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Validity of Prediction of Thoracic Gas Volume and Body Composition Using Air Displacement Plethysmography in People Living with HIV in Southwest Ethiopia

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Abstract

Background: Body composition assessment has become increasingly popular in clinical and research areas. But any body composition measurement technique that is used in both clinical and research settings should be reliable and valid.

Objectives: Our first aim was to compare predicted thoracic gas volume (Vtg_{pred}) with measured thoracic gas volume (Vtg_{meas}) using the BOD POD in people living with HIV/AIDS (PLWHA) in Southwest Ethiopia. The second aim was to determine the effect of thoracic gas volume (Vtg) measurement ways on estimation of body fat (BF) using the BOD POD in PLWHA in Southwest Ethiopia.

Method: Cross-sectional study was conducted on 68 PLWHA who had follow up at Jimma University Specialized Hospital (JUSH). Subjects were collected using convenience sampling technique. Agreement between the methods was tested using paired t-test, Pearson's correlation, linear regression, and Bland-Altman plot.

Result: Much percent of study subjects were malnourished (60.3%). Vtg and percent body fat (%BF) did not differ significantly (p>0.05) between the two modes of assessment (predicted and measured). Strong correlation was observed between Vtgpred and Vtgmeas (r=0.82, p<0.001). Correlation between predicted %BF ($\%BF_{pred}$) and measured %BF ($\%BF_{meas}$) was also strong(r=0.92, p<0.001). The regression of Vtg_{meas}(Y) against Vtgpred (X) (Y=-0.369+1.140X, R^2=0.68, SEE=0.015) did not significantly deviated from the line of identity. Similarly, the regression of $\%BF_{meas}$ (Y) against $\%BF_{pred}$ (X=1·70+0.94X, R^2=0·96) did not significantly deviated from the line of identity. Bland-Altman plot of the differences against the mean of Vtg_{pred} and Vtg_{meas} and the differences against the mean of $\%BF_{pred}$ and $\%BF_{meas}$ showed no systematic differences.

Conclusion: The BOD-POD is a reliable technique to predict Vtg and body composition in PLWHA in Southwest Ethiopia. Therefore, researchers and clinicians can confidently use the predicted Vtg and body fat in place of the measured ones in PLWHA in Southwest Ethiopia.

Keywords: BOD-POD; Body composition; Thoracic gas volume; People living with HIV/AIDS

Abbreviations: ADP: Air Displacement Plethysmodraph; AIDS: Acquired Immune Deficiency Syndrome; BD: Body Density; BF: Body Fat; BH: Body Height; BI: Bioelectrical Impendence; BW: Body Weight; %BF: Percent Body Fat; BMI: Body Mass Index; DXA: Dual-energy X-ray Absorptiometry; FFM: Fat Free Mass; FM: Fat Mass; %FFM: Percent Fat Free Mass; HIV: Human Immunodeficiency Virus; HW/UWW: Hydrostatic Weighting/under Water Weighting; JUCAN: Jimma University and University of Copenhagen Alliance in Nutrition Research; PLWHA: People Living with HIV/AIDS; Vtg: Thoracic Gas Volume; Vtgmeas: Measured Thoracic Gas Volume; Vtgpred: Predicted Thoracic Gas Volume

Introduction

The study of human body composition spans back to 100 years ago and continues to be an active area of basic sciences and clinical research. Nearly every aspects of clinical nutrition, selected areas within many medical specialties and components of exercise science are touched by the study of body composition [1].

Before the development of sophisticated methods of body composition measurement, information on the composition of the human body was obtained using methods such as cadaver analyses and tissue biopsy assessment. These methods have long been a part of the practice of body composition assessment and have contributed greatly to the fundamental knowledge of human body. But, as a body composition assessment technique, each of these methods has its own limitations. Notwithstanding this limitation, most of our information about the composition of the human body has been derived in this manner and has been compiled over the years into the concept of the reference man [2-4].

Body mass index (BMI) and waist-hip ratio have also been used for long to assess body composition [5,6]. Today, several alternative body composition measuring mechanisms are available for researchers and clinicians seeking to assess body composition [7] and new methods continue to be developing [3]. Hence, measurements of body composition are becoming increasingly used in assessment of overall health of people [8].

Body composition measurement techniques are categorized into two groups. These are laboratory techniques and field techniques. Laboratory methods include hydro densitometry (hydrostatic (HW),

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or underwater weighing (UWW)), air displacement plethysmography (ADP) using a BOD POD®, isotope dilution, and dual-energy X-ray absorptiometry (DEXA) etc. Field techniques include skinfolds, anthropometric measurements, near-infrared interactance and bioelectrical impedance (BI) analysis. Contemporary methods such as ultrasound, computed tomography and magnetic resonance imaging are also available but are less common in developing countries because of their expensiveness [3,9,10].

Until recently, UWW has been used as the gold standard method for body composition analysis [11,12]. One of the methods that were evaluated by UWW is ADP. There are several studies that assessed the validity of ADP based on UWW [13-16]. These studies have found that the ADP is a reliable method of body composition measuring and that subjects have found it more preferable to UWW. Because the ADP was evaluated based on UWW (which was a reference method), it is taken as a popular reference method/ gold standard method for body composition assessment [17-19].

Not only ADP was more preferred to UWW, it was also preferentially recommended for assessing body composition than other methods such as BI and three compartment methods [20,21]. Even some studies indicated that techniques like ADP were developed because HW and DEXA have limitations associated with applicability for special populations such as the elderly, disabled, and patients who are chronically ill [22-24]. Great deals of scientific studies were reported in relation to validation of the measurement ways of ADP via the BOD POD system in different people. They were done in children, adults, elderly, pregnant and athletes [25-30]. Despite this, none of them were done in Ethiopian population. But several studies indicated that ethnic origin appears to have an important effect on lung function and body composition [31,32].

As far as the application and use of the BOD POD in patients is concerned, the BOD POD has been applied and studied in a broad array of relevant clinical and research situations such as Huntington disease, cystic fibrosis, breast cancer, Down's syndrome, insulin resistance, and chronic obstructive pulmonary disease, phenylketonuria clinically extreme obese, gastric bypass, nursing mothers, certain ethnic groups and professional football players [22,33-37]. Currently, Jimma University Specialized Hospital in cooperation with Jimma University and University of Copenhagen alliance in nutritional research (JUCAN) is using the BOD POD for assessing body composition of its patients including people living with HIV/AIDS (PLWHA) who are enrolled into the hospital.

Knowledge of body composition of PLWHA has implications for understanding efficacy of nutritional and clinical interventions, diagnosis, prevention, and treatment in clinical settings. Malnutrition and muscular wasting are common among PLWHA. Therefore, it is essential to be able to measure changes in body composition of PLWHA using readily available and validated techniques so that nutritional and pharmacological interventions can be fully evaluated in these people [38,39]. Regarding this, the BOD POD is the best tool for measuring body composition of PLWHA since it needs little expertise, needs only five minutes to measure, and safe to apply in patients. But we must be certain that the ways the BOD POD measures body composition and thoracic gas volume (Vtg) are valid and reliable in PLWHA.

Measurement of body composition and Vtg via the BOD POD is undertaken in two ways. One is predicted measurement at which Vtg and body composition values (such as Percent body fat (%BF), percent fat free mass (%FFM), fat mass (FM), fat free mass (FFM), body density (BD), body volume (BV), body weight (BW) and the others) of the body are predicted using Siri equation which is based on the height, sex and age of the person. The other measurement is that Vtg and the other body composition values are measured as the person undergoes breathing maneuver through a breathing tube connected to the BOD POD [40].

The purpose of this study was to investigate whether or not there is discrepancy between predicted thoracic gas volume (Vtg_{pred}) and measured thoracic gas volume(Vtg_{meas}) using the BOD POD in PLWHA in Southwest Ethiopia and to test the validity of using Vtg_{pred} in place of the Vtg_{meas} in estimating body composition of PLWHA in Southwest Ethiopia.

We have reviewed a great deal of validation studies that are conducted on the BOD POD in patients such as clinically extreme obese, gastric bypass, Down's syndrome, Huntington disease, cystic fibrosis, breast cancer, insulin resistance, and chronic obstructive pulmonary disease, and phenylketonuria [22,34,36,37]. Although there are studies conducted on the problem in different types of patients, there is no any study conducted on the problem in PLWHA. Therefore this is the first study conducted on the problem in PLWHA.

Materials and Methods

Study subjects

The study was conducted in JUSH. Study subjects were 88 PLWHA who were enrolled into JUSH antiretroviral (ART) clinic. Of these 88 subjects, 68 subjects were able to complete the acceptable measurements for both the predicted and measured values. Fifteen patients were unable to perform the breathing maneuver required to obtain measured values of Vtg. Other three participants' data were not full because of instrument malfunction which resulted due to power supply problem encountered during data collection period and one participant could not accomplish the breathing maneuver of the measured values because of problem of exhalation. The remaining one participant gave informed consent and medical information but she was not obedient to be measured by the BOD POD. Thus, data from only the 68 subjects (39 females and 29 males) were used in the analysis. The standard protocol for BOD POD testing was followed for each participant. All participants were asked to refrain from exercise, food stuffs and drink 2 hour prior to the testing. This was done by making them stay at the clinic (ART clinic) for at least 2 hours prior to the measurement. They were also made to void their bladder and abdomen before they were measured by the BOD POD.

The study was conducted according to guidelines of the declaration of Helsinki and all of the procedures were approved by the Ethical Review Board of Jimma University. Written informed consent was obtained from each participant. Subjects were excluded from participation in the study if they were pregnant or lactating, terminally ill from HIV or other serious condition, those who had active tuberculosis or other respiratory disease like asthma, claustrophobic to the sound of the BOD POD and those who did not consent. Before participation, all subjects provided a detailed medical history using a questionnaire underwent a physical examination by ART nurses, and their documents at ART clinic were also referred.

Study outline

Subjects were required to visit the research Laboratory at the pediatric building of JUSH after they had finished the physical examination at ART Clinic near to the pediatric building. Body weight and body height were measured using standard anthropometric scale prior to the subjects were measured by the BOD POD. Body weight was measured to the nearest 0.1 Kg and height was measured to the nearest 0.5 cm with the patients standing back to a standiometer. Both measurements were made in light clothing, bare foot and nothing in their pockets. The values obtained from these two measurements were used to calculate BMI.

ADP testing procedures

ADP measurements were taken using the BOD POD system (Life Measurement Instruments, Concord, CA). The BOD POD was calibrated before each test in accordance with the manufacturer's instructions. During the measurement, participants were asked to remove shoes, and jewelers and they were dressed in a skin-tight swimsuit and a swimming cap. They were weighed using electronic scale and then seated in the calibrated 450 L chamber within the BOD POD. They were instructed to remain still, sit in an upright position, and with their hands positioned on their thighs, breathe normally. A minimum of two BV measurements was conducted, with each test lasting approximately 50 s. If the two measurements differed by >150 ml, a third test was conducted. A detailed description of the principles and procedures of ADP using the BOD POD was described in the manual and in the work of Dempster and Aitkens [40,41]. Each subject underwent both the measured lung volume protocol and the predicted lung volume protocol. For all of the participants, the Siri equation was utilized to convert BD to %BF [42] and the equation can be put as:

%BF=[495/body density]-450

Once %BF is calculated, %FFM can also be determined as follows:

%FFM=100-%BF

The predicted Vtg protocol was performed which was followed by the measured Vtg procedure. Lung volume measurement procedure was deeply explained to them and practiced by each subject prior to the assessment. To get the measured values, they were required to breathe through a breathing tube connected to the BOD POD while wearing a nose clip. A mirror was put on a wall in front of the BOD POD to enable the participants easily see and follow the signal of the computer for exhalation and inhalation procedure. After two to three normal breaths, the subjects were instructed to gently puff into the breathing tube as indicated by the manufacturer's protocol. The measured Vtg value was calculated by the BOD POD software; which was estimated by taking the functional residual capacity (FRC) times half of the tidal volume (V_T) (as measured lung volume is taken at midpoint).

$Vtg_{pred}=FRC+0.5\ V_T$

Both FRC and V_T are also predicted from age and height according to the formulas as described by Crapo [43]. The values for Vtg, %BF, %FFM, FM, FFM, BV, BW, and BD were then recorded by the computer for both predicted and measured tests.

The measurements were not accepted as valid unless they met the criteria of having a merit<1 and an airway Pressure<35 cm H_2O as recommended by the manufacturer company [40]. If a participant's measurement did not meet these criteria, his/her results were not used in the data analysis.

Statistical analysis

Physical characteristics are expressed using mean, standard deviation, and range. Paired t tests were done to check the agreement between the predicted and measured values. Pearson's correlation coefficient was performed to assess the strength of relationships. Comparison of slopes of regression of measured values on predicted values was done using linear regression. Bland-Altman analysis (Bland and Altman) was also implemented to determine levels of agreement. A P value of <0.05 was considered statistically. Data were entered into Epidata version 3.0 and exported to Spss version 16.0 for analysis.

Results

Physical characteristics of the subjects

The physical characteristics of the study population are indicated in Table 1. Among the 68 patients, about 39 (57.4%) were female and 29 (42.6%) were male. Female to male ratio was 1.34 to 1. The mean age of the study population was 34 years and they ranged in age from 22 years to 60 years. They had a mean BMI of 19.22 Kg/m^2 (range 13.2 to 31.2). Despite the fact that the sample contains patients from all category of BMI, most of the patients; that is, about 41(60.3%) were malnourished. Women had a greater BV than men where as they had a lesser BD than men.

None of the patients had active pulmonary tuberculosis (PTB) at the time of study. This is because patients with active PTB and other respiratory infections were excluded from the study. Smoking was not common among them. Only 6(8.8%) patients had previous history of smoking. All of the patients who had history of smoking were men.

Comparison of measured and predicted Vtg

Mean values for the Vtgpred and Vtgmeas, BF, and FFM are shown in Table 2. The mean Vtg_{pred} and mean Vtg_{meas} were 3.30 L and 3.39 L, respectively. Mean Vtg_{pred} was lower than mean Vtg_{meas} by 2.6% (0.09 L). Although it was slightly underestimated, it was not significantly different from Vtg_{meas} (p=0.087). The minimum Vtg_{meas} recorded from the measurement was 1.9 L whereas the maximum Vtg_{meas} recorded was 5.7 L. The range between them is 3.8, which revealed that the study populations are diverse in terms of Vtg.

Pearson's Correlation calculated for Vtg_{pred} and Vtg_{meas} was 0.82, which indicates that there is strong correlation between them (p<0.001). The standard error of estimate (SEE) was 0.015 and the coefficient of

Whole Group (n=68)			Males (n=29)			
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Age(years)	34.5 ± 7.3	22-60	36.7 ± 7.2	22-50	32.0 ± 6.9	22-60
Weight(Kg)	50.1 ± 8.8	35.7-76.0	50.6 ± 6.1	39.4-62.8	49.6 ± 10.4	35.7-76.0
Height(cm)	161.5 ± 8.8	146.5-182.0	168.9 ± 6.8	153.3-182.3	156.1 ± 5.6	146.0-167.3
BMI(Kg/m^2)	19.2 ± 3.5	13.2-31.2	17.7 ± 1.7	15.8-22.3	20.3 ± 4.09	13.2-31.2
predicted Body volume (L)	46.4 ± 9.1	32.14-75.45	46.80 ± 5.97	36.86 ± 59.06	47.6 ± 10.97	32.14-75.45
Measured Body volume (L)	47.5 ± 9.0	32.73-74.93	47.09 ± 5.99	36.8 ± 58.62	47.8 ± 10.91	32.73-74.93
Predicted Body density (Kg/L)	1.0560 ± 0.02	1.0020-1.098	1.0750 ± 0.013	1.048 ± 1.098	1.042 ± .024	1.002-1.096
Measured Body density	1.0052 ± 0.02	1.0004-1.069	1.0680 ± 0.013	1.038 ± 1.089	1.039 ± 0.021	1.0004-1.075
n=number of subjects, SD=standard deviation						

Table 1: Physical characteristics of the patients.

determination (R^2) obtained was 0.68. Therefore, following paired t test and Pearson's product moment correlation, it was found that there was no significant discrepancy between the predicted and measured Vtg.

Linear regression analyses of Vtg and body composition values are shown in Table 3. The scatter plot with the regression line for Vtg_{meas} (Y) against Vtg_{pred} (X) is indicated in Figure 1A. The data points are seen clustered closely about a positively sloping regression line Y=-0.369+1.140X, R^2=0.68, SEE=0.015). Bland and Altman analysis indicated that the bias for the difference between Vtg_{pred} and Vtg_{meas} was −0.094 which is very small value (slightly less than zero). From the negative value of the bias it was realized that the mean Vtg_{pred} was slightly lower than the mean Vtg_{meas} (Table 3).

This supports the finding obtained from the paired t test. The 95% limit for the difference of the two Vtgs was from -0.96 L to 0.78 L which indicates that the data points for the difference between the two measurements versus their mean lie in a very narrow range. Two data points were out of the limit of agreement (Figure 1B).

With the exception of these two data points, all the rest data points of Bland and Altman plot for the predicted and measured Vtgs fell within the 95% limits of agreement.

Comparison of predicted and measured %BF and %FFM

The results obtained for %BF, %FFM, FM and FFM for each type of measurement (predicted and measured) are summarized in Table 2. The mean predicted %BF (%BF_{pred}) was 21.54% whereas the mean measured %BF (%BF_{meas}) was 22.01%. %BF_{pred} was lower than the %BF_{meas} by 0.47% (± 2.0 SD). Although there was slight difference between the predicted and measured %BF, it was not significant (p=0.056). Pearson's correlation between %BF estimated by the predicted Vtg and %BF estimated by measured Vtg indicated that they were strongly correlated(r=0.98; P<0.001). It was also found that 96% of the variation in %BF_{meas} was explained by the %BF_{pred}.

The result from regression analysis of %BF_{meas} against %BF_{pred} is given in Table 3. Figure 2A illustrates the scatter plot for the regression of %BF_{meas} against %BF_{pred}. The regression of %BF_{meas}(Y) on %BF_{pred}(X) had a line Y=1·70+0.94X (R^2=0·96). Bland and Altman analysis of %BF_{pred} and %BF_{meas} is indicated in Table 3 and the scatter plot is indicated in Figure 2B.

The bias between %BF_{pred} and %BF_{meas} is -0.4721% (95% CI, -4.398% to 3.454%). Limits of agreement show that the difference between %BF_{pred} and %BF_{meas} may be 4.398% lower or 3.454% higher than zero. The plot revealed that two data points are out of the 95% CIs.

Mean value for predicted %FFM (%FFM_{pred}) was 78.54% but mean value for measured %FFM (%FFM_{meas}) was 77.22%. %FFM_{pred} was slightly higher than %FFM_{meas}. %FFM_{pred} was over estimated by 1.31%. But there was no significant difference between them (p=0.87). Correlation between them was strong(r=0.87, p<0.001). The findings from linear regressions of them are shown in Table 3. R^2 value from the regression was 0.75 which indicates that 75% of %FFM_{meas} was explained by the %FFM_{pred}. The figure (Figure 3A) shows the scatter plot for the regression of %FFM_{meas} on %FFM_{pred}. A Bland-Altman scatter plot (Figure 3B) demonstrates that the bias between the %FFM_{pred} and %FFM_{meas} was 1.31. The limits of agreement between them was from -11.35% to 13.99%. One data point was out of the limits of agreement.

Comparison of predicted and measured BF and FFM

The comparison of predicted FM (FM_{pred}) with measured FM (FM_{meas}) using paired t test showed a mean FM_{pred} of 11.53 Kg and a mean FM_{meas} of 11.83Kg. Mean difference between them was 0.3 Kg (2.53%). The mean FM_{pred} was slightly lower than FM_{meas} but was not significantly different from the mean FM_{meas} (p=0.110). The correlation between them was strong(r=0.97, p<0.001). R^2 value was 0.95 which indicates that 95% the variation in the FM_{meas} was explained by the FM_{pred}.

Summary of regression of FMmeas on FMpred indicated in Table 4. The figure (Figure 4A) indicates the graph of linear regression of predicted against measured FM. The slope of the regression line was 0.97 while the intercept was 1.001. The Scatter plot from Bland and Altman analysis is indicated in Figure 4B. The bias was - 0.3 and the upper and lower 95% limits of agreement were from -3.37 to 2.75. Two data points were out of the 95% limit of agreement.

The result from the comparison of FFM estimated using Vtg_{pred} and FFM estimated using Vtg_{meas} revealed that the mean predicted FFM (FFM_{pred}) was 38.92 Kg while the mean measured FFM (FFM_{meas}) was 38.89 Kg. They had a mean difference of 0.032. The mean FFMpred was lower than the FFM_{meas} by 0.08%. Although FFM_{pred} was slightly lower, it was not significantly different from the FFM_{meas} (p=0.593). Pearson's correlation between them was 0.99 (p<0.001). They showed

	Predicted (Mean + SD)	Measured (Mean+ SD)	Mean difference	P-value for mean difference	r	R^2	P-value
	3.30 ± 0.57	3.39 ± 0.78	0.094 ± 0.446	0.087	0.82	0.68	<0.001
%BF	21.54 ± 10.53	22.01 ± 10.11	-0.47 ± 2.0	0.056	0.98	0.96	<0.001
%FFM	78.54 ± 10.47	77.22 ± 12.96	1.31 ± 6.46	0.097			<0.001
FM(kg)	11.53 ± 7.009	11.83 ± 6.76	0.31 ± 1.56	0 .110	0.97	0.95	<0.001
FFM(kg)	38.92 ± 5.92	38.89 ± 5.95	0.03 ± .49	0.593	0.99	0.98	<0.001
R: Pearson's Product Moment Correlation; R^2: Coefficient of Determination; SD: Standard Deviation; Vtg: Thoracic Gas Volume; %BF: Percent Body Fat; %FFM: Percent Fat Free Mass; FM: Fat Mass; FFM: Fat Free Mass							

Table 2: Thoracic gas volume and body composition values calculated using predicted and measured thoracic gas volumes (n=68).

	Regression			Bland-Altman	
Parameters	Intercept	Slope	R^2	Bias	95% limits
Vtg_{meas} *vs.* Vtg_{pred}	-0.36	1.14	0.68	-0.094	-0.96 - 0.78
%BFmeas *vs.* %BFpred	1.707	0.94	0.96	-0.47	-4.39 - 3.45
%FFMmeas *vs.* %FFMpred	-7.22	0.86	0.75	1.31	-11.35 - 13.99
FMmeas *vs.* FMpred	1	0.97	0.95	-0.3	-3.37 - 2.75
FFMmeas *vs.* FFMpred	-0.15	0.99	0.98	0.03	-0.90 - 1.00
R^2: Coefficient of Determination; Vtg: Thoracic Gas Volume; %BF: Percent Body Fat; FM: Fat Mass; FFM: Fat Free Mass					

Table 3: Summary of regression and Bland-Altman analysis for predicted and measured values (n=68).

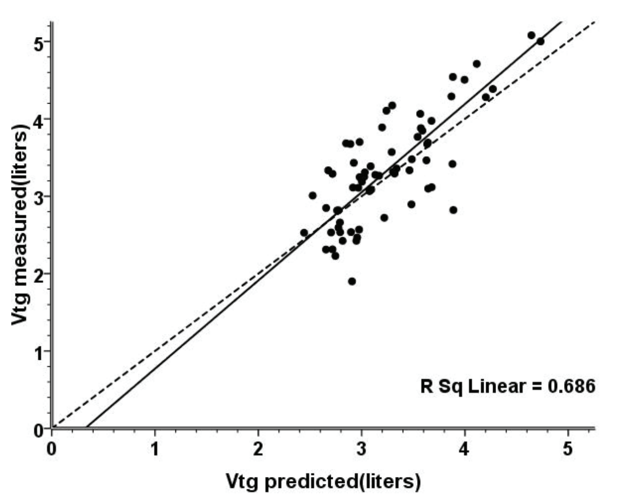

Figure 1A: Regression of measured thoracic gas volume (Vtgmeas) (Y) on predicted thoracic gas volume (Vtg_{pred}) (X). The dashed line represents the line of identity, and the solid line represents the line of best fit for the regression equation which is y=-0.369+1.140x, r=0·82, SEE=0·083).

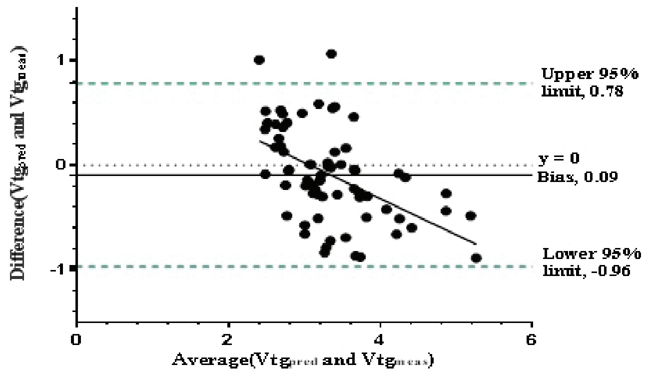

Figure 1B: Bland and Altman scatter plot for predicted thoracic gas volume (Vtg_{pred}) versus measured thoracic gas volume (Vtg_{meas}). The solid horizontal line represents the bias (-0.09 L); the top and bottom dashed lines represent the limits of agreement (-0.96 to 0.78 L).

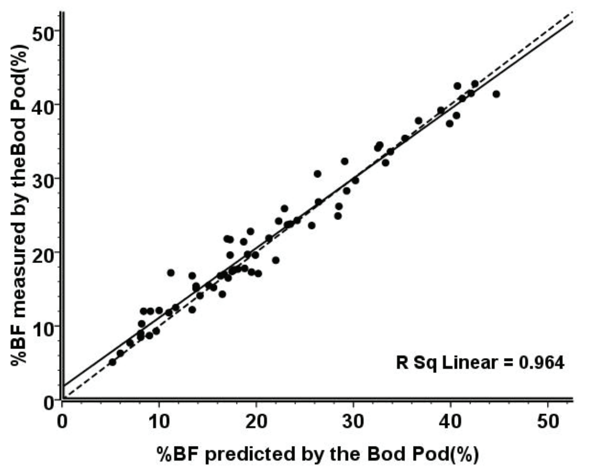

Figure 2A: Regression of $\%BF_{meas}$ calculated using measured thoracic gas volume against $\%BF_{pred}$ calculated using predicted thoracic gas volume. The dashed line represents the line of identity and the solid line represents the line of best fit for the regression equation. The line of best fit is y=1·707 + 0·94x, R^2=0·96, SEE=1.92.

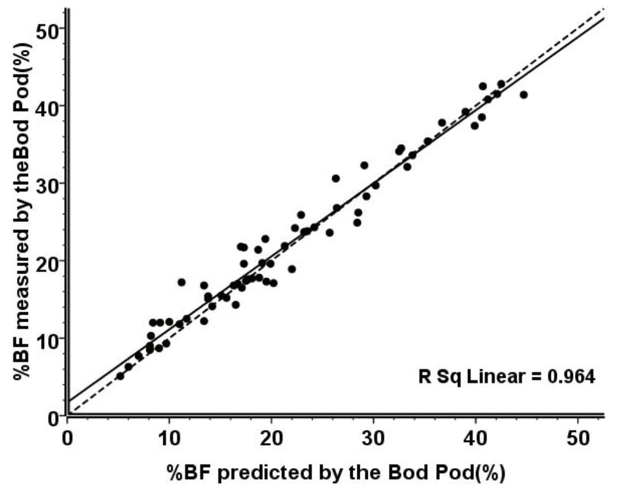

Figure 2B: Bland and Altman scatter plot for %BF (predicted *vs.* measured). The solid horizontal line represents the bias (-0.4); the top and bottom dashed lines represent the limits of agreement (-4.39 to 3.45).

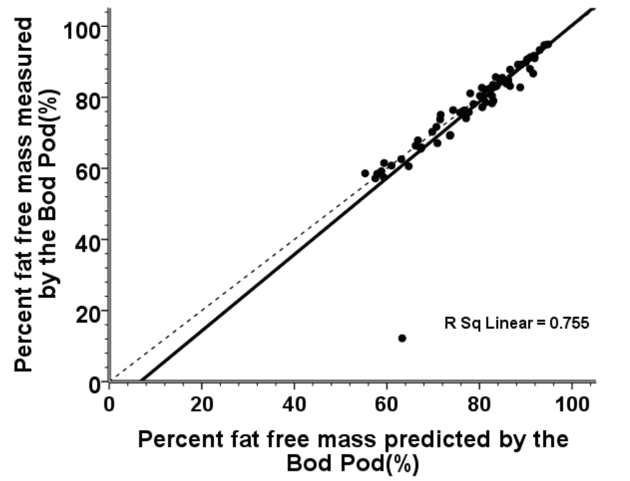

Figure 3A: Regression of measured %FFM against predicted %FFM. The dashed line is the line of identity and the solid line is the line of best fit(Y=-7.22+ 0.86X, R^2=0.75).

the strongest agreement than the other pairs of comparisons made in this study. Following the result, it was realized that the FFM_{pred} was very strongly correlated to the FFM_{meas}.

The graph of regression of FFM_{meas} against FFM_{pred} is shown in Figures 5A, and a summary of this regression is presented in Table 3. From the regression it was found that the regression of FFM_{meas} (Y) against FFM_{pred} (X) resulted a model line of Y=0.99–0.15X, R^2=0.99).

A Bland-Altman analysis was performed to determine whether bias existed between FFM_{pred} and FFM_{meas}. This analysis is presented in right part of Table 3 and the figure (Figure 5B). The bias was closer to zero (0.03) and the 95% limit of agreement was from –0.90 to 1.00. Despite the narrow limit of agreement, four data points were out of the 95% limits.

Discussion

Studies with different objectives had been using the predicted thoracic gas volume in place of the measured thoracic gas volume when

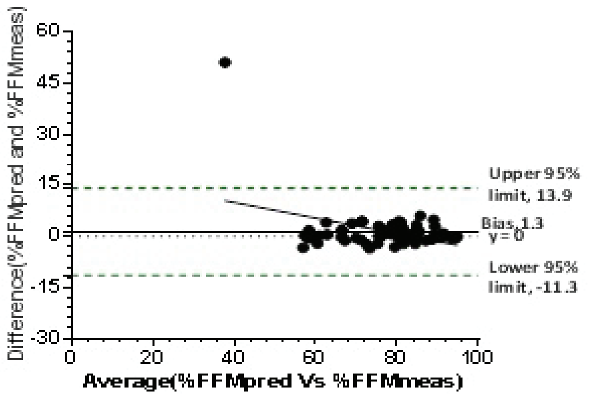

Figure 3B: Bland and Altman scatter plot between predicted %FFM and measured %FFM. The solid line represents the bias which is at y=1.3; the top and bottom dashed lines represent 95% limits of agreement. One data point is an outlier.

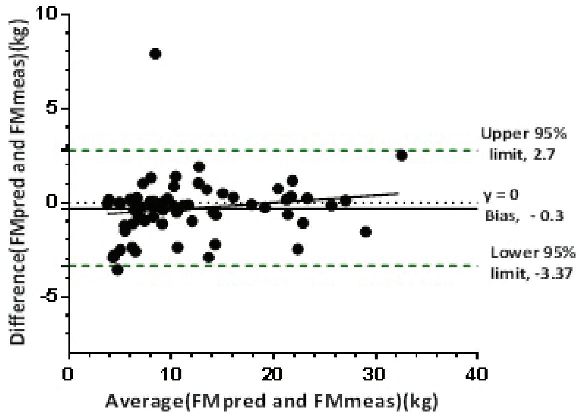

Figure 5A: Regression of measured FFM against Predicted FFM. The dashed line represents the line of identity and the solid line represents the line of best fit (Y=-0.15+0.99X, R^2=0.993).

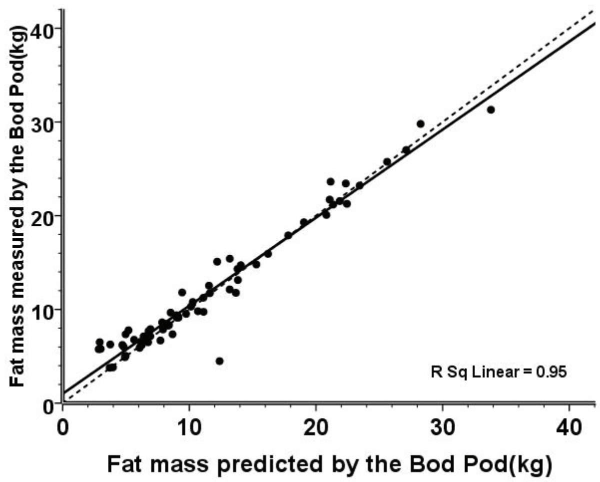

Figure 4A: Regression of measured FM against Predicted FM. The dashed line represents the line of identity and the solid line represents the line of best fit (Y=1.001+0.97X).

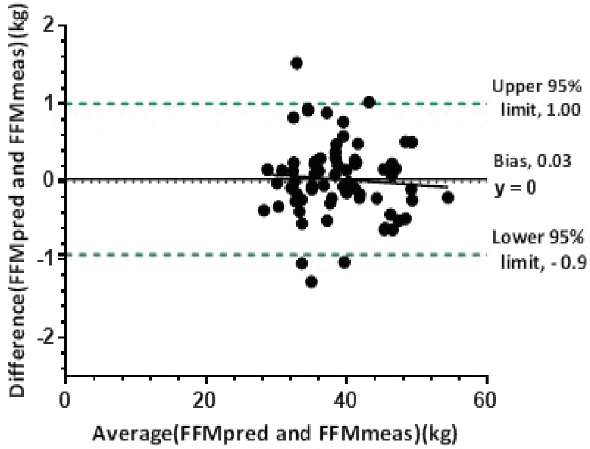

Figure 5B: Bland and Altman scatter between predicted and measured FFM. The solid line represents the bias; the upper and lower dotted lines represent the 95% limits of agreement and the middle dotted line represents the line y=0. Four data points are outliers.

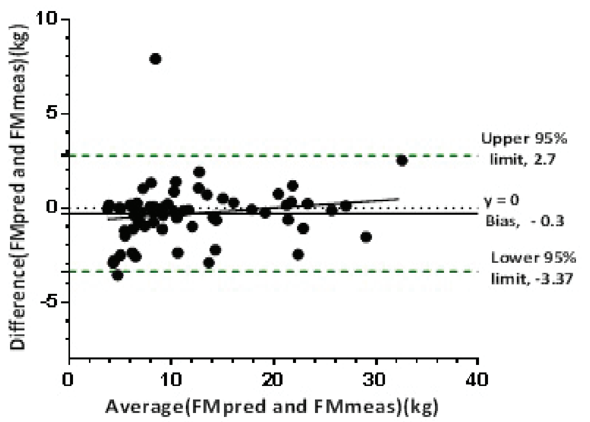

Figure 4B: Bland and Altman scatter plot between predicted and measured FM. The solid line represents the bias (-0.3) and the upper and lower dotted lines indicate the 95% limits.

their subjects were unable to perform the breathing maneuver required to get the measured values [44]. These studies used the predicted thoracic gas volume in place of the measured one because they argue that the predicted thoracic gas volume is not significantly different from the measured one. On the contrary, some other studies argue that the use of predicted thoracic gas volume in place of the measured may produce large prediction error, and so, according to these studies, the predicted thoracic gas volume should not be used in place of the measured thoracic gas volume for assessing body composition [45,46].

The finding of the current study demonstrated that the mean predicted thoracic gas volume did not show significant discrepancy from the mean measured thoracic gas volume using the BOD POD in PLWHA in Southwest Ethiopia. Similarly, percent body fat, percent fat free mass, fat mass and fat free mass which were predicted based on the predicted thoracic gas volume were not significantly different from their respective values which were measured when the participants underwent a breathing maneuver through the breathing tube of the BOD POD.

The percent of study subjects who were malnourished (BMI less<18.5) in the current study was much greater than a comparable study previously done on similar group of people in Srinagarind Hospital, Thailand [47]. The possible reasons for the difference in the proportion of malnourished subjects between the above study and the current study are ethnic difference, the difference in the socioeconomic status and the difference in population norms of the study population.

The proportion of study participants who performed the proper breathing maneuver required to obtaining measured values of thoracic gas volume and body composition in the current study was highly greater than another similar study conducted on adolescents with cystic fibrosis [34]. But it is lower than other studies conducted on healthy adults [45] and children [48]. According to the argument of the study conducted on cystic fibrosis, the ability to produce measured values of thoracic gas volume is independent of disease severity and age. They argued that it may be affected by the test condition of each laboratory.

The current study has found that the predicted and measured thoracic gas volumes did not show significant discrepancy. This result is different from the study conducted on patients of cystic fibrosis [34] and healthy adults [45] which found significant differences between the predicted and measured thoracic gas volumes. The study conducted on healthy adults, though it was conducted with a greater sample size and on healthy adults, it exclusively used 18-years old adults. Therefore, its ability to generalize the finding to the general population was difficult although its sample size was large.

In opposition to the above two studies, the finding of the current study is similar to the study conducted by Demerath et al. [48] and Mcrorry et al. [49]. The result of the current study is also comparable to the study conducted by Westphal et al. [50]. This study was conducted on twenty one healthy elderly people aged from 60 to 82. Although it was conducted in sample size of less than one- third of our study (21 subjects), it found the same finding as our study.

The current study found a mean difference of 0.094 between the predicted and measured thoracic gas volumes. But many similar studies found a higher mean difference than our study. For example, a study conducted by Murphy and his coworkers [34] found a mean difference of 0.19 and a study conducted by Blaney [45] found a mean difference of 0.14. Another similar study conducted by Demerath and his co-workers [48] found a mean difference of 0.20 with 2.0 SD. Therefore, the result of the current study reveals that the difference in the mean of the two thoracic gas volumes is not only insignificant but also it is the smallest of studies conducted by Murphy et al., Blaney and Demerath et al. But another study carried out by Mccrory and his coworkers found a mean difference of 0.054 with 0.063 SD which is less than the mean difference we found [49].

Regarding percent body fat, we found no significant differences between body fat calculated using predicted and measured thoracic gas volumes, which is similar to the finding by McCrory et al. When the current study's finding is compared with other recent similar studies, it is also similar with the study conducted by Ronald Otterstetter and his coworkers [51] and Anderson's study [44]. Each of these studies used a smaller sample size than the current study. Both of these studies used twenty four healthy participants that are enrolled by convenience sampling technique.

Contrary to the finding of the current study, other studies found a significant difference between percent body fat predicted from the predicted thoracic gas volume and the measured thoracic gas volume. For instance, the study conducted by Blaney found a significant difference between predicted percent body fat and measured percent body fat.

Although the current study found no significant difference between the predicted and measured body fat, the p value we found from the comparison of predicted body fat and measured body fat using paired t test was only slightly greater than the boundary (p=0.056). It shows that discrepancy might be resulted if the subjects do not conform to measurement protocol and if all the cautions indicated by the manufacturer company are not met. The same idea was also indicated by the study conducted by AJ Murphy [34]. AJ Murphy argued that the variation in the findings among different studies may be attributed to inter-laboratory method variation, differences in test conditions and the combined limitations of the methods. So it is important to tie to the guidelines of the manufacturer company and American/European thoracic societies. In the guidelines, it is indicated that, the subject to be measured should breathe with his/her normal tidal breath. In our data we saw that, in an individual basis, the values obtained from the two measurements were almost similar when the participants breathed with their normal tidal volume. The results differed when the subjects underwent under ventilation and hyperventilation. The results may be determined by the way the subjects breathe. Hence, the subjects can alter their estimates of body fat by changing the way they breathe in the BOD POD resulting in inaccurate results. Therefore, technicians should always inform their subjects to breath with their normal tidal breathing.

It should also be well known that all the environmental influences must be considered as indicated by the manufacturer factory and other studies [40,52]. Moreover, the subjects should sit still with their hands on their lap during the measuring process in order to obtain an appropriate value of thoracic gas volume and body fat as indicated by the above studies.

Regression analysis of the measured body fat against the predicted revealed that there is linear relationship between them. This finding is similar to the finding from Ronald Oterstteter [51]. Further analysis by using Bland-Altman plot indicated that the scatter plot of the difference versus the mean of BF predicted and measured has a bias of 0.47% and the 95% limit is from -4.398 to 3.454. The bias we found is almost similar to the Ronald Otersteter's which is 0.5%.

In this study, it was also indicated that fat free mass estimated by predicted thoracic gas volume did not significantly differed from fat free mass estimated using measured thoracic gas volume. The predicted and measured fat free masses were also agreed strongly. This is also similar to the study conducted on patients with cystic fibrosis [34].

Like any other study, the current study has limitation. The main limitation of the current study is the study populations were users of anti-retroviral drugs. Therefore, the possible effect of the drugs on thoracic gas volume and body fat is taken as the limitation of the current study.

Conclusion

This study has shown that the predicted thoracic gas volume and body fat do not show significant difference from the measured thoracic gas volume and body fat using the BOD POD in PLWHA in Southwest Ethiopia. As a result, using predicted thoracic gas volume values rather than measured thoracic gas volume when assessing body composition of people living with HIV/AIDS in southwest Ethiopia does not bring any significant effect on estimation of body fat percentage. Therefore, when using the BOD POD to assess body composition of people living with HIV/AIDS in Southwest Ethiopia, predicted thoracic gas volume can directly replace the measured thoracic gas volume. This has special importance in cases when certain individuals cannot perform the breathing maneuver required to get measured values.

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Disclosure

The authors report no conflicts of interest in this work.

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