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☐ Original Article ☐

Need for Cross-calibration of Body Composition Even with the Same Model of Dual-energy X-ray Absorptiometry

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Objectives: The purpose of this study was to compare total body fat mass, lean mass, and bone mineral content in addition to regional fat measured by the same model of equipment installed in different places, and to determine the extent of agreement.
Materials and Methods: Twenty seven healthy volunteers aged 20 years and over received two consecutive total body scans using the same dual-energy X-ray absorptiometry model of installed in different places. All scans were conducted on the same day.
Results: Relatively good agreements were shown in fat mass, the percent of tissue fat, android fat, and gynoid fat. However, there were two outliers each in lean mass and bone mineral content based on the limits of agreement.
Conclusions: These results indicate the need for cross-calibration even with the same model of equipment.

Key Words: Absorptiometry, Body composition, Bone density, Calibration, Humans

Dual-energy X-ray absorptiometry (DXA) was introduced in 1988.[1] It has become the most commonly used technique to determine bone mineral density in the spine and hip. DXA scanners are also able to perform whole-body scans and measure three body composition components: lean and fat mass, as well as bone mineral.[2] The measurement of body composition is generating much interest because of the relationships between fat and lean tissue mass with health and disease. The recently marketed iDXA fan beam model from GE Lunar uses multiple detectors to measure body composition.[3]

Accurate assessment of body composition is essential when monitoring diseases such as obesity, and evaluating the health status by degrees of fat distribution or fat changes after intervention. Differences in the results are generally greatest between devices from different manufacturers,[4] but also occur for different models from the same manufacturer[5] and even for different devices of the same maker and model.[6] Therefore, there have been many cross-calibration studies with the development of new technology. However, most previous cross-calibration studies were conducted between pencil-beam and fan-beam.[3,7,8] Although there were some studies on cross-calibration between two fan-beam DXA systems; for example, GE Lunar Prodigy versus GE Lunar iDXA,[9,10] no study has focused on body composition. Moreover, there is little data on cross-calibration between the same iDXA with respect to body composition.

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The purpose of this study was to compare total body fat mass, lean mass, and bone mineral content (BMC) in addition to regional fat measured by the same model of equipment installed in different places.

MATERIALS AND METHODS

1. Subjects

Twenty-seven healthy Korean women volunteers aged 20 years or older were recruited from the Endocrinology and Metabolism Clinic at Ajou University Hospital. Pregnant or lactating women were excluded. Height was measured without shoes and was recorded to the nearest 0.1 cm. Participants were weighed on a flat and uncarpeted surface, and weight was recorded to the nearest 0.1 kg. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Informed consent was obtained from all subjects, and the study was approved by the Institutional Review Board of the Ajou University Hospital (AJIRB-DEV-DE3-11-083).

2. Body composition measurements using iDXA

Two consecutive total body scans were conducted on each subject using the same model of iDXA equipment (GE Lunar iDXA; GE Healthcare, Madison, WI, USA) installed in different places. All scans were performed on the same day. Two instruments were installed at the Laboratory of Endocrinology and Metabolism, and at the Health Promotion Center, respectively. All scans were analyzed using enCORE Software, version 13.40. Total body fat mass (kg), lean mass (kg), and BMC (kg) were measured. Participants lay supine on the scanning table with the ankles together. Arms were positioned to the side with palms flat on the table, or towards either side of the body, depending on the size of the participant. Participants were required to lie still and no movement was detected for any of the scans. The coefficient of variation for DXA assessment of body composition in this laboratory was 0.38% for fat tissue. For precise scanning, a single qualified technologist set the equipment according to the manufacturer's guideline and scanned both instruments located in different places.

Total and regional fat, lean- and bone-tissue distributions were also assessed. The android fat was determined by the proportion of fat in the trunk region (area between an upper horizontal border below the chin, a lower border formed by the oblique lines passing through the hip joint, and vertical borders lateral to the ribs), whereas the gynoid fat was determined by the proportion of fat in the leg region (area below the upper border formed by the oblique lines passing through the hip joints), both expressed as percent of total body fat.[11]

3. Statistical analyses

Data of body composition were analyzed and compared by the independent *t*-test to test the precisions of the densitometers. Linear regression analysis and Bland-Altman analysis[12,13] were used to derive translation equations and establish the agreement between the two scanners. In the Bland-Altman analysis, the mean differences between the same equipments were plotted against mean values of body composition measurements. Limits of agreement were defined as the mean difference plus and minus 1.96 times the standard deviation of the differences. All statistical analyses were performed using SPSS software, version 16 (SPSS, Chicago, IL), and P values <0.05 were considered significant.

RESULTS

Twenty-seven females participated in this study. Table 1 shows the anthropometric variables of the study subjects. The mean age was 57.3±8.2 years (range: 37 to 68 years) and the mean BMI was 23.2±3.3 kg/m^2 (range: 18.2 to 31.8 kg/m^2).

Table 1. Anthropometric variables of subjects (N=27)

Variables	Results	Range
Age (years)	57.3±8.2	37~68
Height (cm)	153.5±5.7	142.2~164.1
Weight (kg)	54.7±8.2	43.5~76.1
BMI (kg/m^2)	23.2±3.3	18.2~31.8

BMI, body mass index.
Data are presented as mean±standard deviation.

Table 2. Descriptive statistics for scanner measurements for the subjects (N=27)

Variables	Scanner	Mean	Standard deviation
Fat mass (kg)	1	18.84	5.45
	2	18.96	5.27
Lean mass (kg)	1	33.97	3.63
	2	33.57	3.72
BMC (kg)	1	1.89	0.24
	2	1.90	0.24
Tissue fat (%)	1	33.89	5.47
	2	34.34	5.26
Android fat (%)	1	35.71	9.61
	2	35.81	9.25
Gynoid fat (%)	1	37.47	4.39
	2	37.56	4.52

Scanner 1 and 2 represent the iDXA installed in the Laboratory of Endocrinology and Metabolism and the Health Promotion Center, respectively.
BMC, bone mineral content.

Descriptive results measured by the two iDXA equipments are shown in Table 2. All data measured by the two scanners did not show significant differences.

The results of linear regression analysis are shown in Figs. 1 and 2. All the scanned results showed close linear relationships. In Fig. 1, all the r^2 values were close to 1 and the slopes were between 0.966 and 1.022 (all P<0.001). The percent of regional fat measured by two iDXA scanners showed similar results with those of Fig. 1. The slopes of Fig. 2 were also close to 1.

To verify the agreement of data from the two equipments, Bland-Altman plot was drawn in Figs. 3 and 4. Relatively good agreements were shown in fat mass (kg), the percent of tissue fat, android fat, and

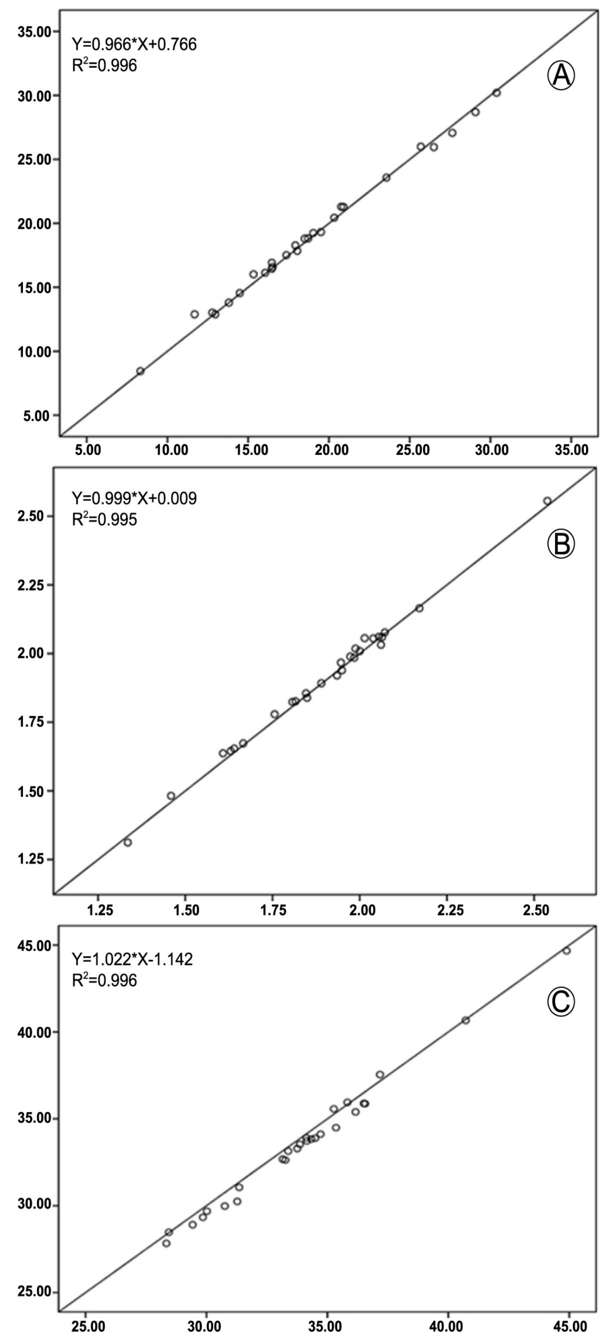

Fig. 1. Linear correlation of (A) Fat mass, (B) Lean mass, (C) Bone mineral content, as measured by the GE Lunar iDXA scanners installed in the Laboratory of Endocrinology and Metabolism (X axis) and the Health Promotion Center (Y axis).

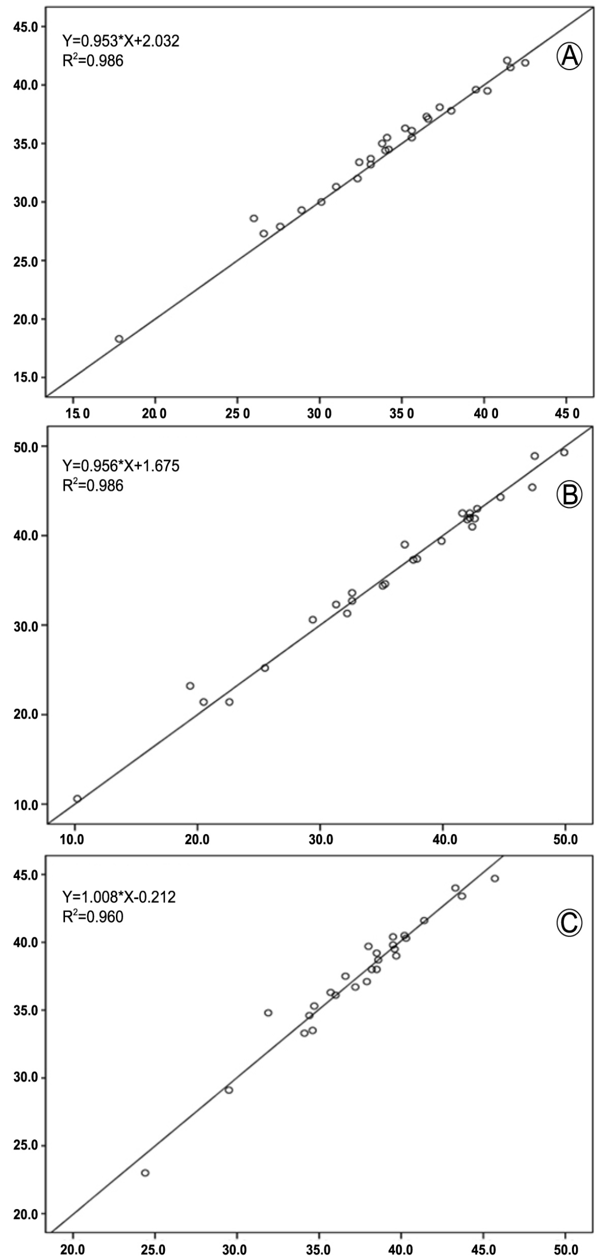

Fig. 2. Linear correlation of (A) Tissue fat (%), (B) Android fat (%), (C) Gynoid fat (%), as measured by the GE Lunar iDXA scanners installed in the Laboratory of Endocrinology and Metabolism (X axis) and the Health Promotion Center (Y axis).

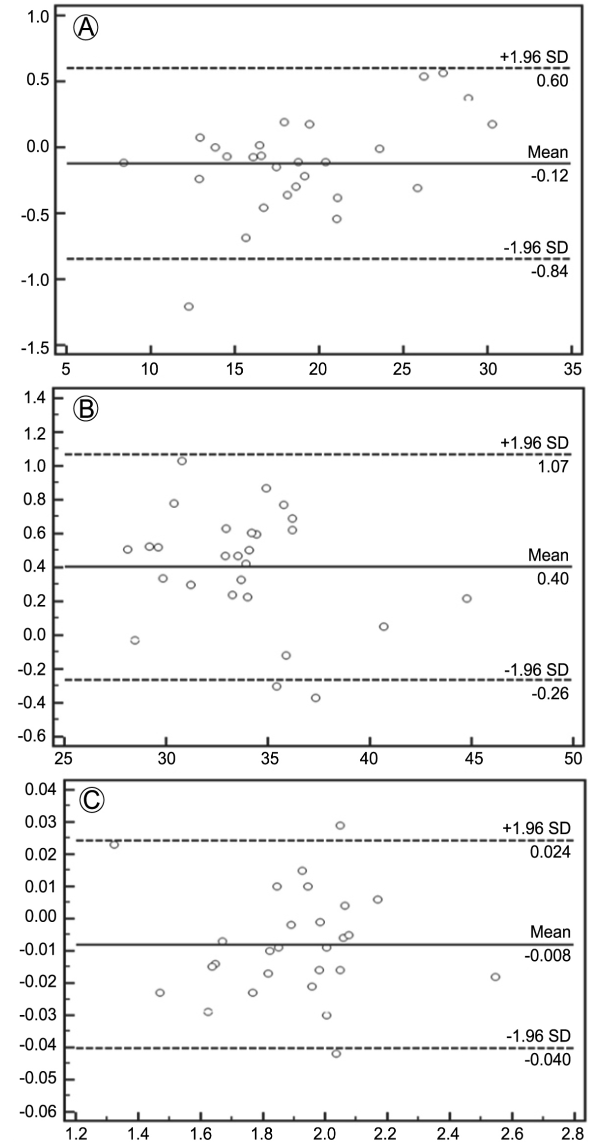

Fig. 3. Agreement between two GE Lunar iDXA scanners by Bland-Altman analysis. X axis represent the mean values and Y axis represent difference values between two data. (A) Fat mass (kg), (B) Lean mass (kg), (C) BMC (kg). Limits of agreement (dashed lines) are shown as mean values±1.96 × SD.

gynoid fat, but there were two outliers each in lean mass (kg) and BMC (kg) based on the limits of agreement.

In summary, body composition analysis data from the two iDXA scanners showed good correlations, but they did not show good agreement in lean mass and BMC. Therefore, cross-calibration was needed, and equations using linear regression analysis were reported in the Figs. 1 and 2.

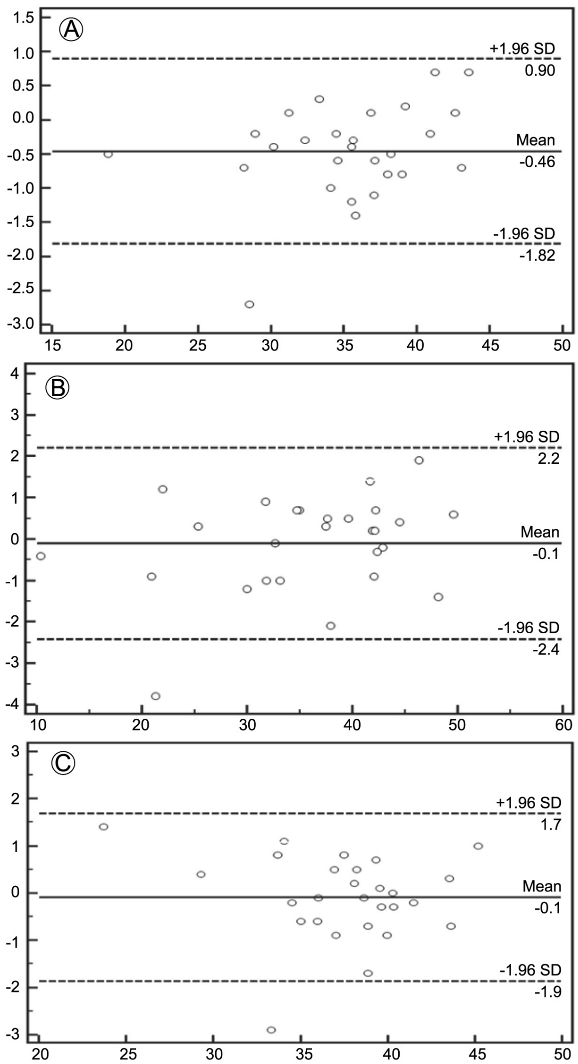

Fig. 4. Agreement between two GE Lunar iDXA scanners by Bland-Altman analysis. X axis represent the mean values and Y axis represent difference values between two data. (A) Tissue fat (%), (B) Android fat (%), (C) Gynoid fat (%). Limits of agreement (dashed lines) are shown as mean values±1.96 × SD.

DISCUSSION

This study was performed to determine whether cross-calibration equations are needed or not when the body compositions are measured by the same model of equipments installed in different places. In our study, body composition analysis data from two iDXA scanners showed an excellent correlation, but the agreement between two data was insufficient.

These results are consistent with those of previous studies. Lantz et al.[6] compared bone mineral density and body composition results of two DXA instruments from the same manufacturer (Lunar DPX-L). In their study, the differences in BMD values and soft tissue mass between two machines were not acceptable. Discrepancies in measurements from different software used in the same type of DXA instrument from the same manufacturer were reported.[14] In another study,[5] significant differences existed in regional body composition analysis between different fan-beam scanners, even those produced by the same maker. Moreover differences in regional fat mass were greatest in people with higher fat mass. Of course, systemic differences have been reported frequently between densitometers from different manufacturers.[3,15,16]

In Bland-Altman's plot, differences within mean ± 1.96×SD may indicate that two measurement methods are interchangeable.[12] Clinical laboratory standards state that more than three outliers per 100 observations are suggestive of major flaws in the measurement system.[14] To this point, only one outlier could be acceptable in 27 subjects. In the Bland-Altman plot of this study, there was single outlier in four regions and the outlier was found the same subject whose BMI was 18.79 kg/m^2. This finding differed from a prior observation that some individuals displayed marked differences, particularly subjects with high BMI.[5] On the other hand, there were two outliers in the lean mass and BMC, respectively. One of the subject whose BMI was 27.04 kg/m^2 was implicated in both lean mass and BMC. The other two outliers' BMI were 25.50 and 23.84 kg/m^2 in the lean mass and BMC, respectively.

Interestingly, we could expect good agreement based on the criteria of limit of agreement with mean±2×SD because outliers in this study did not exceed one case. However, in most studies, the limit of agreement is assumed to be mean±1.96×SD.

The strength of our study is that cross-calibration was performed in vivo. Although cross-calibrations based on phantoms and in vitro studies are helpful, differences between in vitro and in vivo cross-calibrations results have been reported.[4,17] Moreover, many previous cross-calibration studies using DXA devices have mainly focused on measuring the regional BMD of the spine and femur. Since obesity became a worldwide problem, there is an increasing interest in the use of body composition. This study may provide information for further studies, since to date there has been a lack of cross-calibration studies on body composition.

There is a limitation in this study. Obesity or underweight increases precision errors in DXA measurements.[18] According to the BMI classification, two subjects were underweight (<18.5 kg/m^2) and one subject was obese (>30 kg/m^2).

In conclusion, cross-calibration is required on comparing and monitoring the body composition analysis, even though data were measured by the same model of equipment, based on the results of correlation and agreement evaluation in this study.

Conflict of interest: All authors have no conflicts of interest.
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