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Original Article

Evaluation of a Leg-to-Leg Bioimpedance Device in the Estimation of Abdominal Visceral Fat for the Elderly – Comparison with CT

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SUMMARY

Background: This study aimed to assess the accuracy of the standing leg-to-leg bioelectrical impedance analyzer (LBIA) for estimating abdominal visceral fat with body mass index (BMI) scores ranging from non-overweight to obese in elderly Chinese individuals.
Methods: The abdominal visceral fat area (VFA) at the lumbar level of L4-L5 was measured for 100 elderly (age 68.5 ± 8.5 years) individuals using LBIA and computed tomography (CT) (respectively represented as VFA_{LBIA} and VFA_{CT}). The VFA from LBIA were compared with those from CT under various BMI levels.
Results: The average BMI of the subjects was 24.3 ± 4.1 kg/m^2 (58 non-overweight individuals had BMIs < 25 kg/m^2, and 42 overweight individuals had BMIs ≥ 25 kg/m^2). The correlation coefficient (r) of VFA_{LBIA} and VFA_{CT} was r = 0.707 with a standard estimate of error (SEE) = 21.96 cm^2, and the limit of agreement (LOA) was in the range of −67.46 to 58.48 cm^2. The r value for non-overweight and overweight was 0.707 ($p < 0.001$) and 0.356 ($p < 0.001$), SEE was 21.36 cm^2 and 20.42 cm^2 with LOA values ranged between −68.40 to 46.00 cm^2 and −61.79 to 71.19 cm^2.
Conclusion: The LBIA results showed that each obese group all has large LOA when compared with the CT reference values. The study suggests that the LBIA accuracy for estimating VFA is limited in the Chinese elderly population.

1. Introduction

Obesity has begun to replace undernutrition and infectious disease in becoming the most significant contributor to ill health in the modern society around the globe. Obesity has become a serious problem as a result of the prevalence of cheap, processed food filled with a lot more sugar, salt, and saturated fat over time in developed countries[1]. Fat metabolism varies in different parts of the body. Existing research indicated that abdominal obesity was an important health index and had a positive relationship with indicators of metabolic syndrome, such as insulin resistance, hypertension, dyslipidemia, and pathoglycemia[2].

The fat distributed around the abdominal skin adipose tissue considered abdominal subcutaneous fat, while the fat separating the organs considered visceral fat. Methods for estimating visceral fat, or the area of abdominal obesity, include anthropometric measurement, such as measuring the indicators of waist circumference, waist hip ratio (WHR), body mass index (BMI)[3], and the Lange skinfold caliper[4]. These methods are rapid, simple and non-invasive and are often used in epidemiological studies, but they are limited for their low accuracy. To measure body and abdominal fat, the most prevalent methods recognized in the literature are CT and magnetic resonance imaging (MRI)[5,6].

Compared to the aforementioned methods for measuring body fat, bioelectrical impedance analysis (BIA) may obtain electrical impedance signals detected from our physiological tissues and organs. This technology offers advantages in that it is rapid, easy, low-cost and non-invasive[7]. Additionally, a number of agreements and studies on the safety, measurement standardization, bio-

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electricity-related variables, validity, clinical applications and restrictions of BIA have been published[8]. Ryo et al[9] applied bioelectrical impedance technology to measure the impedance of the cross-section of the waist, thereby estimating the abdominal visceral fat area (VFA). Browning et al[10] performed assessments with the integrated results of both the waist circumference measurement and the abdominal VFA measured from the impedance of the cross-section of the waist. Shimomura et al[11] used the height, weight, gender, age, and the impedance between the legs as estimation variables; this design is the same model as the standing leg-to-leg BIA for the estimation of abdominal visceral fat. Compared to the two previous estimations of VFA by BIA, the leg-to-leg BIA is more convenient and has also been widely applied in family health care. However, only a few studies are available on the validation of the method's accuracy. The literature is scarce on the validation of the leg-to-leg BIA in the measurement of abdominal visceral area of Asians and elderly individuals[12].

Based on the above considerations, we assumed that the results of VFA measurements for the elderly in Taiwan's Chinese by the leg-to-leg BIA and CT imaging would be similar, with a high correlation, no significant systematic deviation, and a small confidence interval. Therefore, the abdominal visceral fat of elderly individuals in Taiwan was measured using both the leg-to-leg BIA and CT imaging, and the results in groups of different genders and non-overweight and overweight individuals were compared to investigate whether the VFA measurement results were significantly different between the two methods.

2. Materials and methods

2.1. Study design and subjects

The subjects of this study were selected using a non-random purposive sampling method. Middle-aged and older adults in central Taiwan, 55 years of age or older and with good mobility skills, were recruited via posters. The subjects were required to complete a thorough health questionnaire, including personal information, physical characteristics, health status, and disease history. All participants with endocrine, nutritional and major chronic diseases, such as diabetes mellitus, cancer, kidney dysfunction, and liver diseases, were excluded from this study; after screening, 100 subjects were included. The study procedure was approved by the ethics committee of human trials at the Nantou Tsaotun Psychiatric Center (IRB-103035) and Ta-Li Jen-AI Hospital (IBR-97-02) and was implemented in the Taichung Hospital and Ta-Li Jen-AI Hospital of the Ministry of Health and Welfare.

2.2. Anthropometry

The body weight of the participants was measured using a Weight-Tronix (Scale Electronic Development, New York, USA) electronic scale. The height of the participants without shoes was measured using a stadiometer (Holtain, Crosswell, Wales, UK). The waist circumference (WC) was measured at a level parallel to the height of the navel, and the hip circumference (HC) was measured at the widest part of the hip using a standard measuring tape.

2.3. Four-plate standing bioelectrical impedance analyzer

A BC-305 (Tanita Corp, Tokyo, Japan) four-plate standing leg-to-leg BIA (hereinafter referred to as LBIA) was used in this study. Based on the built-in estimate equation and the height, sex, and age of the corresponding subject, the VFA at the lumbar level of L4-L5 of the subject could be estimated. With every 10 cm^2 as a level and with a level resolution of 0.5, the VFA values obtained are presented as VFA_{LBIA}. Before the actual measurement using LBIA, the VFA_{LBIA} was first measured for five participants with an interval of three days to evaluate the reliability the LBIA measurement.

2.4. Computed tomography

A Somatorn Sensation 64 CT system (Siemens Corp., Germany) with its operating software (software version syngo CT2005A) was used to perform a CT scan on the abdominal area. To scan the monolithic image in the middle of the lumbar L4-L5 vertebral area, each subject, wearing only a cotton hood, was asked to lay on the central CT scanning platform and lifted both arms straight over his/her head. Based on the procedures recommended by Yoshizumi et al[5] the abdominal visceral fat and the abdominal subcutaneous fat area were colored in the scanned image for the area calculation, wherein the threshold CT value of adipose tissue was (-260 ± 3) - (-10 ± 3) Hu. The abdominal cross-sectional area (ACSA), the abdominal VFA, and the abdominal subcutaneous fat area (SFA) at the lumbar level of L4-L5 of the subject obtained by CT scanning were represented as $ACSA_{CT}$, VFA_{CT} and SFA_{CT}, respectively. Before the actual CT scanning measurement, the CT scanning for the abdominal cross-sectional area at the lumbar L4-L5 level was first performed twice for five participants over a 3-day interval to analyze the reliability of the CT measurement.

2.5. Experimental procedures

Each experiment in this study was started at 2:00 p.m. daily. Before the test, the participants fasted for 4 h, with no intense exercise for 24 h and no consumption of alcohol or diuretics for one week. After the urine in the bladder was emptied before the test, the weight, height, waist circumference, hip circumference, bioelectrical impedance analysis and CT scanning measurements were sequentially collected. All measurements for each subject were completed within 2 h. The anthropometric measurement, CT scanning, and the operation of the bio-impedance measurement in this study were performed by research assistants and radiologists.

2.6. Statistical analysis

The data analysis in this study was performed using SPSS ver. 17 (SPSS Inc., Chicago, IL, USA). The results were presented as means ± SD. The correlation of VFA_{LBIA} and VFA_{CT} was described using Pearson's product moment correlation, and their relationship was represented with a simple linear regression equation. The Bland-Altman method[13] was used to describe the difference (bias ± SD) and the limit of agreement (95% confidence interval, bias ± 2 SD) of VFA_{BIA} and VFA_{CT}. The difference between the two methods was compared using an independent samples *t*-test. Moreover, the participants were grouped according to gender and different levels of BMI, in which the group with BMI <25 kg/m^2 was defined as the non-overweight group and the group with BMI ≥ 25 kg/m^2 was defined as the overweight and obese group.

3. Results

In this study, a total of 100 subjects with an average age of 68.5 ± 8.5 years were included. The average BMIs were 25.1 ± 3.5 kg/m^2 for the male subjects and 23.7 ± 3.7 kg/m^2 for the female subjects. The subjects' characteristics and measurement results are shown in Table 1. The calculated correlation coefficients of VFA_{CT} and VFA_{LBIA} for the male, female and total subjects were 0.565, 0.548, and 0.707 respectively in the non-overweight group; 0.600, 0.398, and 0.365 in the overweight group; and 0.540, 0.682, and 0.707 in the total group. The distribution of the VFA_{CT} and