NUTRITION RESEARCH 35 (2015) 982–989

Available online at www.sciencedirect.com

ScienceDirect

www.nrjournal.com

Original Research

Cross-mode bioelectrical impedance analysis in a standing position for estimating fat-free mass validated against dual-energy x-ray absorptiometry

Ai-Chun Huang[a,1], Yu-Yawn Chen[b,1], Chih-Lin Chuang[c], Li-Ming Chiang[d], Hsueh-Kuan Lu[e], Hung-Chi Lin[f], Kuen-Tsann Chen[g], An-Chi Hsiao[c], Kuen-Chang Hsieh[h,i,*]

[a] Department of Leisure, Recreation, and Tourism Management, Tzu-Hui Institute of Technology, Pingtung, Taiwan
[b] Department of Physical Education, National Taiwan University of Sport, Taichung, Taiwan
[c] Department of Radiology, Jen-Ai Hospital, Taichung, Taiwan
[d] College of Health Science, Movement Activities and Lifetime Fitness, East Stroudsburg University of Pennsylvania, East Stroudsburg, PA, USA
[e] Sport Science Research Center, National Taiwan University of Sport, Taichung, Taiwan
[f] Division of Gastroenterology and Hepatology, Taichung Veterans General Hospital, Taichung, Taiwan
[g] Department of Applied Mathematics, National Chung Hsing University, Taichung, Taiwan
[h] Office of Physical Education and Sport, National Chung Hsing University, Taichung, Taiwan
[i] Research Center, Charder Electronic Co, Ltd, Taichung, Taiwan

ARTICLE INFO

Article history:
Received 11 April 2015
Revised 26 August 2015
Accepted 27 August 2015

Keywords:
Bioelectrical impedance analysis
Body composition
Dual-energy x-ray absorptiometry
Electric impedance
Fat-free mass
Obesity

ABSTRACT

Bioelectrical impedance analysis (BIA) is commonly used to assess body composition. Cross-mode (left hand to right foot, Z_{CR}) BIA presumably uses the longest current path in the human body, which may generate better results when estimating fat-free mass (FFM). We compared the cross-mode with the hand-to-foot mode (right hand to right foot, Z_{HF}) using dual-energy x-ray absorptiometry (DXA) as the reference. We hypothesized that when comparing anthropometric parameters using stepwise regression analysis, the impedance value from the cross-mode analysis would have better prediction accuracy than that from the hand-to-foot mode analysis. We studied 264 men and 232 women (mean ages, 32.19 ± 14.95 and 34.51 ± 14.96 years, respectively; mean body mass indexes, 24.54 ± 3.74 and 23.44 ± 4.61 kg/m^2, respectively). The DXA-measured FFMs in men and women were 58.85 ± 8.15 and 40.48 ± 5.64 kg, respectively. Multiple stepwise linear regression analyses were performed to construct sex-specific FFM equations. The correlations of FFM measured by DXA vs FFM from hand-to-foot mode and estimated FFM by cross-mode were 0.85 and 0.86 in women, with standard errors of estimate of 2.96 and 2.92 kg, respectively. In men, they were 0.91 and 0.91, with standard errors of the estimates of 3.34 and 3.48 kg, respectively.

Abbreviations: BIA, bioelectrical impedance analysis; BMI, body mass index; CR, cross-mode; DXA, dual-energy x-ray absorptiometry; FFM, fat-free mass; FM, fat mass; HF, hand-to-foot mode; LAI, left arm impedance; RAI, right arm impedance; RLI, right leg impedance; SEE, standard error of the estimate; TI_1, trunk impedance; TI_2, cross-trunk impedance.

* *Corresponding author at:* Office of Physical Education and Sport, National Chung Hsing University, 250 Kuo Kuang Rd, Taichung 402, Taiwan, ROC. Tel.: +886 4 24063766x227; fax: +886 4 24065612.
E-mail address: abaqus0927@yahoo.com.tw (K.-C. Hsieh).
[1] Contributed equally.

http://dx.doi.org/10.1016/j.nutres.2015.08.005

Bland-Altman plots showed limits of agreement of −6.78 to 6.78 kg for FFM from hand-to-foot mode and −7.06 to 7.06 kg for estimated FFM by cross-mode for men, and −5.91 to 5.91 and −5.84 to 5.84 kg, respectively, for women. Paired *t* tests showed no significant differences between the 2 modes ($P > .05$). Hence, cross-mode BIA appears to represent a reasonable and practical application for assessing FFM in Chinese populations.

1. Introduction

The rates of overweight and obesity are increasing at alarming rates worldwide [1,2]. In the past, public health organizations sought to increase the awareness of the risks associated with overweight and obesity mainly by using the body mass index (BMI) as an indicator of these conditions [3]. However, there are limitations to the current anthropometric measurement methods, including not only BMI but also, for example, skinfold thickness and body circumference. These methods can be both time-consuming and inaccurate when estimating total body fat in the general population, and such limitations decrease the utility of periodically monitoring individuals' adiposity to prevent obesity. Currently, dual-energy x-ray absorptiometry (DXA) is considered one of the most accurate methods for assessing body composition [4].

Bioelectrical impedance analysis (BIA) is a safe, quick, low-cost, noninvasive method that has been widely used clinically in hospitals and epidemiologic research institutions [5,6] for assessing various populations, including teenagers, athletes, and abnormal-weight subjects [7–10]. The BIA method has become increasingly popular for assessing body composition because of its simple, reproducible steps [5,6]. When validating BIA using DXA as the reference method, however, it produced inconclusive results across different studies [11–13]. Bioelectrical impedance analysis methods use various measuring modes to evaluate body composition, such as the hand-to-hand, foot-to-foot, and hand-to-foot modes. Among these modes, hand-to-foot BIA conducted in the supine position using tetrapolar gel electrodes and an 8-electrode impedance meter has demonstrated good accuracy for measuring fat-free mass (FFM) [14–16]. Moreover, recent studies have found that the hand-to-foot mode in the standing position generated better results when evaluating body composition than the other 2 modes [17,18]. Although this mode has been well validated in the supine position, it is time-consuming when compared with measurements in the standing position. Thus, more studies are needed to validate the accuracy and precision of standing BIA.

When developing techniques to evaluate the FFM and the percentage of body fat, BIA prediction equations have focused on young, healthy populations [19,20]; however, equations focusing on verifications in obese and older populations are also required [21,22]. We may be able to estimate the body fat percentage, or fat mass (FM), via a BIA equation [23]. Based on the principles of the 2-component BIA prediction equation, however, we would first need to know the FFM to calculate the FM. Hence, the accuracy for estimating FFM would be the most important part of the BIA equation.

Cross-mode BIA presumably uses the longest electrical current path in the human body to measure impedance. We therefore hypothesized that the longest current path of cross-mode impedance measurements may provide more accurate results than the traditional hand-to-foot BIA prediction equation. Accordingly, we here measured the impedance value using both cross-mode and hand-to-foot mode BIA in the standing position. We used the same anthropometric parameters and FFM reference values obtained from DXA measurements, and applied stepwise regression analysis to investigate the FFM prediction accuracy for male and female subjects using the 2 different methods.

2. Methods and materials

2.1. Participants

A purposive sampling approach was adopted to recruit subjects 17 to 75 years of age in Taiwan. The subjects were recruited by advertisements in the local communities. A flowchart of the subject screening is shown in Fig. 1. A total

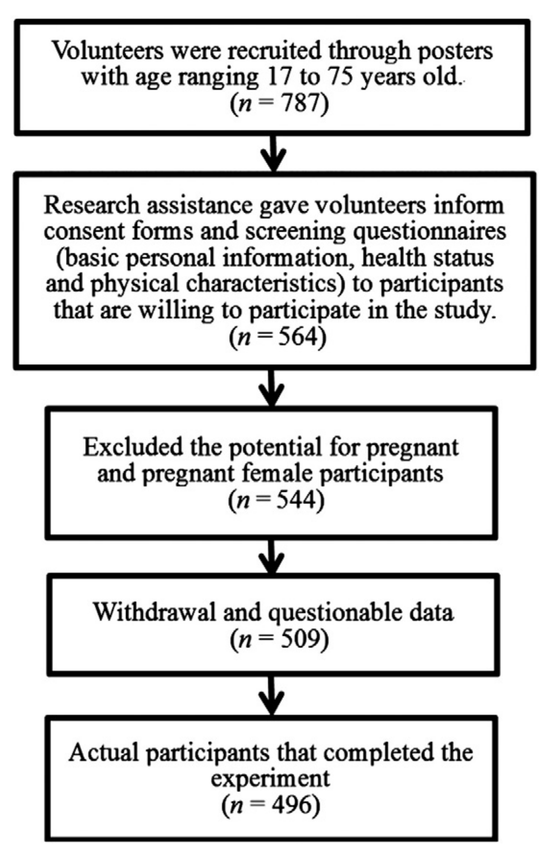

Fig. 1 – Flowchart of the study participant selection.