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Original Article

iDXA, Prodigy, and DPXL Dual-Energy X-ray Absorptiometry Whole-Body Scans: A Cross-Calibration Study

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Abstract

Purpose: Total body fat, lean, and bone mineral content (BMC) in addition to regional fat and lean mass values for arms, legs, and trunk were compared across a pencil-beam (Lunar DPXL) and 2 fan-beam (GE Lunar Prodigy and GE Lunar iDXA) dual-energy X-ray absorptiometry (DXA) systems.

Methods: Subjects were a multiethnic sample of 99 healthy adult males (47%) and females (mean ± SD: age, 46.3 ± 16.9 yr; weight, 73.4 ± 16.6 kg; height, 167.6 ± 9.7 cm; body mass index, 26.0 ± 5.2 kg/m^2) who had whole-body scans performed within a 3-h period on the 3 systems. Repeated measures ANOVA was used to test the null hypothesis that the mean values for the 3 systems were equal. Translation equations between the methods were derived using regression techniques.

Results: Bone mineral content (BMC): For both genders, total BMC by iDXA was lower ($p \leq 0.004$) than the other systems. Lean: for males, iDXA was lower ($p \leq 0.03$) than the other systems for total, trunk, and arms. For females, DPXL estimated higher ($p < 0.001$) lean mass compared with the other systems for total, trunk, and arms, but iDXA estimated greater legs lean mass. For both genders, all DPXL mean values were greater than Prodigy mean values ($p < 0.001$).

Fat: in females, all the 3 systems were different from each other for total, trunk, and legs ($p \leq 0.04$). For arms, DPXL and iDXA were higher than Prodigy ($p < 0.0004$). For males, DPXL was less ($p < 0.001$) for total body, trunk, and legs compared with the other 2 systems and greater than Prodigy only for arms ($p < 0.0007$). These data were used to derive translation equations between systems. For several measurements, the differences between systems were related to gender.

Conclusion: For estimation of BMC and body composition, there was high agreement between all DXA systems ($R^2 = 0.85–0.99$). Even so, cross-calibration equations should be used to examine data across systems to avoid erroneous conclusions.

Key Words: Body composition; cross-calibration; densitometry; fan beam; iDXA; pencil beam.

Introduction

The accurate assessment of body composition for purposes of disease classification, disease risk, or presence (osteopenia and osteoporosis), current health status by level of fatness and fat distribution, and changes in these components after an intervention is imperative. One technique commonly used to assess body composition is dual-energy X-ray absorptiometry (DXA) which provides information on both bone mineral content (BMC) and soft tissue content of the whole-body and regions (arms, legs, and trunk). Over the past several years, a number of different DXA systems have come onto the market and into research laboratories *(1–3)* where the principal technology differs.

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One advancement made in DXA technology has been the transition from a pencil-beam densitometer used in early systems (Lunar's DPX and DPXL) to a fan-beam densitometer used in the currently available systems (GE/Lunar's Prodigy and iDXA systems). Fan-beam systems use multiple detectors that allow for quicker scan acquisition and clearer image resolution but a higher though still minimal radiation dose *(4)*. The results from cross-calibration studies comparing BMC, fat, and lean tissue estimates from the DPXL pencil-beam system vs the Prodigy fan-beam system in children *(5)* and in adults *(4,6)* have shown differences across systems.

The latest densitometer for body composition and bone mineral assessment is the iDXA (GE Lunar) that employs a fan-beam technology with a greater number of detectors than earlier models. As yet it is unknown how the iDXA compares to previous DXA models. For ongoing longitudinal studies where follow-up body composition studies must be performed on a DXA system different from that on which the baseline studies were performed, it becomes essential that a cross-calibration study be performed to allow comparison of data collected on the different systems. Therefore, the use of cross-calibration equations is recommended to compare results between these systems.

The aim of this study was to compare total body fat, lean, and BMC in addition to regional fat and lean mass values for arms, legs, and trunk between a pencil-beam (Lunar DPXL) and 2 fan-beam (GE Lunar Prodigy and GE Lunar iDXA) DXA systems.

Materials and Methods

Subjects

The sample consisted of healthy multiethnic adults recruited to participate in a study to cross-calibrate 3 different DXA systems. Flyers placed locally in the community were used to recruit subjects. In total, 99 participants (47 males and 52 females) were tested on all 3 DXA systems. Participants ranged in age from 18 yr to 81 yr and ranged in BMI from normal to obese. The maximal weight for inclusion as a study participant was limited by the upper weight limit restriction of the DPXL and Prodigy systems (300 lb).

Study Procedures

Subjects completed all testing at the Body Composition Unit (New York Obesity Research Center) at St. Luke's-Roosevelt Hospital. Scans were performed using a total body scan mode on each of the DXA systems within a 3-h period. Body weight and height were measured wearing a hospital gown and foam slippers, and with the use of calibrated scale (Weight Tronix, New York, NY) and stadiometer (Holtain Stadiometer, Crosswell, Wales). Body mass index (BMI) was calculated (kg/m^2) from height and weight. Informed consents were obtained on all subjects before commencement of testing. The study was approved by the Radiation Safety Committee and Institutional Review Board of St. Luke's-Roosevelt Hospital.

Dual-Energy X-ray Absorptiometry

Total body fat, lean, and BMC were measured with 3 whole-body DXA scanners using a total body scan mode: DPXL, Prodigy, and iDXA (GE Lunar, Madison, WI) and analyses were performed using the following software versions: DPXL 4.7e, Prodigy 8.80, and iDXA 10.40. Using specific anatomic landmarks as previously described *(7)*, regions including the arms, legs, and trunk were demarcated. For soft tissue quality control purposes relating to the densitometers, monthly scans were performed using methanol and water bottles with a volume of 8 L to simulate fat and fat-free soft tissues, respectively *(8,9)*.

Pencil-beam technology is used in the DPXL system, whereas the Prodigy and iDXA are both fan-beam systems. DXPL uses an X-ray source at 78 kVp and a K-edge filter to produce stable beams of X-rays at energies of 38 and 70 keV. The Prodigy uses a narrow fan beam at an angle of 4.5°, orientated parallel to the long axis of the body using a peak X-ray energy of 80 kVp, a current of 3 mA, and a K-edge filter produces energies at 38 and 70 keV. The Prodigy system uses 16 detectors that are energy-sensitive cadmium zinc telluride, 5 cm long, allowing for rapid photon counting *(10)*. The iDXA system uses a staggered array of 64 CZT-HD digital detectors to enhance the precision and eliminate dead space between detectors creating a high resolution image *(11)*. The enhanced digital detectors increase the image resolution for bone especially, although this comes at the cost of a higher radiation dose. The radiation dose for a total body scan set on standard thickness using iDXA is 0.03 mSv (30% of the radiation dose received in a chest X-ray), which is greater than earlier systems (DPXL 0.002 mSv and Prodigy 0.004 mSv; 2% and 4% of the radiation dose received in a chest X-ray, but still less than the radiation dose received during a chest X-ray (0.1 mSv) *(12)*.

Scan times for a total body scan using DPXL is approximately 20 min and for the Prodigy and iDXA are less than 10 min each. Other notable upgrades made to the iDXA system were done to accommodate scanning of heavier/obese subjects. These include a greater upper weight limit of 450 lb (205 kg), a greater height of the arm to capture subjects with a greater trunk thickness, a wider bed platform (94 cm for iDXA vs 73 cm for prodigy), and a lower bed platform making mounting of the platform easier for patients or subjects. Even though there is a wider bed platform in the iDXA system, the field of view increased only minimally from the Prodigy system (196 cm long by 66 cm wide for iDXA vs 197 cm long by 60 cm wide for Prodigy).

Statistical Analysis

Descriptive statistics, including means, standard deviations, minimum and maximum values were calculated for all variables by gender. The hypothesis that the mean measurements of the 3 scanners were equal was tested using repeated measures analysis of variance. Multiple comparisons among the mean measurements from the 3 scanners were performed using Fisher's protected least significant difference