Using Body Mass Index, Bioelectrical Impedance Analysis, and Skinfold Thickness to calculate the lean body mass for a 21-year-old non-athlete Caucasian female

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Abstract

Lean body mass is an important nutritional indicator to determine the health status of individuals. A variety of anthropometric and non-anthropometric measurements, including but not limited to Body Mass Index (BMI), Bioelectrical Impedance Analysis (BIA), and Skinfold Thickness (SFT), are widely applied in the clinic as an estimation of lean body mass. In this experiment, the lean body mass in a 21-year-old non-athlete Caucasian female was calculated by using BMI, BIA, and SFT and their corresponding equations. The purpose of this experiment was to analyze the capacity of these three measurements in estimating the subject's lean body mass. The experiment showed that the subject's lean body mass percentage was 77.4% and 79.8% respectively by using BMI and BIA analysis. Results based on skinfold measurement and its corresponding prediction equations showed the lean body mass percentage with a variation from 78.57% to 83.08%. The experiment demonstrated that the combination of different measurements in calculating the subject's lean body mass would help to narrow the values of lean body mass percentage to a certain scope, which can facilitate a rough estimate. However, further research is needed to evaluate the accuracy of different measurements based on the gold standard (*DEXA Scan*).

Introduction

Lean body mass is regarded as an important nutritional indicator to evaluate the health status of individuals. Nutritional interventions could be conducted earlier based on the level of lean body mass for the patients during their medical treatment.[1] Lean body mass has demonstrated its valuable application in guiding exercise scientists and nutritionists to tailor athletes food intake. Coaches are also able to optimize training plans for athletes based on their lean body mass condition.[2] Older adults with much lean mass loss are at a higher risk of osteoporosis and a series of chronic diseases in metabolism and cardiovascular system.[3] For people who intend to get a weight loss in body fat, their lean body mass tends to decrease as well. Calculating the lean body mass can facilitate them to regulate their weight loss strategy accordingly with a supplementation in nutrients.[4] Therefore, effective measurements for lean body mass calculation are helpful to guide nutritional interventions in patients, sports training for athletes, and nutrient supplementation among certain populations.

Body Mass Index (BMI) is one of the most common measurements in medical research to identify the body composition of an individual. However, its failure to make a distinction between adipose tissue and lean body mass has made BMI less accurate for subjects with high muscle mass.[5] Lean body mass was calculated based on an equation for an estimation of body fat percentage. The equation was derived from a collection of data from populations aged 7 to 83 years old in an experiment.

Bioelectrical Impedance Analysis (BIA) directly measures the body fat percentage through a flow of electrical current from subject's hands to feet. This measurement can well distinguish body fat from lean body mass, as adipose tissue makes the main contribution to the electrical resistance, where the resistance in lean body mass is very small. In this case, the BIA analysis is not accurate among patients with fluid shift, due to their abnormal hydration status that would affect the electrical current.[1]

Skinfold Thickness (SFT) is a good anthropometric method for measuring subcutaneous fat, which fits all ages including infants and older adults because of its reliability, low cost, and noninvasiveness.[6] For females, skinfolds from biceps, subscapular, suprailiac, thigh and triceps need to be measured, to meet the requirements for different prediction equations. More specifically, the body fat percentage is calculated from body density, and body density is derived from prediction equations with skinfolds data.

The purpose of this experiment was to compare and evaluate different measurements by calculating the lean body mass of a 21-year-old non-athlete Caucasian female, through the data of BMI, BIA and SFT, as well as their corresponding prediction equations. In measuring the BMI, the body fat percentage was calculated based on the prediction equation and the subject's age; the measurement of BIA was used to directly estimate the body fat percentage; SFT measurement was applied to calculate the body density and then body fat percentage, based on different prediction equation that results in variations of values. Lean body mass was calculated by subtracting the body fat from total body weight. Despite the diversity of measurement methods, the results for the subject's lean body mass is expected to be within a certain scope. BMI, BIA, and SFT are expected to provide good estimation for the lean body mass.

Methods

The subject was a 21-year-old non-athlete Caucasian female, self-reported in healthy condition, with no intensive exercise activities before the measurement.

Weight and height of the subject were measured twice on the *Seca* scale stadiometer, and the BMI was calculated based on the value of weight (kg) and height^2 (m^2), where **BMI =** $\frac{\textbf{weight (kg)}}{\textbf{height}^2\textbf{(m}^2\textbf{)}}$. The Body fat percentage was calculate based on the prediction equation

(*Deurenberg* et al., 1991)[7]: **% Body Fat = 1.20×BMI + 0.23 (age) - 10.8 (G) -5.4** *(G = 1 if male and 0 if female)*. Lean body mass percentage was also calculated, where **% Lean Body Mass = 100% - % Body Fat**.

Omron Body Fat analyzer was applied to directly calculate the value of body fat percentage. Personal information including age, weight, height, sex, and athleticism needs to be recorded to the analyzer before measurement.

Skinfold measurement (SFT) was applied with the *Lange* Skinfold Caliper on the right side of the body, where anatomical position is preferred in measuring the subject. As the subject is female, skinfolds were measured from biceps, subscapular, suprailiac, thigh and triceps. Measurements at these specific locations were illustrated in the Laboratory Manual.[7] At least three measurements were taken at the same position, where the mean values were recorded.

Three skinfold predication equations for females were applied to calculate body density, which were described in the Laboratory Manual[7]:

Equation 1.1 (*Wilmore and Behnke*, 1970)

$$\textbf{Density (g/cc)} = \mathbf{1.06234 - 0.00068(X_4) - 0.00039(X_7) - 0.00025(X_6)}$$

X_4 = subscapular skinfold (mm); X_7 = triceps skinfold (mm); and X_6 = thigh skinfold (mm)

Equation 1.2 (*Jackson, Pollack & Ward*, 1980)

$$\textbf{Density (g/cc)} = \mathbf{1.0994921 - 0.0009929(\sum X_{10}) + 0.00000023(\sum X_{10})^2 - 0.0001392(Age)}$$

$\sum X_{10}$ = *Sum of the suprailiac, thigh and triceps skinfolds (mm)*

Equation 1.3 (*Durnin and Womersley*, 1974)

$$\textbf{Density (g/cc)} = \mathbf{C - (M \times \log \sum X_9)}$$

$\sum X_9$ = *Sum of the biceps, subscapular, suprailiac and triceps skinfolds (mm)*

Body fat percentage was then calculated based on the values of body density from the equations above. The prediction equations were also described in the Laboratory Manual[7]:

Equation 2.1 (*Brozek* et al. equation)

% Body Fat = [(4.570/D) - 4.142] × 100 *D = density (g/cc)*

Equation 2.2 (*Siri* equation)

% Body Fat = [(4.95/D) – 4.50] × 100 *D = density (g/cc)*

Equation 2.3 (*Heyward and Wagner*, 2004)

The equations developed by Heyward and Wagner are varied in population, age, and gender. According to the subject information, the appropriate equation was picked up from the equation chart:

% Body Fat = [(4.96/D) - 4.51] × 100 D = *density (g/cc)*

% Lean body mass was also calculated, where

% Lean Body Mass = 100% - % Body Fat.

Results

The subject's BMI was calculated based on her height (169.15 cm) and weight (55.3 kg), which was 19.33. The values of body fat and lean body mass measured from BMI and BIA are shown in the table below (Table 1). The values of body density, body fat and lean body mass calculated from SFT and its prediction equations are also shown in the table below (Table 1).

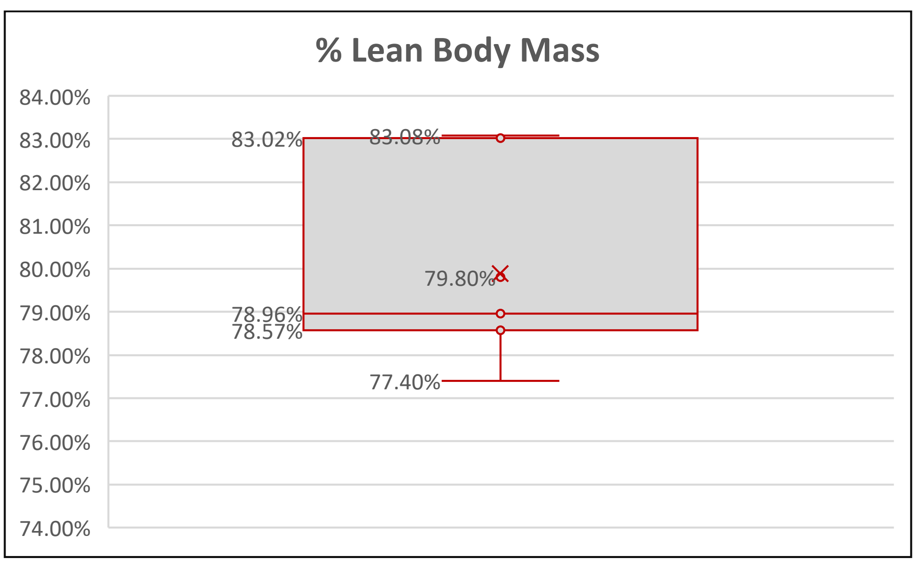
The Boxplot (Chart 1) shows how a combination of data in % Body Fat are distributed within a certain scope from 77.4% to 83.08%. The mean % Lean Body Mass is 79.88%, and the standard deviation is 0.02.

Table 1 Summary of body composition by BMI, BIA, and SFT with corresponding prediction equations

Measurement	Prediction Equation 1	Body Density	Prediction Equation 2	% Body Fat	% Lean Body Mass	Body Fat (kg)	Lean Body Mass (kg)
BMI	N/A	N/A	*Deurenberg et al.*	22.6 %	77.4 %	12.50 kg	42.8 kg
BIA	N/A	N/A	N/A	20.2 %	79.8 %	11.17 kg	44.13 kg
SFT	*Wilmore & Behnke*	1.05	*Brozek et al.*	21.04 %	78.96 %	11.64 kg	43.66 kg
SFT	*Wilmore & Behnke*	1.05	*Siri*	21.43 %	78.57 %	11.85 kg	43.45 kg
SFT	*Wilmore & Behnke*	1.05	*Heyward & Wagner*	21.38 %	78.62 %	11.82 kg	43.48 kg
SFT	*Jackson, Pollack & Ward*	1.06	*Brozek et al.*	16.93 %	83.07 %	9.36 kg	45.94 kg
SFT	*Jackson, Pollack & Ward*	1.06	*Siri*	16.98 %	83.02 %	9.39 kg	45.91 kg
SFT	*Jackson, Pollack & Ward*	1.06	*Heyward & Wagner*	16.92 %	83.08 %	9.36 kg	45.94 kg
SFT	*Durnin & Womersley*	1.05	*Brozek et al.*	21.04 %	78.96 %	11.64 kg	43.66 kg
SFT	*Durnin & Womersley*	1.05	*Siri*	21.43 %	78.57 %	11.85 kg	43.45 kg
SFT	*Durnin & Womersley*	1.05	*Heyward & Wagner*	21.38 %	78.62 %	11.82 kg	43.48 kg

Chart 1 A data collection for % Lean Body Mass

(Mean = 79.88 %, SD = 0.02)



Discussion

In this experiment, different values of the subject's lean body mass percentage were obtained through a variety of measurements and prediction equations, resulting in a variation from 77.4% to 83.08%. The values of lean body mass calculated from the BMI, BIA, and SFT were within a certain range (79.88%±2%), which may provide a rough estimate on the subject's body composition. The gold standard such as *DEXA Scan* was expected to be used as a norm to assess the accuracy of different measurements. However, due to the absence of gold standard in this experiment, the accuracy of these three measurements could not be evaluated.

The BMI value is mainly associated with height and weight, which makes it hard to differentiate the lean body mass and body fat. In this experiment, the predication equation for BMI was mainly based on a selected population, which may lead to limited accuracy in calculation. The subject's BMI was 19.33, which is classified as normal range. The lean body mass percentage calculated from BMI was 77.4%, which is at the lower limit compared to the values from BIA and SFT analysis.

BIA analysis is able to directly calculate the body fat percentage through electronic current, but it could be largely affected by the altered hydration status and fluid balance of the individuals. In this experiment, BIA analysis showed that the subject's body fat percentage was 20.2%, and thus the lean body fat percentage was 79.8%. The value of lean body fat percentage was pretty close to the mean value in the data collection for % Lean Body Mass (Chart 1). As the subject was healthy and had no manifestation of hydration, BIA analysis might be reliable to estimate the subject's lean body mass.

SFT measurement provides a series of values based on different equations for body density and body fat percentage. In the process of measuring subcutaneous fat, technician error may occur due to the lack of professional training for measurement. The accuracy may also be affected by skin thickness, hydration status, and exercise. In addition, the skinfold measurement assumed subcutaneous fat as the total body fat, so the prediction of visceral fat was limited. In this SFT measurement, the lean body mass percentage ranged from 78.57% to 83.08%. *Heyward & Wagner* equation takes ethnicity, age, gender, and physical fitness into consideration, which makes it more targeted to fit different populations than the *Brozek et al.* and *Siri* equations.

Conclusion

The purpose of this experiment was to evaluate the efficacy of BMI, BIA, and SFT measurements in the process of calculating subject's lean body mass. The study found that with the combination of different measurements, the value of lean body mass percentage could be narrowed down to a certain range, which may be applied as a way for rough estimate. However, this experiment didn't demonstrate the accuracy of various measuring methods, and thus the gold standard such as *DEXA Scan* is expected to be applied in the further research to calculate the exact value of lean body mass and analyze the deviation among these methods.

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