

ORIGINAL ARTICLE

The effect of acute fluid consumption on measures of impedance and percent body fat using leg-to-leg bioelectrical impedance analysis

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Objective: To examine the effect of acute fluid consumption on measures of impedance and percent body fat (%BF) using a common leg-to-leg bioelectrical impedance analyzer system.

Design: Cross-sectional design with treatment order determined using a counterbalanced assignment.

Setting: University laboratory.

Subjects: In total, 21 recreationally active men (mean age 19.7 ± 1.0 years; body mass index 24.2 ± 2.3 kg/m²) volunteered to participate in this study.

Intervention: Subjects had their body composition assessed on three separate occasions. After an initial baseline body composition measurement, subjects consumed 591 ml of water (H₂O), a carbohydrate/electrolyte drink (CHOE), or received nothing, used as the control (CON). Subjects were reassessed 20, 40, and 60 min after baseline (POST). Urine specific gravity (USG) was recorded at baseline and 60 min POST to assess hydration state.

Results: There were no significant changes in impedance or total body water (TBW) for any of the measurement time periods after drinking H₂O or a CHOE beverage. Body weight (BW) ($P < 0.0001$) and %BF ($P < 0.02$) increased significantly 20 min POST and remained elevated at the 40 and 60 min POST time periods. After drinking, USG significantly decreased ($P < 0.0001$) 60 min POST from baseline. For the CON trial, there were no significant changes in BW, %BF, TBW, or USG over time.

Conclusions: Fluid consumption had no effect on lower-body impedance despite causing significant changes in hydration state. A slight overestimation in %BF (~0.5%) was observed due to increased BW in the H₂O and CHOE trials. This finding may have little practical significance when assessing body composition by LBIA.

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Introduction

The use of bioelectrical impedance analysis (BIA) to estimate percent body fat (%BF) in laboratory and clinical settings has

increased in recent years (NIHTAC, 1996). Partially responsible for this dramatic increase in popularity may be the development of the relatively inexpensive and easy to use leg-to-leg bioelectrical impedance (LBIA) analyzers. The LBIA method, which measures lower-body impedance (leg-to-leg) as an individual stands on a scale-like platform, differs from the traditional BIA method, which measures whole-body impedance (arm-to-leg) and requires the accurate placement of gel electrodes at specific anatomical locations. LBIA has been found to have overall performance characteristics for impedance measurement and body composition analysis similar to traditional BIA while offering the advantage of increased speed and ease of measurement (Nunez *et al.*, 1997). Standard error of estimate and pure error values

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ranging from 3.6 to 4.2 %BF have been reported when LBIA was compared to hydrostatic weighing in collegiate wrestlers (Dixon *et al.*, 2005).

The BIA method introduces a low level electrical current into the body and measures the impedance, or resistance to the current flow. Fat-free mass, due to its fluid and electrolyte content, is an excellent conductor of electrical current. Adipose tissue contains little water and therefore is a poor conductor (i.e., higher impedance). This differential response to an electrical current is the basis of the BIA assessment of body composition. A potential source of error with the BIA method may be intraindividual variability in hydration state (Jackson *et al.*, 1988; Heyward and Wagner, 2004). Therefore, controlling pretest behaviors that may alter hydration state is recommended when using BIA (Heyward and Wagner, 2004).

For instance, no eating or drinking within 4 h of the test is a common BIA pretesting guideline (Heyward and Wagner, 2004). However, there is a lack of consensus within the scientific literature relative to the impact of hydration status and BIA measures (Elsen *et al.*, 1987; Deurenberg *et al.*, 1988; Gomez *et al.*, 1993; Kushner *et al.*, 1996). Previous studies examining the traditional arm-to-leg BIA method have reported significant changes in whole-body impedance and total body water (TBW) following fluid consumption (Deurenberg *et al.*, 1988; Gomez *et al.*, 1993; Kushner *et al.*, 1996). In contrast, Elsen *et al.* (1987) found that arm-to-leg impedance was unaffected by the consumption of up to 1000 ml of H₂O or an oral rehydration solution (100 mEq cationic electrolytes per liter). To date, the effect of fluid consumption on lower-body impedance and %BF measured by the relatively new LBIA devices is unknown. As such, the purpose of this study was to examine the effect of acute fluid consumption on measures of impedance and %BF using a common LBIA system.

Subjects and methods

Subjects

In total, 21 recreationally active collegiate men (mean \pm s.d.; age, 19.7 \pm 1.0 years; height, 1.75 \pm 0.07 m; body mass, 74.8 \pm 8.8 kg; body mass index (BMI), 24.2 \pm 2.3 kg/m²) volunteered to participate in this study. The study protocol and methods were approved by the Institutional Review Board of The University of Scranton and all subjects signed an informed consent form prior to participation.

Study procedures

Each subject reported to the body composition laboratory for testing on three consecutive days. Subjects followed the manufacturer recommended LBIA pretesting guidelines before assessment and all measurements were performed in the morning following an overnight fast. After an initial baseline measurement of impedance, %BF, TBW, and BW,

subjects consumed 591 ml (i.e., 20 ounces) of water (H₂O), a common carbohydrate/electrolyte drink (POWERade™, Coca-Cola Company, Atlanta, GA, USA), or received nothing, which served as the control (CON). The carbohydrate/electrolyte (CHOE) drink was selected because of the comparatively higher electrolyte content of the beverage (~65 mg sodium; ~65 mg potassium; ~45 g of carbohydrate). Subjects were permitted 5 min to consume each beverage. The treatment order for each subject was determined using a counterbalanced assignment. The LBIA measures were reassessed 20, 40, and 60 min following (POST) the baseline measure in each treatment condition. During the 60 min POST treatment time period, subjects sat quietly. Laboratory temperature was maintained at a constant 22°C for all assessments. Urine specific gravity (USG), measured by a hand-held optical refractometer (Atago, model A300CL), was recorded at baseline and 60 min POST. Urinary measures have been reported to be an effective method of assessing hydration state (Shirreffs, 2003). Body mass and height were determined using a physician's balance beam scale and stadiometer (Detecto, Webb City, MO, USA) for the computation of BMI.

Leg-to-leg bioelectrical impedance analysis

LBIA measurements were determined using a Tanita single frequency body fat analyzer; model TBF-300A (Tanita Corporation of America Inc., Arlington Heights, IL, USA). All subjects were instructed to adhere to the following standard BIA guidelines (Heyward and Wagner, 2004): (a) no food or drink within 4 h of the test, (b) no exercise within 12 h of test, (c) no alcohol consumption within 48 h of the test, (d) empty bladder within 30 min of the test, and (e) no diuretic medications within 7 day of the test. Subject compliance to these guidelines was confirmed prior to each experimental trial. Each subject, wearing only swimming shorts, stood erect with bare feet placed properly on the contact electrodes of the LBIA instrument. As previously described (Nunez *et al.*, 1997), the LBIA system consists of four contact electrodes (two anterior and two posterior) that are mounted on the surface of a platform scale. A low energy, high frequency, electrical signal (500 μ A, 50 kHz) is passed through the anterior electrode on the scale platform, and the voltage drop is measured on the posterior electrode. Lower body impedance between the right and left legs and BW were measured simultaneously while the subject stood on the LBIA scale. The LBIA analyzer using preprogrammed proprietary equations developed by the manufacturer automatically calculated %BF. The 'athletic mode' was selected based on subject activity levels as per the manufacturer's guidelines.

Statistical methods

Data were analyzed using SPSS 10.1 for Windows (SPSS, Inc., Chicago, IL, USA). All values are expressed as mean \pm s.d.

unless otherwise noted. The between-day coefficient of variations (CV) for LBIA impedance were calculated as s.d./mean \times 100%. Separate one-way analysis of variance (ANOVA) with repeated measures were used to detect significant differences in impedance, %BF, body weight (BW) and TBW for each of the experimental trials (i.e., CON, H₂O, and CHOE). Pairwise comparisons were conducted using the Bonferroni adjustment for multiple comparisons to discriminate between means when ANOVA yielded significant results. Paired samples *t*-tests were performed to determine possible differences in USG between the baseline and 60 min POST time periods for each treatment condition. Statistical significance was established *a priori* at $P < 0.05$ for all analyses.

Results

The between-day CVs for impedance ranged from 0.1 to 5.8% with group means of $2.2 \pm 1.7\%$ (day 1–2), $2.4 \pm 1.9\%$ (day 1–3), and $1.9 \pm 1.5\%$ (day 2–3). Following fluid consumption (H₂O or CHOE), there were no significant changes in impedance or TBW for any of the measurement time periods. During the CON trial, impedance was significantly greater ($P = 0.03$) at 60 min POST ($502.0 \pm 57.6 \Omega$) than baseline ($496.8 \pm 56.6 \Omega$, Figure 1). At 20 min POST, BW increased significantly ($P < 0.0001$) in the H₂O and CHOE trials above baseline and remained elevated at the 40 min and 60 min POST time periods (Figure 2). A significant increase in %BF was also observed in the H₂O ($P < 0.01$) and CHOE ($P < 0.02$) trials above baseline at the 20 min, 40 min, and 60 min POST time periods (Figure 3). USG significantly decreased ($P < 0.0001$) 60 min POST from baseline for the H₂O (1.012 ± 0.008 vs 1.024 ± 0.004 g/ml) and CHOE (1.009 ± 0.006 vs 1.022 ± 0.004 g/ml) ingestion trials. There

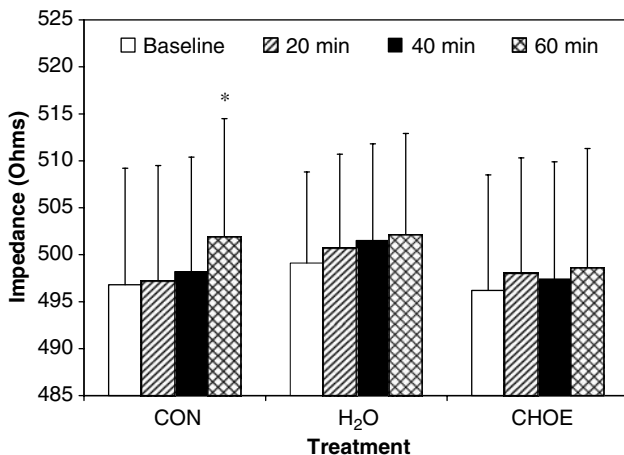


Figure 1 Impedance over time for each treatment (mean \pm s.e.m.). *Significantly different from baseline, 20 min, and 40 min, $P < 0.03$.

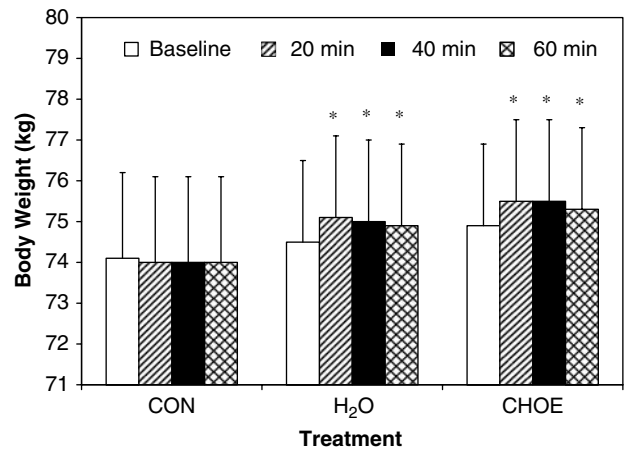


Figure 2 BW values over time for each treatment (mean \pm s.e.m.). *Significantly different from baseline, $P < 0.0001$.

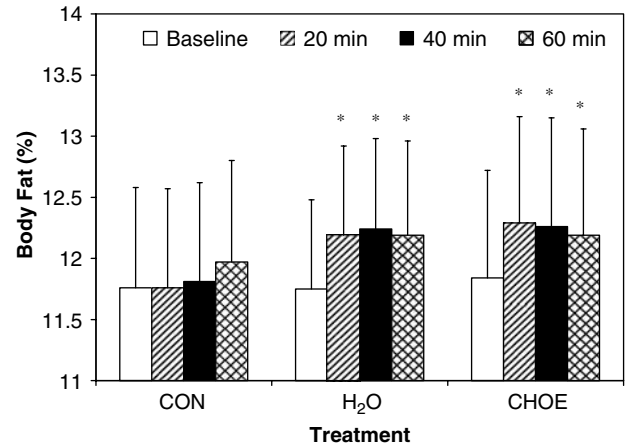


Figure 3 Percent body fat values over time for each treatment (mean \pm s.e.m.). *Significantly different from baseline, $P < 0.02$.

were no significant changes ($P > 0.05$) in BW, %BF, TBW, or USG over time in the CON group.

Discussion

Owing to the ease of measurement, LBIA has become a common method of assessing body composition. To increase the accuracy of measurement, it is recommended that individuals should avoid consuming fluids within 4 h of the test (Heyward and Wagner, 2004). Our subjects, after performing an overnight fast, met this recommendation. Previous research examining the traditional arm-to-leg BIA method has demonstrated significant changes in impedance following fluid consumption (Deurenberg *et al.*, 1988; Gomez *et al.*, 1993; Kushner *et al.*, 1996). The current

investigation examined the impact of acute fluid consumption on impedance and %BF using the relatively new LBIA method for assessment. Two solutions, H₂O and a common CHO drink (i.e., POWERade™) were administered during this investigation.

The consumption of a 591 ml H₂O or a CHO drink before LBIA body composition assessment had no impact on impedance or TBW for up to 60 min after ingestion in this study. Previous research examining the effect of acute fluid consumption on LBIA measurements is nonexistent; therefore, direct data comparisons are not possible. Data from studies examining the effect of fluid consumption on impedance and TBW using the traditional arm-to-leg BIA method are inconsistent (Elsen *et al.*, 1987; Deurenberg *et al.*, 1988; Gomez *et al.*, 1993; Kushner *et al.*, 1996). Deurenberg *et al.* (1988) reported that 20 min after drinking a cup (200 ml) of normal tea, body impedance had not changed significantly, but 20 min after drinking 200 ml of beef tea (bouillon) impedance was significantly decreased by $4 \pm 4 \Omega$. Elsen *et al.* (1987) assessed the effect of drinking 750 or 1000 ml of an oral rehydration solution or pure water. No significant changes in resistance were seen immediately after the consumption of either volume or type of fluid. The results of Elsen *et al.* (1987) are similar to the current findings. Conversely, Gomez *et al.* (1993) reported that resistance significantly increased immediately after drinking approximately 1200 ml of water, a hypotonic rehydration beverage, or an isotonic solution, and remained elevated for up to 90 min postconsumption. The comparatively larger volume of fluid consumed may have been responsible for the significant changes in impedance and TBW reported by Gomez *et al.* (1993). Collectively, the arm-to-leg BIA studies indicate that the timing of the measurement and the type and amount of fluid ingested may influence impedance measurements. The volume and type of fluid consumed presently was insufficient to cause significant changes in lower-body impedance. Future investigations should further examine the possible relation between the fluid volume and type, and LBIA impedance measures.

Although impedance and TBW were unchanged, %BF increased significantly at 20 min and remained elevated 60 min POST in both fluid consumption trials. The increase in %BF was very small (~0.5%) and therefore may have limited practical significance when assessing an individual's body composition using LBIA. The increased BW (~0.5 kg) noted in the H₂O and CHO trials were due to fluid consumption, and resulted in the slight increase in %BF observed in this study.

Bartok *et al.* (2004) reported that dehydration also affected Tanita-measured BW, but not impedance. As a result, body composition estimates were changed in the wrestlers in that study despite no change in impedance, which is consistent with our data. An interesting finding in the present study was that impedance increased over time but TBW and %BF remained unchanged in the CON group. The %BF value, as calculated by the LBIA analyzer, is derived from a proprietary

formula combining impedance and weight measurements with height, gender, and age information. Collectively, these data indicate that fluctuations in BW caused by fluid consumption or dehydration may be more important in altering LBIA %BF than impedance. More analysis is required to further examine the relation between impedance, BW, and %BF when using LBIA.

It is currently recommended that subjects refrain from drinking 4 h prior to LBIA assessment of body composition to control for fluctuations in hydration status. Our data indicate that a moderate amount of H₂O or CHO drink consumed within 1 h of assessment has little impact on LBIA measures of body composition in healthy, recreationally active male subjects. As such, the current pretesting fluid consumption guideline may not be warranted in this population when using LBIA for assessment. The impact that fluid ingestion has on LBIA body composition values beyond 1 h cannot be determined from this study. In addition, our findings on healthy, recreationally active male subjects cannot be generalized to other populations (e.g., women, children, older adults, sedentary individuals, etc.) that may differ significantly in body composition characteristics. Further examination of fluid consumption on LBIA body composition measures in specialized populations is warranted.

Interestingly, USG significantly decreased following fluid consumption despite causing no change in lower-body impedance or TBW, and a relatively small increase of %BF (~0.5%). A USG value ≤ 1.020 g/ml has been selected by the National Collegiate Athletic Association (NCAA) as an indicator of euhydration (COMMITTEE, NWR, 1988). According to NCAA guidelines, most subjects (70%) in this study arrived to the laboratory in a dehydrated state (USG > 1.020 g/ml) primarily due to the fluid restriction during the overnight fast. However, 1 h after drinking the H₂O or CHO beverage, 90% of those subjects met the NCAA criteria for euhydration (USG ≤ 1.020 g/ml). The decrease in USG was unaffected by the type of beverage consumed (mean \pm s.d.; H₂O = 0.012 ± 0.008 , CHO = 0.013 ± 0.006). This finding is of importance because LBIA has been proposed as a possible method of assessing %BF in NCAA collegiate wrestlers during the Weight Certification Program (WCP). As part of the WCP, a wrestler must meet euhydration standards before body composition assessment and a minimum competitive weight can be calculated at the beginning of each season (COMMITTEE, NWR, 1988). The NCAA initiated the WCP during the 1998–1999 season in an attempt to reduce the unhealthy weight loss practices that have been reported in the sport of wrestling (ACSM, 1996). Our data indicate that a dehydrated wrestler may pass the hydration test by consuming a relatively small volume (591 ml) of fluid 1 h before body composition assessment without significantly affecting %BF estimates. This finding presents a significant limitation to the potential inclusion of LBIA as a method of assessing body composition during the wrestling WCP.

In summary, the ingestion of 591 ml of fluid (H₂O or CHO) prior to LBIA body composition assessment had no effect on lower-body impedance despite causing significant changes in USG. BW was significantly increased resulting in the slight overestimation of %BF. Although statistically significant, the %BF overestimation was relatively small and may have little practical significance.

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