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Research article

EFFECT OF INTERMITTENT SUB-MAXIMAL EXERCISE ON PERCENT BODY FAT USING LEG-TO-LEG BIOELECTRICAL IMPEDANCE ANALYSIS IN CHILDREN

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ABSTRACT
The purpose of this investigation was to determine the effect of intermittent sub-maximal exercise on percent body fat (%BF) estimated by leg-to-leg bioelectrical impedance analysis (LBIA) in children. Fifty-nine children (29 girls; 30 boys) mean age 9.0 ± 1.3 years participated in this study. LBIA measured %BF values were obtained immediately before and within five minutes after completing an intermittent exercise protocol consisting of three 8-minute sub-maximal exercise bouts (2.74 $km \cdot hr^{-1}$, 0% grade; 4.03 $km \cdot hr^{-1}$, 0% grade; and 5.47 $km \cdot hr^{-1}$, 0% grade) each separated by a 5-min seated rest period. The three exercise bouts corresponded to 56%, 61% and 71% of maximal heart rate. Significant differences ($p < 0.001$) were observed for fat mass, fat free mass, total body water, and body weight, post-exercise in both groups. Significant reductions ($p < 0.001$) in %BF were observed post-exercise in the female (23.1 ± 9.9 *vs.* 21.8 ± 9.9 %) and male (23.3 ± 10.5 *vs.* 21.8 ± 10.2 %) children when compared to pre-exercise values. However, for the majority of the subjects (females = 86%; males = 73%) the decrease in %BF post-exercise was less than 2.0 %BF. These data indicate that sub-maximal intermittent exercise, that may be representative of daily free-form activities in children, will most likely have a limited impact on %BF estimates when the assessment is performed immediately post-exercise.

KEY WORDS: Bioelectrical impedance analysis, body fat, sub-maximal exercise, children.

INTRODUCTION

Leg-to-leg bioelectrical impedance analysis (LBIA) is a fast, easy to administer, and relatively inexpensive method of evaluating body composition. The LBIA method introduces a low level electrical current into the body and measures the lower-body impedance, or resistance to the current flow as the individual stands on a scale-like platform (Nunez et al., 1997). Fat-free mass, due to its fluid and electrolyte content, is an excellent conductor of electrical current (i.e., low impedance), while adipose tissue which contains little water is a poor conductor (i.e., high impedance). From impedance, fat-free mass and percent body fat (%BF) can be estimated using equations developed for adults and children (Heyward and Wagner, 2004). The LBIA method differs considerably from the traditional bioelectrical impedance analysis (TBIA) method, which measures whole-body impedance (arm-to-leg) and requires the specific anatomical placement of gel electrodes. Due to the ease of operation, interest in using LBIA to estimate %BF has grown, especially in settings where body composition assessments are often performed without the benefit of properly-trained personnel (e.g. school districts).

To increase the accuracy of the measurement, it is recommended that clients adhere to a series of pre-testing guidelines which are designed to control for fluctuations in hydration status. Previous research examining TBIA (arm-to-leg) has demonstrated that the increased blood flow to skeletal muscle and skin, and sweating during aerobic exercise can influence impedance measurements (Kushner et al., 1996). As such, it is currently recommended that no exercise be performed within 12 hours of the test (Heyward and Wagner, 2004). However, little evidence exists examining the effect that aerobic exercise has on the relatively new LBIA technology. If necessary, stringent pre-testing guidelines may significantly limit the practicality of utilizing LBIA as a body composition assessment method in children.

Research examining the effect of exercise on estimated %BF using LBIA in children is limited. Goss et al. (2003) examined the effect of progressive cycle ergometry exercise to VO_{2peak} in male and female children (age; 10.9 ± 0.8, 11.5 ± 0.7 years, respectively) using a common LBIA analyzer (Tanita: Model TBF-305). Relatively small decreases in %BF (≤1.2%) were observed post-exercise (Goss et al., 2003). The authors noted that the changes in %BF post-exercise were similar to the day-to-day variability of the LBIA system (Goss et al., 2003). Recently, Andreacci et al. (2006) examined the effect of maximal treadmill exercise on LBIA (Tanita: Model TBF-300A) %BF in male and female children (age; 9.1 ± 1.0 years). Comparable to Goss et al. (2003) similar reductions in %BF were observed in both groups (mean difference: females = 1.6%, males = 1.5%). Collectively, the %BF reductions observed following maximal/peak exercise tests were relatively small and may have little practical significance in the assessment of %BF in children (Andreacci et al., 2006; Goss et al., 2003). However, children tend to demonstrate daily physical activity patterns that consist of multiple intermittent bouts of sub-maximal effort rather than a single maximal effort (Robertson et al., 2001; Sleap and Tolfrey 2001; Sleap and Warburton, 1996). To our knowledge, the effect of intermittent sub-maximal exercise on %BF estimates determined by LBIA has yet to be explored in children. As such, the purpose of this investigation was to determine the effect of intermittent sub-maximal exercise on %BF estimated by LBIA in children.

METHODS

Participants

Twenty-nine girls (age: 9.2 ± 1.3 yr; height: 1.35 ± 0.09 m; body mass: 35.3 ± 9.7 kg) and thirty boys (age: 8.8 ± 1.3 yr; height: 1.33 ± 0.09 m; body mass: 34.6 ± 10.7 kg) participated in this investigation. Ten (34.5%) girls and 13 boys (43.5%) were considered overweight/obese [i.e. BMI ≥ the 85th percentile for age and gender]. Prior to participation, parents' informed written consent and subjects' written assent were obtained according to the requirements established by the Bloomsburg University Institutional Review Board.

Experimental design

All participants made two visits to the laboratory on separate days. The first visit consisted of an orientation, which included parental consent/assent to participate, the collection of anthropometric measurements, and familiarization with the respiratory metabolic mouthpiece and treadmill. During the second visit subjects exercised on a treadmill at three different sub-maximal workloads.

Testing procedures

During the experimental exercise session, each subject performed 3 separate 8-minute bouts of treadmill walking. All subjects completed the exercise workloads in the following order: *1)* 2.74 $km \cdot hr^{-1}$, 0% grade; *2)* 4.03 $km \cdot hr^{-1}$, 0% grade; and *3)* 5.47 $km \cdot hr^{-1}$, 0% grade. Each 8-minute, sub-maximal exercise workload was followed by a 5-minute seated rest period to aid in recovery. Heart rate was measured continuously throughout the exercise test using a Polar HR Monitor (Polar Electro, Inc., Woodbury, NY). Subjects were not permitted to consume any fluids during the exercise test.

Body composition was assessed using a leg-to-leg bioelectrical impedance analyzer (LBIA; Tanita Model #TBF-300A). LBIA measures of %BF were obtained immediately before and within five minutes following the sub-maximal exercise test. Prior to the LBIA assessment of body composition, subjects removed their shoes and socks so that height could be determined using a Detecto physician's scale. Subjects' gender and height (cm) were entered into the LBIA system. The 'standard' mode was used for all LBIA measurements, as recommended by the manufacturer. The LBIA system provided measures of body weight, %BF, impedance, fat mass, fat free mass and total body water. Subjects' stood erect with bare feet placed properly on the contact electrodes while wearing a t-shirt and shorts. Leg-to-leg impedance of the lower extremities and body weight were measured simultaneously while the subject stood on the scale. The %BF was then

Table 1. Body composition determined by LBIA before and after sub-maximal exercise. Data are means (±SD).

	Female (n = 29)		Male (*n* = 30)	
	Pre	**Post**	**Pre**	**Post**
% Body Fat	23.2 (9.9)	21.8 (9.9) ***	23.3 (10.5)	21.8 (10.2) ***
Impedance (Ω)	617.3 (61.7)	598.9 (58.1) ***	590.6 (55.8)	569.8 (52.4) ***
Body Mass (kg)	35.3 (9.7)	35.2 (9.7) ***	34.6 (10.7)	34.5 (10.6) *
Fat Mass (kg)	8.9 (5.8)	8.5 (5.7) ***	8.9 (7.1)	8.4 (6.9) ***
Fat Free Mass (kg)	26.3 (4.7)	26.7 (4.7) ***	26.6 (5.0)	26.1 (5.1) ***
Total Body Water (kg)	19.3 (3.4)	19.6 (3.5) ***	18.8 (3.7)	19.1 (3.8) ***

* and *** denote $p < 0.05$ and 0.001 respectively as compared with pre-test.

automatically calculated using the analyzer's pre-programmed prediction equations provided by the manufacturer. Laboratory temperature was maintained at a constant 23.5 °C for all tests and LBIA measurements. Testing was administered at the same time of day for all subjects.

Statistical analysis

Statistical analyses were performed using SPSS 11.0 for Windows (SPSS Inc, Chicago, IL). All values are expressed as mean ± standard deviation (*SD*). Statistical significance was established *a priori* at $p < 0.05$. Paired sample t-tests (i.e. pre- and post) were used to examine the LBIA body composition data in both groups. Pearson correlation coefficients were computed between the pre- and post-exercise LBIA %BF values for the entire subject sample. In addition, separate gender specific correlations were also computed on these data. Bland-Altman plots (Bland and Altman, 1986) were used to assess individual differences in impedance and %BF from pre- to post-exercise.

RESULTS

The LBIA body composition data are presented as a function of gender and time in Table 1. Significant differences were observed for %BF, impedance, body weight, fat mass, fat free mass and total body water when compared to pre-exercise values in both groups. Significant correlations were also observed between pre- and post-exercise %BF for the total sample ($r = 0.996$, $p = 0.0001$), and female ($r = 0.997$, $p = 0.0001$) and male ($r = 0.995$, $p = 0.0001$) subjects. Bland-Altman plots (Bland and Altman, 1986) exploring for systematic differences in impedance and %BF for the male and female children are depicted in Figure 1 and Figure 2, respectively. In the figures, the difference in impedance (Figure 1) and %BF (Figure 2) from pre- to post-exercise is plotted against body mass. The solid line represents the mean difference and the dashed lines correspond to ± 2 *SD*. No apparent systematic differences were found for impedance or %BF in the female and male children post exercise.

DISCUSSION

In order to increase the accuracy of LBIA measurement it is recommended that individuals perform no exercise within 12 hours of the assessment to control for fluctuations in hydration status (Heyward and Wagner, 2004). Little evidence exists regarding the effect that pre-assessment exercise has on body composition measurements using the relatively new LBIA analyzers. Previous research has reported small reductions in LBIA measurements of impedance and %BF following maximal exercise in children (Andreacci et al., 2006; Goss et al., 2003). However, a single bout of maximal exercise is not a regular component of a child's daily physical activity pattern. Instead, multiple bouts of intermittent sub-maximal effort are more the norm in children (Robertson et al., 2001; Sleap and Tolfrey 2001; Sleap and Warburton, 1996). This study examined the impact of intermittent sub-maximal treadmill exercise on %BF estimated using a commercially available LBIA system.

The primary finding of this investigation was that intermittent sub-maximal treadmill exercise had a minimal effect on mean %BF determined by LBIA in female and male children. This finding is consistent with previous research that examined the effect of maximal treadmill and cycle exercise on %BF estimated by LBIA in children (Andreacci et al., 2006; Goss et al., 2003). Goss et al. (2003) reported small mean reductions in both impedance (~11Ω and ~10Ω) and %BF (1.2% and 0.4%) following load incremental cycle exercise in female and male children, respectively. Similarly, Andreacci et al. (2006) reported reductions in both impedance (~26Ω and ~26Ω) and %BF (1.6% and 1.5%) following incremental treadmill exercise. The authors suggested that the slightly larger reductions in impedance and %BF following treadmill exercise

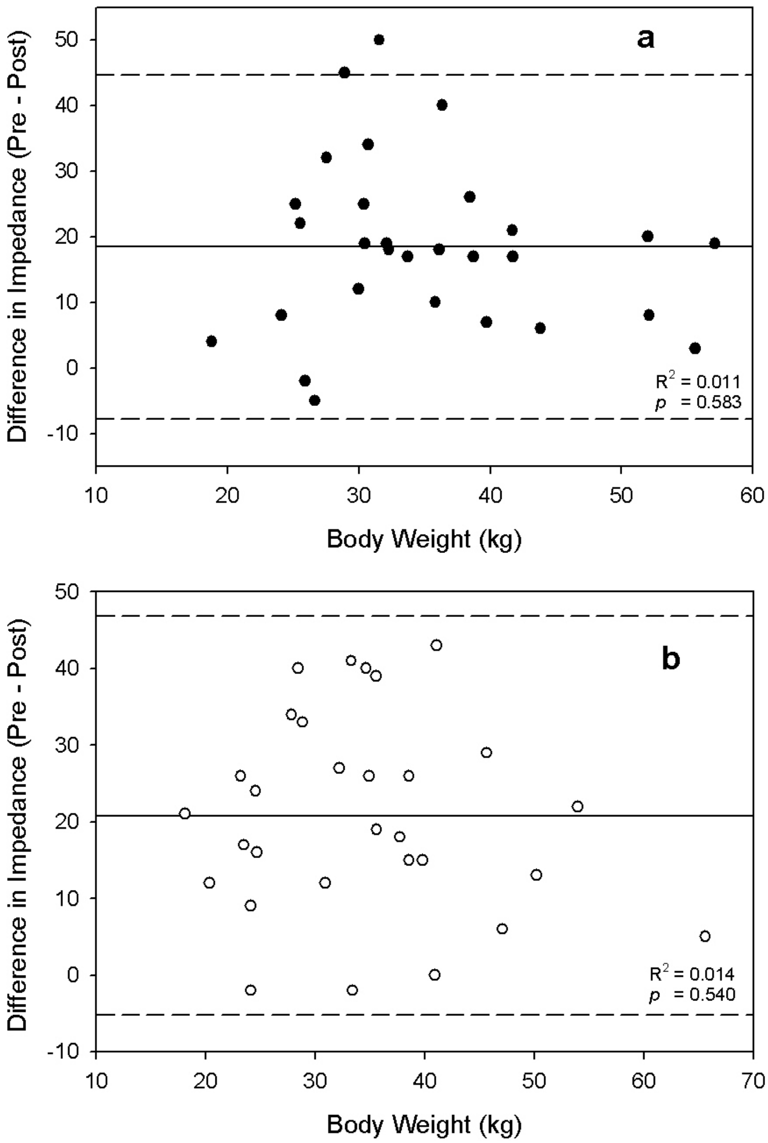

Figure 1. Scatter plots exploring individual differences in impedance following intermittent sub-maximal treadmill exercise. The difference between pre- and post-exercise impedance is plotted against body weight for the female (●; **a**) and male (○; **b**) children. Values greater than zero indicate a decrease from pre- to post-exercise. The mean difference is represented by the solid line, and the dashed lines represent ± 2 *SD* from the mean.

may have been due to the increased blood flow to active upper and lower body muscle tissue when compared to cycle exercise which involves primarily the lower body (Andreacci et al., 2006).

The design of the current intermittent sub-maximal protocol reduced the intensity but increased the duration of exercise (24 min) over the relatively short maximal treadmill (8.34 ± 1.2 min) and peak cycle (9.21 ± 2.3 min) exercise bouts performed in the previous investigations (Andreacci et al., 2006; Goss et al., 2003). The present reductions in impedance (~18.4Ω and ~20.8Ω) and %BF (1.4% and 1.5%) compare favorably to previous findings on maximal exercise in children (Andreacci et al., 2006; Goss et al., 2003).

Nunez et al. (1997) evaluated within and between-day coefficient of variations (CVs) for impedance using a similar leg-to-leg BIA analyzer in healthy adults aged 18-79 years. The CVs for within-day impedance measurements ranged from 0.4 to 1.5% (mean = 0.9 ± 0.5%) and the between-day CVs ranged from 1.0 to 3.6% (mean = 2.1 ± 1.0%). Similarly, Dixon et al. (2006), using the same LBIA analyzer as the present investigation, reported between-day CVs for impedance ranging from 0.1 to 5.8% (mean = 2.2 ± 1.7%) in 21 recreationally active men (mean age 19.7 ± 1.0 yrs). As such, the difference between pre- and post-exercise body composition measurements in the present investigation may be due to exercise-induced

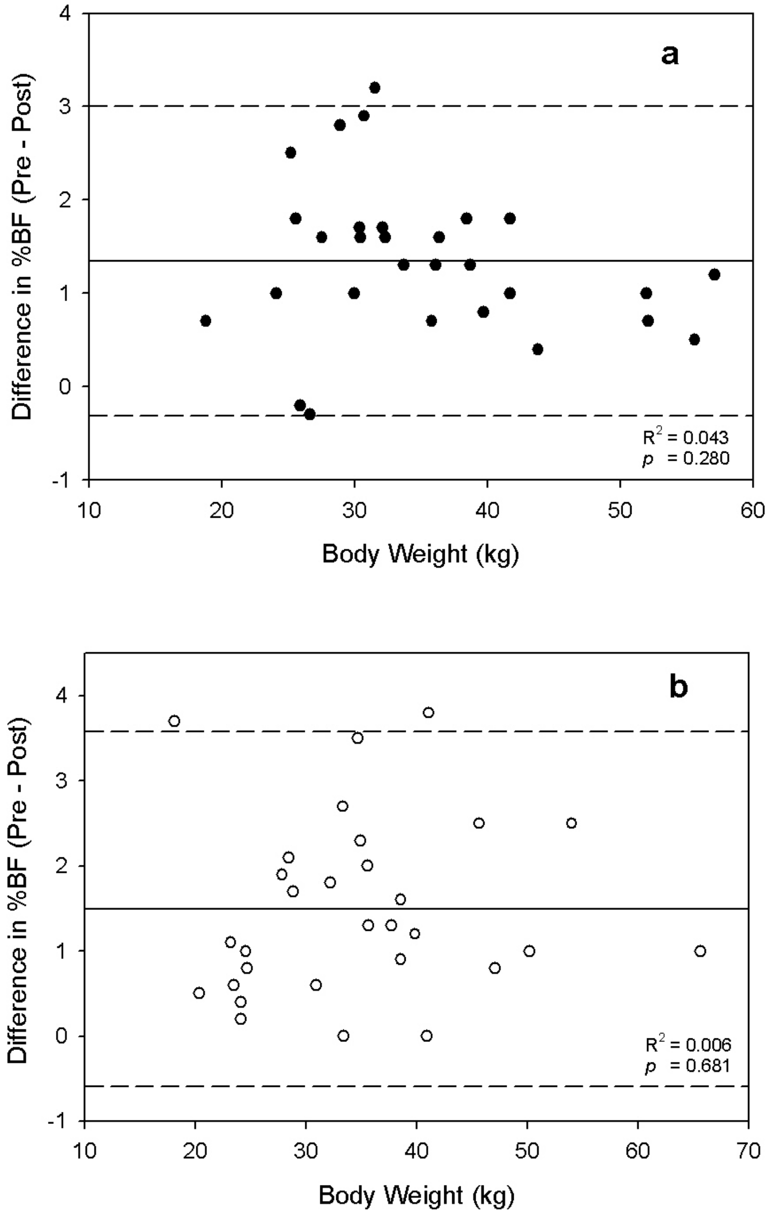

Figure 2. Scatter plots exploring individual differences in %BF following intermittent sub-maximal treadmill exercise. The difference between pre- and post-exercise %BF is plotted against body weight for the female (●; **a**) and male (○; **b**) children. Values greater than zero indicate a decrease from pre- to post-exercise. The mean difference is represented by the solid line, and the dashed lines represent ± 2 *SD* from the mean.

alterations in body fluid distribution, body weight, or the result of within day instrument variability.

As demonstrated in the Bland-Altman plots, no systematic differences were observed for impedance or %BF after exercise. It is apparent from examining the individual data points that intermittent sub-maximal exercise did reduce LBIA impedance and %BF estimates from pre-testing values for a large percentage of the sample. However for the majority of the subjects (females = 86%; males = 73%), the decrease in %BF post-exercise was less than 2.0 %BF (Figure 2). Sub-maximal exercise of a longer duration may cause larger reductions in impedance and %BF estimates post-exercise. Future investigations should explore the possible relationship between exercise duration and LBIA body composition measurements in children and in other age groups.

In the present investigation, the LBIA post-exercise assessments were conducted immediately following the exercise bout and therefore our findings cannot be generalized to any exercise that precedes the assessment by a longer duration (e.g. 1 hr, 3 hr, etc.). Nonetheless, the greatest changes in LBIA body composition variables 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 (Kushner et al. 1996). The examination of exercise that precedes LBIA assessment by longer durations is warranted to further clarify whether the pre-testing recommendation of no exercise 12 hours before testing is necessary.

CONCLUSIONS

In summary, the children exercised at three different intensities (2.74, 4.03, and 5.47 km·hr^{-1} at 0% grade) for a duration of 8 minutes each. This corresponded to 56%, 61% and 71% of their age predicted maximal heart rate. We feel that the current exercise protocol is more representative of the activity patterns of children than maximal/peak exercise tests. These data indicate that intermittent sub-maximal exercise, that may be more representative of daily free-form activities in children, will most likely have a limited impact on mean LBIA %BF estimates (≤ 1.5%BF) when the test is conducted immediately following exercise. However, where precision is critical, consistency in testing procedures such as conducting LBIA assessments prior to exercise is recommended for controlling possible exercise-induuced alterations in body composition measurements.

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KEY POINTS

- LBIA measures of body weight, percent body fat, fat mass, fat free mass and total body water were significantly lower after the intermittent sub-maximal exercise.
- The reductions in percent body fat for girls (1.4%) and boys (1.5%) compare favorably to previous investigations.
- Intermittent exercise, that may be representative of daily free-form activities in children, will most likely have a limited impact on LBIA percent body fat estimates.

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