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# *On the Run*—Comparing Bioimpedance Analysis (BIA) Using Portable Devices †

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**Abstract:** Bioelectrical impedance analysis (BIA) is a non-invasive indirect method that allows for measurement of lean and fat body mass. The main goal of this exploratory study was to compare the results from two different portable BIA devices. We found that only fat-free mass and body fat mass were directly comparable between *InBodyS10* (Teprel, Porto, Portugal) and *seca mBCA 525* (Bacelar, Porto, Portugal) medical portable BIA devices.

**Keywords:** body composition; bioimpedance analysis; body fat mass; fat-free mass; skeletal muscle

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## 1. Introduction

Bioelectrical impedance analysis (BIA) is a non-invasive indirect method that estimates body composition based on the electrical conductivity of the body using a conversion equation suitable for routine clinical monitoring [1]. BIA measures the resistance (R) when an alternating current of low intensity and high frequency flows between electrodes placed on the body's extremities, which is inversely proportional to the quantity of water and electrolytes [2]. Using a portable BIA device allows for quick measurements of lean and fat body mass [3]. Of note, when performed in different positions (standing or lying down), the fluid and electrolyte distribution in the body will not be the same and may influence the results [4]. The purpose of this work was to perform a preliminary analysis comparing the results from two different bioelectrical impedance devices for the evaluation of body composition in individuals with obesity.

## 2. Materials and Methods

Measurements were conducted with the medical devices *InBodyS10* (standard BIA) and *seca mBCA 525* (portable BIA) in patients with obesity who were candidates for bariatric and metabolic surgery at Centro Hospitalar Universitário do Algarve (CHUA). All measurements were performed in the supine position according to each manufacturer's instructions. Statistical analysis was performed using GraphPad Prism v.8. Correlations between variables were performed and the correlation index $r^2$ is indicated in figures. Means were compared using a paired $t$ test. A $p$ value < 0.05 was considered statistically different.

## 3. Results

Portable devices for the analysis of body composition are useful for self-administration and monitoring [5]. In this study, portable medical body composition analyzers were compared. The BIA device available at CHUA was considered the "standard" device (*InBodyS10*), while the *seca mBCA 525* system was defined as the "portable" device. This comparison is important because the "standard" BIA, accessible in a hospital setting, is not always available for use in research. When comparing specific measurements, we found that the device *InBodyS10*, using a direct segmental multi-frequency bioelectrical impedance analysis (DSM-BIA) method, performs 30 impedance (Z) measurements by using 6 frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz, 1000 kHz), 15 reactance (Xc) measurements and 15 phase angle (θ) measurements by using 3 frequencies (5 kHz, 50 kHz, 250 kHz) at each of the five parts of the body (right arm, left arm, trunk, right leg, and left leg) (Table 1).

**Table 1.** Bioelectrical impedance variables evaluated by each device.

| Variables | Standard | Portable |
|---|---|---|
| BIVA | X | √ |
| Bioelectrical Impedance (Z) (Ω) [1] | √ | X |
| Reactance (Xc) [1] | √ | X |
| Phase Angle (Phi) | X | √ |
| Phase Angle (θ) [1] | √ | X |

Abbreviations: BIVA, bioelectric impedance vector analysis; [1] measurements were independently performed and results are given for the right arm, left arm, trunk, right leg, and left leg. Symbols: X, not available; √, available.

The portable device *seca mBCA 525* allows for bioimpedance measurements (impedance (Z), resistance (R), reactance (Xc), and phase angle (φ)) using two different methods: 8-point bioimpedance measurement and 4-point bioimpedance measurement (measuring the right half of body) using the following frequencies: 1; 2; 5; 10; 20; 50; 100; 200; and 500 kHz on the right arm, left arm, right leg, left leg, right half of the body, and torso. However, measurements of various body segments are given in one single variable, and no distinctions are made (Table 1). Regarding variables related to water in the body, the values for extracellular and total body water (and respective ratios) were available from both BIA devices (Table 2).

**Table 2.** Body water variables evaluated by each device.

| Variables | Standard | Portable |
|---|---|---|
| ICW (l) | √ | X |
| **ECW (l)** | **√** | **√** |
| **TBW (l)** | **√** | **√** |
| **ECW/TBW** | **√** | **√** |
| ICW (l) [1] | √ | X |
| ECW (l) [1] | √ | X |
| TBW (l) [1] | √ | X |
| ECW/TBW [1] | √ | X |

Abbreviations: ICW, intracellular water; ECW, extracellular water; TBW, total body water; ECW/TBW ratio; [1] measurements were independently performed and results are given for the right arm, left arm, trunk, right leg, and left leg. Symbols: X, not available; √, available. Bold highlights the common variables in both devices.

From the above measurements, each device calculates variables such as the fat-free mass (FFM) and the fat mass (FM) based on prediction equations [6]. When comparing both devices, only FFM, skeletal muscle mass (SKM), and body fat mass (BFM) were represented in the same units (Table 3).

To validate whether the common variables would be comparable and their values interchangeable in both devices, specific parameters obtained from three individuals were compared (Figure 1). We found that the average values for body extracellular water (Figure 1A) and skeletal muscle mass (Figure 1D) were statistically different between devices, highlighting that these values are not comparable. However, the mean values of total body water (Figure 1B), fat-free mass (Figure 1C), and body fat mass (Figure 1E) obtained were similar in both BIA devices.

**Table 3.** Specific body composition variables evaluated by each device.

| Variables | Standard | Portable |
|---|---|---|
| **FFM (Kg)** | √ | √ |
| FFMI (Kg/m$^2$) | X | √ |
| **SKM (Kg)** | √ | √ |
| Arm Muscle Circumference (cm) | √ | X |
| Lean Mass [1] | √ | X |
| **BFM (Kg)** | √ | √ |
| FMI (Kg/m$^2$) | X | √ |
| Body Fat (%) | √ | X |
| Visceral Fat (l) | X | √ |
| VFA (cm$^2$) | √ | X |

Abbreviations: FFM, fat-free mass; FFMI, fat-free mass index; SKM, skeletal muscle mass; BFM, body fat mass; FMI, fat mass index; VFA, visceral fat area. [1] measurements were independently performed and results are given for the right arm, left arm, trunk, right leg, and left leg. Symbols: X, not available; √, available. Bold highlights the common variables in both devices.

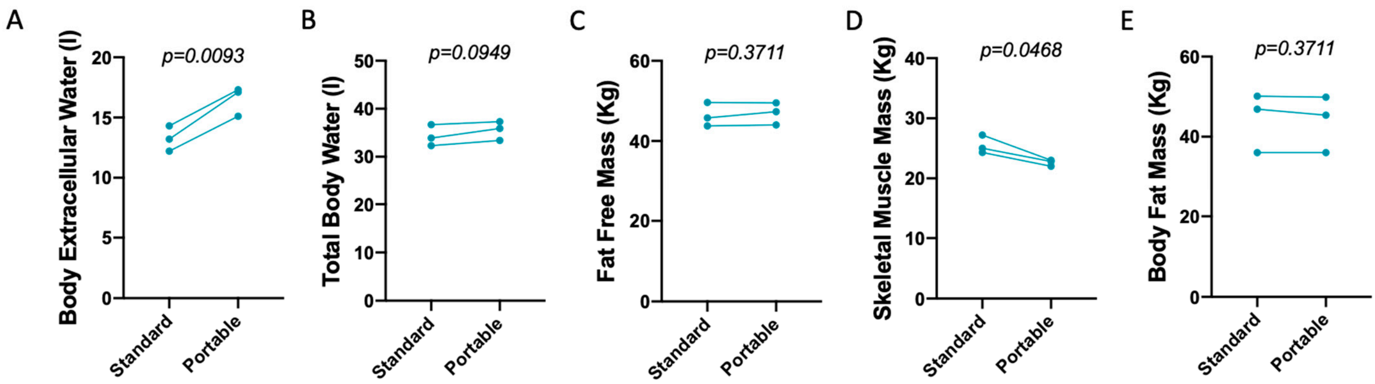


**Figure 1.** Variables in common from BIA devices. (**A**) body extracellular water (L); (**B**) total body water (L); (**C**) fat-free mass (Kg); (**D**) skeletal muscle mass (Kg); (**E**) body fat mass (Kg). The *p* value for the paired *t* test is indicated in each panel.

These results were also evidenced when performing correlations with each individual value (Figure 2). In this case, it was clear that skeletal muscle mass was not comparable (Figure 2D), while body extracellular water (Figure 2A) and total body water (Figure 2B), based on the observed linearity, could be comparable if a correcting factor was included. Nevertheless, based on the almost overlapping values, fat-free mass (Figure 2C) and body fat mass (Figure 2E) are the variables that showed the greatest comparability between both BIA devices.

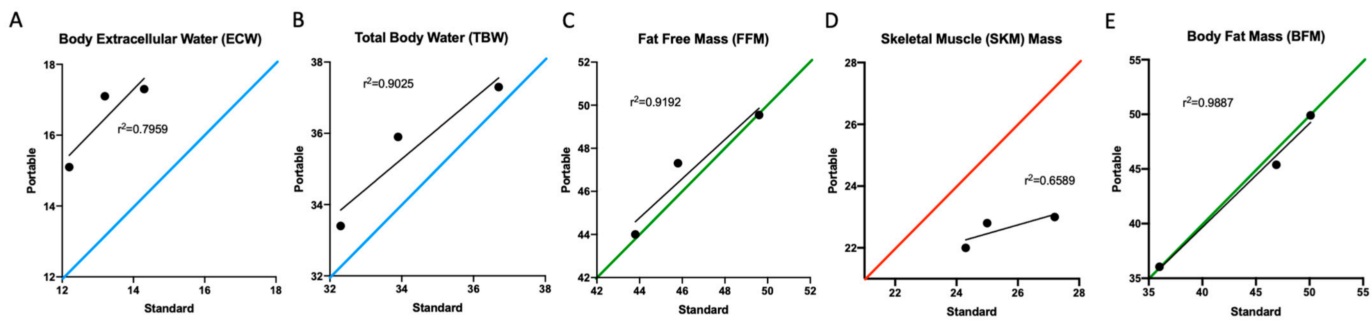


**Figure 2.** Correlation between the values obtained from BIA devices. (**A**) body extracellular water (L); (**B**) total body water (L); (**C**) fat-free mass (Kg); (**D**) skeletal muscle mass (Kg); (**E**) body fat mass (Kg). The correlation index r$^2$ is indicated in each panel. Colored lines represent theoretical full linearity (blue, partially comparable; green, comparable; red, not comparable).

## 4. Conclusions

From this exploratory study, we conclude that the results obtained from different BIA devices should be always very carefully analyzed and are not fully interchangeable. Nevertheless, we found that the obtained values for fat-free mass and body fat mass were highly similar, which means certain parameters are less subject to variations between devices.

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**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Centro Hospitalar Universitário do Algarve (CHUA) (protocol code: UAIF 066/2023, date of approval: 2 June 2023).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data supporting the findings of this study are available on request to the corresponding author.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

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