.

To estimate the FFM with BIA measurement, there are several equations for adults that use resistance and reactance data. The current equations are Horie et al. (14), Kyle et al. (13), and Rutten et al. (15). However, there is no equation designed for older adults with overweight and obesity, although 36.1% of patients seeing a dietitian are 65 years or older (16).

Yet, there is no equation for estimating FFM in overweight and obese older adults (10). The equation of Horie et al. is commonly used to estimate FFM in overweight and obese adults (14). However, it does not appear to be suitable for estimating FFM in overweight and obese older adults (10). Therefore, the aim of this study is to develop an equation that accurately estimates FFM in overweight and obese older adults (55+) based on resistance measured with BIA.

Methods

To create the new equation, baseline data from 3 weight loss intervention studies were used: the Muscle Preservation Study (MPS) (17), Weight loss with Protein and Exercise (WelPrex) (18), and Protein and lifestyle intervention to preserve muscle mass in obese older type 2 diabetes patients (PROBE) (19), all conducted by the Nutrition and Exercise research group at the Amsterdam University of Applied Sciences. In these studies, several measurements were preformed to estimate the body composition of older adults who were overweight or obese. Measurements were performed using BIA and BodPod to estimate body composition. With BIA it was possible to estimate the FFM and the BodPod FFM data was used as a reference. The new equation should estimate FFM for older adults (55+) with overweight and obesity based on the resistance data of the BIA measurements.

Subjects

The three previous studies examined weight loss in overweight and obese older adults aged 55 years and older. Participants in the various studies were all recruited in the area of Amsterdam by means of flyers and advertisements in local newspapers. To participate in any of the studies, they had to meet eligibility criteria. BMI and waist circumference were used to determine whether the older adults were overweight or obese. The criteria varied per study. In MPS, the criteria for BMI were that it should be higher than 30 kg/m2 or higher than 28 kg/m2 if waist circumference was higher than 88 cm for women and 102 cm for men. In Welprex, BMI had to be higher than 28 kg/m2 or higher than 25 kg/m2 with the same waist circumference criteria, and in PROBE, BMI had to be higher than 30 kg/m2 or higher than 27 kg/m2 with the same waist circumference criteria. Further eligibility criteria could be found in the Dutch Trial Register (MPS: NTR2751, Welprex: NTR4556, PROBE: NTR4497). Data were excluded if not all measurements of a participant were available. The studies were all approved by the Medical Ethics Committees and written informed consent was obtained from all subjects. The MPS study took place from 2011 to 2012, Welprex in 2014, and PROBE from 2014 to 2017.

Measurements

Sex and age were recorded, and body height was measured with a wall-mounted ruler (MPS: Seca 222, Probe: Grood DGI 250D), using the same standard operating procedure (SOP) in all studies. A calibrated scale (Life Measurement) was used to measure body weight. For BIA measurements, the Bodystat Quadscan 4000 was used in all three studies and measurements were taken using the same SOP. Air displacement plethysmography measurements were taken with BodPod using the same protocol in all three studies. In addition, participants were not allowed to eat for 5 hours before the measurements, had not exercised or been in a sauna for at least 14 hours, and were not allowed to smoke or drink alcohol on the day of the measurement. All studies were conducted at the Amsterdam Nutritional Assessment Center.

BIA and BodPod

By using the BIA measurement, it is possible to estimate the body composition. The BIA (Bodystat Quadscan 4000) is a measurement in which four alternating currents are sent through the body using electrodes on the right hand and foot. These are alternating currents of 5, 50, 100 and 200 kHz. For the current study, only the 50 kHz measurements were used as this is still the standard for BIA devices (20). The body offers resistance to this alternating current, which was detected by the BIA. The FFM could then be calculated using an equation. The BIA device was calibrated daily as described in the SOP. It was important that the measurement was performed correctly according to the procedures of the SOP (21).

The BodPod was used as a reference method to compare the estimated FFM based on BIA measurements to. The BodPod was used as a reference method because the BodPod is an indirect measurement method and the BIA is a double indirect measurement method. This is because the BIA measures impedance, which is then used to calculate the FFM. With the BIA measurement, many assumptions are made, for instance: that the most suitable equation is used, and that the water balance is equal for each person. The BodPod measures the body weight and volume of a person, with volume measured by air displacement in the cabin. This data can then be used to calculate the density of the body. Then, FM is calculated using the Siri equation (22) and FFM is calculated by subtracting FM of the total body weight. For the BodPod measurement, participants wore swimwear or tight-fitting underwear, and a swim cap, so the volume of hair was not included in the measurement (23).

Current equations

At the moment, 3 equations are often used for the estimation of body composition in adults based on the BIA measurement in dietetic practice (12). These are the Horie et al. equation (13), the Kyle et al. equation (11) and the Rutten et al. equation (14) (Table 1).

Table 1. Current bioelectrical impedance analysis equations

Population	**Source**	**N**	**Reference method for FFM**	**Equation**	**BIA-instrument**
Morbidly obese preoperative gastric bypass patients (18-62 y)	Horie et al.	119	BodPod	FFM = kg - (23.25 + (0.13 x age) + (1 x kg) + (0.09 x R) - (0.80 x Ht))	Quadscan
Healthy adults (22-94 y)	Kyle et al.	343	DEXA	FFM = - 4.104 + (0.518 x Ht^2/R) + (0.231 x kg) + (0.130 x Xc) + (4.229 x sex)	Xitron 4000b
Patients with stable COPD (>50 y)	Rutten et al.	1087	DEXA	FFM = - 11.81 + (0.245 x kg) + (0.298 x Ht^2/Z) + (0.148 x Ht) + (5.284 x sex)	Bodystat

kg=weight in kilograms; R=resistance; Ht=height in cm; Xc=reactance; Z=impedance; sex: 0=female; 1=male

Statistical analyses

Variables available to be tested in the new equation were age, sex, height, body weight, resistance, reactance, and impedance. A literature search was conducted to see if there were any other known variables that could affect the FFM to see if they should be used in the development of the equation. Since no other variables seemed to have an impact, the equation was created using these variables.

The outcome of the newly developed equation is FFM. When the FFM is known, the FM can also be calculated by subtracting the number of kilograms of FFM from the total body weight. Since FFM is a continuous variable, a prediction model was built using multiple linear regression analysis. Statistical analysis was performed using IBM SPSS statistics version 27. A correlation between variables was considered strong when higher than 0.7 (24). Correlation was analyzed for all variables. If a correlation was strong, the variable was excluded from the regression analysis. By adding the variables to the regression model, it was determined which variable explained the most variance. This variable was then locked with the Enter method and the best fitting variable was added again until most of the variance was explained. A variable was considered a good predictor of FFM if it was

significant. A p-value of ≤ 0.05 was considered statistically significant. If a variable was not significant but the explained variance (r^2) was higher with the variable in the model, that variable was also added to the model. Cross-validation of the newly developed equation was then performed by randomly drawing a sample of 25% of the data set and testing the new equation on this sample. Based on the available literature on cross-validation (25), a training set of 75% and a test set of 25% were selected (25). The 25% sample was used to analyze the performance of the equation on a different population.

The estimated FFM of the current equations and the newly developed equation were compared to the measured FFM by ADP using BodPod. To analyze the validity of the equations, the percentages of underestimates, accurate estimates, and overestimates were calculated. If the estimated FFM differed from the measured FFM by more than -1.8 kg, this was defined as an underestimation. An estimation was defined as accurate if the difference between the estimated FFM and the measured FMM was less than 1.8 kg, either 1.8 kg higher or lower than the measured FFM. If the estimated FMM differed from the measured FFM by more than +1.8 kg, it was defined as overestimation. The deviation of 1.8 kg was chosen based on the available literature (26).

In addition, the validity of the equations was determined using bias (the mean difference between the measured FFM and the estimated FFM), correlation (r), explained variance (r^2), and the standard error of estimate (SEE). In addition, the mean absolute error was calculated because it is valuable for practical purposes, as the mean absolute error can provide information about the average absolute deviation of the FFM between the estimated and measured FFM (27).

Bland-Altman analyzes were performed, with the mean of the measured FFM and the estimated FFM as the X variable and the difference between the measured FFM and the estimated FFM as the Y variable. The limits of agreement were calculated by the mean bias ± 1,96* SD. Bland-Altman analyzes are often used to show the correlation between two measurement methods (28), in this case between the BIA and the BodPod.

In general, the BIA becomes less accurate as the BMI increases (29). Therefore, BMI is divided into 4 categories to analyze whether FFM is more overestimated with higher BMI. To determine a difference in BMI among underestimates, accurate estimates, and overestimates of FFM, the mean BMI per estimate was calculated. Differences were tested by One-Way-ANOVA and Chi-sqaure. The distribution of underestimates, accurate estimates, and overestimates were analyzed by crosstabs.

In addition, Chi-square was used to determine whether there was a significant difference between underestimates, accurate estimates, and overestimates of FFM per equation and gender. The same analysis was performed for age categories (55-65 and > 65 y). Since body composition differs between males and females and body composition changes with age, this could affect the BIA measurement (2, 30).

Results

Subjects

For this study, we obtained baseline data from 297 subjects from the MPS, Welprex, and PROBE studies. Of these 297 subjects, 22 subjects were excluded from this study due to exclusion criteria (not all measurements available or age < 55 years). The mean (± SD) age of the study population was 64.3 (± 6.0) years, 50% were male, the mean BMI (±SD) was 32.8 (± 4.4) kg/m2, and 72% were obese. The mean (± SD) FFM of the study population was 55.1 ± 11.5 kg and the mean (± SD) FM was 40.5 ± 10.9 kg (Table 2). Appendix A shows the FFM index by age and BMI category (Table 7).

Table 2. Baseline characteristics of the subjects of the MPS, Welprex and PROBE study[1]

Characteristic	**N = 275**
Male sex, n (%)	136 (50)
Age, y	64.3 ± 6.0
Height, m	1.71 ± 0.92
Body weight, kg	95.6 ± 14.9
BMI, kg/m²	32.8 ± 4.4
BMI 25-29.9, n (%)	77 (28)
BMI >30, n (%)	198 (72)
FFM, BodPod, kg	55.1 ± 11.5
FM, BodPod, kg	40.5 ± 10.9

[1]Values are means ± SDs unless otherwise indicated.

New equation

After running a linear regression, only reactance proved to be insignificant. Reactance did not contribute to a higher explained variance, therefore reactance was not included in the equation. A correlation of 0.986 was found between resistance and impedance ($p < 0.001$), and therefore impedance was not included in the new equation (Table 3).

Table 3. Bioelectrical impedance analysis equation

Population	N	Criterion measure	Equation	BIA-instrument
Overweight and obese older adults 55+ y	275	BodPod	Predicted FFM (kg) = -21.649 + (7.075 * Sex) – (0.100 * age) + (0.484 * Height) + (0.164 * Body weight) – (0.038 * Resistance)	Quadscan 4000

Sex: 0 = female; 1 = male, Height in cm, Body weight in kilograms, Resistance in ohm

Validity of current equations compared to new equation

The validity of the three current equations and the new equation are presented by different methods (Table 4). In the second column the mean FFM in kilograms of the different equations are presented, with the mean FFM of the newly developed equation being closest to the measured FFM of BodPod. In the next three columns the percentages of underestimates, accurate estimates, and overestimates are presented. The three current equations mostly overestimate the FFM, while the new equation has a fairly even distribution of underestimates, accurate estimates, and overestimates, which can also be seen in Figure 1. In the last three columns the r, r^2 and SEE of the different equations are presented. The new equation has the highest r and r^2 and the lowest SEE.

In addition, the agreement between the estimated FFM and the measured FFM was evaluated using Bland-Altman plots for each equation presented in Figure 2. The BMI was divided into 4 categories to determine whether the level of BMI was related to the accuracy of the estimated FFM in the different equations. The middle line showed the mean bias between the FFM of the equation and the BodPod measurement. The limits of agreement are presented as the top and bottom lines (Table 4).

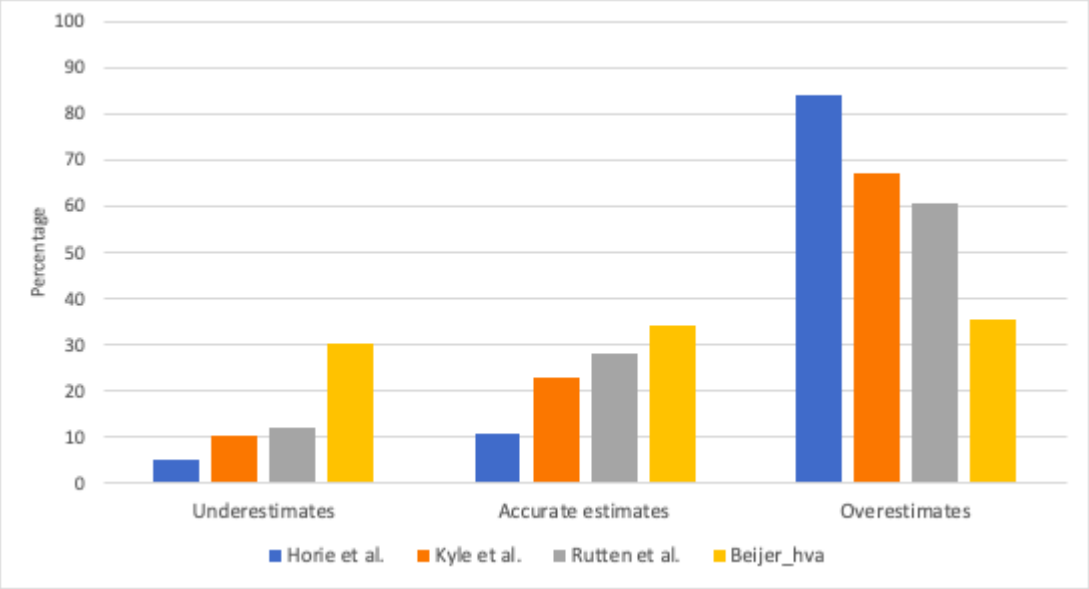

Figure 1. Percentages of under-, accurate and overestimates of FFM by BIA equations

Table 4. Evaluation of BIA equations for estimating FFM in 275 overweight and obese adults aged 55 years and older

FFM equation	Mean FFM ± SD (kg)	Under estimates[A] (%)	Accurate estimates[B] (%)	Over estimates[C] (%)	Bias ± SD (kg)	Limits of agreements ± SD (kg)	Mean absolute error ± SD (kg)	r	r^2	SEE[D] (kg)
Measured FFM (BodPod)	55.1 ± 11.5									
Horie et al.	61.5 ± 11.8	5	11	84	6.4 ± 4.8	-2.9, 15.9	6.8 ± 4.3	0.916	0.839	4.6
Kyle et al.	58.6 ± 10.9	10	23	67	3.5 ± 4.2	-4.7, 11.7	4.4 ± 3.2	0.931	0.867	4.2
Rutten et al.	58.0 ± 10.1	12	28	60	2.9 ± 4.1	-5.0, 10.9	4.0 ± 3.0	0.935	0.875	4.1
Beijer_hva	55.4 ± 10.8	30	34	36	0.3 ± 3.8	-7.2, 7.8	3.1 ± 2.3	0.943	0.889	3.8

[A]Percentage under –1.8 kg
[B]Percentage between –1.8 and 1.8 kg
[C]Percentage above 1.8 kg
[D]SEE: Standard Error of the Estimate

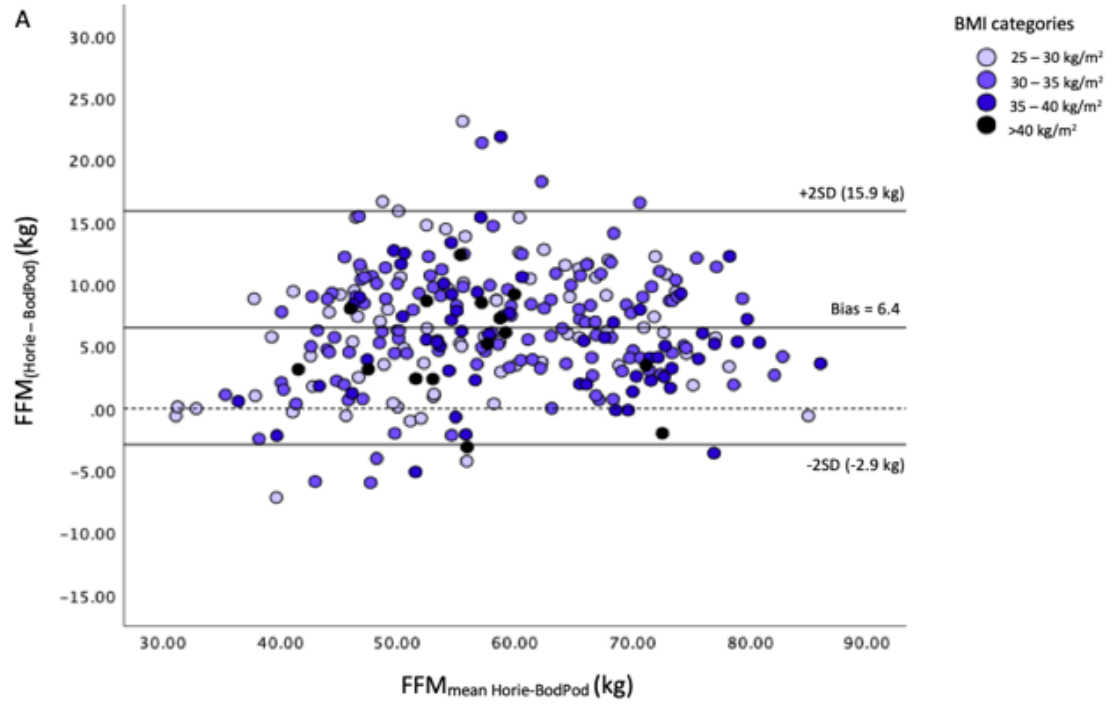

Figure 2A. Bland-Altman Plots of the difference between the measured and predicted FFM; Horie et al. Limits of Agreement are shown at the lines in plot, dotted lines show 0, which represents the perfect agreement.

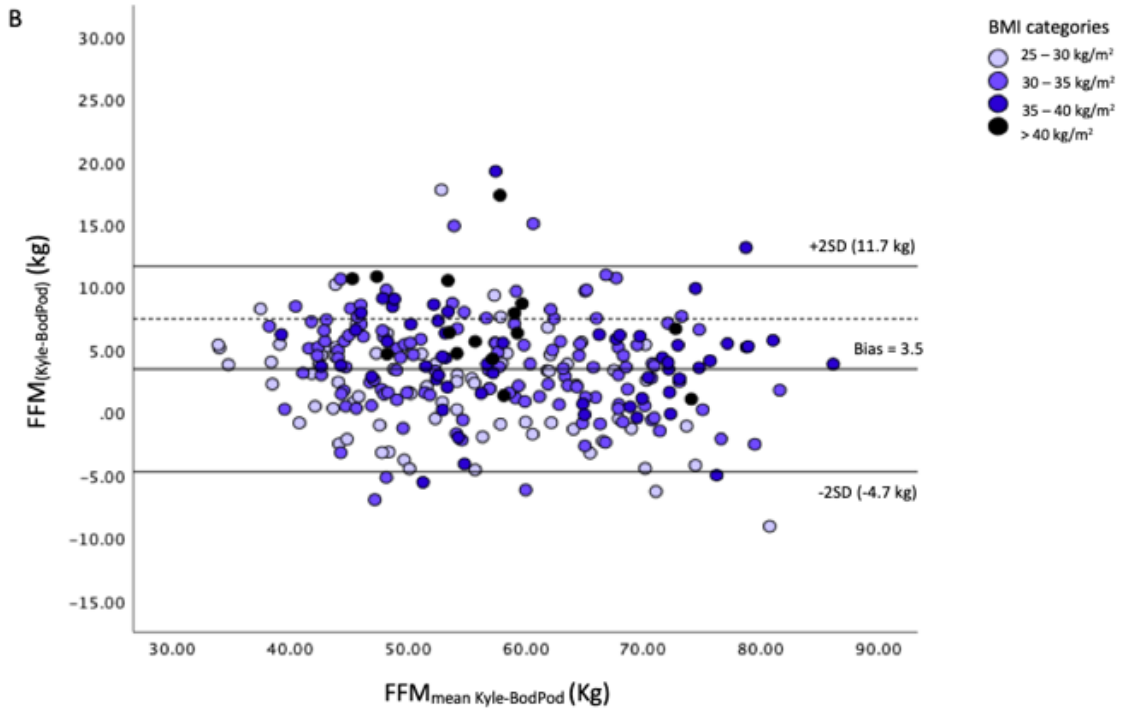

Figure 2B. Bland-Altman Plots of the difference between the measured and predicted FFM; Kyle et al. Limits of Agreement are shown at the lines in plot, dotted lines show 0, which represents the perfect agreement.

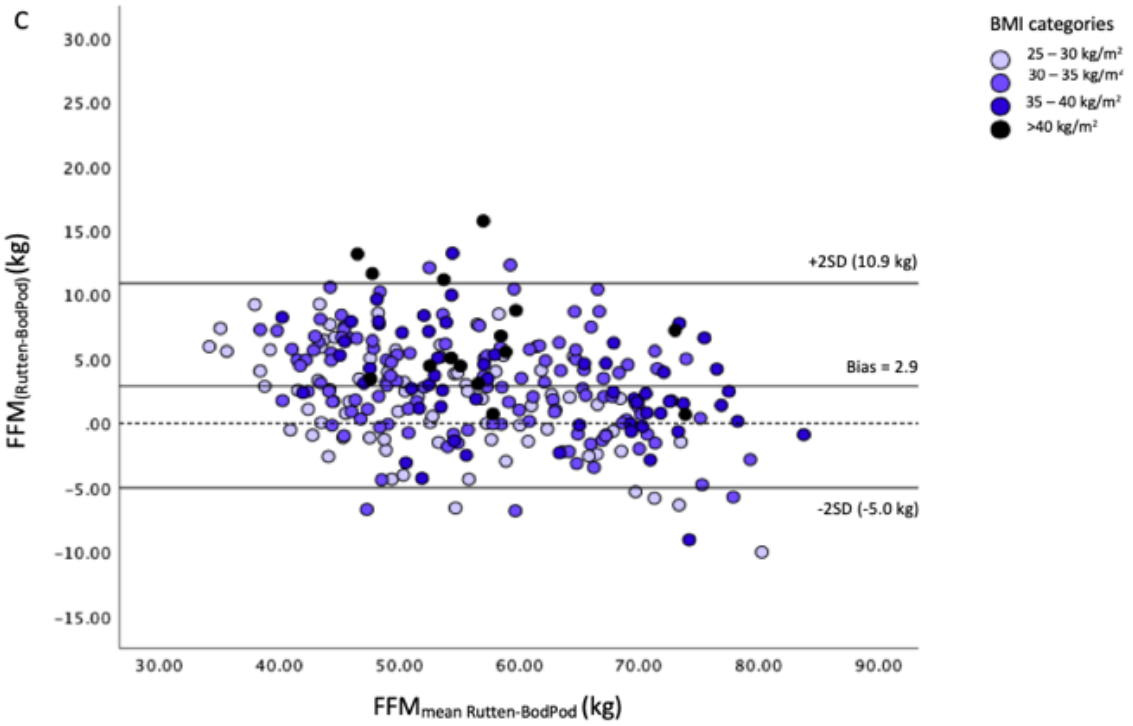

Figure 2C. Bland-Altman Plots of the difference between the measured and predicted FFM; Rutten et al. Limits of Agreement are shown at the lines in plot, dotted lines show 0, which represents the perfect agreement.

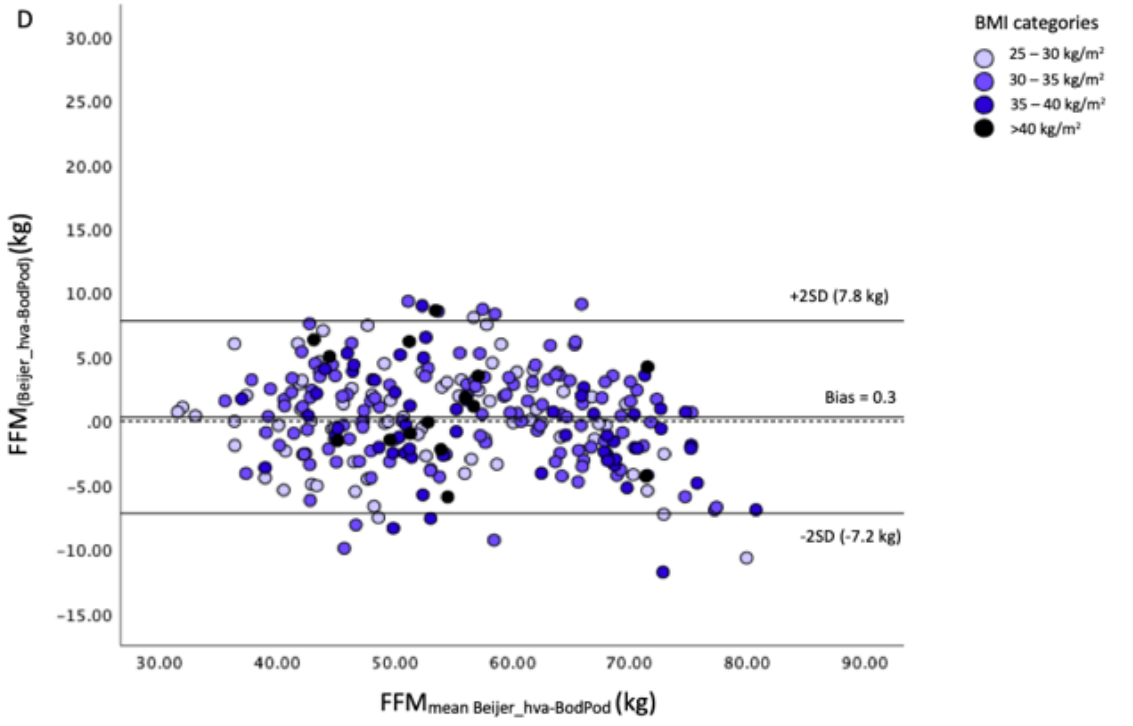

Figure 2D. Bland-Altman Plots of the difference between the measured and predicted FFM; Beijer_hva. Limits of Agreement are shown at the lines in plot, dotted lines show 0, which represents the perfect agreement.

The FFM was overestimated by the Kyle and Rutten equations 87% of the time (Table 5). A significant difference (Kyle, p = 0.004 and Rutten p = 0.02) was found for these equations in the BMI category > 40 kg/m2. The Kyle and Rutten equations overestimated FFM significantly more in the BMI category > 40 kg/m2 compared to lower BMI categories. With the Horie and Beijer_hva equations, FFM was also overestimated at higher BMI in most cases, but the percentage of overestimations relative to BMI was not significant. Besides that, no significant difference was found between the estimated FFM in different age categories in any of the equations. For gender, a significant difference was found between the estimated FFM in the Rutten equation (p = 0.001). For the other equations, no significant difference was found between the estimated FFM and gender.

Table 5. Division of under-, accurate and overestimates per BMI category. A: Horie, B: Kyle, C: Rutten, D: Beijer_hva

A

BMI, kg/m²	Underestimates (%)	Accurate estimates (%)	Overestimates (%)
25-30	1	20	79
30-35	5	7	88
35-40	7	12	81
>40	13	0	87

B

BMI, kg/m²	Underestimates (%)	Accurate estimates (%)	Overestimates (%)
25-30	19	25	56
30-35	7	26	67
35-40	7	15	78
>40	0	13	87

C

BMI, kg/m²	Underestimates (%)	Accurate estimates (%)	Overestimates (%)
25-30	19	29	52
30-35	9	29	62
35-40	10	28	62
>40	0	13	87

D

BMI, kg/m²	Underestimates (%)	Accurate estimates (%)	Overestimates (%)
25-30	29	35	36
30-35	26	34	40
35-40	43	33	24
>40	20	33	47

Cross-validation

To determine the validity of the Beijer_hva equation, cross-validation was performed with a random selection of 25% of the data set. The same parameters as in Table 4 were calculated to analyze the validity of the Beijer_hva equation. The validity of the Beijer_hva equation decreased for the 25% sample compared to the whole data set (Table 6). In appendix B the syntax of the results is shown.

Table 6. Cross-validation Beijer_hva equation 25% sample

FFM equation	Mean FFM ± SD (kg)	Under estimates[A] (%)	Accurate estimates[B] (%)	Over estimates[C] (%)	Bias ± SD (kg)	Limits of agreements ± SD (kg)	Mean absolute error ± SD (kg)	r	r^2	SEE[D] (kg)
Beijer_hva	56.1 ± 11.2	29%	33%	38%	0.5 ± 4.2	-7.6, 8.7	3.3 ± 2.6	0.937	0.787	4.2

[A]Percentage under –1.8 kg
[B]Percentage between –1.8 and 1.8 kg
[C]Percentage above 1.8 kg
[D]SEE: Standard Error of the Estimate

Discussion

In the present study, a new equation is developed based on baseline data from 275 overweight and obese older adults. The results show that the current equations accurately predict FFM in only one-third of the study population. For the new equation, this percentage is slightly higher, but still unacceptably low. However, the equation appears to be suitable for estimating FFM in groups of older adults with overweight and obesity.

Although the new equation has a high r and r2, the SEE is higher than desirable. For high accuracy, the SEE must be less than 2.0 kg. For men, a SEE of 4.0 kg is considered fairly good, whereas a SEE of > 4.0 kg is not recommended for women (26). The new equation works best for this population, but since only a small percentage is accurately estimated, the equation cannot be used in practice for this population. The bias of the current equations is high for all three, while a good bias must be as low as possible, and at least below 1.8 kg (26). The bias of the newly developed equation is 0.3 kg. This means that the estimate is off by 0.3 kg on average when observing changes in FFM across groups. Considering the mean absolute error, the estimated FFM may differ by 3.1 kg, which means that the equations do not work well for individuals. For the Horie et al. equation, the currently used equation for overweight and obese adults, the estimated FFM can vary up to 6.8 kg for individuals. Compared to the Beijer_hva equation, the Horie et al. equation can vary up to 3.7 kg more estimated FFM. Although the Beijer_hva equation provides better estimates than the current equations for this population, the new equation must not be used in nutritional practice for estimating FFM at a given time point. A deviation of 3.1 kg from the estimated FFM in individuals is too high to be useful.

The new equation can potentially capture changes in FFM and divide people into those with low FFM and those with nonlow FFM, which should be explored through further research. If the equation proves suitable to classify people with low FFM and nonlow FFM, it can potentially be used to detect obese patients with sarcopenia. The literature indicates that BIA is more commonly used to detect sarcopenic obesity in the elderly (31).

Regarding the estimates of FFM in obese individuals, higher cell membrane reactance and differences in dissolved electrolytes in intracellular and extracellular water seem to lead to an overestimation of FFM (32). In obese individuals, the distribution of body water differs from that of lean individuals. The relative ratio of extracellular water to total body water is higher in obese individuals (32). In individuals with a higher BMI, an impedance of 50 kHz appears to measure mainly extracellular water and only partially intracellular water. The amount of body water in obese individuals varies not only due to biological differences, but also depends on the amount of body fat and individual characteristics. For this reason, there are often more individual measurement errors in obese people when FFM is determined using BIA measurements (32).

The literature shows that FFM is often overestimated in obese adults, which is also reflected in the present study. The equations of Horie et al., Kyle et al., and Rutten et al mostly overestimate FFM in this population. However, the Beijer_hva equation shows fewer overestimates. A significant difference between the BMI and underestimates and overestimates groups is found in the Kyle et al. and Rutten et al. equations, but not in the Horie and Beijer_hva equations. This can be explained by the fact that the Horie and Beijer_hva equations are based on populations with overweight and obesity, which is not the case with the Kyle and Rutten equations.

The high overestimates can be explained by the fact that overweight and obese people often have a higher amount of visceral and ectopic fat (33). Because the torso only contributes for 10% of the total resistance in a BIA measurement, the FFM is often overestimated in overweight and obese people (11). The high percentage of abdominal fat contributes to the overestimation of FFM in overweight and obese people (12). Therefore, it may be useful to include waist circumference in further studies.

Measuring body composition in obese older adults remains difficult. As BMI increases, the validity of the BIA decreases. The BIA assumes that the body consists of 5 cylinders with a uniform cross-section. This is not the case in obese adults and especially in older adults who are obese (12). Visceral fat increases with age and subcutaneous fat decreases. Intramuscular fat also increases (2). This explains why current equations for other populations do not estimate the correct FFM in obese older adults (34). According to the literature, age and gender could affect the accuracy of the estimated FFM (9, 30). However, the results show that no significant difference is found in the Beijer_hva equation for age and sex according to the accuracy of the estimated FFM.

Cross-validation shows that the Beijer_hva equation performs less when a 25% sample is used. Prediction models usually perform well for the population for which they are developed, but often worse for other populations (35). Therefore, it is very important to evaluate a model against another data set. This is done through an internal validation technique, where a 25% sample is randomly drawn from the entire data set, and the equation is retested on this sample. Since external validation is the most reliable validation technique, it would be better to evaluate a model in this way. However, since no other dataset is available for this purpose, internal validation is the best option. Therefore, it is important to use external validation for future research.

A strength of this study is that a large sample (N = 275) is used to develop the new equation. In addition, the BodPod data is used as reference data for the comparison of the FFM because it is considered a valid reference method (11). A limitation of this study is that only BIA baseline data is used to develop the new equation. If data from multiple measurement points is available, it would be possible to look at changes over time and perhaps develop a better equation. This is because the literature shows that BIA is suitable for estimating differences in FFM over time in groups and individuals (32). When BIA is used to estimate FFM as a baseline measurement, the estimate is less accurate compared to DXA and BodPod (11).

Conclusion

In conclusion, the current and the Beijer_hva equations are not suitable for accurately estimating FFM in overweight and obese older adults (55+) at a given time. The Beijer_hva estimates FFM in overweight and obese older adults more accurately than the current equations. However, the Beijer_hva equation does not estimate FFM accurately enough to be used in dietetic practice. In dietetic practice, the change in FFM in individuals over time is monitored. Because weight loss can be a health risk in overweight and obese older adults, a low deviation of the FFM estimate is important. Therefore, further research is necessary to determine whether the Beijer_hva equation is suitable to accurately monitor FFM in individuals over time. However, the Beijer_hva equation can accurately estimate the mean FFM of a group.

Recommendations

The current study shows that the newly developed equation is not recommended for use in dietetic practice. The estimate of FFM per person is not accurate in most cases. However, the newly developed equation is suitable for estimating the mean FFM in groups of older adults (55+) with overweight and obesity. Further studies should clarify whether body water composition affects the estimation of FFM in older adults. BIA is sensitive to the chemical composition of FFM, which may change with growth, aging, and disease (9). This could affect the impedance measured by BIA and thus the amount of body water and FFM.

In addition, further research should be conducted to determine whether accurate estimate of FFM with BIA is not possible in overweight and obese older adults due to changes in body composition and physique. By conducting the same study in overweight and obese older adults, measuring FFM with the BodPod and estimating it with the BIA, it is possible to determine whether the BIA still largely overestimates FFM. Therefore, it is important to determine if the BIA should be used to estimate FFM in this population.

When conducting the same study, it may be valuable to include the waist circumference variable to see how this affects the estimation of FFM in overweight and obese older adults. This is because abdominal fat contributes to a large overestimation of FFM in overweight and obese individuals (33).

The reliability of the Beijer_hva equation can be determined in further studies by applying the equation to multiple measurement time points and comparing it to a reference method. The FFM estimated by Beijer_hva is not valid but could be reliable. By comparing the change in FFM of the reference with the estimated change in FFM.

Regardless of which equation is used to estimate FFM, dietitians can compare the FFM index with the value from the percentile table (Table 7). The FFM index is based on 275 older people (55+) who are overweight and obese, to see which group the person would be placed in. It can also be used to determine if someone has an FFM that is low. An FFM index below P10 is considered low (36).

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Appendix A

Table 7. Percentile table FFM index for overweight and older adults divided into age and BMI categories

		P5		P10		P25		P50		P75		P90		P95	
AGE (Y)	**BMI**	M	F	M	F	M	F	M	F	M	F	M	F	M	F
55-65	**<30.0**	17.1	12.4	17.7	13.3	18.9	14.9	19.7	16.3	20.4	17.3	22.9	18.5	.	19.1
	>30.0	18.2	14.7	18.8	15.3	19.8	16.1	21.5	17.1	22.6	18.7	23.9	20.2	24.2	20.6
>65	**<30.0**	16.9	12.9	17.1	13.5	18.1	14.6	19.0	15.4	20.4	16.6	21.0	18.0	21.2	.
	>30.0	18.4	15.0	19.0	15.3	19.7	16.1	20.6	17.2	21.7	18.7	22.5	19.5	23.4	20.6

Appendix B

```
*Create variable impedance*
COMPUTE Impedance=sqrt((RESI_50kHz * RESI_50kHz) + (REAC_50kHz * REAC_50kHz)).
EXECUTE.

*Create variable gender, female is 0 instead of 2*
RECODE GENDER (1=1) (2=0) INTO Gender.
EXECUTE.

*Filtering out extreme values and exclusion criteria*
USE ALL.
COMPUTE filter_$=(LEEFTIJD >= 55 & RESI_50kHz < 900 & REAC_50kHz < 900).
VARIABLE LABELS filter_$ 'LEEFTIJD >= 55 & RESI_50kHz < 900 & REAC_50kHz < 900 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

*Create variable FFM_Horie*
COMPUTE FFM_Horie=WEIGTH_kg - (23.35 + (0.13 * LEEFTIJD) + (1 * WEIGTH_kg) + (0.09 *
RESI_50kHz)
   - (0.80 * LENGTH_cm)).
EXECUTE.

*Create variable FFM_Kyle*
COMPUTE FFM_Kyle=-4.104 + (0.518 * LENGTH_cm * LENGTH_cm / RESI_50kHz) + (0.231 *
WEIGTH_kg) +
   (0.130 * REAC_50kHz) + (4.229 * Gender).
EXECUTE.

*Create variable FFM_Rutten*
COMPUTE FFM_Rutten=- 11.81 + (0.245 * WEIGTH_kg) + (0.298 * LENGTH_cm * LENGTH_cm /
Impedance) +
   (0.148 * LENGTH_cm) + (5.248 * Gender).
EXECUTE.

*Create variable FM_BODPOD*
COMPUTE FM_BODPOD=WEIGHT_kg - FFM_BODPOD.
EXECUTE.

*Create BMI categories*
RECODE BMI (Lowest thru 29.99=1) (30 thru Highest=2) INTO BMI_cat.
EXECUTE.

* Table 2. characteristics subjects*
FREQUENCIES VARIABLES=Gender BMI_cat AGE LENGTH_cm WEIGHT_kg BMI FFM_BODPOD
FM_BODPOD
  /STATISTICS=STDDEV MEAN
  /ORDER=ANALYSIS.
```

```
*Analyzing correlations between variables*
CORRELATIONS
  /VARIABLES=AGE LENGTH_cm WEIGHT_kg BMI RESI_50kHz REAC_50kHz Impedance Gender
  /PRINT=TWOTAIL NOSIG FULL
  /MISSING=PAIRWISE.

* Table 3. Block 1 creating equation using stepwise linear regression*
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER AGE.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER WEIGHT_kg.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER RESI_50kHz.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER REAC_50kHz.
```

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER Gender.

*Block 2*
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER AGE.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER WEIGHT_kg.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER REAC_50kHz.
```

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER Gender.

*Block 3*
   REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER AGE.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER WEIGHT_kg.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER REAC_50kHz.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER Gender.
```

```
* Block 4*
  REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER Gender
  /METHOD=ENTER AGE.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER Gender
  /METHOD=ENTER WEIGHT_kg.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER Gender
  /METHOD=ENTER REAC_50kHz.

*Block 5*
 REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER Gender
  /METHOD=ENTER WEIGHT_kg
  /METHOD=ENTER AGE.
```

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER Gender
  /METHOD=ENTER WEIGHT_kg
  /METHOD=ENTER REAC_50kHz.

* Block 6*
  REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER LENGTH_cm
  /METHOD=ENTER RESI_50kHz
  /METHOD=ENTER Gender
  /METHOD=ENTER WEIGHT_kg
  /METHOD=ENTER AGE
  /METHOD=ENTER REAC_50kHz.

*Table 3. *
COMPUTE FFM_Beijer=-21.649 + (7.075 * Gender) - (0.100 * AGE) + (0.484 * LENGTH_cm) + (0.164
*  WEIGHT_kg) - (0.038 * RESI_50kHz) .
EXECUTE.

*BMI divided into 4 categories*
RECODE BMI (Lowest thru 29.99=1) (30.0 thru 34.99=2) (35.0 thru 39.99=3) (40.0 thru Highest=4)
INTO
   BMI_categories.
EXECUTE.

*Figure 2A, Bland Altman plot Horie & BodPod*
COMPUTE Diff_Horie_BodPod=FFM_Horie - FFM_BODPOD.
EXECUTE.

COMPUTE Mean_Horie_BodPod=(FFM_Horie + FFM_BODPOD) / 2.
EXECUTE.

T-TEST
  /TESTVAL=0
  /MISSING=ANALYSIS
  /VARIABLES=Diff_Horie_BodPod
  /ES DISPLAY(TRUE)
  /CRITERIA=CI(.95).
```

```
GRAPH
  /SCATTERPLOT(BIVAR)=Mean_Horie_BodPod WITH Diff_Horie_BodPod BY BMI_categories
  /MISSING=LISTWISE.

 *Figure 2B, Bland Altman plot for Kyle & BodPod *
COMPUTE Diff_Kyle_BodPod=(FFM_Kyle - FFM_BODPOD).
EXECUTE.

COMPUTE Mean_Kyle_BodPod=(FFM_Kyle + FFM_BODPOD) / 2.
EXECUTE.

T-TEST
  /TESTVAL=0
  /MISSING=ANALYSIS
  /VARIABLES=Diff_Kyle_BodPod
  /ES DISPLAY(TRUE)
  /CRITERIA=CI(.95).

GRAPH
  /SCATTERPLOT(BIVAR)=Mean_Kyle_BodPod WITH Diff_Kyle_BodPod BY BMI_categories
  /MISSING=LISTWISE.

 *Figure 2C, Bland Altman plot for Rutten & BodPod*

COMPUTE Diff_Rutten_BodPod=FFM_Rutten - FFM_BODPOD.
EXECUTE.

COMPUTE Mean_Rutten_BodPod=(FFM_Rutten + FFM_BODPOD) / 2.
EXECUTE.

T-TEST
  /TESTVAL=0
  /MISSING=ANALYSIS
  /VARIABLES=Diff_Rutten_BodPod
  /ES DISPLAY(TRUE)
  /CRITERIA=CI(.95).

GRAPH
  /SCATTERPLOT(BIVAR)=Mean_Rutten_BodPod WITH Diff_Rutten_BodPod BY BMI_categories
  /MISSING=LISTWISE.

*Figure 2D, Bland Altman plot for Beijer & BodPod*

COMPUTE Diff_Beijer_BodPod=FFM_Beijer - FFM_BODPOD.
EXECUTE.

COMPUTE Mean_Beijer_BodPod=(FFM_Beijer + FFM_BODPOD) / 2.
EXECUTE.
```

```
T-TEST
  /TESTVAL=0
  /MISSING=ANALYSIS
  /VARIABLES=Diff_Beijer_BodPod
  /ES DISPLAY(TRUE)
  /CRITERIA=CI(.95).

GRAPH
  /SCATTERPLOT(BIVAR)=Mean_Beijer_BodPod WITH Diff_Beijer_BodPod BY BMI_categories
  /MISSING=LISTWISE.

*Creating bias variables equations*
 COMPUTE Absolute_error_Horie=ABS(Diff_Horie_BodPod).
EXECUTE.

COMPUTE Absolute_error_Kyle=ABS(Diff_Kyle_BodPod).
EXECUTE.

COMPUTE Absolute_error_Rutten=ABS(Diff_Rutten_BodPod).
EXECUTE.

COMPUTE Absolute_error_Beijer=ABS(Diff_Beijer_BodPod).
EXECUTE.

*Table 4. Mean absolute error*
DESCRIPTIVES VARIABLES=Absolute_error_Horie Absolute_error_Kyle Absolute_error_Rutten
    Absolute_error_Beijer
  /STATISTICS=MEAN STDDEV MIN MAX.

*Table 4.  Mean bias equations*
DESCRIPTIVES VARIABLES=Diff_Horie_BodPod Diff_Kyle_BodPod Diff_Rutten_BodPod
Diff_Beijer_BodPod
  /STATISTICS=MEAN STDDEV MIN MAX.

*Table 4. Mean FFM*
DESCRIPTIVES VARIABLES=FFM_Horie FFM_Kyle FFM_Rutten FFM_Beijer FFM_BODPOD
  /STATISTICS=MEAN STDDEV MIN MAX.

*Table 4. r, r², and SEE*
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER FFM_Horie.
```

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER FFM_Kyle.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER FFM_Rutten.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER FFM_Beijer.

*Recode predictions into under-, accurate-, and overestimations*

RECODE Diff_Horie_BodPod (Lowest thru -1.801=-1) (-1.8 thru 1.8=0) (1.801 thru Highest=1) INTO
    Accurate_Horie.
EXECUTE.

RECODE Diff_Kyle_BodPod (Lowest thru -1.801=-1) (-1.8 thru 1.8=0) (1.801 thru Highest=1) INTO
    Accurate_Kyle.
EXECUTE.

RECODE Diff_Rutten_BodPod (Lowest thru -1.801=-1) (-1.8 thru 1.8=0) (1.801 thru Highest=1) INTO
    Accurate_Rutten.
EXECUTE.

RECODE Diff_Beijer_BodPod (Lowest thru -1.801=-1) (-1.8 thru 1.8=0) (1.801 thru Highest=1) INTO
    Accurate_Beijer.
EXECUTE.

*Table 4. Accuracy of predictions*

FREQUENCIES VARIABLES=Accurate_Horie Accurate_Kyle Accurate_Rutten Accurate_Beijer
  /ORDER=ANALYSIS.

*Table 5. Mean BMI in under, accurate and overestimated FFM groups*

MEANS TABLES=BMI BY Accurate_Horie Accurate_Kyle Accurate_Rutten Accurate_Beijer
  /CELLS=MEAN COUNT STDDEV.
```

```
CROSSTABS
  /TABLES=BMI_categories BY Accurate_Horie
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ
  /CELLS=COUNT ROW
  /COUNT ROUND CELL.

CROSSTABS
  /TABLES=BMI_categories BY Accurate_Kyle
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ
  /CELLS=COUNT ROW
  /COUNT ROUND CELL.

CROSSTABS
  /TABLES=BMI_categories BY Accurate_Rutten
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ
  /CELLS=COUNT ROW
  /COUNT ROUND CELL.

CROSSTABS
  /TABLES=BMI_categories BY Accurate_Beijer
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ
  /CELLS=COUNT ROW
  /COUNT ROUND CELL.

*Anova test equations*

ONEWAY BMI BY Accurate_Horie
  /MISSING ANALYSIS
  /CRITERIA=CILEVEL(0.95)
  /POSTHOC=BONFERRONI ALPHA(0.05).

ONEWAY BMI BY Accurate_Kyle
  /MISSING ANALYSIS
  /CRITERIA=CILEVEL(0.95)
  /POSTHOC=BONFERRONI ALPHA(0.05).

ONEWAY BMI BY Accurate_Rutten
  /MISSING ANALYSIS
  /CRITERIA=CILEVEL(0.95)
  /POSTHOC=BONFERRONI ALPHA(0.05).

ONEWAY BMI BY Accurate_Beijer
  /MISSING ANALYSIS
  /CRITERIA=CILEVEL(0.95)
  /POSTHOC=BONFERRONI ALPHA(0.05).
```

Table 6. Cross validation Beijer equation

```
COMPUTE filter_$=(uniform(1)<=.25).
VARIABLE LABELS filter_$ 'Approximately 25% of the cases (SAMPLE)'.
FORMATS filter_$ (f1.0).
FILTER  BY filter_$.
EXECUTE.

REGRESSION
  /DESCRIPTIVES MEAN STDDEV CORR SIG N
  /SELECT=filter_$ EQ 1
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA COLLIN TOL CHANGE
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=STEPWISE FFM_Beijer
  /SCATTERPLOT=(*ZRESID ,*ZPRED)
  /RESIDUALS HISTOGRAM(ZRESID) NORMPROB(ZRESID)
  /CASEWISE PLOT(ZRESID) OUTLIERS(3).
```

Table 6. Crossvalidation

```
DESCRIPTIVES VARIABLES=Diff_Beijer_BodPod
  /STATISTICS=MEAN STDDEV MIN MAX.

DESCRIPTIVES VARIABLES=Absolute_error_Beijer
  /STATISTICS=MEAN STDDEV MIN MAX.

DESCRIPTIVES VARIABLES=FFM_Beijer
  /STATISTICS=MEAN STDDEV MIN MAX.

FREQUENCIES VARIABLES=Accurate_Beijer
  /ORDER=ANALYSIS.

T-TEST
  /TESTVAL=0
  /MISSING=ANALYSIS
  /VARIABLES=Diff_Beijer_BodPod
  /ES DISPLAY(TRUE)
  /CRITERIA=CI(.95).

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT FFM_BODPOD
  /METHOD=ENTER FFM_Beijer.
```