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Original Research

Time Course Toward Baseline of Hand-to-Foot BIA Measures Following An Acute Bout of Aerobic Exercise

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ABSTRACT

International Journal of Exercise Science 11(2): 640-647, 2018. The purpose of this study was to determine the time course of BIA-derived body fat percentage (BF%) and total body water (TBW) values in the 1 h following a moderate bout (60% heart rate reserve [HRR]) of steady state aerobic exercise in apparently healthy men. College-aged adult males (n=15) had their BF% and TBW estimated via BIA before (PRE), immediately (IP), 10 min (10P), 20 min (20P), 30 min (30P), 40 min (40P), 50 min (50P), and 60 min (60P) post a 30 min bout of moderate treadmill exercise. Exercise intensity was 60% of subjects' HRR. Compared to PRE values, BIA-derived BF% and TBW were significantly lower and higher, respectively, from IP-30P (all $p<0.05$). However, BF% and TBW values for 40P-60P were not statistically significant compared to PRE (all $p>0.05$). The 95% limits of agreement for BF% and TBW were narrowest for IP (±1.5%; ±0.5kg) and widest at 50P (±2.1%; ±0.7kg), respectively. The time periods that produced significantly different BF% and TBW values (i.e., IP, 10P, 20P, and 30P) had smaller 95% limits of agreement than the time periods that produced non-significantly different mean values (i.e., 40P, 50P, and 60P). The 12 h recommendation of avoiding aerobic exercise prior to BIA testing appears to be too stringent. Results from the current study found that BIA-derived BF% and TBW measured at 40P, 50P and 60P were similar to PRE. Furthermore, if BIA is used after aerobic exercise, but prior to 40P, practitioners should consider adjusting for the systematic error (e.g., increase BIA-derived BF% IP by 2.3%).

KEY WORDS: Body composition, body fat percentage, total body water, bioimpedance

INTRODUCTION

Bioelectrical impedance analysis (BIA) is often utilized by exercise physiologists to estimate body fat percentage (BF%) and total body water (TBW). The attractiveness of BIA is due to its low cost, quick administration time, and ease of use. Under resting conditions, BIA has been shown to be more reliable than other commonly used field metrics of BF%, such as the skinfold technique (1). In order to determine body composition, BIA utilizes the passing of an electrical current through the body in order to assess resistance and reactivity of tissue.

The basic principle of the BIA technique is that the electrical current passed through the body is impeded (e.g., resisted) by adiposity. High conductivity in lean tissue is attributed to a larger amount of water and electrolyte content (13). The impedance values derived from BIA are entered into a prediction equation in order to calculate TBW, fat-free mass (FFM) and subsequently BF%. One assumption of BIA is that FFM consists of 73% water (16). This assumption can be violated in many circumstances, especially when aerobic exercise is performed prior to testing, which can result in plasma volume shifts, changes in hydration and electrolyte status.

Importantly, an acute bout of aerobic exercise prior to BIA analysis would likely lead to measurement error if changes in TBW occur (e.g., sweat loss). Two studies (2,7) found that immediately following a bout of steady state aerobic exercise, BIA-derived BF% was significantly lower than pre-exercise values, which was exacerbated following higher intensity aerobic exercise. However, the BIA measurements were only performed immediately post-exercise, preventing determination of the time course when BIA values returned to baseline.

Most manufacturers recommend avoiding aerobic exercise 12 h prior to conducting a BIA test to reduce error (14,20). Despite this being a common guideline, the 12 h time restriction provides limitation to both research settings and applied settings in terms of adherence. There are no studies that examine the time course of aerobic exercise on the recovery of BIA-derived BF% and TBW following aerobic exercise. It is useful to determine the exact time point that BIA values return to baseline following a brief bout of aerobic exercise. Identifying the specific time point that BIA values return to baseline after aerobic exercise would be helpful in practical settings where controlling consumer behavior (e.g., physical activity prior to testing) is most difficult. Therefore, the purpose of this study was to determine the time course of BIA-derived BF% and TBW values in the 1 h following a moderate bout (60% heart rate reserve [HRR]) of steady state aerobic exercise in apparently healthy men.

METHODS

Participants

Fifteen college-aged men volunteered to participate in this study (mean ± SD: age = 23.73 ± 3.7 years, height = 176.6 ± 6.8 cm, weight = 81.1 ± 10.3 kg; BMI = 25.9 ± 3.1). Prior to testing, participants were instructed to adhere to pretesting guidelines, which included avoidance of caffeinated drinks and food within 3 h of testing in addition to no exercise 12 h before (9-11). Participants reported to the exercise physiology laboratory for one visit. All participants completed a health-history questionnaire and provided written informed consent as approved by the host university's Institutional Review Board.

Protocol

Upon arrival, height was measured with a stadiometer (SECA 213, Seca Ltd., Hamburg, Germany). Urine specific gravity (USG) was then measured with a hand-held refractometer (Atago SUR-NE, Atago Corp Ltd., Tokyo, Japan) and required to be < 1.020 prior to BIA measurements in order to be considered adequately hydrated (5). Following USG measurements, pre-exercise nude body weight was measured on a digital weighing scale (Tanita BWB-800, Tanita Corporation, Tokyo, Japan). Afterwards, BIA-derived BF% and TBW measures were taken before the bout of aerobic exercise (PRE) in a thermoneutral environment (21.8 ± 1.4°C), which served as the baseline measurement for BIA-derived BF% and TBW. For each measurement, height, weight, resistance R, and reactance Xc were recorded. During testing, participants lay on a gurney on their backs, face up, with arms and legs at their side without having any contact with the the body. The right hand and right foot were then wiped with an alcohol pad and allowed time to dry. Once each surface dried, two electrodes were placed on the right hand and two electrodes on the right foot. After proper electrode placement, BIA-derived BF% and TBW measurements were collected by a single frequency (50kHz) hand-to-foot BIA device (Quantum IV, RJL systems, Clinton MI). Lastly, the BIA device utilized in the current study was previously validated against a 4-compartment model (18).

After completion of the PRE measures, participants completed a 30 min steady state bout of aerobic exercise on a treadmill (Q55XT, Quinton Instrument Co., Seattle, WA) at an intensity of 60% HRR while wearing a Polar heart rate monitor (T31, Polar, Kemplee, Finland). Predicted maximal heart rate (HRmax) was estimated using 220-age. Resting heart rate was measured following PRE BIA-derived BF% and TBW measures by the heart rate monitor with participants lying supine on a gurney for 3 min, which is a similar protocol as previous research (19). The lowest heart rate observed during that time frame was used as resting heart rate. During aerobic exercise, participants were required to maintain a heart rate within ± 5 beats per minute of the target heart rate range. Exercise intensity was controlled for each participant by adjusting the treadmill grade or speed throughout testing.

Immediately following aerobic exercise, participants' post-exercise nude body weight and USG were measured. After weighing, participants returned to the gurney, assumed the supine position, and had BIA-derived BF% and TBW taken immediately post-exercise and at 10 min intervals for 1 h post exercise. All BIA measurements were labeled as follows: PRE, immediately post-exercise (IP), 10 min post-exercise (10P), 20 min post-exercise (20P), 30 min post-exercise (30P), 40 min post-exercise (40P), 50 min post-exercise (50P), and 60 min post-exercise (60P). Participants remained in supine position for the entire time (i.e., IP to 60P) during post-exercise body composition values. Test-retest reliability for the BIA device used in our laboratory has consistently shown *ICC* > 0.90 in a similar population (17,19). Therefore, the changes in post-exercise body composition values are likely attributed to the bout of aerobic exercise and not the within-day reliability of the device.

Statistical Analysis

Data for all participants were analyzed with a software package (SPSS Statistics version 22.0 Chicago, IL). A series of one-way repeated measures were used to determine the differences in mean BIA-derived BF% and TBW (PRE vs. post-exercise measures). When necessary, *post hoc* analyses were completed using the Bonferonni technique. The effect size was determined using Cohen's d. For determining the magnitude of the effect size Hopkin's scale was utilized as follows: 0-0.2 = trivial, 0.2-0.6 = small, 0.6-1.2 = moderate, 1.2-2.0 = large, >2.0 = very large

(11). The constant error (CE) was determined as the differences between the PRE BIA measures (i.e., BF% and TBW) and each post-exercise BIA-derived BF% measure (i.e., CE = BIA-derived BF% PRE – BIA-derived BF% IP). The method of Bland-Altman was used to compare the 95% limits of agreement for each BIA-derived BF% and TBW post-exercise measure vs. BIA-derived BF% and TBW PRE (3).

RESULTS

The means, SD, Cohen's *D*, and 95% limits of agreement for the BIA-derived BF% measures are shown in Table 1. Compared to PRE values, BIA-derived BF% was significantly lower at IP, 10P, 20P, and 30P. Cohen's *d* procedure indicated a moderate effect size IP and small effect sizes for 10P, 20P, and 30P. BIA-derived BF% 40P, 50P and 60P were not significantly different from BIA-derived BF% PRE, with trivial effect sizes for each. The 95% limits of agreement were the largest for 50P (± 2.1%) and smallest IP (±1.5%).

Table 1. Comparison of BIA-derived BF% PRE and all post-exercise BIA measures (n = 15).

Time	(Mean ± SD)	p	Cohen's *d*	CE ± 1.96 SD	Upper	Lower
PRE	22.4 ± 3.6	---	---	---	---	---
IP	20.1 ± 3.5	<0.001	0.65	2.3 ± 1.5	3.8	0.8
10P	20.3 ± 3.4	<0.001	0.58	2.0 ± 1.7	3.7	0.3
20P	21.0 ± 3.6	<0.001	0.38	1.4 ± 1.7	3.1	-0.3
30P	21.4 ± 3.7	0.002	0.25	0.9 ± 1.8	2.7	-0.9
40P	22.1 ± 3.7	0.337	0.07	0.3 ± 2.1	2.4	-1.8
50P	22.3 ± 3.7	0.906	0.01	0.0 ± 2.1	2.1	-2.1
60P	22.5 ± 3.6	0.530	0.04	-0.2 ± 2.0	1.8	-2.2

BIA = bioelectrical impedance analysis; BF% = body fat percentage; CI = confidence interval; CE = constant error; IP = immediate post; 10P = 10 min post-exercise; 20P = 20 min post-exercise; 30P = 30 min post-exercise; 40P = 40 min post-exercise; 50P = 50 min post-exercise; 60P = 60 min post-exercise

Table 2. Comparison of BIA-derived TBW (kg) PRE and all post-exercise BIA measures (n = 15).

Time	(Mean ± SD)	p	Cohen's *d*	CE ± 1.96 SD	Upper	Lower
PRE	46.8 ± 6.6	---	---	---	---	---
IP	48.3 ± 6.7	<0.001	0.22	-1.5 ± 0.5	-1.0	-2.0
10P	48.1 ± 6.6	<0.001	0.20	-1.3 ± 0.6	-0.7	-1.9
20P	47.7 ± 6.7	<0.001	0.13	-0.9 ± 0.6	-0.3	-1.5
30P	47.4 ± 6.7	0.001	0.09	-0.6 ± 0.6	0.0	-1.2
40P	47.0 ± 6.7	0.287	0.02	-0.2 ± 0.7	0.5	-0.9
50P	46.8 ± 6.6	0.912	0.00	0.0 ± 0.7	0.7	-0.7
60P	46.8 ± 6.7	0.839	0.01	0.0 ± 0.6	0.6	-0.6

BIA = bioelectrical impedance analysis; TBW = total body water; CI = confidence interval; CE = constant error; IP = immediate post; 10P = 10 min post-exercise; 20P = 20 min post-exercise; 30P = 30 min post-exercise; 40P = 40 min post-exercise; 50P = 50 min post-exercise; 60P = 60 min post-exercise

The means, SD, Cohen's *D*, and 95% limits of agreement for the BIA-derived TBW measures are shown in Table 2. Mean BIA-derived TBW was significantly higher IP, 10P, 20P, and 30P, compared to PRE, but not significantly different at 40P, 50P, and 60P. The effect size was small at IP, but trivial for all other post-exercise BIA-derived TBW measures. The 95% limits of agreement were the largest for 50P (± 0.7 kg) and smallest at IP (±0.5 kg). Post-exercise body mass was significantly lower than PRE (0.4 kg; $p < 0.001$) despite similar PRE and post-exercise USG values (1.010 ± 0.005 vs. 1.010 0.004, respectively; $p = 0.873$).

DISCUSSION

The purpose of this study was to determine the time course of BIA-derived BF% and TBW values in the 1 h following a moderate bout (60% HRR) of steady state aerobic exercise in apparently healthy men. The results of this study revealed that IP, 10P, 20P, and 30P BIA-derived BF% and TBW were significantly different from PRE whereas 40P, 50P, and 60P were not significantly different from PRE. However, the time periods that produced significantly different BF% and TBW values (i.e., IP, 10P, 20P, and 30P) had smaller 95% limits of agreement than the time periods that produced non-significant mean values (i.e., 40P, 50P, and 60P). Although there were significant mean differences IP, 10P, 20P, and 30P, the systematic error can be adjusted during these time periods (e.g., increase BIA-derived BF% IP by 2.3%) in order to estimate BF% and TBW values that are similar to baseline measurements. However, the group mean BIA-derived BF% and TBW values returned to baseline at 40P following an acute bout of moderate aerobic exercise. Therefore, practitioners that evaluate body composition via BIA after aerobic exercise should consider findings of the current study and wait until 40P if avoiding aerobic exercise on a treadmill 12 h prior to testing cannot be adhered. Lastly, practitioners should use caution when administering BIA after exercise modalities (e.g., cycling) and populations (resistance trained, aerobically trained, etc.) that differ from that of the current study until further research is conducted.

Post-Exercise Values: Previous studies have evaluated the effects of aerobic exercise on BIA-derived BF% and TBW (2,6,7,13). Similar to the current study, Dixon et al. (7) reported a decrease in BF% of 1.2 and 1.7%, when using leg-to-leg and segmental BIA, respectively, IP exercise. The decrease in BIA-derived BF% immediately after aerobic exercise was associated with a significant over-estimation of BIA-derived TBW (7), similar to findings of the current study. Other studies using varying BIA devices such as segmental, leg-to-leg, arm-to-arm, and hand-to-foot BIA also observed similar post-exercise BF% responses (e.g., lower IP BIA-derived BF% values than PRE) (2,6). The current study supports the previous studies showing that BIA-derived BF% is altered following a 30 min bout of aerobic exercise.

As previously mentioned, most research has compared BIA-derived BF% and TBW values at PRE and IP whereas limited information was available on values obtained after this time point. In a study by Liang & Norris (13), investigators reported BIA mean values were not significantly different at PRE and 1 h post-exercise. However, the exact time point that BIA returned to baseline was unknown, which is one of the novel findings of the current study. Furthermore, BIA has advanced in recent years since the previous findings of Liang and Norris (13) and the magnitude of the effect of aerobic exercise on more sophisticated bioimpedance technology was unknown.

Influencing Factors of BIA: There are several factors that influence BIA. Hydration status is an important factor due to sensitivities in estimated TBW. As such, deviations from a euhydration state directly alter BIA-derived BF% measurements (8). Sweat loss experienced during exercise results in decreased TBW causing an artificial increase in estimated TBW (7) due to the disproportional loss of water relative to electrolytes (i.e., an increased fluid electrolyte concentration) (10). Furthermore, increases in TBW via BIA have been found in athletes completing ultra-endurance events compared to baseline even though the participants were in a more dehydrated state with a decreased body mass during the post measurements (10,12).

Other potential mechanisms for the difference in BIA-derived BF% and TBW following a bout of aerobic exercise could be due to the redistribution of blood flow from the circulation to working tissue (i.e., plasma volume shifts). Resting skeletal muscles receive approximately 20% of blood flow, but during aerobic exercise, blood flow to active skeletal muscles increases almost 25 times in accordance with the metabolic demand (21). Additionally, body temperature increases during aerobic exercise as a result of increased metabolism. Increases in skin and core body temperature have shown to reduce impedance (9,15). Consequently, blood flow to the skin is also increased in order to cool core body temperature (4), which can have an impact on BIA-derived values.

In the current study, there was a significant reduction in body weight of 0.4 kg following the bout of aerobic exercise indicating a high degree of sweating (4). Because the BIA is dependent upon a consistent fluid equilibrium, acute fluctuations in the fluid compartments may influence the measurement. Therefore, it seems plausible that a change in blood flow from rest to exercise to accommodate the increased metabolic demand of active skeletal muscle and the rise in core temperature could be a contributing factor to the differences seen in BIA-derived BF% and TBW PRE and post-exercise.

Limitations: One limitation of the current study is that there was not a control testing session. However, as previously mentioned, the BIA device evaluated in the current study has consistently produced ICC > 0.90 for BF% and TBW (17,19). Therefore, the changes in BF% and TBW after aerobic exercise is likely attributed to the bout of exercise and is less likely due to the within-day reliability of the device. In addition, the HR_{max} value used to calculate HRR was predicted instead of being measured during a graded exercise test or from other previous age-prediction equations, which might be more accurate (22). As a result, some of the participants could have been exercising at an intensity that did not reflect a moderate-intensity bout of aerobic exercise. However, the novel findings provide a solid foundation for future research, which should examine the amount of time that BIA-derived BF% and TBW reaches baseline values following acute bouts of aerobic exercise at different intensities in addition to the 95% limits of agreement during the different time periods.

In conclusion, the current study examined the changes in BIA-derived BF% and TBW before and after a moderate bout of aerobic exercise. Although bioimpedance directions recommend avoiding aerobic exercise 12 h prior to testing, this guideline appears to be arbitrary. The current study has implications for fitness enthusiasts who have high-end training regiments and busy schedules that make it difficult for adhering to common bioimpedance pretesting guidelines.

Findings of the current study indicate that BIA-derived BF% and TBW return to baseline approximately 40 min after a moderate bout of aerobic exercise. However, the 95% limits of agreement were smallest during time periods (i.e., IP, 10P, 20P, and 30P) that produced significantly different post-exercise mean values. Therefore, BIA-derived BF% and TBW values can be determined at 40P, 50P and 60P. However, if BIA is used after aerobic exercise, but prior to 40P, practitioners should consider adjusting for the systematic error (e.g., increase BIA-derived BF% IP by 2.3%).

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