An Examination of Three Bioelectrical Impedance Body Composition Devices in College Students

Original Research

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Abstract

Introduction: Having inexpensive, convenient, and accurate body composition devices available is helpful. The purpose of this study was to determine whether three bioelectrical impedance body composition analyzers are acceptable methods for measuring body composition.

Methods: Participants included 40 college students (18 males and 22 females, 17-22 years, 19.5yrs ± 1.09,). Each participant's percent body fat (%BF) was tested by a Bod Pod®, a handheld Omron HBF-306, a handheld Omron HBF-300, and a standing scale Health-o-meter model BFM081DQ1-63. Repeated measures ANOVA and Bonferroni corrected post hocs were performed to determine statistical differences for %BF among the four devices. A Bland-Altman plot was used to visualize the %BF difference between the Bod Pod and Omron HBF-306.

Results: Mean and SD %BF values for the devices were Bod Pod (19.6 ± 10.70), HBF-300 (16.6 ± 8.07), HBF-306 (18.2 ± 7.75), and Health-o-meter (21.7 ± 11.18). Repeated measures ANOVA revealed statistically significant differences ($p < 0.0001$) in %BF among the four devices. Bonferroni correction post hoc analysis revealed significant differences among 5 of 6 pairwise comparisons. Bod Pod and HBF 306 were not significantly different ($p=0.0584$). The HBF-300 underestimated %BF by 3%, and the Health-o-Meter overestimated %BF by 2.1% compared to the Bod Pod.

Conclusions: This study found only one of the three BIA devices to measure body composition accurately. Thus, it is recommended to choose the handheld Omron HBF-306 if one is looking for an inexpensive, convenient, and portable option. Otherwise, it is recommended to use a gold-standard device such as the Bod Pod.

Key Words: BIA, Percent Body Fat, Accuracy

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Introduction

Body composition (BC) is a measurement of fat mass and fat-free mass. BC is an important measure that has clinical repercussions in sports performance, health, and fitness assessments. For instance, having a BC measure aids medical practitioners in evaluating the health of their patients who may be at risk for having excessive amounts of fat mass content that would qualify them as overweight or obese. It is well-documented that obesity contributes to a host of medical conditions.[1,2] Due to the risks associated with obesity, it is important for medical practitioners to screen for obesity in their patients using an accurate BC device.

A method for measuring BC that is gaining popularity is bioelectrical impedance analysis (BIA). BIA is a method that exposes a person to an undetected alternating current, which measures electrical resistance in the body, with the resistance used in an algorithm to compute BC.[3] Compared to other BC measurements, BIA has shown mixed results in accuracy. Several studies have shown that BIA devices differ significantly in their BC accuracy compared to gold standard methods such as dual-energy x-ray absorptiometry (DEXA).[4,5] Other research has produced more positive results for the efficacy of BIA devices. Two studies found BIA to be a valid and accurate method for measuring BC equivalent to gold standard methods such as DEXA and magnetic resonance imaging (MRI).[6,7] Research has also found BIA valid across different population groups, such as active college students and individuals with cerebral palsy.[8,9] Additional research found that BIA is relevant in group epidemiological studies but not individual settings.[10]

The gold standards for measuring BC include MRI, DEXA, underwater weighing (UWW), and air displacement plethysmography (Bod Pod).[11,12] Although these methods are highly accurate, they have many disadvantages, including high costs, lengthy waiting periods for results, and requiring trained persons to operate the equipment.[6] These disadvantages limit the use of these methods. Thus, BIA could fill clinical needs for measuring BC in large populations since it is a relatively low-cost, portable method and does not require extensive training. As the research on the efficacy and reliability of BIA devices in measuring BC is inconclusive, more studies are needed to evaluate the accuracy of BIA methods. The purpose of this study was to determine whether three bioelectrical impedance analyzers, compared to the Bod Pod, are accurate methods to measure body composition.

Methods

Participants

Participants included 40 male and female college students from a small Midwest university. Participants included both athletes and non-athletes, aged 17 to 22 years. Participants were recruited via an invitation through email and word of mouth. Participants were instructed to abstain from exercising, eating, or consuming caffeine four hours before the test. They also were instructed not to consume alcohol 24 hours prior and to consume two to four cups of water about two hours before testing. The subjects could void as needed. Each participant read and signed an informed consent form prior to testing. Participants under 18 years of age required parental/guardian signature prior to testing. One participant was 17 years of age and thus required parental signature. Potential participants with medical complications, pregnant, and under 17 years of age were excluded from participating. Inclusion criteria included being a college student, between ages 17 and 24, and following the pre-testing guidelines. The Institutional Review Board (IRB) approved the study before testing.

Protocol

Participants were tested in the exercise lab at a small Midwestern University. A Bod Pod and three bioelectrical impedance analyzers (BIA) were used to measure the %BF of each subject. First, subjects had their height measured. Participants' weight was measured on a scale before entering the Bod Pod. %BF, fat mass, and fat-free mass were also measured using the Bod Pod. Next, the participants' %BF was measured by the BIA devices in the order of the handheld Omron HBF-306, the handheld Omron HBF-300, and the standing scale Health-o-meter model BFM081DQ1-63.

Instruments/Measures

The Bod Pod® was used first. It has been shown to be a valid measure of body compostion.[13] The Bod Pod was calibrated prior to testing. Participants were instructed to wear only spandex-style undergarments, a swim cap, and to remove all jewelry. The Bod Pod measured body weight, %BF, FM, and FFM. The software used to calculate results was the Bod Pod Body Composition Tracking System.

Statistical Analysis

Data analysis was performed in Excel. Descriptive statistics included mean, standard deviation, minimum, and maximum values. A repeated measures ANOVA performed in Excel was used to determine the statistical main effect among the four devices for %BF. The Bonferroni correction post hoc analysis was used to determine statistical differences among the four devices. Statistical significance was set at $p \leq 0.05$ for ANOVA testing and $p \leq 0.0083$ for the Bonferroni correction. Bland-Altman plot with 95% limits of agreement was used to visualize the mean differences in %BF between Bod Pod and HBF-306. Intraclass correlation coefficient (ICC) was calculated to quantify the reliability among the four devices for measuring percent body fat.

Results

Table 1. shows the participant characteristics. There were 18 male and 22 female participants. Of the 40 participants, 27 were athletes and 13 were non-athletes.

Table 1. Participant Characteristics.

Characteristic	Mean ± SD	Min – Max
Age (yr)	19.5 ± 1.09	17 – 22
Weight (kg)	67.7 ± 12.41	48.7 – 101.6
Height (cm)	170.6 ± 9.30	153.0 – 193.0
BMI	23.1 ± 3.35	18.3 – 35.4
FFM (kg)	54.3 ± 11.06	38.5 – 78.7
FM (kg)	13.4 ± 8.83	3.1– 42.8

Note: FFM and FM were measured with Bod Pod. FFM = Fat-Free Mass, FM = Fat Mass, BMI = Body Mass Index

Descriptive data for %BF from the four devices is shown in Table 2. The ANOVA revealed a significant main effect (F = 22.17, p < 0.0001) in %BF among the four devices. Post-hoc analysis showed significant differences among 5 of 6 pairwise comparisons. The Bod Pod was significantly different from the HBF-300 (p < 0.0001) and the Health-o-Meter (p = 0.00046). The HBF 306 was significantly different from the HBF 300 (p < 0.0001) and the Health-o-Meter (p < 0.0001). The HBF 300 significantly differed from the Health-o-Meter (p < 0.0001). The Bod Pod and HBF-306 were not significantly different (p = 0.058). The HBF-300 underestimated %BF by 3% and the Health-o-Meter overestimated %BF by 2.1% on average compared to the Bod Pod. The Bland-Altman pot (Figure 1) revealed a constant bias of 1.5% and a possible proportional bias. At lower average %BF, the HBF-306 appears to overestimate %BF, and at higher average % BF, it appears to underestimate %BF. The intraclass correlation coefficient was 0.867, indicating a good reliability among the different devices for percent body fat.

Table 2. %BF Descriptive Data

%BF Measure	Mean ± SD	Min – Max
Bod Pod	19.6 ± 10.70	4.7 – 42.2
HBF-300	16.6 ± 8.07	4.2 – 38.7
HBF-306	18.2 ± 7.75	5.7 – 40.3
Health-o-Meter	21.7 ± 11.18	7.9 – 43.9

Note. 5 of 6 pairwise comparisons were significantly different. Only Bod Pod and HBF-306 were not (p = 0.0584).

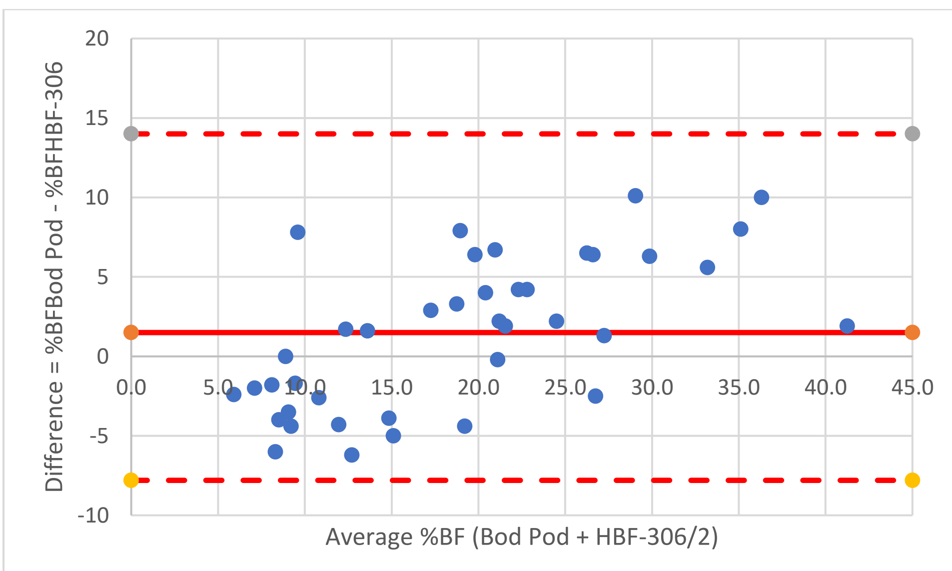

Figure 1. Bland-Altman Plot of individual %BF differences between Bod Pod and HBF-306. The solid line represents the constant bias (1.5%). The dashed lines are the 95% confidence interval (-7.8 to +14%). %BF = percent body fat.

Discussion

The purpose of this study was to evaluate the accuracy of three Bioelectrical Impedance Analysis (BIA) devices in measuring body composition (BC). The findings showed that the HBF-300 and the Health-o-Meter devices provided measurements that differed significantly from those obtained by the Bod Pod, the reference method. In contrast, the

HBF-306 device did not significantly differ from the Bod Pod's measurements, suggesting better accuracy. Additionally, there were significant differences in measurements between the HBF-306 and the other two BIA devices, suggesting variability in BIA device accuracy. Notably, the HBF-300 underestimated body fat percentage by 3%, while the Health-o-Meter overestimated by 2.1% on average, compared to the Bod Pod.

Previous research comparing BIA devices to the Bod Pod reported findings similar to those of this study. The results of study of adolescent aged 13 to 17 years that compared %BF measurements from ADP (Bod Pod), BIA, DEXA, and anthropometry indicated agreement in %BF values between the Bod Pod and BIA, although these two methods had significantly higher values compared to DEXA and anthropometry.[14] Additional research by Kalra et al. found that a foot-to-foot BIA device correlated with a Bod Pod in measuring %BF amongst a South Asian population.[15] Another study by Houska et al.[16] comparing %BF measurements between BIA, ADP, and underwater weighing in female athletes reported similar findings to Vincente-Rodríguez et al.[14], as all three methods were strongly correlated. However, the ADP and BIA methods significantly overestimated %BF compared to underwater weighing. All three studies found BIA and ADP to have similar measurements, though not with other gold standard methods.

Previous research comparing BIA to gold standard methods other than ADP reported mixed agreement with this study's findings. Studies noted that BIA devices are accurate measures of BC comparable to multiple gold standard methods.[6,7] Similar to this study's findings, other research has concluded that BIA devices differ significantly in their BC accuracy compared to gold standards such as DEXA.[4,5]

Methodological Considerations:
This study had two limitations. First, though pretesting guidelines were communicated to participants well in advance, it was impossible to ensure that all participants honestly adhered to every procedure, such as not refraining from consuming caffeine several hours before testing. A second limitation is that this study's findings are not generalizable to all populations due to its narrow focus on college students.

One strength of this study was that participants followed a consistent testing procedure for the Bod Pod and BIA devices. All participants were measured by the Bod Pod and then measured by the three BIA devices in the same order every time. Uniform pretesting guidelines were also given to each participant beforehand. A second strength of the study was that multiple BIA devices were included. This allowed for comparison among various BIA devices and the Bod Pod, producing a comprehensive analysis of the BIA's accuracy.

Implications:
The primary implication of this study is that if BIA devices are accurate measures of BC comparable to gold standard methods, there is justification for the increased use of BIA devices in clinical settings to screen for overweight or obese individuals. As previously noted, BIA devices are cheap, easily accessible, and produce results quickly compared to gold standard methods. The clinical use of BIA devices could reduce the time, money, and resources that medical practitioners and patients spend assessing BC when such assessments are becoming more critical due to the continued rise of obesity nationwide.

While the accuracy of BIA devices is promising, research is yet to conclusively determine if BIA is an accurate BC method comparable to gold standards. Therefore, additional research should be conducted to assess the accuracy of BIA devices against all the gold standard methods and in different population groups. In clinical settings, BIA should be limited to the general population for routine physical checkups and not be used with vulnerable patients as they likely need more accurate results.

Conclusions
This study determined only one (HBF-306) of the three BIA devices to be an accurate measure of body composition. The other two BIA devices (HBF-300 and Health-O-Meter) produced %BF estimates significantly different from the Bod Pod. Thus, out of the three BIA devices tested in this study, it is recommended to choose the handheld Omron HBF-306 if one is looking for an inexpensive, convenient, and portable option. Otherwise, it is recommended to use a Gold-Standard device such as the Bod Pod.

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