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Original Article

The Impact of Feet Callosities, Arm Posture, and Usage of Electrolyte Wipes on Body Composition by Bioelectrical Impedance Analysis in Morbidly Obese Adults

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Key Words

Bioelectrical impedance · Body composition · Morbid obesity · Callosities · Fat mass · Standardization

Abstract

Objective: This study evaluated the impact of feet callosities, arm posture, and use of electrolyte wipes on body composition measurements by bioelectrical impedance analysis (BIA) in morbidly obese adults. ***Methods:*** 36 morbidly obese patients (13 males, aged 28–70 years, BMI 41.6 ± 4.3 kg/m^2) with moderate/severe feet callosities participated in this study. Body composition (percent body fat (%BF)) was measured while fasting using multi-frequency BIA (InBody 720®), before and after removal of callosities, with and without InBody® electrolyte wipes and custom-built auxiliary pads (to assess arm posture impact). Results from BIA were compared to air displacement plethysmography (ADP, BodPod®). ***Results:*** Median %BF was significantly higher with auxiliary pads than without (50.1 (interquartile range 8.2) vs. 49.3 (interquartile range 9.1); $p < 0.001$), while no differences were found with callosity removal (49.3 (interquartile range 9.1) vs. 50.0 (interquartile range 7.9); NS) or use of wipes (49.6 (interquartile range 8.5) vs. 49.3 (interquartile range 9.1); NS). No differences in %BF were found between BIA and ADP (49.1 (IQR: 8.9) vs. 49.3 (IQR: 9.1); NS). ***Conclusion:*** Arm posture has a significant impact on %BF assessed by BIA, contrary to the presence of feet callosities and use of electrolyte wipes. Arm posture standardization during BIA for body composition assessment is, therefore, recommended.

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Introduction

Morbid obesity is characterized by large alterations in body composition; notably increases in fat mass and total body water due to an expansion of extracellular water volume compared to intracellular water [1]. This brings challenges when trying to assess body composition in this population. Little research is available on what methods of body composition can be used on this patient group [2–5].

Air displacement plethysmography (ADP), using the commercial system BodPod® (COSMED, Rome, Italy), is a method commonly utilized to measure body composition in the severely obese [6]. ADP is often employed as it is user-friendly and has good agreement with body composition measurements derived from hydrostatic weighing [7, 8]. However, ADP is expensive, and the equipment is stationary. An alternate technique used to measure body composition in severely obese individuals is bioelectric impedance analysis (BIA) [1, 4, 9].

Since BIA was introduced in the 1980s, it has become an increasingly popular tool for estimating body composition because it is easy to use, noninvasive, relatively inexpensive, portable, and can be performed across a wide range of subjects [9–11]. However, BIA values can be affected by several factors, including body position, hydration status, consumption of food and beverages, ambient air and skin temperature, and recent physical activity [10, 12]. Therefore, the standardization of measurement conditions, whenever possible, should be performed in order to obtain accurate, valid, and reliable data [10, 12].

The quality of BIA has improved greatly over recent years with the introduction of multi-frequency BIA [13], which measures resistance and reactance at multiple frequencies. The InBody 720® (InBody, Seoul, South Korea) is a commercially available model of multi-frequency BIA. The InBody 720 manual instructs the individual being measured to form an angle of 15° between the arms and trunk, while holding on to the hand electrodes [14]. However, no specific recommendations are provided on how to obtain and maintain such an angle. In clinical practice, the authors have observed a substantial variation in angles when clinical staff performs these measurements. The manual also recommends the use of InBody electrolyte wipes, namely when the examinee presents with dry palms and soles.

The rate of water accumulation at BIA contact sites may be affected during measurements, as skin contact with the electrodes disrupts natural transpiration [15, 16]. The rate of water accumulation in the stratum corneum can be further exacerbated by the presence of callosities, as new stratum corneum forming underneath calluses is less hydrated than normal [16]. To our knowledge, no study has looked at the potential impact of common feet callosities, arm posture, and use of electrolyte wipes on body composition measurements derived from BIA. The primary aim of this study was to evaluate the impact of feet callosities, arm posture, and the use of InBody electrolyte wipes on the body composition measurements obtained using BIA (InBody 720), in morbidly obese adults. The secondary aim was to compare body composition measurements obtained by BIA in morbidly obese patients with those obtained by ADP (BodPod; COSMED).

Material and Methods

Subjects and Study Design

36 study participants (13 males, 23 females, aged 28-70 years) were recruited from the Obesity Outpatient Clinic of St. Olavs University Hospital in Trondheim, Norway. Adults with BMI ≥ 35.00 kg/m^2 deemed in need of feet callus removal (as assessed by podiatrist) were included in this study. The exclusion criteria were intractable plantar keratosis (painful plantar calluses located under the metatarsal heads) [17], pregnancy, and patients with medical electrical devices or suffering from diseases causing water retention (edema, renal insufficiency, hypertension etc.). This study was conducted according to the guidelines laid

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Fig. 1. Study participant measured on InBody 720 using custom-made auxiliary pads.

down in the Declaration of Helsinki and was approved by the Regional Ethics Committee, Central-Norway (Ref. 2012/1018). Written informed consent was obtained from all participants.

A power calculation was performed based on expected differences in % body fat (%BF) between pairs of measurements. A sample size of 33 participants would be needed to detect a difference of 2.5% in body fat, assuming a standard deviation for this variable of 3.5, at a power of 80%, and a significance level of 5%. A sample size of 36 participants was necessary to allow for a predicted dropout rate of around 10%. This study followed a repeated measures design, where body composition was assessed using BIA before and after pedicure, with or without auxiliary pads and wipes, and also using ADP. All participants were treated as one group, tested under all conditions, and served as their own controls.

Detailed Protocol

Participants were asked to attend the research unit of the Obesity Outpatient Clinic at St. Olavs Hospital, Trondheim, on three occasions: a preliminary assessment session and two consecutive measurement days. At the preliminary session, feet soles were assessed by an authorized podiatrist for eligibility. Study partici-

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pants with moderate to severe calluses on their feet were included in the study. For both measurement days, participants were asked to come in fasting, for standardization purposes.

On day 1, study participants had their feet photographed for a pre-post pedicure comparison, had their height measured, and were assessed using BIA (InBody 720) wearing only undergarments. Three sets of body composition measurements were taken using the BIA on day 1. Body composition data obtained was estimated from impedance measured at six different frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz, 1,000 kHz). Information from all frequencies was used to calculate total body water, from which body fat was estimated. During the first measurement, participants were asked to step onto the InBody 720 and have their arms extended out at approximately 15° arm posture (in accordance with InBody recommendations). For the second measurement, participants were given custom-built auxiliary pads made out of Plastazote®, an inert material that is water resistant and non-conductive [18], to help participants hold their arms out at an exact 15° angle (fig. 1). This test was performed in order to determine if the recommended 15° posture is crucial for obtaining accurate measurements. The InBody 720 was weight-adjusted to compensate for the weight of the auxiliary pads (the scale in the InBody was re-adjusted by 0.4 kg to account for the weight of the pads). The third measurement was similar to the first; however, in addition, participants were also asked to moisten the palms of their hands and soles of their feet with the electrolyte wipe recommended by InBody. This was the BIA measurement used for comparison purposes with ADP.

Following the completion of all BIA measurements, participants underwent one final measurement of body composition using ADP. This measurement followed the recommended procedure provided by the manual (participants were measured in their non-metallic undergarments using the Brozek equation recommended for this study population, while wearing the BodPod swim cap) and lung volume was predicted. Once the participants had been measured, they were served breakfast and sent over to the podiatrist to remove feet calluses (pedicure).

On day 2, the study participants had their feet photographed prior to BIA measurements (for pre-post pedicure comparison). Body composition measurements taken on day 2 were similar to the third measurement performed on day 1: participants were instructed to hold arms at a posture of 15°, and electrolyte wipes were used. All measurements were conducted by the same person.

Statistical Analysis

Statistical analysis was performed using the PASW Statistics 20 (SPSS Inc., 2012 Chicago, IL, USA). Statistical significance was set at $p < 0.05$. Limits of agreement for %BF were analyzed using Bland-Altman difference plots for all four sets of measurements (pre-post pedicure, with and without auxiliary pads, with and without electrolyte wipes, and BIA and ADP). Since the data was not normally distributed, Wilcoxon's signed-rank tests with continuity correction were conducted to determine whether the difference in %BF was statistically significant for the four sets of measurements. The impact of arm posture was assessed by comparing measurements 1 and 2 on day 1, wipes versus no wipes was assessed by comparing measurements 1 and 3 on day 1, callosities removal was assessed by comparing measurement 3 on day 1 with measurement 1 on day 2. For the comparison with ADP, measurement 1 on day 1 from BIA was used.

Results

The overall characteristics of the participants included in the study can be seen in table 1. The median %BF and interquartile range for the four sets of measurements performed can be seen in table 2. %BF measured with auxiliary pads was found to be significantly higher ($p < 0.001$) than %BF measured without pads. No statistically significant differences were found in %BF between pre-post pedicure, with and without the usage of wipes, or between BIA and ADP.

Bland-Altman plots for the different measurements performed can be seen in figure 2. The standard deviation of the difference in %BF values measured by BIA and ADP were significantly higher than that of the other three measurements. Figure 2C, depicting %BF measurements obtained with versus without auxiliary pads, showed a fixed bias, or a systematic difference (average 0.92) between the measurements, supporting the results of the Wilcoxon's

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Table 1. General characteristics of study participants; data presented as average mean ± standard deviation

	Male (n = 13)	Female (n = 23)	Total (n = 36)
Age, years	44.8 ± 11.3	46.8 ± 10.6	46.1 ± 10.6
Height, cm	181.2 ± 7.1	168.0 ± 5.7	172.7 ± 8.9
Weight, kg[a]	142.4 ± 19.8	114.6 ± 12.3	124.6 ± 20.4
BMI, kg/m^2[a]	42.5 ± 5.2	40.6 ± 4.0	41.6 ± 4.3

[a]Weight and BMI reported were measured using BIA following the equipment guidelines (with electrolyte wipes, no pads).

Table 2. %BF assessed under different measurements

Measurement	N	Median	IQR	p value
Pedicure	36			
Pre		49.30	9.12	0.09
Post		50.00	7.85	
Electrolyte wipes	36			
No wipes		49.60	8.49	0.32
With wipes		49.30	9.12	
Auxiliary pads	32[a]			
No pads		49.30	9.12	<0.001
With pads		50.10	8.20	
Instruments	35[b]			
ADP		49.10	8.90	0.48
BIA		49.30	9.12	

[a]Missing values due to technical difficulties.
[b]Missing value due to the inability of a study participant to fit inside the BodPod.

signed-rank test described above. Figure 2A, B, and D, depicting %BF measurements obtained pre-post pedicure, with versus without usage of wipes, and BIA versus ADP, respectively, did not show any systematic differences, despite the large spread.

Discussion

The need for standardization of body composition measurements derived from BIA has been systematically emphasized [10, 12]. The present study assessed the impact of arm posture, use of electrolyte wipes, and removal of feet calluses (pedicure) on %BF estimated from multi-frequency BIA. Our findings revealed that arm posture had a significant impact on %BF measured by multi-frequency BIA in morbidly obese adults. Feet calluses and the usage of InBody electrolyte wipes, on the other hand, did not have a statistically significant effect on %BF data acquired from BIA. Moreover, %BF measurements obtained using BIA in severely obese adults were not statistically different compared to those obtained using ADP. Knowledge on this topic is of high clinical importance, as BIA is becoming a widespread method for assessing body composition in clinical settings. As far as the authors are aware, the effect of arm posture, use of electrolyte wipes, and removal of feet calluses on %BF derived from BIA had never been examined.

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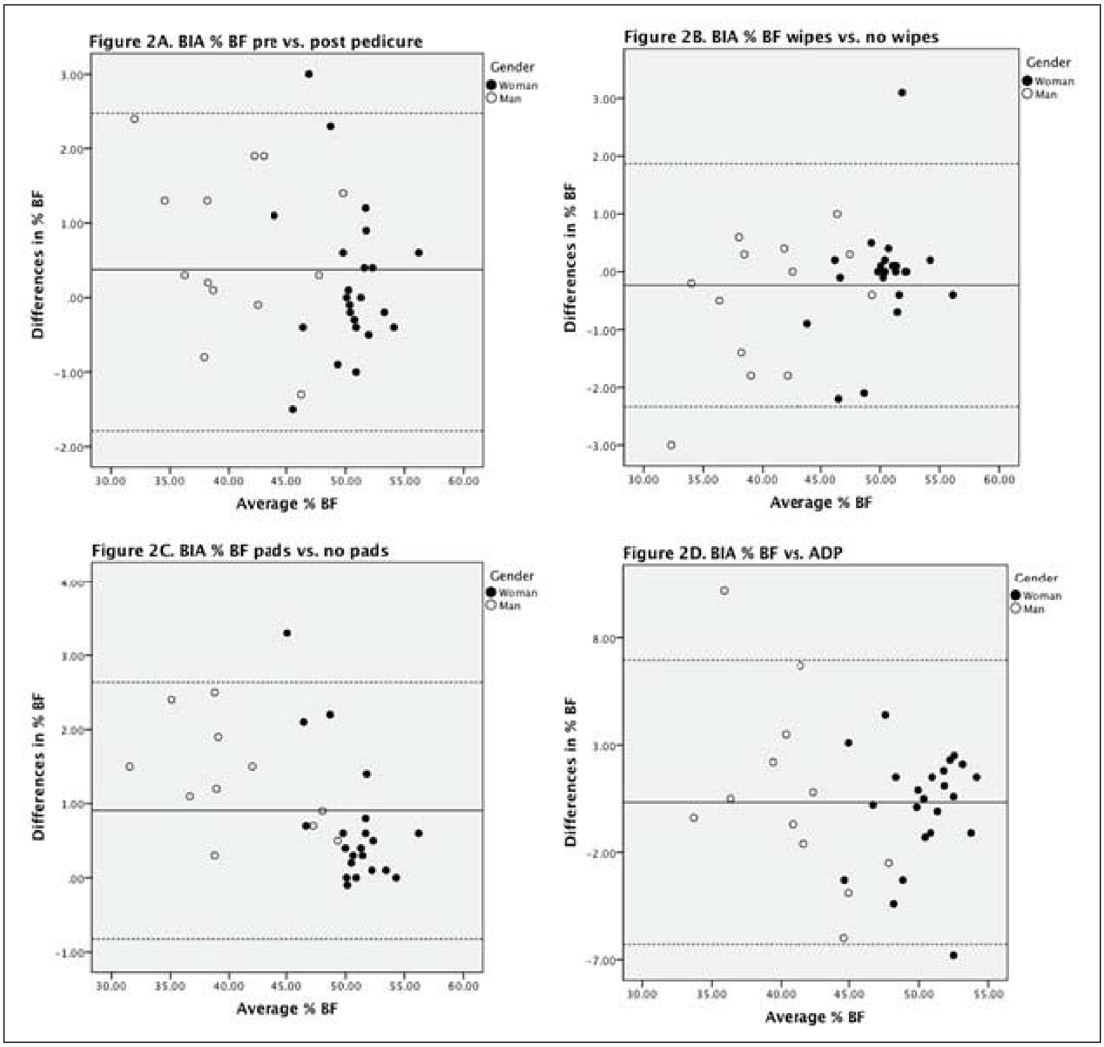

Fig. 2. Bland-Altman plots of the measurements performed, showing mean and ± 2 standard deviations.

Upon evaluating the impact of arm posture by using custom-made auxiliary pads on the measurement of %BF using BIA, the authors found that arm posture impacts BIA measurements. %BF was significantly higher when the BIA measurement was performed with pads than without (mean difference of 1.04 ± 0.87%). The authors believe that the difference in %BF between these two pairs of measurements may not only be due to the angle between the arms and the torso, but also due to the pads preventing excess skin and adipose tissue of the arms from touching the trunk. Therefore, the use of auxiliary pads, could, allow for a better standardization of BIA measurements.

Hard and/or dry skin is a potential factor that could affect BIA measurements [10, 12]. For that reason, the authors wanted to explore the impact of feet callosities on BIA measurements, as it is a common skin condition in the morbidly obese [19]. The removal of callosities, however, did not have a statistically significant effect on %BF, indicating that the presence of feet calluses does not affect the outcome of BIA measurements.

InBody electrolyte wipes are not widely available and, therefore, not used systematically in clinical practice. Little information is available on its effectiveness in moistening hard, dry skin. Since this study recruited adults with moderate to severe callosities, the authors felt that

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electrolyte wipes should be provided to each study participant to test if the use of wipes would impact BIA measurements. The findings revealed that the use of electrolyte wipes is not needed in clinical practice to provide reliable measurements through BIA in the morbidly obese population, even in those with feet callosities.

The assessment of Bland-Altman plots for the BIA measurements showed a wide spread, which indicates a weak agreement between the measurements and insinuates poor repeatability of BIA measurements. This leads the authors to conclude that the standard BIA equations are inadequate for estimating %BF in severely obese patients. The limits of agreement performed on the comparison of %BF values between BIA and ADP also depicted a large spread in agreement, which suggests that one method is not better than the other. The authors are able to infer from this assessment that BIA and ADP can be used interchangeably to measure body composition in the morbidly obese. Furthermore, %BF values obtained were not statistically different from one another (mean difference of 0.33%). This finding is consistent with the results reported in another study, where body fat estimations from both methods were found not to differ significantly and to have good accuracy and precision [20]. However, a study done by Hillier and colleagues [21, 22] showed BIA and ADP to be highly correlated in normal-weight individuals despite a mean difference of 3.1%. Due to this high mean difference, the study had recommended BIA and ADP not to be used interchangeably. Due to discrepant findings in literature, using both methods interchangeably should be done with caution, as BIA has a tendency to overestimate lean mass in severely obese individuals due to variations in soft tissue hydration [23], while ADP has a tendency to underestimate lean mass as a greater level of hydration can be misconceived as fat mass [24]. Further studies comparing BIA and ADP in this population are, therefore, needed.

This study has some limitations that need to be discussed. First, with the exception of the mentioned exclusion criteria, other medical conditions and/or medications that may have altered the body composition measurements were not taken into consideration. Of the 36 participants, 4 participants were taking medications where edema could be a possible side effect. However, it is unlikely that medication had a significant impact on the findings. Secondly, the standardization of all procedures was challenging. For instance, no instructions were given by the manufacturer on how to apply the electrolyte wipes. Some participants were successfully able to apply the electrolyte wipes while standing on the platform, while others had to lean on an object or sit down to apply the electrolyte wipes and then take a few steps to get to the InBody 720 platform. Moreover, the actual arm-torso angle when the patient was instructed to hold a 15° without pads was also not evaluated or standardized because the InBody 720 manual does not specify how this should be performed. Lastly, the majority the participants had callosities that formed predominantly around the heel of the foot and the sides of the foot, instead of the plantar region that would be in direct contact with the BIA electrodes. Therefore, the removal of calluses outside of the plantar region is unlikely to have a big impact on body composition derived from BIA.

In conclusion, the use of electrolyte wipes does not seem to be necessary to provide reliable measurements through BIA in the morbidly obese population. The presence of feet calluses does not affect the outcome of BIA measurements. Contrastingly, arm posture appears to be of significance in clinical practice during body composition measurements with BIA in morbidly obese individuals. This study was able to shed light on avoidable systematic errors that could result from varied arm posture during BIA measurements, based on the recommendations provided by Biospace. The authors stress the need for more instructions to be given by the manufacturer to address how to reduce systematic errors that can be produced during BIA measurements; standardization of arm posture is, therefore, recommended. Further studies should look into the effect of arm positioning and possible thigh contact on

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BIA measurements of body composition, as these may also impact measurement outcomes. This study also found that BIA provided similar %BF measurements as ADP in the morbidly obese population. Using these two methods interchangeably should be done with caution. More and larger studies are needed to confirm these findings.

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Disclosure Statement

The authors declared no conflict of interest.

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