J. Phys. Ther. Sci.
24: 791–793, 2012

Relationships among Hydrostatic Weighing, BMI, and Skinfold Test Results in College Students

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Abstract. [Purpose] The purpose of this study was to investigate relationships among the results of hydrostatic weighing, BMI, and skinfold measurements. [Subject] The participants of this study were eighteen male and female students. [Methods] Hydrostatic weighing, BMI, and skinfold body composition tests were conducted. The participants were divided into two groups based on gender, and a multivariate analysis of variance (MANOVA) was used to determine the differences between the groups. [Results] The female group had significantly higher values in the three body composition tests than the male group. [Conclusion] The results show that the females had higher values for each of the three different body composition tests. However, it is not clear why the females had higher values. Therefore, it will be necessary to find more accurate methods of measuring body composition.
Key words: Hydrostatic weighing, Skinfold, Body fat

(This article was submitted Feb. 13, 2012, and was accepted Mar. 13, 2012)

INTRODUCTION

Body composition is one of the most important components of an individual's health and physical fitness[1)]. Even though fat has essential functions, such as cushioning the organs, providing energy, and in the construction of cell membranes, an excessive amount is a sign of health problems. Too much body fat has been associated with not only increased risks of coronary artery disease, hypertension, Type II diabetes, and cardiovascular disease, but also decreased physical performance[2)]. Also, osteoporosis has been linked to too little body fat[1)]. Therefore, an appropriate amount of body fat is a key to staying healthy, and even though young adults have a healthy body, it is important to know how much body fat an individual has, and to measure it regularly to assess health risks.

Due to advances in medicine and technology, life expectancy is increasing. However, many people of all ages suffer from diseases because of a lack of physical activity and unhealthy eating habits. One of the most serious problems in this society is obesity, which has been linked to several serious diseases that are common not only among the elderly but also among young adults. The causes of obesity can be divided into the two categories: biological, and behavioral or environmental factors[3)].

College students are exposed to many risk of obesity because they like to eat fast food to save their time. Stated differently, they are more affected by environmental factors than biological ones. As a result, an accurate method of assessing the body composition of young adults is becoming an imperative.

Hydrostatic weighing is considered the "Gold Standard" for measuring body composition, even though it requires expensive equipment and needs a special place to assess it[4)]. In this method, the subject's density is found by weighing under water. The idea of underwater weighing is based on the buoyancy of the human body, with fat being more buoyant than lean tissue. The measurement of body density is based on Archimedes' principle, which states that the body loses mass equal to the amount of water displaced by the body when immersed in water[5)].

Another useful and common way of measuring body composition is the skinfold caliper test. Not only is it not expensive compared other tests, but it can also save time[6)]. This method is based on the assumption that most of total body fat is subcutaneous. Heyward[1)] has reported that the values for subcutaneous fat measured by the skinfold caliper test are similar to the values obtained from magnetic resonance imaging. The skinfold caliper measurement demonstrates a high reliability with test-retest correlations as high as 0.96 for persons tested after a one-day waiting period[5)]. However, if the technician's skills are poor, the results of this test may be inaccurate.

The body mass index (BMI) is one of the most popular and simple body composition indexes. The measurement of body weight and height, which contribute to the calculation of BMI, is simple, inexpensive and non-invasive. BMI is simply based on height and weight, and it fails to assess lean muscle mass or body fat percentage, and indicates most lean individuals are overweight simply by definition. BMI has been investigated and is widely utilized as a non-invasive method of estimating body fat percentage. Keys, Fidanza, Karvonen, Kimura and Taylor[7)] investigated the accuracy of using BMI measurements to predict the percentage of body

fat. They compared the results of hydrostatic weighing, and found that moderate correlations ranging from 0.70 to 0.80 existed between the two measurements. The purpose of this study was to investigate the relationships among the results of hydrostatic weighing, BMI, and skinfold caliper measurements.

SUBJECTS AND METHODS

Subjects

The participants of this study were eighteen males and female students (mean ± SD age, 23.05 ± 2.48 years; height, 169.89 ± 8.62 cm; weight, 68.56 ± 12.11 kg) who had no history of disease since entering university. Also, none of the subjects were receiving medication, and all were nonsmokers. Written informed consent was obtained from all the participants.

Testing Instruments and Procedures

Three different body composition tests, hydrostatic weighing, skinfold, and BMI, were conducted. Anthropometric measurements were taken. Skinfold measurement was performed using the Jackson/Pollock (*J-P*) method. The three sites used for the men were the thigh, chest, and abdomen, and those used for women were the thigh, triceps, and suprailium.

Calculations of Body Fat

The data were used in the following equations to find the body density and body fat percentage all of our participants.

Hydrostatic:

Body density = Body Mass in Air / (Body Mass in Air − Body Mass in Water)

% Body Fat = (495 / Body Density) − 450

Body Mass Index:

Body density = Weight (kg) / Height^2 (m)

% Body Fat = 1.20 × BMI + (0.23 × Age) − (10.8 × Sex) − 5.4

Where: Sex = 1 for men and 0 for women

Skinfolds:

Men

Body density = 1.1093800 − 0.0008267SSF + 0.0000016SSF^2 − 0.0002574 Age

Women

Body density = 1.0994921 − 0.0009929SSF + 0.0000023SSF^2 − 0.0001392 Age

Where:

SSF (male) = sum of chest, abdomen, and thigh skinfolds (mm)

SSF (female) = sum of triceps, thigh, and suprailium skinfolds (mm)

Table 1. Characteristics of the subjects

Variable	Mean ± SD	Low	High
Age (years)	23.05 ± 2.5	21	29
Weight (kg)	68.6 ± 12.1	37	84
Height (cm)	169. 9 ± 8.6	152	185
Skinfold (%)	22.4 ± 8.4	5.0	33.2
Body Mass Index (%)	23.4 ± 4.7	15.7	31.2
Hydrostatic Weighing (%)	18.4 ± 7.6	3.0	29.7

Data were presented as mean ± SD. A multivariance analysis of variance (MANOVA) was performed to determine the differences between gender of the body composition tests. Significance was accepted at $p<0.05$ in all statistical analyses. Data were analyzed using the statistical analysis tools of SAS 8.0 software.

RESULTS

Table 1 displays the characteristics of the study population. The mean percentage of body fat in the skinfold test was 22.4 ± 8.4%, ranging from 5.0 to 33.2%. Mean BMI was 23.4 ± 4.7%, ranging from 15.7 to 31.2%. The mean percentage of body fat by hydrostatic weighing was 18.4 ± 7.6%, ranging from 3.0 to 29.7%.

The analysis revealed a significant difference between groups based on gender in the skinfold test, $F(1, 16) = 12.78$; $p<0.05$. Tukey's HSD test showed that the female group had significantly higher values in the skinfold test than the male group ($p<0.05$). The analysis also revealed that there was a significant difference between gender in BMI, $F(1, 16) = 22.40$; $p<0.05$. Tukey's HSD test showed that the females had significantly higher BMI than the males ($p<0.05$). A significant difference between males and females was found in the hydrostatic weighing test, $F(1, 16) = 12.67$; $p<0.05$. Tukey's HSD test showed that the female group had significantly higher hydrostatic weighing values than the male group ($p<0.05$).

DISCUSSION

In the results of the descriptive statistics, the highest SD is seen in the skinfold test (± 8.4), because the results of the skinfold test are affected by the technician's measuring skills. The SDs of the two other tests are ± 4.7 for BMI and ± 7.6 for the hydrostatic weighing test. BMI had the lowest SD due to the simple calculation of body composition using weight and height. However, BMI is more likely to fail to assess lean muscle mass or exact body fat percentage than other body composition measures. Although BMI is not the best measurement for body composition, it is widely used to measure body composition because it is a simple, inexpensive, and convenient test procedure.

Our hypothesis was that there would be a significant gender differences shown by the three different body composition tests. In the result, the female group had higher body fat value than the male group due to the fact that automati-

cally males have higher lean body mass than fat.

The differing results of the body composition tests are associated with many factors, especially performers' measuring skills. It is important for technicians to measure exact body composition; therefore, it is necessary to practice the measuring procedure and know the benefits of each body composition test to increase the reliabilities of the tests. One limitations of this study was that the participants of this study were 18 students. Therefore, the statistical power was not insufficient to provide a strong conclusion to this research. Further research should be conducted with greater numbers of participants to increase the statistical power.

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