



Body Composition

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**EFFECT OF A 1 LITER FLUID LOAD ON BODY
COMPOSITION MEASURED BY AIR DISPLACEMENT
PLETHYSMOGRAPHY AND BIOELECTRICAL IMPEDANCE**

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ABSTRACT

Heiss CJ, Gara N, Novotny D, Heberle H, Morgan L, Stufflebeam J, Fairfield M. Effect of a 1 liter fluid load on body composition measured by air displacement plethysmography and bioelectrical impedance. *JEPonline* 2009;12(2):1-8. The purpose of this study was to determine if there is a difference in the body composition results measured by bioelectrical impedance analysis (BIA) using hand-to-hand (HBIA) and arm-to-leg (ALBIA) devices as well as air displacement plethysmography (ADP) using the Bod Pod before vs. after a 1 liter fluid load. A total of 35 males and females completed the study. Body composition was measured by the three methods after an overnight fast (baseline) and within 10 min of consumption of the fluid load. Body weight was significantly greater after fluid consumption ($P < 0.001$). Percent body fat was significantly greater after fluid consumption for each device ($P < 0.01$); HBIA (20.2 ± 8.7 vs. 20.6 ± 8.6), ALBIA (23.6 ± 7.7 vs. 24.3 ± 7.9), and ADP (23.6 ± 9.1 vs. 24.7 ± 9.0). Therefore, ingesting a 1 liter fluid load just prior to measurement does appear to increase percent body fat results as determined by HBIA, ALBIA, and ADP, and thus protocol for measurements needs to be standardized in terms of fluid ingestion just prior to measurement.

Keywords: ADP, Bod Pod, Hydration, BIA

INTRODUCTION

Adiposity is associated with morbidity, but weight and height alone are sometimes not sufficient to accurately predict health outcomes (1). Since body composition can differ greatly between individuals with the same height and weight, percent body fat is a better indicator of adiposity and is used increasingly by health professionals. In addition, tracking changes in lean and fat mass is of interest for many individuals, including athletes, those with health problems that can result in wasting, and those desiring anabolism.

Bioelectrical impedance analysis (BIA) and air displacement plethysmography (ADP), using the Bod Pod, are two common methods used to measure body composition. Because it is relatively inexpensive, highly portable, and easy to use, hand-to-hand BIA (HBIA) is an increasingly popular method of body composition measurement. For measurement with this device, the subject stands holding the device handles at arm's length while a current is passed through the body. While still convenient and portable, the whole-body, or arm-to-leg BIA (ALBIA) measurement requires precise placement of electrodes on hands and feet for conduction of the current while the subject is lying supine. Impedance to the current is measured by the BIA devices, and regression equations, using such variables as impedance, height, weight, age, and gender are used to predict body composition.

ADP determines body density by determining body volume by air displacement and body weight. Fat and fat-free mass can be derived from body density (2). The Bod Pod, the only commercially available device for ADP, requires the subject to sit in form fitting attire, such as a bathing suit, in a chamber for the period of time required for measurement. The Bod Pod is expensive and not as portable as the BIA devices, but is used increasingly in research and clinic settings. Although hydrostatic weighing has traditionally been considered the gold standard for determining body composition via body density determination, the Bod Pod is more practical than hydrostatic weighing in terms of technical expertise, subject cooperation, speed of measurements, and accommodation of a variety of populations (3).

An assumption in body composition measurement is that the ratio of body water, protein, and mineral content is the same among individuals (2). Some studies indicate that hydration status influences body composition results by hydrostatic weighing, BIA, and ADP (4-8). Thus, determining if recent fluid intake affects body composition measures is important to establish standard protocol for measurements.

Percent body fat by BIA was significantly higher after a fluid load in one study (7), while other studies indicate that a fluid load does not influence BIA body composition results (9-11). If a fluid load influences body density by increasing body volume and/or weight, body composition results by ADP could be affected. Vukovich and Peeters (4) found that the ingestion of 1000ml water significantly increased the percent body fat results by ADP in 18 strength trained men, while McCrory et al. (12) found that ingestion of 12 oz carbonated beverage increased ADP percent body fat by 0.9%.

The purpose of this study was to ascertain if a recent water load influences body composition results by two BIA methods and ADP to determine if fluid ingestion needs to be considered in the protocol for these instruments.

METHODS

Subjects

Volunteers were recruited from nutrition courses at the university and word of mouth. A total of 35 healthy subjects (5 males, 29 females) participated in the study. A group of 10 subjects (1 male, 9

females) participated in a control study. This study was approved by the Missouri State University Institutional Review Board. Written informed consent was obtained from each participant prior to data collection.

Procedures

Participants reported to the laboratory in the morning after an overnight fast, not having exercised for at least 4 h. Subjects were required to void prior to measurements, and wore form fitting Lycra shorts or bathing suits for the measures. Height was measured to the nearest half inch using a stadiometer and weight to the nearest 0.1 kg using the Bod Pod system scale.

Body composition was determined by: 1) BIA using the hand-held Body Logic Pro Model HBF-300 (Omron Healthcare, Inc., Vernon Hills, IL); 2) BIA using the arm-to-leg (RJL Systems Inc, Clinton Township, NC) and 3) ADP using the Bod Pod (Life Measurement Instruments, Concord, CA). Predicted lung volume was used for the ADP measurement, and the Siri equation (2) was used to calculate body composition for Caucasian subjects and the Ortiz (13) equation was used to calculate body composition in the African American subject. All measurements were conducted by trained technicians according to manufacturer protocol.

After initial body composition measurements (time 0), participants drank 1 liter of bottled water within 10 min. Body composition measurements were repeated immediately after consumption (time 1).

The 10 control subjects followed the same procedure as described above, except that they did not consume water in the 10 min interval between measurements.

Quality control and calibration procedures were conducted for the Bod Pod at the beginning of each data collection day according to manufacturer protocol. Coefficient of variation was 2.2% for the ADP and < 1% for the BIA. Qualified technicians performed all measurements.

Statistical Analyses

Descriptive statistics were performed on demographic and anthropometric data, and paired t-test was performed to determine differences in body composition by each method before and after water consumption, or in the case of the control subjects, at time 1 and time 2. Data were analyzed using the Statistical Package for Social Sciences (14), and significance was set at $P < 0.05$. Data are reported as mean \pm standard deviation.

RESULTS

Thirty-five subjects completed the study; HBIA measurement could not be obtained from one subject. The participants were primarily female (83%) and Caucasian (97%), with 1 African American subject. Mean age was 23.8 ± 7.9 and mean body mass index was 23.5 ± 4.5 . See Table 1 for descriptive data.

Table 1. Subject characteristics (N=35)

Characteristic	Before Fluid Load Mean\pmSD	Range
Age (y)	23.8 \pm 7.9	15 - 49
Height (cm)	169.05 \pm 7.4	152.4 – 184.2
Weight (kg)	67.5 \pm 14.7	46.5 – 115.9
BMI	23.5 \pm 4.5	18.2 – 38.8

Body weight was significantly greater after fluid consumption compared to before ($P<0.001$), with an average increase of 0.95 ± 0.24 kg after fluid consumption. Body composition data are presented in Table 2. Compared to baseline body composition measurements (time 0), percent body fat was significantly higher after the consumption of 1 liter of fluid (time 1) for each device (HBIA, ALBIA, and ADP). The mean absolute value difference in percent body fat between time 0 and time 1 was $0.4\pm 0.4\%$, $1.2\pm 1.1\%$, and $1.5\pm 1.1\%$ for HBIA, ALBIA, and ADP, respectively. An increase in percent body fat value at time 1 compared to time 0 was recorded in 74%, 89%, and 83% of subjects for HBIA, ALBIA, and ADP, respectively. Fat mass and body volume were significantly higher, and body density was significantly lower at time 1 compared to time 0 for ADP ($P<0.001$). There were no differences in lean mass between time 0 and time 1 for any of the devices, and no difference in fat mass for the ALBIA and HBIA measures between time 0 and time 1. Impedance was significantly higher at time 1 (548 ± 69 ohm) for the ALBIA compared to time 0 (544 ± 65 ohm).

Table 2. Body composition before and after a 1 liter fluid load

Measure	Pre fluid Mean \pm SD	Post fluid Mean \pm SD	P-value
HBIA¹			
%fat	20.2 \pm 8.7	20.6 \pm 8.6	0.001
Lean mass (kg)	51.6 \pm 12.5	51.5 \pm 12.6	0.63
Fat mass (kg)	14.0 \pm 9.7	14.0 \pm 9.6	0.63
A-LBIA²			
%fat	23.6 \pm 7.7	24.3 \pm 7.9	0.007
Lean mass (kg)	49.7 \pm 11.3	51.2 \pm 9.1	0.16
Fat mass (kg)	17.5 \pm 9.8	17.3 \pm 8.8	0.85
ADP³			
%fat	23.6 \pm 9.1	24.7 \pm 9.0	0.001
Lean mass (kg)	50.9 \pm 8.9	51.4 \pm 8.9	0.28
Fat mass (kg)	16.7 \pm 9.8	17.6 \pm 9.7	0.001
Body volume(l)	60.0 \pm 12.2	63.5 \pm 14.8	0.001
Body density (g/ml)	1.087 \pm 0.024	1.082 \pm 0.024	0.001

¹HBIA: Hand-to-Hand Bioelectrical Impedance Analysis; N=34

²A-LBIA: Arm-to-Leg Bioelectrical Impedance Analysis; N=35

³ADP: Air displacement plethysmography using the BOD POD;

N=25

no difference in impedance between time 0 and time 1 by ALBIA (541.4 ± 78.2 and 542.2 ± 87.1 ohms, respectively). Percent body fat was significantly higher ($P<0.008$), fat mass was significantly higher ($P<0.01$), and lean mass was significantly lower ($P<0.01$) at time 1 compared to time 0 for the HBIA.

DISCUSSION

Results from the present study suggests that a 1 liter fluid load will influence percent body fat results when body composition is measured by HBIA, ALBIA, and ADP using the Pod Bod. This is an important finding for consideration in practical settings, as exercise, climate, some medical conditions such as renal and liver disease, and fluid loading can influence hydration status, and thus, body composition results. Directly related to the protocol of fluid loading in the present study, those with anorexia nervosa have been known to water load just prior to weighing-in with health care professionals to achieve target weights (15). In addition, athletes frequently ingest significant amounts of fluid to rehydrate after exercising.

Control Study

Control subjects included 9 females and 1 male, 9 of whom were Caucasian with 1 “other” ethnicity. Mean age was 23.8 ± 7.9 and mean body mass index was 26.5 ± 9.3 , and mean body mass index was 25.4 ± 4.3 .

Body composition data for the control study are shown in Table 3. There was no difference in body weight between time 0 (baseline) and time 1 (10 min later, with no fluid consumption), 70.8 ± 15 and 70.8 ± 14.9 kg, respectively. There were no differences in body composition parameters (lean mass, fat mass, and percent fat) at time 0 and time 1 for ALBIA and ADP and no difference in body volume or body density by ADP between time 0 and time 1. There was

In terms of the influence of a fluid load on BIA measurements, the present study demonstrates that percent body fat values increase after ingestion of a fluid load by both hand-held and arm-to-leg devices. Resistance values were not available for the HBIA, but resistance from the ALBIA measurements was significantly higher after the fluid load compared to baseline. Other studies are in agreement with the present study. Saunders et al. (7) found that a fluid load totaling 3% of body weight (approximately 1.8 liters) in 15 athletes resulted in increased resistance and percent body fat, and there was no difference in the impact of a sports drink vs. water. Gomez et al. (16) reported an increase in resistance following water intake measured 4-90 min after ingestion, and Rising et al. (17) found an increase in resistance after 700ml of fluid ingestion in Pima Indians. It would seem logical that a fluid load would decrease rather than increase resistance, and result in a lower rather than higher percent body fat result. However, the time period between ingestion of the water and the BIA measurements in the present study was much shorter than the 2 hour time period it takes for ingested fluid to equilibrate into intracellular and interstitial pools (18). The fluid at the time of the post consumption measurement was likely still in the extracellular/intravascular compartment. The water load was thus interpreted as an increase in adiposity likely due to the influence of body weight in the BIA regression equation.

Table 3. Body composition before and after a 10 minute interval with no fluid load (control)

<i>Measure</i>	<i>Time 0 Mean±SD</i>	<i>Time 1 Mean±SD</i>	<i>P-value</i>
HBIA¹			
<i>%fat</i>	25.5±6.9	26.0±7.0	0.008
<i>Lean mass (kg)</i>	52.4±10.0	52.1±10.1	0.01
<i>Fat mass (kg)</i>	18.4±7.6	18.7±8.0	0.01
A-LBIA²			
<i>%fat</i>	27.2±8.0	26.2±6.8	0.22
<i>Lean mass (kg)</i>	51.0±11.5	51.7±11.5	0.20
<i>Fat mass (kg)</i>	19.6±7.4	18.6±.4	0.22
ADP³			
<i>%fat</i>	30.4±9.9	30.6±9.8	0.64
<i>Lean mass (kg)</i>	48.9±11.9	48.8±11.7	0.55
<i>Fat mass (kg)</i>	21.9±10.5	22.0±10.5	0.57
<i>Body volume(l)</i>	65.3±17.2	63.4±14.1	0.43
<i>Body Density (g/ml)</i>	1.063±0.027	1.063±0.027	0.72

¹HBIA: Hand-to-Hand Bioelectrical Impedance Analysis; N=10

²A-LBIA: Arm-to-Leg Bioelectrical Impedance Analysis; N=10

³ADP: Air displacement plethysmography using the BOD POD; N=10

Some studies show no difference in body composition by BIA before vs. after a fluid load (9-11). Heiss et al. (10) found that 350ml of a sports drink did not influence body composition by BIA in 32 subjects. Dixon et al. (11) found no difference in body composition by BIA after consumption of 591ml water or sports drink by 21 men. Gallagher et al. (19) and Slinde and Rossander-Hulthén (20) found decreased impedance and percent body fat results by BIA after the consumption of fluid, but in both cases, food accompanied fluid consumption. Notably, the amount of fluid in the present study was larger than those studies.

Only a few researchers have examined the effect of fluid intake and hydration status on ADP measurements. In agreement with the present investigation, studies indicate that a fluid load is interpreted as an increase in fat mass. McCrory et al. (12) found that 350ml of a carbonated beverage increased body fat by 0.9%, but the gas in the carbonated beverage may have contributed to their results. Heiss et al. (10), however, found that consumption of 350ml of a sports drink did not influence ADP body composition results. Vukovich and Peeters (4) found that the threshold for fluid intake to have an effect on ADP measures was 1000ml when they measured the body composition of subjects after drinking 500ml increments of water. In agreement with the present study, they found that a 1 liter fluid load resulted in increased body volume and percent body fat.

The density of water is 1.0 gm/ml (depending on environmental conditions), halfway between the assumed densities of fat and lean tissues, 0.9 gm/ml and 1.1 gm/ml, respectively (21). Since the density of water is halfway between the density of fat and lean tissue, the water load should not have influenced body density. Apparently, the increase in body weight (approximately 1 kg) is not in proportion to the increase in body volume following a 1 liter fluid load, resulting in a lower body density. In fact, the body density was higher before vs. after the fluid load in the present study. Because the same fluid load would result in a greater proportional weight gain in lean vs. obese individuals, the effect of a fluid load on body composition results by ADP could differ in those populations. The subjects in the present study and the Vukovich and Peeters study (4) were generally lean. Le Carvenec et al. (8) examined the effect of a 1, 2, or 4 liter water load on body composition by ADP in obese adults, and found that the water load resulted in a significantly lower lean mass and higher fat mass. In their study, each liter of water was associated with an approximate 0.5% overestimation of adiposity. Thus, a 1 liter fluid load appears to influence body composition results in lean and obese populations.

The small sample size and high proportion of female subjects limit the generalization of the results of this study. A specific volume fluid may have differing effects in people of different sizes, and this study did not examine influence of body size. For the Bod Pod measurements, predicted lung volume was used in the protocol. The lung volume was not measured using the procedure available with the Bod Pod device, as this would introduce an additional source of error, and the investigators did not want differences in measures to be reflective of error in lung volume measurement. Although the control study indicated that changes in body composition before vs after ingestion of the fluid were not due to time between measurements for ALBIA and ADP, percent body fat and fat mass were higher, and lean mass lower in a second measurement obtained 10min after an initial measurement. Thus, results for the effect of the fluid load on body composition for the HBIA must be interpreted with caution; differences in body composition may simply reflect machine drift and not a change due to fluid loading. Although this is purely speculation by the investigators, the change in body composition by HBIA between time 0 and time 1 could be due to a change in temperature in the metal hand grips between measurements, resulting in a change in conductance of the current.

CONCLUSIONS

The results from this study indicate that a 1liter fluid load is interpreted as an increase in adiposity by HBIA, ALBIA, and ADP. Although the increase in percent body fat was small with the fluid load, it may be important for those desiring precise tracking of body composition changes. In a practical setting, fluid loading by those with eating disorders and hydration changes with disease, exercise, and environment may influence body composition results. Thus, hydration protocol for the HBIA, ALBIA and Bod Pod need to be established and adhered to. Specifically, several hours should pass after a fluid load before body composition is measured by BIA and ADP to allow time for body fluids to equilibrate. Future studies with different amounts and types of fluid in people with differing body sizes would be useful.

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