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Original Research

Foot-to-foot bioelectrical impedance accurately tracks direction of adiposity change in overweight and obese 7- to 13-year-old children

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ABSTRACT

Body composition measurements are valuable when evaluating pediatric obesity interventions. We hypothesized that foot-to-foot bioelectrical impedance analysis (BIA) will accurately track the direction of adiposity change, but not magnitude, in part due to differences in fat patterning. The purposes of this study were to examine the accuracy of body composition measurements of overweight and obese children over time using dual-energy x-ray absorptiometry (DXA) and BIA and to determine if BIA accuracy was affected by fat patterning. Eighty-nine overweight or obese children (48 girls, 41 boys, age 7-13 years) participating in a randomized controlled trial providing a family-centered, lifestyle intervention, underwent DXA and BIA measurements every 3 months. Bland-Altman plots showed a poor level of agreement between devices for baseline percent body fat (%BF; mean, 0.398%; +2SD, 8.685%; −2SD, −7.889%). There was overall agreement between DXA and BIA in the direction of change over time for %BF (difference between visits 3 and 1: DXA −0.8 ± 0.5%, BIA −0.7 ± 0.5%; P = 1.000) and fat mass (FM; difference between visits 3 and 1: DXA 0.7 ± 0.5 kg, BIA 0.6 ± 0.5 kg; P = 1.000). Bioelectrical impedance analysis measurements of %BF and FM at baseline were significantly different in those with android and gynoid fat (%BF: 35.9% ± 1.4%, 32.2% ± 1.4%, P < .003; FM: 20.1 ± 0.8 kg, 18.4 ± 0.8, P < .013). Bioelectrical impedance analysis accurately reports the direction of change in FM and FFM in overweight and obese children; inaccuracy in the magnitude of BIA measurements may be a result of fat patterning differences.

1. Introduction

The prevalence of childhood overweight and obesity is of great concern among pediatric health care practitioners. Body mass index (BMI) is a tool commonly used to assess the success of interventions that aim to reduce adiposity. However, these tools are of limited use in children during interventions aimed at reducing fat mass (FM) as weight and

Abbreviations: ANOVA, analysis of variance; BIA, bioelectrical impedance analysis; BMI, body mass index; DXA, dual-energy x-ray absorptiometry; FFM, fat-free mass; FM, fat mass; %BF, percent body fat.

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height increase due to growth, and do not reflect changes in body composition [1]. It is therefore important to identify practical methods of assessing body composition.

Dual-energy x-ray absorptiometry (DXA) is widely used as a reference method in research to assess body composition [2]. It is useful in pediatric assessments of body composition because it is noninvasive, precise, and rapid; measures of FM, fat-free mass (FFM) and bone density can be obtained in as little as 3 minutes. Furthermore, DXA can provide regional assessment of body composition (android and gynoid adiposity). However, DXA is not likely to be found in clinical practice because it is expensive, is nonportable, and requires a trained specialist for operation [3]. Bioelectrical impedance analysis (BIA) is a method more likely to be used in clinical settings because of its portability, low cost, ease of use, and safety [4]. Bioelectrical impedance analysis technology uses an alternating current through the body via electrodes placed on a hand and foot (hand-to-foot BIA) or via metallic footpads (foot-to-foot BIA). Depots of body water and electrolytes, such as muscle and blood, will conduct the current, whereas tissues such as fat and bone will resist the flow of the current [5].

Cross-sectional studies have demonstrated that hand-to-foot BIA is not as accurate as DXA in determining percent body fat (%BF), FM, and FFM in children; %BF and FM are overestimated in lean participants and underestimated in the overweight [6,7]. However, a recent longitudinal study of normal-weight and overweight children showed that hand-to-foot BIA accurately tracked change in FM, FFM, and %BF for 1 year as compared with DXA [8]. In children, assessment of the accuracy of foot-to-foot BIA, as compared with DXA, has been limited to cross-sectional studies [9–11]. In adults, android and gynoid fat patterning have been identified as contributing to inaccuracies in foot-to-foot BIA measurements of body fat [12]. It is unclear whether or not the accuracy of foot-to-foot BIA is affected by fat distribution in children. We therefore hypothesized that foot-to-foot BIA would accurately track the direction of adiposity change, but not magnitude, and that differences in fat patterning would affect BIA measurements. Therefore, the objectives of this study were to compare the accuracy of body composition measurements of overweight and obese children by DXA and BIA over time and to determine if BIA accuracy is affected by fat patterning.

2. Methods and materials

2.1. *Participants*

Eighty-nine healthy children ranging from 7 to 13 y (girls: 9.7 ± 1.7 years, n = 48; boys: 10.0 ± 1.7 years, n = 41) participated in this study. The participants, all from the greater Montréal, Québec area, form a subset of children recruited as part of the McGill Youth Lifestyle Intervention with Food and Exercise (MY LIFE) study (NCT01290016). Ethical approval was obtained from the McGill University Faculty of Medicine Institutional Review Board. The MY LIFE study is a 1-year, family-centered, lifestyle intervention with the aim of reducing adiposity in overweight and obese school-aged children. Participants were measured at baseline (BL) and then followed up at 3-month intervals for a period of 1 year (5 total measures). The children were randomized into (1) an intervention group that received 6 individualized counseling sessions within this 1-year period and (2) a control group that received counseling sessions after 1 year. Further details on the MY LIFE study including recruitment methods, study design, and intervention details have been published elsewhere [13]. Three consecutive measurements closest to the BL visit of participants were used, as BL BIA data were not available for all children (time in the study for first measurement: BL: n = 61; 3 months: n = 14; 6 months: n = 15). In other words, children who had their first BIA measurement at the BL visit had subsequent measurements at 3 months and 6 months; those whose first measurement was taken at the 3-month visit were subsequently measured at 6 months and 9 months, and so on. Pubertal stage was either self-reported or reported by a parent and classified using Tanner staging [14,15]. Data on parental ethnicity were also collected via questionnaire; parents identified themselves as white, black, Hispanic, first nations, Asian, native Hawaiian/other Pacific islander, or other race.

2.2. *Anthropometry*

Weight was measured using a standard balance platform beam scale (Detecto, Webb City, MO, USA) and recorded to the nearest 0.1 kg. Height was measured in singlet using a SECA 213 portable stadiometer (SECA Medical Scales and Measuring Systems, Hamburg, Germany) and recorded to the nearest 0.1 cm. Body mass index was calculated as weight (kg) × [height (m)]^2. The World Health Organization's AnthroPlus Software [16] was used to determine the BMI-for-age z score. Waist circumference was measured in singlet between the lowest rib and iliac crest at the level of the umbilicus to the nearest 0.1 cm with a standard, nonstretchable tape measure [17]. Trained dietitians and nurses performed all measurements.

2.3. *Body composition*

At each visit, children underwent a full-body DXA scan using a Hologic Discovery A fan beam densitometer with APEX software version 13.3:3 (Hologic Inc, Bedford, MA, USA), to assess %BF, FM, and FFM. Android/Gynoid ratio measurements were also taken to assess the effect of fat patterning on accuracy of BIA. This ratio, determined by the software, is based on the measurement of android fat, located approximately between the anterior pelvis and the midpoint of the lumbar spine and of gynoid fat, located between the head of the femur and midthigh. Daily calibration of the equipment was performed using a phantom spine (Hologic phantom no. 14774) provided by the manufacturer. Children were measured in light clothing without metal clasps, zippers, and so on, lying in a supine position. Radiation exposure of participants was low, not exceeding 10 μSv per visit, falling well below limits for x-ray exposure [18].

Body composition of each participant was also measured using a foot-to-foot BIA (Tanita TBF-310; Tanita Corp, Tokyo, Japan). Participants were asked to remove their shoes and socks for measurement purposes. Sex, age, and height were entered into the machine, as well as an estimated clothing