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Effect of an Acute Exercise Session on Body Composition Using Multi-Frequency Bioelectrical Impedance Analysis in Adults

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Abstract: The purpose of this investigation was to examine the effect of an acute bout of aerobic exercise (AE) and resistance exercise (RE) on body composition measured by multi-frequency bioelectrical impedance analysis (MBIA) in adults. Ninety-five recreationally active young adults (46 women and 49 men) reported for testing on three occasions. After an initial MBIA assessment, subjects performed 45 minutes of continuous AE, RE, or did nothing, which served as the control (CON). During the AE trial, subjects performed an acute bout of treadmill exercise at 60%-75% of their age predicted maximal heart rate ($APHR_{max}$). The RE trial consisted of an 8-exercise circuit consisting of; 3 sets of 10-12 repetitions at 65%-75% of their one-repetition max (1RM) for each exercise. During the CON trial, subjects sat quietly in the laboratory. Body composition was reassessed immediately following the exercise bouts for comparison. Mean percent body fat (%BF) decreased following the exercise bouts (AE = 0.7%, RE = 1.6%; $P < 0.001$) likely due to significant ($P < 0.001$) reductions in impedance (AE: 40Ω, 32Ω, and 29Ω; RE: 45Ω, 29Ω, and 28Ω) measured at 5, 50 and 500 kHz. Conversely, significant increases in %BF (0.7%, $P < 0.05$), body mass (0.2 kg, $P < 0.001$), and impedance at 5 and 50 kHz (15Ω and 16Ω; $P < 0.001$) were observed following the CON trial. These findings support that MBIA assessments should be performed prior to exercise in order to prevent exercise-induced reductions in %BF values.

Key words: BIA, bioimpedance, percent body fat, body mass.

1. Introduction

Obesity is a major public health problem in the United States, which causes a wide range of serious complications and increases the risk of illness and premature death. According to the Center for Disease Control and Prevention, health problems associated with obesity include: increased risk of type 2 diabetes [1], sleep apnea, asthma [2], joint problems and musculoskeletal discomfort [3], gallstones [4], stroke [5], and cancer [6]. In addition, obesity is also associated with high blood pressure and high cholesterol, both of which contribute to cardiovascular disease which is the leading cause of death in the United States [7]. Body mass index data indicates that obesity has been significantly increasing among the US population over the past 30 years [8], with recent estimates showing that nearly one-third of adults being classified as obese (32.2% of men and 35.5% of women) [9].

As awareness of the obesity epidemic has increased, so too has the interest in effective weight management programs designed to improve eating behaviors and increase physical activity. To encourage participation, employers often offer incentives to employees who lose weight [10]. In order to track the effectiveness of these intervention programs, accurate methods of measuring body composition are necessary [11].

One popular method of assessing body composition is bioelectrical impedance analysis (BIA). During the assessment a small, undetectable electrical current is passed through the body, and the resistance to the

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current flow (impedance) is measured by the analyzer [12, 13]. Lean body mass is highly conductive to the current flow because of a high water and electrolyte content (low impedance), while fat mass is a poor conductor [11]. From the impedance measurement, BIA devices estimate body composition [body mass (BM), lean body mass (LBM), and total body water (TBW)] [14]. Multiple BIA analyzers are currently available including leg-to-leg (LBIA), segmental (SBIA), and multi-frequency (MBIA) device.

Acute shifts in fluid and electrolyte balance which occur throughout the day have been shown to alter BIA body composition estimates by altering the impedance measurement [15]. As such, several pretesting guidelines have been designed to control for these fluctuations in hydration [14]. For instance, avoiding exercise 12 hours prior to testing is a common BIA guideline. Previously, Dixon et al. in two separate studies, examined the effect of aerobic exercise [13] and resistance exercise [16] on body fat using LBIA and SBIA devices. Following 40 minutes of aerobic exercise at 60%-75% of the individual's age predicted heart rate maximum ($APHR_{max}$), they found a 1.5% mean decrease in LBIA assessed percent body fat (%BF), and a 1.2% mean decrease in SBIA in 63 recreationally active adults (31 women; 32 men) [13]. In another study [16], %BF reductions (LBIA = 0.4%; SBIA = 1.2%) were also observed following an eight exercise resistance training circuit in 86 young adults (45 women; 41 men). Recently, Andreacci et al. examined the impact that cycle ergometry exercise had on %BF estimates using LBIA and SBIA [12]. Seventy-four college-aged adults performed two 30-minute exercise sessions, as well as a day which served as the control. The subjects' body composition was measured pre and post exercise, it was found that cycle ergometry altered mean %BF estimates of LBIA 0.5%, and SBIA 1.0% [12].

Although previous studies have explored the impact of acute exercise on LBIA and SBIA body composition measurements, to our knowledge, no studies have examined MBIA technology. MBIA differs from the majority of LBIA and SBIA devices by incorporating three electrical frequencies (5, 50, and 500 kHz) into the measurement rather than a single standard frequency of 50 kHz [17]. The multiple frequencies enable the determination of both extracellular and intracellular water [18]. Extracellular water can be determined using low frequencies (≤ 50 kHz), while higher frequencies (≥ 200 kHz) are necessary to penetrate cell membranes and determine intracellular water [18]. This MBIA determination of intracellular fluid is an assessment that previous single-frequency BIA technology could not provide.

Previous research has shown changes in LBIA and SBIA body composition measures following acute bouts of exercise [12, 13, 16]. The impact that exercise has on the more advanced MBIA technology is currently unknown. Given that MBIA expands upon this originally technology by determining both intracellular and extracellular water, one may anticipate greater exercise-induced alterations in body composition measures. As such, the purpose of this study was to examine the effect of an acute bout of aerobic exercise (AE) and resistance exercise (RE) on body composition measured by MBIA (InBody 520) in adults.

2. Methods

2.1 Experimental Approach to the Problem

Each subject reported to the exercise physiology laboratory on three separate occasions within a seven-day period. In order to control for experimental bias, the testing order was counterbalanced prior to the first day.

On the initial visit, anthropometric data was recorded for each subject. During each visit, subjects underwent an initial MBIA assessment (PRE). Subjects then performed 45 minutes of a RE, AE, or the control (CON) trial. During the RE trial, each subject completed an eight-exercise circuit protocol consisting of three sets of 10-12 repetitions for each exercise.

During the AE trial, all subjects were asked to complete 45 minutes of treadmill exercise at 60%-75% of their $APHR_{max}$. During the CON trial, subjects were asked to sit quietly for the duration of 45 minutes. Subjects were provided with a bottle of water (500 mL) for consumption during all three trials. A second MBIA assessment was then performed immediately following each trial (POST).

2.2 Subjects

Ninety-five (49 men, 46 women) recreationally active college aged adults were recruited for the study, subject characteristics can be observed in Table 1. Subjects were recruited via flyers posted throughout the campus. The Bloomsburg University Institutional Review Board approved the study protocol and methods. Each subject completed a Physical Activity Readiness Questionnaire (PAR-Q), as well as an informed consent form prior to participation.

2.3 Procedures

Prior to testing, subjects were asked to adhere to strict pretesting guidelines: (1) no food or drink two hours prior to testing; (2) no exercise 12 hours prior to testing; (3) no alcohol consumption 48 hours prior to testing; and (4) no diuretics seven days prior to testing. Compliance to the guidelines was verbally confirmed before each experimental trial. Urine specific gravity (USG), was measured by a hand-held digital fiberoptic refractometer (Misco Corp., Cleveland, OH, USA), prior to the initial MBIA assessment, in order to determine hydration state [19].

The AE exercise bout consisted of 45 minutes of continuous walking/jogging on a treadmill. The exercise intensity was determined as a percentage of each individual's $APHR_{max}$, and kept between 60%-75%. A polar heart monitor was used to ensure that subjects remained within the desired target HR range during the test. Subjects were permitted to adjust speed and grade as needed during the test to remain within the target HR zone.

The RE trial required each subject to complete an eight-exercise circuit protocol consisting of three sets of 8-12 repetitions at 65%-75% of their one repetition max (1RM) for each exercise. The eight exercises included; dumbbell chest press, lat pull-down, lunges, abdominal crunches, seated row, shoulder press, bicep curl, and triceps extension. Three full circuits were performed within the 45 minutes, at their own pace. HR was recorded after each circuit set using a polar heart monitor.

The MBIA measurements were measured using the InBody 520 (Biospace Co., Beverly Hills, CA, USA). The InBody 520 measured the direct segmental impedance across both legs, arms and trunk at multiple frequencies (5, 50, and 500 kHz). The InBody system has an 8-point electrode placement, which contacts the body at two points in each hand and foot. Body mass, and five segmental impedance measurements (right arm, left arm, trunk, right leg, and left leg) are automatically measured while the subject stood erect holding the electrodes with their bare feet placed properly on the contact electrodes on the MBIA platform. As recommended by the manufacturer [18], the subject's arms were held straight-down without touching the sides of their trunk.

2.4 Statistical Analysis

Data was analyzed using SPSS 22 for Windows (SPSS, Inc., Chicago, IL). All values are expressed as

Table 1 Subject Characteristics.

	Age (yrs)	Height (cm)	Body mass (kg)	BMI (kg/m^2)
Women (*n* = 46)	21.2 ± 1.9	164.4 ± 5.2*	62.9 ± 7.8*	23.2 ± 2.4*
Men (*n* = 49)	22.1 ± 3.3	177.5 ± 6.8	81.8 ± 13.3	25.9 ± 3.8
Total (*n* = 95)	21.7 ± 2.6	170.9 ± 6.0	72.4 ± 10.6	24.6 ± 3.1

All values are mean ± *SD*. BMI = body mass index.
*$P < 0.05$ difference when compared to men.

mean ± SD, if normally distributed. Paired samples *t*-tests were used to detect significant differences (pre vs. post) in the MBIA body composition for each of the experimental trials. Statistical significance was established a priori at $P \leq 0.05$ for all analyses. Bland-Altman plots [20] were used to assess individual differences in %BF, plotted against BM pre- to post exercise. The reliability (intraclass correlation coefficient) of the body composition variables determined by MBIA for each experimental trial exceeded 0.843.

3. Results

The MBIA body composition data of the group for the CON, RE, and AE trials are presented in Table 2. Following RE, significant ($P < 0.05$) reductions were observed for fat mass (1.2 kg), %BF (1.6%), and impedance (45Ω, 29 Ω, and 28Ω) at the levels of 5, 50, and 500 kHz respectively (Table 2). Significant ($P < 0.05$) increases were also observed after RE in body mass (0.1 kg), TBW (1.0 kg), intracellular water (0.6 kg), and extracellular water (0.3 kg). No significant differences were observed post exercise in FFM in the RE trial (Table 2). USG measured prior to exercise averaged 1.02 g/ml. The average HR for all subjects during the resistance trial was 139 ± 19 beats per minute.

Following AE, significant ($P < 0.05$) reductions in body mass (0.1 kg), FM (0.4 kg), %BF (0.7%), and impedance (40Ω, 32Ω, and 29Ω) at the levels of 5, 50, and 500 kHz respectively, were observed. Significant ($P < 0.05$) increases were observed in FFM (0.4 kg), TBW (0.3 kg), intracellular water (0.1 kg), and extracellular water (0.1 kg; Table 2). Measured USG averaged 1.02 g/ml. The average HR for all subjects during the aerobic trial was 144 ± 19 beats per minute.

During the control (CON) trial significant ($P < 0.05$) increases were observed in body mass (0.2 kg), fat mass (0.5 kg), %BF (0.6%), and impedance at 5 kHz (15Ω) and 50 kHz (16Ω). Significant ($P < 0.05$) decreases were observed in FFM (0.3kg), TBW (0.2 kg), and extracellular water (0.1 kg). No changes were observed in intracellular water, or impedance at the level of 500 kHz (Table 2). The average measure of USG was 1.02 g/ml.

Bland-Altman plots were used to show the difference in %BF (pre – post) vs. body mass, for each condition (Fig. 1A, 1B, 1C). There was no relation between the magnitude of %BF change (pre-post) and BM in any of the trials.

4. Discussion

Due to the prevalence of obesity, many people are concerned with losing weight and keeping track of their body fat, thus measuring body composition has become popular in health and fitness facilities. A simple, fast and noninvasive method of monitoring adiposity, such as BIA, is needed by those that prescribe and monitor exercise. When using BIA technology, specific pretesting guidelines have been recommended in order to increase the accuracy of the measurements, including no exercise within 12 hours prior to the test [14]. This investigation examined the effect of two different exercise modalities (resistance and aerobic) on body composition determined by the relatively new MBIA technology. The primary finding of this investigation was that impedance and %BF measurements were significantly reduced following both 45 minutes of RE and AE in the men and women.

RE resulted in significant reductions in MBIA measured impedance (45Ω, 29Ω, and 28Ω) and %BF (1.6%). These findings are consistent with previous work that examined the effects of RE on single frequency (50 kHz) BIA. Dixon et al. [16] assessed eighty six recreationally active adults (45 women and 41 men) before and after a RE bout. Significant reductions in SBIA measured %BF (women 0.9%; men 1.4%), impedance (women 22.2Ω; men 22.3Ω), and fat mass (women 0.6kg; men 1.3kg) were observed following RE. In the present study, the reductions in the MBIA impedance at 50 kHz (29Ω) and %BF (1.6%) were slightly larger than those previously reported using

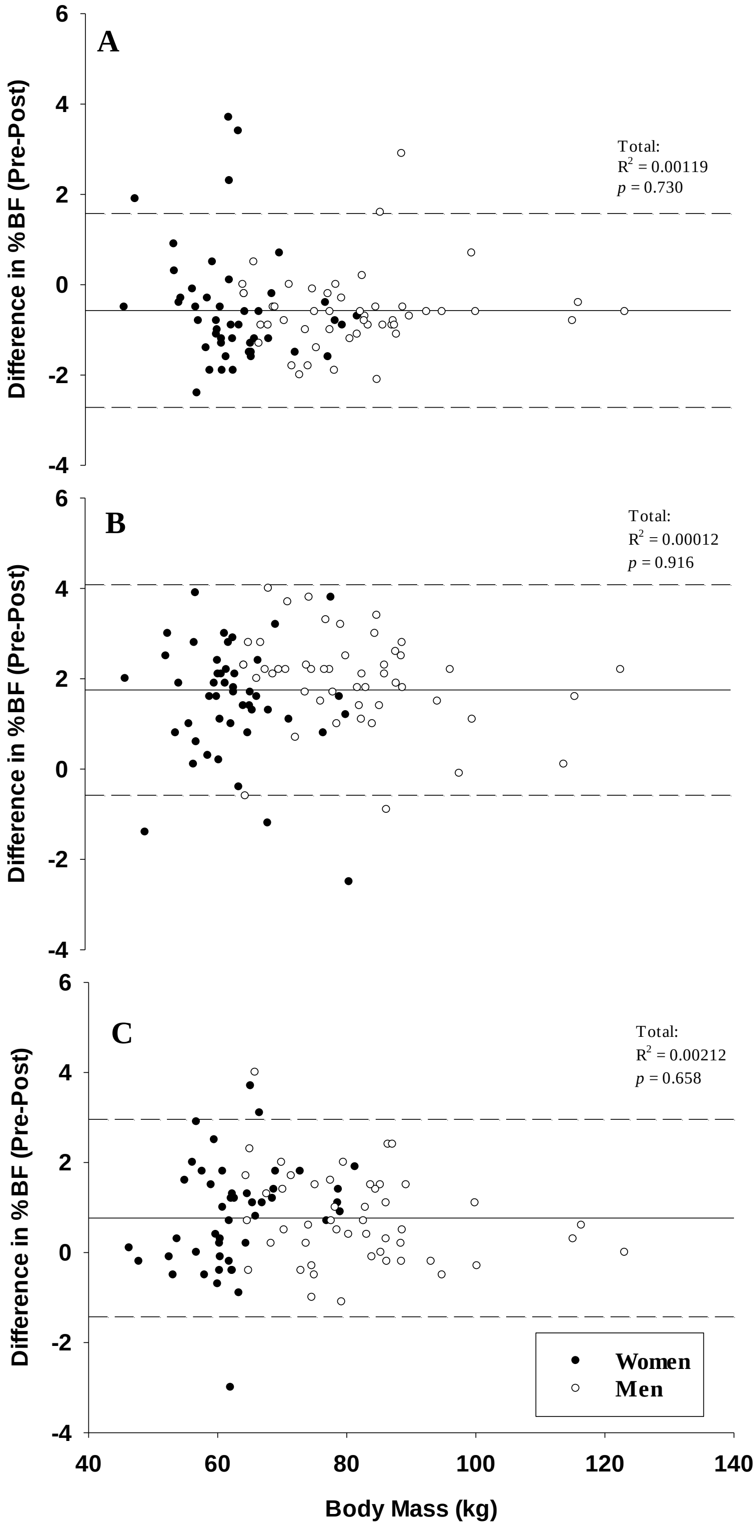

Fig. 1 Scatter plots exploring individual differences between pre and post exercise %BF is plotted against body mass for women (●) and men (○); A) Control, B) Resistance Exercise, and C) Aerobic Exercise. Values greater than 0 indicate a %BF decrease from pre to post. The mean difference is represented by the solid line, and the dashed lines represent ± 2 SD from the mean.

Table 2 MBIA body composition measurements during all treatment conditions.

	Control		Resistance		Aerobic	
	Pre	Post	Pre	Post	Pre	Post
Body Mass (kg)	72.8 ± 14.3	73.0 ± 14.3*	72.6 ± 14.3	72.7 ± 14.3*	72.6 ± 14.4	72.5 ± 14.3*
Fat Free Mass (kg)	57.9 ± 12.6	57.6 ± 12.6*	58.1 ± 12.6	58.8 ± 12.8	58.1 ± 12.6	58.5 ± 12.6*
Fat Mass (kg)	14.8 ± 7.2	15.3 ± 7.3*	14.5 ± 7.1	13.3 ± 7.1*	14.6 ± 7.2	14.2 ± 7.2*
Intracellular Water (kg)	26.7 ± 6.0	26.6 ± 6.0	26.9 ± 5.9	27.5 ± 6.1*	26.9 ± 5.9	27.0 ± 5.9*
Extracellular Water (kg)	15.7 ± 3.3	15.6 ± 3.3*	15.7 ± 3.3	16.0 ± 3.4*	15.7 ± 3.3	15.8 ± 3.3*
Total Body Water (kg)	42.4 ± 9.2	42.2 ± 9.3*	42.6 ± 9.3	43.6 ± 9.5*	42.6 ± 9.2	42.9 ± 9.3*
% Body Fat	20.4 ± 7.9	21.0 ± 8.1*	20.0 ± 8.2	18.4 ± 8.1*	20.0 ± 8.2	19.3 ± 8.3*
5 (Ohms)	1272.7 ± 181.0	1287.8 ± 192.6*	1279.4 ± 184.6	1234.4 ± 175.3*	1279.6 ± 187.8	1239.3 ± 186.7*
50 (Ohms)	1099.8 ± 176.7	1116.1 ± 191.0*	1106.1 ± 182.5	1077.1 ± 173.5*	1101.1 ± 185.2	1069.0 ± 184.2*
500 (Ohms)	941.4 ± 159.1	947.5 ± 173.8	945.4 ± 163.0	917.7 ± 155.0*	943.5 ± 166.9	914.3 ± 164.7*

All values are mean ± SD. Pre = pre-exercise; Post = post-exercise, *$P < 0.05$ as compared to pretest.

SBIA technology [16] indicating that MBIA may be more sensitive to exercise-induced fluid alterations. When assessing body composition using the MBIA analyzer, it is apparent that resistance exercise results in %BF and impedance reductions post-exercise. These findings confirm that RE performed before MBIA assessment has a significant influence on body composition measurements, supporting the traditional bioelectrical impedance pretest exercise recommendations.

Similarly, AE significantly reduced MBIA measured impedance (40Ω, 32Ω, and 29Ω) at the 5, 50, and 500 kHz levels respectively, and %BF (0.7%). Previously, Dixon et al. [13] investigated the effects of AE on %BF in 63 college aged adults (31 women; 32 men). Similar reductions in LBIA and SBIA measured %BF estimates were observed in that study; LBIA: women 0.5%, men 1.6%; SBIA: women 1.0%, men 1.0%. Significant reductions in impedance at 50 kHz were also observed in LBIA (20Ω reduction in both women and men), and SBIA (19Ω and 18Ω; women and men, respectively). Andreacci et al. [12] examined the effects of cycle ergometry exercise on LBIA and SBIA-determined %BF estimates in 74 college aged adults (38 women; 36 men). Significant reductions in %BF (LBIA: 0.5%; SBIA: 1.0%) and impedance (LBIA: 2.9Ω; SBIA: 10.2Ω) were reported following 30 minutes of cycle ergometry at 70% HR_{max}. Although the MBIA %BF reduction observed presently was similar to those previously reported using LBIA and SBIA technology, the MBIA impedance reduction at 50 kHz, was much greater (32Ω) compared to the 20Ω (LBIA), and 19Ω (SBIA) reported by Dixon and colleagues [13]. The present study and that by Dixon et al. [13] reported larger alterations following exercise than Andreacci et al. [12] with 2.9Ω (LBIA) and 10.2Ω (SBIA). The variations in findings may be at least partially explained by differences in the mode (treadmill vs. cycle ergometry) and duration of exercise.

During the CON trial, significant increases were found in body mass (0.2 kg) and impedance (15.4Ω and 16.3Ω) at the 5 and 50 kHz levels, respectively. These findings support those by Dixon et al. [13, 16] and Andreacci et al. [12] who performed similar trials. Body mass, and impedance were shown to increase during the CON trial most likely due to fluid consumption.

Previous research has examined the effects of exercise on LBIA and SBIA analyzers, which measure impedance at a single frequency. MBIA use three different electrical frequencies (5, 50, and 500 kHz) enabling one to examine the impact of RE and AE exercise on the intra- and extracellular water values. In support of previous research, impedance and %BF values were reduced following exercise. The observed reduction can possibly be explained because of the fluid shift induced by exercise; increased perfusion to the active muscle tissue during the exercise.

5. Conclusion

The findings in the present study, should benefit those currently assessing adiposity using MIBA technology in fitness-wellness centers, where it may be difficult and impractical for these people to adhere to stringent pretesting guidelines, prior to having their %BF assessed. Our findings indicate that the observed change in %BF, while statistically significant, may hold little practical significance in the field setting when assessed using MBIA technology. Therefore, restricting the client's exercise behavior prior to the assessment may not be needed, however these results may be more significant in a clinical setting. However, precision is critical, so MBIA assessments should be performed prior to exercise to eliminate potential exercise-induced alterations in body composition measurements, caused by fluid shifts. This information is important for coaches, personal trainers, athletic trainers, as well as other health and fitness professionals who may use this technology to monitor body composition in the field.

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