Pediatric Exercise Science, 2003, 15, 216-222

Does Exercise Testing Affect the Bioelectrical Impedance Assessment of Body Composition in Children?

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This investigation examined the impact of a cycle ergometry exercise test (CET) on body composition determined using leg-to-leg bioelectrical impedance analysis (BIA; Tanita Model TPF-305). Fifty three children (25 males, 28 females) aged 10–12 yr participated. BIA measures of body fat (BF) were obtained immediately before and within five min of a multistage CET administered to assess peak oxygen consumption. Correlations ($P = 0.01$) of 0.99 were noted between the pre and post CET measures of BF. A systematic difference was not found in BIA measures obtained before and after CET. BF decreased by 0.4 and 1.2% following CET in the male and female subjects, respectively.

Bioelectrical impedance analysis (BIA) is frequently used in health-fitness, athletic, physical education and research settings to assess body composition (3,4,9,10). This technique recognizes lean and fat free tissue act differently as electrical conductors. Specifically, fat with comparatively low water and electrolyte content resists the transmission of an electrical current while the opposite holds true for lean tissue. Equations that utilize resistance/reactance to electrical current to predict body fat (i.e. BIA) have been developed for use with children, adults and athletes (4). Bioelectrical impedance analysis takes very little time, is easy to administer, requires no specialized training, is non-invasive, portable and non-threatening. These factors make BIA an attractive instrument to assess body composition (4,7). However, a potential limitation to the use of BIA is that previous exercise may affect the subsequent determination of body composition. The increase in body temperature (2) and skin blood flow and/or altered distribution of body water secondary to exercise may influence resistance and reactance and therefore the calculation of percent body fat (4,7). Lukaski et al. (7) reported that resistance and reactance were greater and percent fat lower when pre-exercise behaviors were not strictly controlled in male and female college athletes. In contrast, Liang and Norris (5) reported that 30 min of moderately (83% HRmax) intense treadmill exercise did not affect body composition measured with BIA in men

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whose average age was 28.4 ± 7.5 yr. Despite the lack of consensus regarding the impact of previous exercise on BIA measures of body composition most investigations that employ BIA technology require subjects to abstain from exercise for at least 12 hr before assessing body composition. In addition, manufacturers of BIA instruments typically specify that measurements should be conducted following 12 hr of inactivity. Such a restriction limits the practical utility of BIA and failure to adhere to these procedures may result in significant measurement errors.

However, the impact of previous exercise on the BIA measurement of body composition has not been evaluated in children. Therefore, the present investigation was undertaken to examine the impact of standard cycle ergometer exercise testing on BIA determined body composition. This has important implications for the use of BIA in health-fitness or physical education settings where the control over pre-test exercise behaviors in children is problematic. It is anticipated that the results of this investigation may influence when and how BIA is used in clinical or research settings involving children.

Methods

Subjects for this investigation were volunteers who were recruited with parental consent. A total of 53 children (28 females; 25 males) ranging in age from 10–12 yrs. participated. Subject characteristics are presented in Table 1. Bioelectrical impedance measures of percent body fat were obtained immediately before and within five min following a progressive multistage cycle ergometer test administered to assess VO_{2peak}.

Oxygen uptake was measured using standard open circuit spirometry. The initial power output was set at 25 W and increased by 25 W every 2 min. The exercise test was terminated when subjects were unable to maintain a pedal rate of 50 rev $\cdot$ min^{-1} for 15 consecutive seconds . Total exercise time (mean ± SD) was 9.21 ± 2.3 min.

Prior to the BIA assessment of body composition subjects removed their shoes and socks. Next, height was assessed using a Detecto physician's scale. Subject height in cm was then entered in the BIA system (Tanita Model #TBF-305) and the appropriate gender option was selected. The "child" mode was used for all

Table 1 Subject characteristics

	Age (yr)	Height (cm)	Weight (kg)	VO_{2peak} (ml/kg/min)
Female	10.9	149.0	48.8	30.5
$N = 28$	±0.8	±9.6	±2.5	±2.8
Male	11.5	148.8	49.9	35.7
$N = 25$	±0.7	±8.1	±2.2	±3.0

Note. Values are mean ± standard deviation.

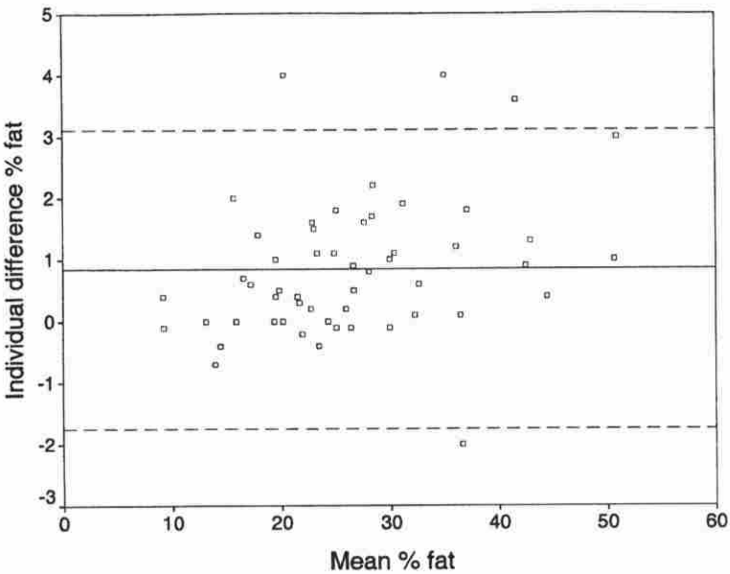

Figure 1 — Altman-Bland plot of the difference in percent fat determined before and after a cycle ergometer test versus the average percent fat determined by the two measures. The solid line represents the mean difference and the dashed lines represent two standard deviations.

BIA measures. This BIA system provides measures of body weight, percent fat and impedance. Subjects, wearing t-shirts and shorts, were asked to stand upright with their legs straight and feet parallel. The heel and forefoot were placed on the metal electrode plates of the BIA system. Next a subthreshold electrical current was transmitted through the body from leg to leg. Prior to the BIA measurements the soles of the subjects' feet were cleaned with alcohol and dried with a standard bath towel. Percent fat was calculated using equations provided by the manufacturer. Room temperature was maintained at 72 °F for all exercise tests and BIA measurements. All of the tests were administered between 1100 and 1400 hr.

Two factor ANOVAs with the main effects of time (i.e., pre and post) and gender were used to examine the BIA body composition data. All analysis were performed using SPSS Windows 2001 Statistical package. The level of significance was established *a priori* at 0.05. Pearson product moment correlations were performed on the pre- and post-exercise BIA per cent body fat values for the entire subject pool. In addition, separate gender specific correlations were also conducted on these data. In order to explore any systematic differences in body composition between the pre and post-test measures the difference in pre and post percent fat was plotted against the average percent fat (Figure 1). Correlations were also performed on the differences between pre and post test measures and the average percent fat.

Table 2 Body Composition Determined by BIA Before and After a Progressive Cycle Ergometer Test

Variable	Male ($N = 25$)		Female ($N = 28$)	
	Pre	Post	Pre	Post
% fat	24.3[1] ± 9.9	23.9 ± 9.7	29.7[1] ± 8.5	28.5 ± 8.1
Resistance (Ohms)	540.0 ± 63.1	530.2 ± 56.7	562.7 ± 134.7	552.4 ± 86.2
Body Weight (kg)	49.9 ± 2.2	50.0 ± 2.3	48.8 ± 2.5	48.8 ± 2.5

Note. Values are means ± standard deviation. [1]significant ($p > 0.05$)

Results

The means ± SD for the BIA body composition data are presented as a function of gender and time in Table 2. The female subjects had a greater ($p > 0.05$) percentage body fat 29.7 ± 8.5% vs 24.3 ± 9.9% than the males prior to the administration of the exercise test. The ANOVA revealed a significant gender by time interaction for percent fat ($F = 5.596$, $p = 0.022$). The female subjects had a comparatively greater decrease in percent fat (1.2% fat) than the male (0.5% fat) subjects following the exercise test. No other significant main effects or interactions were noted. Significant correlations between the pre and post-test responses were observed for the total groups ($r = 0.99$; $p = 0.01$) and female ($r = 0.99$; $p = 0.01$) and male ($r = 0.99$; $p = 0.01$) cohorts. In Figure 1, the difference in percent fat obtained before and after the cycle ergometer test is plotted versus the mean percent fat determined from the two time periods. The solid line represents the mean difference between the two time periods and the dashed lines correspond to two standard deviations. The Altman-Bland distribution does not indicate a systematic difference between the two measurement periods. A correlation of $r = 0.31$ ($p = 0.22$) was observed between the difference in pre and post exercise BIA percent fat and mean percent fat.

Discussion

When using BIA to assess body composition in adults a commonly accepted procedural guideline is that subjects should refrain from exercise for at least 12 hr prior to the measurement. However, it is unknown whether exercise testing undertaken prior to the BIA assessment of body composition influences the outcome variables in children. Therefore, this investigation was undertaken to examine the impact of a progressive cycle ergometer exercise test on body composition measured using a leg-to-leg BIA system.

Percent body fat decreased by 1.2 and 0.4% following exercise in the female and male children, respectively. Within day variability of a similar leg-to-leg BIA system has been shown to range from 0.4 to 1.5% (mean = 0.9 ± 0.5%) in healthy adults aged 18–79 years, under conditions in which pre- measurement behaviors were controlled (8). In addition the magnitude of change in percent fat noted presently was similar to that reported in male subjects (mean age = 28.3 yr) who exercised on a treadmill for 30 min at an intensity equal to 83% of age predicted maximal heart rate. This was accompanied by a reduction in body weight of 1.1 kg. In the present investigation, given the thermoneutral environment coupled with the relatively short exercise bouts (9.21 ± 2.3 min) it is unlikely that there would be a change in body weight due to sweat loss. In fact, body weight was unaffected by the cycle ergometer test. As such, the difference between pre- and post-exercise BIA body composition in the present investigation may be due to altered body fluid distribution, increases in skin temperature, some other unmeasured variable or simply the result of within day instrument variability.

Liang and Norris (5) used exercise as a forcing function to alter skin temperature and body water distribution (i.e. increased skin blood flow with a concomitant reduction in central blood volume) in an attempt to manipulate the BIA assessment of body composition. BIA measures in this investigation were obtained using a four terminal impedance system in which electrodes were placed on the contralateral and ipsilateral sides of the body. Measures were obtained with subjects in a supine position. Both mean skin temperature and subcutaneous blood flow were significantly increased secondary to walking or running at 147–188 m · min^{-1}; 2–5% grade for 30 min. However, the percent fat values obtained by BIA were not changed. These findings failed to support the hypothesis that metabolic and hemodynamic responses to exercise influence BIA measures of body composition.

Lukaski et al. (6) also employed a four terminal impedance system in a study of 104 female and male college athletes. The authors report that the failure to control pre-test behaviors (i.e., eating and exercise) or hydration status resulted in significant errors in the BIA determined body composition. The mean percent fat for the combined female and male subject pool was higher (X ± SEM; 16.7 ± 0.5%) in the measurement condition in which the pre-test behaviors relative to eating, fluid intake and activity/exercise were strictly enforced when compared with the "ad libidum" or uncontrolled (X ± SEM; 13.2 ± 0.4%) condition. In addition body mass was 2.3 kg lower in the uncontrolled condition owing perhaps to sweat loss following participation in intercollegiate practices and/or other vigorous exercise. This is a somewhat larger decrease in body mass than was reported by Liang and Norris (1.0 kg) and in the present investigation (5). Alterations in total body water resulting from exercise may play an important role in explaining the impact of previous exercise on BIA fat measurement. The failure of a 1.0 kg decrease in body weight to affect BIA measures of body composition (4) coupled with the significant impact on BIA determined percent fat of a 2.3 kg decrease in body weight (6) it follows that a dose response relation may exist between fluid loss and body composition measured with BIA.

Practical Applications

A standard progressive cycle ergometer test administered to determine VO_2peak resulted in a comparatively greater decrease in BIA percent fat in females than males. The small reduction in percent fat in the female (1.2%) and male (0.4%) cohorts as a result of cycle ergometer exercise testing is consistent with the prevailing theory on exercise and electrical impedance. The increase in skin temperature and the change in body water distribution in response to acute exercise may alter bioelectrical conductivity resulting in a decrease in the BIA determined percent fat. However, the changes in percent fat noted presently are similar to the day to day variability of the BIA system (8). As such these differences may have limited practical significance. When using BIA in a health-fitness setting to characterize cardiovascular risk associated with body fatness in children, failure to control activities/exercise behaviors in the period of time immediately preceding the measurement may not be critical. However, it is unknown whether exercise of longer duration or greater volume than examined presently, will influence BIA measures in children. Additionally, it should be noted that the change in percent fat from pre- to post-exercise ranged from 0.1 to 4.0% and 0.2 to 3.0% in the female and male groups, respectively. When BIA is used in a prescriptive context to make individual recommendations relative to weight management or to track the efficacy of behavioral interventions this degree of error may not be acceptable. In research or clinical settings, where precision is critical, care must be taken to insure consistency in the experimental paradigm with respect to the timing of the BIA measurements relative to exercise testing. As such obtaining BIA measurements prior to cycle ergometer testing in children may be an appropriate strategy.

In the present investigation a moderate quantity of exercise resulted in a small decrease in BIA percent fat. Future research should investigate whether a dose response relation exists between the volume of exercise and the change in BIA measures in pediatric populations. Similarly, the relation between sweat loss and BIA percent fat measures should be explored. Additional potential areas of research dealing with children, BIA and exercise could include different exercise modalities (i.e., resistance exercise, aerobic dance, etc.) the time necessary to return to homeostasis following exercise or exercise testing and the impact of skin temperature, body temperature and body fluid distribution on BIA measures. In addition most previous research has employed total body BIA systems obtained from different manufacturers and subjects were assessed while in a supine position. The current study used a leg-to-leg BIA instrument and the subjects were standing upright during the measurement period. The length of the conduction circuit and/or body position may affect the relation between BIA measures of body composition and previous exercise (4). Therefore, it is unknown whether other types of BIA systems (i.e., arm-to-arm, four terminal) would result in similar findings with respect to exercise testing and percent fat. In addition, the relative contribution of impedance in the calculation of percent fat may differ between prediction equations. Therefore exercise may have a variable impact on BIA determined fat and lean tissue that is contingent upon the specific system that is employed. These may be other relevant avenues of pediatric body composition research.

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