International Journal of Body Composition Research 2008 Vol. 6 No. 1: 27–34 © Smith-Gordon

Submitted 12 December 2007 accepted after revision 15 February 2008

Effect of aerobic exercise on percent body fat using leg-to-leg and segmental bioelectrical impedance analysis in adults

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Objective: The purpose of this study was to determine the effect of maximal (MAX) and sub-maximal (SUB) aerobic exercise on percent body fat (%BF) using leg-to-leg and segmental bioelectrical impedance analysis (SBIA).
Methods: Sixty-three healthy, recreationally active adults (31 women; 32 men) completed a MAX and SUB exercise bout on separate days. Leg-to-leg bioelectrical impedance analysis (LBIA; model: TBF-300A) and SBIA (model: BC-418) body composition measurements were obtained immediately before (PRE) and within five minutes of completing (POST) exercise.
Results: The %BF estimates determined by the LBIA and SBIA analyzers were significantly reduced following MAX (range = 1.0-1.8%BF) and SUB (range = 1.2-1.7%BF) exercise in both groups ($P<0.05$). Significant reductions in impedance, body mass, and fat mass were also observed in the women and men, while fat-free mass and total body water significantly increased POST ($P<0.05$). Individual differences in body mass had no influence on the %BF change POST.
Discussion: The results of this study indicate that treadmill exercise conducted before LBIA and SBIA assessment reduces mean %BF estimates; for the majority of subjects (LBIA = 79%; SBIA = 85%) the reduction was less than 2.0 %BF. In many cases, the context of the BIA assessment (clinical/research trial vs routine physical examination) may determine whether variance of this magnitude has any practical significance.

Keywords: bioimpedance, body composition, foot to foot, body fat

Introduction

The use of bioelectrical impedance analysis (BIA) to assess percent body fat (%BF) in clinical and health-related settings has increased in recent years [1-3]. Partially responsible for this increased popularity may be the development of the relatively new contact-electrode systems, leg-to-leg BIA (LBIA) and segmental BIA (SBIA). LBIA and SBIA introduce a single frequency (50 kHz) electrical current into the body and measure the impedance to current flow. Fat-free mass, due to its high water and electrolyte content, is highly conductive whereas adipose tissue contains little water and is therefore a poor conductor (ie higher impedance). This differential response to an electrical current is the basis of the BIA assessment of body composition. These scale-like analyzers differ considerably from the traditional BIA method that requires the accurate placement of gel electrodes at specified anatomical locations. Owing to the appeal, the LBIA and SBIA analyzers are portable, fast, relatively inexpensive, and require no specialized training to operate.

A potential source of error with the BIA method is intra-individual variability in hydration state. Previous research examining the traditional BIA method has demonstrated that impedance is affected by factors that produce shifts in body fluids or electrolytes [4,5]. At a 50 kHz frequency, LBIA and SBIA are primarily reflecting the extracellular water compartment from which total body water, fat-free mass and %BF are estimated by pre-programmed equations [6]. The accuracy of the body composition estimates (eg %BF) provided by the BIA method is dependent upon the accuracy and precision of the impedance measurement [7]. Therefore, controlling pretest behaviors that may alter hydration state is recommended when using BIA [6,7]. For instance, exercise has been shown to decrease impedance possibly due to a shift in body fluid distribution from the trunk to active skeletal tissue in the extremities and body water loss through sweating [6,7]. As such, no exercise within 12 hours of the test is a traditional BIA pretest guideline [6]. Although subjects may adhere to such a guideline in a controlled laboratory setting, compliance in the field may be unlikely. If necessary, stringent pretest guidelines significantly reduce the practicality of utilizing the LBIA and SBIA analyzers for body composition assessment.

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Current evidence demonstrates that aerobic exercise performed prior to LBIA assessment has a significant, but minimal effect on mean impedance (range = 18 to 26 Ω) and %BF (range = 0.4 to 1.6 %BF) estimates in children [8-10]. As such, it has been suggested that compliance with the pretest exercise guideline may not be necessary in certain instances (eg school physical) when variance of this magnitude may be considered to have little practical significance [8-10]. Whether exercise prior to LBIA assessment influences %BF estimates in adults is less clear. Demura et al [11] reported small but statistically significant reductions in LBIA-measured %BF (mean difference = 0.8%) following sixty minutes of lower-body cycle ergometry in healthy young adults; however, only the muscles of the lower body were activated in that investigation. The effect that treadmill exercise, which incorporates both upper and lower body musculature, has on LBIA measurements in adults is unknown.

The SBIA analyzer contains a scale-like platform, similar to LBIA, accompanied by two hand-grip electrodes. Fat-free mass and %BF estimates are provided for each segmental region and %BF for the 'whole-body' is based on the foot-hand impedance measurement. To our knowledge, the effect of aerobic exercise on SBIA measurements has yet to be investigated. The purpose of this investigation was to determine the effect of maximal (MAX) and sub-maximal (SUB) aerobic exercise on %BF using LBIA and SBIA. It is anticipated that our findings may further clarify whether the traditional BIA pretest exercise guideline is necessary with the new LBIA and SBIA contact-electrode technology.

Methods

Subjects

In total, 63 healthy, recreationally active adults (31 women; 32 men) between 18 and 23 years of age volunteered to participate in this study. Testing was conducted at two separate testing sites; Lock Haven University (LBIA only) and Bloomsburg University (LBIA and SBIA). The Institutional Review Board at each respective institution approved the study protocol and methods. All subjects signed an informed consent form prior to participation.

Study procedures

Each subject reported to the body composition laboratory for testing on two separate occasions. During the initial visit, a MAX exercise test was performed on a motorized treadmill. During the second visit, a 40-min SUB exercise test of varying intensity was performed on the same treadmill. BIA measurements, using the LBIA and SBIA analyzers, were recorded immediately before (PRE) and within 5-min of completing (POST) both exercise tests. The treatment order for each subject was determined using a counterbalanced assignment. The laboratory temperature was maintained at a constant 22º C for all assessments.

Aerobic exercise testing

Maximal oxygen consumption (VO_{2max}) was assessed using the Modified Astrand treadmill protocol. Initially, subjects selected a workload between 5-8 miles per hour at 0% grade. Every two minutes thereafter the grade was increased 2.5% while maintaining the selected speed. The attainment of VO_{2max} was accepted when the participants demonstrated any two of the following three criteria: (1) a change in VO_2 of < 2.1 mL × kg^{-1} × min^{-1} with increasing exercise intensity at near-maximum treadmill stages; (2) a respiratory exchange ratio of ≥1.15; and (3) heart rate within 10 beats of the age-predicted maximum heart rate (MHR) at the end of the exercise test [12]. Expired concentrations of oxygen and carbon dioxide were analyzed by open circuit spirometry using a ParvoMedics TrueOne 2400 metabolic measurement system (Salt Lake City, UT).

The SUB exercise bout consisted of 40 minutes of continuous walking/jogging on the treadmill at a varied intensity. The exercise protocol was determined as a percentage of each individual's MHR as follows: (a) 5-min warm-up, (b) 10 min at 60-65% MHR, (c) 10 min at 65-70% MHR, (d) 10 min at 70-75% MHR, and (e) 5-min cool down. A polar heart monitor was used to insure subjects remained within the desired target heart rate range during the test. The exercise intensity was controlled by adjusting treadmill speed and grade throughout the test.

Bioelectrical impedance assessment

Prior to testing, all subjects were instructed to adhere to the following traditional BIA guidelines [6]: (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 d of the test. Subject compliance to these guidelines was confirmed prior to each experimental trial.
LBIA measurements were determined using a Tanita body fat analyzer; model TBF-300A (Tanita

Table 1. Subject characteristics.

Sex	Age (yr)	Height (cm)	Body mass (kg)	BMI (kg m^{-2})	VO_{2max} (ml kg^{-1} min^{-1})
Women (n = 31)	20.0 ± 1.4	164.8 ± 5.9	62.4 ± 10.0	23.0 ± 3.4	42.1 ± 5.5
Men (n = 32)	20.7 ± 1.7	175.1 ± 9.5	79.2 ± 11.3	25.1 ± 3.1	55.8 ± 7.8

All values are mean ±SD

Table 2. LBIA body composition measurements before and after exercise.

	Women (n = 31)				Men (n = 32)			
	Maximal		Sub-maximal		Maximal		Sub-maximal	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Body fat (%)	22.5 ± 7.0	20.7 ± 6.8*	22.0 ± 6.7	20.5 ± 6.4*	11.5 ± 5.0	10.1 ± 4.6*	11.1 ± 5.0	9.9 ± 4.9*
Impedance (ohms)	532.9 ± 48.5	507.7 ± 44.6*	521.4 ± 47.4	501.9 ± 41.2*	462.6 ± 51.9	440.6 ± 45.4*	457.2 ± 45.8	437.6 ± 41.3*
Body mass (kg)	62.2 ± 10.2	62.1 ± 10.1*	62.5 ± 10.3	62.3 ± 10.2*	79.5 ± 11.6	79.3 ± 11.5*	79.9 ± 11.2	79.6 ± 11.2*
Fat mass (kg)	14.6 ± 7.2	13.2 ± 6.9*	14.3 ± 6.7	13.3 ± 6.5*	9.5 ± 5.3	8.3 ± 4.8*	9.2 ± 5.1	8.2 ± 5.0*
Fat-free mass (kg)	47.6 ± 4.5	48.6 ± 4.6*	48.2 ± 4.7	48.9 ± 4.9*	70.1 ± 7.9	71.1± 8.0*	70.7 ± 7.9	71.3 ± 7.9*
Total body water (kg)	35.1 ± 3.2	35.6 ± 3.4*	35.3 ± 3.5	35.8 ± 3.6*	51.3 ± 5.8	52.0 ± 5.9*	51.7 ± 5.7	52.2 ± 5.8*

All values are mean ± SD. *P< 0.05 as compared to pre-test. LBIA leg-to-leg bioelectrical impedance analysis PRE immediately before exercise POST within 5 minutes of completing exercise.

Table 3. SBIA body composition measurements before and after exercise.

	Women (n = 24)				Men (n = 18)			
	Maximal		Sub-maximal		Maximal		Sub-maximal	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Body fat (%)	23.6 ± 6.3	22.6 ± 6.4*	23.5 ± 6.4	22.3 ± 6.5*	15.8 ± 5.6	14.8 ± 5.6*	15.8 ± 5.4	14.1 ± 5.7*
Impedance (ohms)	675.2 ± 67.5	660.2 ± 61.4*	672.7 ± 66.5	653.8 ± 63.2*	512.0 ± 40.5	500.9 ± 38.5*	510.4 ± 42.7	492.1 ± 36.7*
Body mass (kg)	63.6 ± 10.8	63.4 ± 10.8*	63.8 ± 11.0	63.5 ± 11.0*	84.6 ± 10.8	84.3 ± 10.8*	85.0 ± 10.6	84.5 ± 10.6*
Fat mass (kg)	15.5 ± 6.9	14.9 ± 6.9*	15.5 ± 7.0	15.0 ± 7.2*	13.8 ± 6.2	12.9 ± 6.1*	13.8 ± 6.0	12.6 ± 5.8*
Fat-free mass (kg)	48.1 ± 4.8	48.5 ± 4.7*	48.2 ± 4.9	48.7 ± 5.1*	70.8 ± 6.3	71.4 ± 6.5*	71.2 ± 6.4	72.0 ± 6.2*
Total body water (kg)	35.2 ± 3.5	35.5 ± 3.5*	35.3 ± 3.6	35.7 ± 3.7*	51.8 ± 4.6	52.3 ± 4.8*	52.1 ± 4.7	52.7 ± 4.6*

All values are mean ± SD. *P< 0.05 as compared to pre-test. SBIA segmental bioelectrical impedance analysis PRE immediately before exercise POST within 5 minutes of completing exercise.

Corporation of America, Inc., Arlington Heights, IL). Each subject, wearing only a t-shirt and shorts, stood erect with bare feet placed properly on the contact electrodes of the LBIA instrument. As previously described [2], the LBIA system consists of four contact electrodes (two anterior; two posterior) that are mounted on the surface of a platform scale. A low energy, single frequency, electrical signal (50 kHz, 500 μA) is passed through the anterior electrode on the scale platform, and the voltage drop is measured on the posterior electrode. Lower body impedance and body mass were measured simultaneously while the subject stood on the LBIA scale. The LBIA analyzer automatically calculates %BF using pre-programmed proprietary equations developed by the manufacturer.

The BC-418 8-contact electrode analyzer (Tanita Corporation of America, Inc., Arlington Heights, IL) was used to collect SBIA measurements. Each subject, wearing only a t-shirt and shorts, stood erect holding the hand electrodes with bare feet placed properly on the contact electrodes of the SBIA instrument. As previously described [13], the SBIA system consists of four contact electrodes (two anterior; two posterior) that are mounted on the surface of a platform scale and each extremity hand-grip has an anterior and posterior electrode. All measurements are carried out using a constant single frequency current (50 kHz, 500 μA). Whole-body impedance is measured as a foot-hand electrical pathway. Like LBIA, the SBIA analyzer automatically calculates %BF using pre-programmed proprietary equations developed by the manufacturer.

Statistical analysis

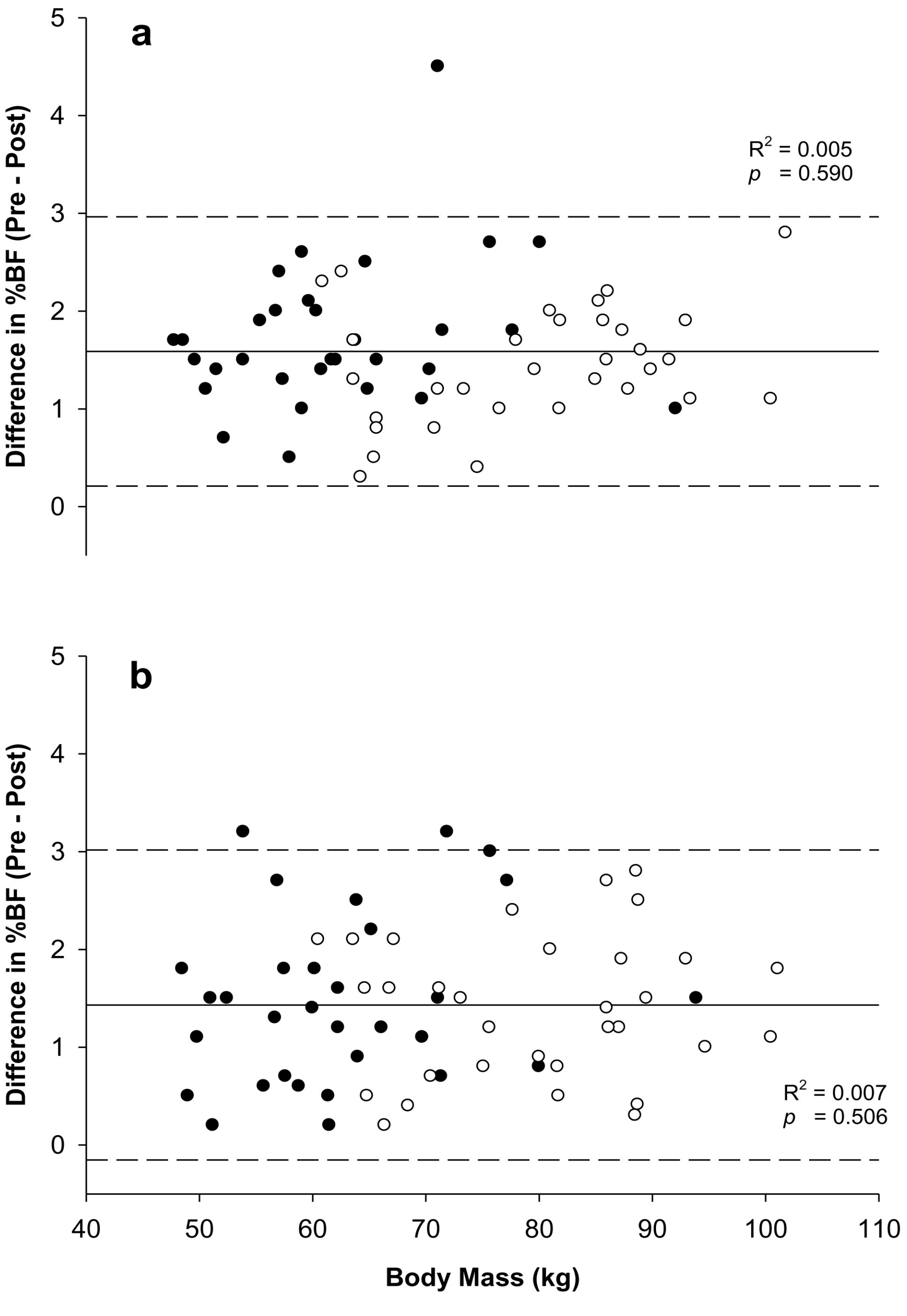
Data were analyzed using SPSS 11.5 for Windows (SPSS, Inc., Chicago, IL). All values are expressed as mean ± SD. Paired samples *t*-tests were used to detect significant differences in impedance, %BF, body mass, fat mass, fat-free mass and total body water for each of the experimental trials. The Holm's sequential Bonferroni method was used for control of Type I error for multiple comparisons. Mean differences (PRE – POST) for impedance and %BF between LBIA and SBIA were also examined using paired samples *t*-tests to determine whether both analyzers detected similar changes. Bland-Altman plots were used to assess individual differences in %BF PRE to POST [14]. Statistical significance was established a priori at P<0.05 for all analyses.

Results

Subject characteristics of the 63 adults (31 women; 32 men) that participated in this investigation are presented in Table 1. The mean MAX exercise test durations were 9:23 and 11:20 (min:sec) for the women and men, respectively. The SUB exercise intensity for the three 10-minute workloads corresponded to 64%, 70% and 74% of age-predicted MHR. The average duration between exercise tests was 6.7 ± 3.5 days.

LBIA body composition data for the MAX and SUB

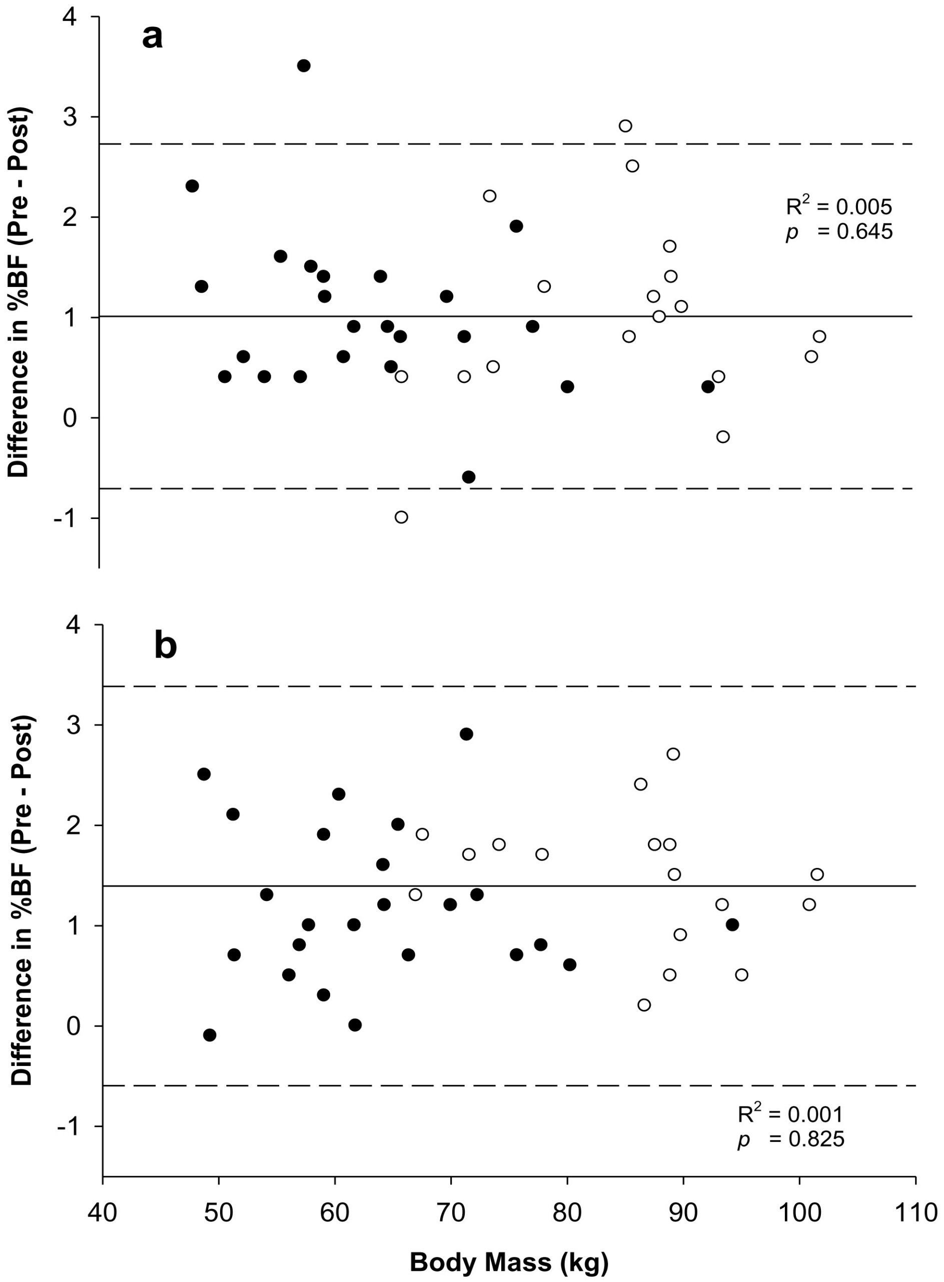
Figure 1. Scatter plots exploring individual differences in LBIA-measured %BF following MAX (a) and SUB (b) treadmill exercise. The difference between PRE and POST exercise %BF is plotted against body mass for the women (•) and men (○). Values greater than zero indicate a decrease from PRE to POST. The mean difference is represented by the solid line and the dashed lines represent ± 2 SD from the mean.



exercise tests are presented in Table 2. Significant reductions in mean %BF were observed POST when compared to PRE during the MAX (women = 1.8%; men = 1.4%) and SUB (women = 1.5%; men = 1.2%) exercise tests in both groups ($P<0.05$). Similarly, significant reductions in impedance, body mass, and fat mass were observed in the women and men following MAX and SUB exercise ($P<0.05$). Conversely, fat-free mass and total body water significantly increased POST in the women and men following both exercise tests ($P<0.05$).

SBIA body composition data for the MAX and SUB exercise tests are presented in Table 3. Significant reductions in mean %BF were observed POST when compared to PRE during the MAX (women = 1.0%; men = 1.0%) and SUB (women = 1.2%; men = 1.7%)

Figure 2. Scatter plots exploring individual differences in SBIA-measured %BF following MAX (a) and SUB (b) treadmill exercise. The difference between PRE and POST exercise %BF is plotted against body mass for the women (•) and men (○). Values greater than zero indicate a decrease from PRE to POST. The mean difference is represented by the solid line and the dashed lines represent ± 2 SD from the mean.



exercise tests in both groups ($P<0.05$). Significant reductions in impedance, body mass, and fat mass were also observed in the women and men following MAX and SUB exercise ($P<0.05$). Fat-free mass and total body water significantly increased POST in the women and men following both exercise tests ($P<0.05$).

Similar changes (mean difference = PRE – POST) in impedance and %BF were determined by the LBIA and SBIA analyzer during the SUB exercise test in both the women and men. Following MAX exercise, significantly larger reductions in impedance (mean difference = 10Ω and 11Ω) and %BF (mean difference = 0.8% and 0.4%) were observed with LBIA when compared to SBIA in the women and men, respectively ($P<0.05$).

According to the Bland-Altman plots (Figures 1 and 2), body mass had no apparent influence on the subject's %BF change POST during MAX or SUB exercise. Total sample differences in %BF PRE to POST (mean ± SD) were 1.6 ± 0.7 and 1.4 ± 0.8 for LBIA (Fig 1) and 1.0 ± 0.9 and 1.4 ± 1.0 for SBIA (Fig 2), MAX and SUB exercise, respectively. As shown in Figure 1, when using the LBIA analyzer for assessment, every exercise bout (MAX and SUB combined; N = 126 exercise tests) resulted in some reduction in %BF POST. More specifically, the %BF reduction was less than 1.0 %BF in 22% of the subjects, between 1.0-2.0 %BF in 57% of the subjects, and by more than 2.0 %BF in 21% of the subjects (Fig. 1). Similarly, when using the SBIA analyzer, a reduction in %BF was observed following 94% of the exercise bouts (MAX and SUB combined; N = 84 exercise tests; Fig. 2). The %BF reduction was less than 1.0 %BF in 41% of the subjects, between 1.0-2.0 %BF in 44% of the subjects, and by more than 2.0 %BF in 15% of the subjects (Fig. 2). For the 4 subjects that demonstrated an increase in SBIA-measured %BF POST, the increase was less than 1.0 %BF.

Discussion

Due to the ease of measurement, contact-electrode BIA analyzers have become an attractive method of assessing body composition. To increase the accuracy of BIA measurement it is recommended that individuals perform no exercise 12 hours prior to the assessment to avoid a temporary disruption to fluid and electrolyte equilibrium [6]. If necessary, compliance with such a recommendation significantly limits the practicality of utilizing these analyzers to assess body composition in the field. This investigation examined the effect of MAX and SUB aerobic exercise on %BF using a commercially-available LBIA and SBIA analyzer. This study confirms that performing MAX or SUB exercise prior to BIA assessment has a significant influence on the recorded %BF value thereby supporting the pretest exercise recommendation in order to avoid a temporary alteration in hydration status [6].

Following MAX treadmill exercise in the present investigation, significant reductions in LBIA-measured impedance (~25Ω and ~22Ω) and %BF (1.8% and 1.4%) were observed in the women and men, respectively. Reductions in LBIA-measured impedance (~20Ω and ~20Ω) and %BF (1.5% and 1.2%) were also observed following the SUB exercise bout in the women and men, respectively. These findings are consistent with previous research that examined the effect of aerobic exercise on LBIA-measured %BF in children [8-10]. In two previous investigations, comparable reductions in LBIA-measured impedance and %BF following both MAX (~26Ω and ~26Ω; 1.6% and 1.5%) and intermittent SUB (~18Ω and ~21Ω; 1.4% and 1.5%) treadmill exercise were reported in girls and boys, respectively [9,10]. Presently, the Bland-Altman analysis revealed that the majority of the subjects (LBIA = 79%; SBIA = 85%) demonstrated reductions of less than 2.0 %BF POST. This also compares favorably to previous research that examined the effect of intermittent sub-maximal exercise on LBIA-measures in children [10]. Eighty-six percent of the girls and 73% of the boys demonstrated reductions of less than 2.0 %BF following treadmill exercise in that investigation. Interestingly, changes of a similar magnitude were observed in both the adults in the present study and children (age range = 7-10 yrs). It appears that gender, age, height, and body mass differences may have little effect on LBIA measurements following aerobic exercise. The same model LBIA analyzer (Tanita; TBF-300A) was used in each of the aforementioned investigations.

Unlike LBIA, which uses a leg-to-leg electrical pathway, the SBIA analyzer estimates %BF for the 'whole-body' based on the left foot-hand impedance measurement. Reductions in SBIA-measured impedance and %BF were observed following the MAX (~15Ω and ~11Ω; 1.0% and 1.0%) and SUB (~19Ω and ~18Ω; 1.2% and 1.7%) treadmill exercise bouts, women and men, respectively. To our knowledge, this is the first study to examine the effect of aerobic exercise on SBIA measurements. Despite utilizing different electrical pathways, both the LBIA and SBIA analyzers responded similarly to SUB exercise. Conversely, significantly greater reductions in LBIA-measured impedance and %BF were observed when compared to SBIA during the MAX exercise bout. It appears that high-intensity treadmill exercise induces a greater effect on LBIA body composition measures than those determined by the SBIA analyzer. These data warrant a further exploration of potential sensitivity differences between LBIA and SBIA relative to exercise intensity and mode.

The %BF value, as calculated by the analyzers, is derived from proprietary equations combining impedance and body mass measurements with height, gender, and age information. Therefore, in addition to impedance, body mass changes can affect the %BF estimations. Previously, Dixon et al [15] examined the effect of acute fluid consumption on measures of impedance and %BF using LBIA. Although impedance and total body water were unchanged 20 minutes after drinking 20 ounces of fluid, %BF increased significantly. The increased body mass (~500 g) due to fluid consumption resulted in the slight increase in %BF (~0.5%) in that study. Presently, significant reductions in mean body mass (range = 100-400g) were observed in the women and men following the aerobic exercise bouts most likely due to sweating. It is anticipated that the exercise-induced body mass loss influenced %BF reductions in this study; however, to what extent cannot be determined without access to the manufacturer's equations. Collectively, data from our laboratory indicate that when using the LBIA and SBIA analyzer-equipped proprietary equations, body mass may be a more important determinant of %BF than impedance [9,10,15].

As with any new measurement device the operational characteristics are of importance. Traditional BIA studies have reported the reliability (coefficient of variation; CV) for multiple resistance measurements is generally about 1% to 2% for within-day assessments and 2% to 3.5% for between-day measures [6]. Previous studies have evaluated within and between-day CV for the LBIA and SBIA analyzers [2,13,15]. Nunez et al. [2] evaluated a LBIA analyzer in healthy adults aged 18-79 years. The CV's for within-day impedance measurements ranged from 0.4 to 1.5% (mean = 0.9 ± 0.5%) and the between-day CV ranged from 1.0 to 3.6% (mean = 2.1 ± 1.0%). Similarly Dixon et al. [15], using the TBF-300A LBIA analyzer, reported between-day CV for impedance ranging from 0.1 to 5.8% (mean = 2.2 ± 1.7%) in 21 recreationally active men. Pietrobelli et al. [13] evaluated the BC-418 SBIA analyzer and reported within-day and between-day CVs for %BF ranging from 0.8 to 1.4% and 2.3 to 3.7%, respectively. Presently, the change in %BF from PRE to POST ranged from 0.2 to 4.5% and -1.0 to 3.5% when using the LBIA and SBIA analyzers, respectively. Taken collectively, the difference between the PRE and POST body composition measurements in the present investigation may be due to exercise-induced alterations in body fluid distribution, body mass, some other unmeasured variable or the result of within-day instrument variability.

Limitations of the present investigation include that our subject sample consisted of primarily healthy, recreationally-active adults. The effect that treadmill exercise has on LBIA and SBIA body composition measures in other populations (eg older adults, sedentary individuals, etc) cannot be determined from this study. In addition, our findings cannot be generalized to exercise that precedes the assessment by a longer duration than that examined currently. The greatest change in BIA body composition measurements may be expected to occur immediately post-exercise due to increases in blood flow to active muscle tissue, cutaneous blood flow, and skin temperature during the exercise bout [16]. Nonetheless, the examination of exercise that precedes assessment by longer durations is warranted to further clarify whether avoiding exercise 12 hours before testing is necessary.

In summary, the development of the contact-electrode BIA analyzers has provided clinicians with a fast and relatively inexpensive method of assessing body composition. Previous research examining the traditional BIA method has recommended controlling pretest behaviors that may alter hydration state to improve accuracy. Our findings indicate that aerobic exercise conducted before LBIA and SBIA body composition assessment reduces mean %BF estimates; for the majority of subjects (LBIA = 79%; SBIA = 85%) the reduction was less than 2.0 %BF. When one considers the exercise-induced %BF reductions observed presently with the inherent prediction error for BIA which ranges from 3.0 to 4.0 %BF in adults [6], it is apparent that exercise may further reduce the accuracy and precision of this method. When using the BIA analyzers in research or clinical settings to track the effectiveness of weight management programs this degree of error may be unacceptable. As such, when precision is critical, we recommend adhering to the traditional BIA pretest exercise guideline to avoid exercise-induced alterations in body composition measures. Obviously, stringent pretest guidelines do limit the practicality of utilizing these devices in the field. In certain instances, such as a routine physical where the assessment of body fatness is often used to characterize health risk, variance of this magnitude may be considered to have little practical significance, and therefore controlling exercise behavior immediately before the assessment may not be essential.

Acknowledgements – We gratefully acknowledge Dr. Eric S. Rawson for assisting in recruitment, Phillip Longnecker, Patrick Ward, Tiffany Bosworth, Jamie Bremen and Jennifer Nilsen for assisting in data collection, and all subjects for their participation in this investigation.

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