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Original Article

Obesity Increases Precision Errors in Total Body Dual-Energy X-Ray Absorptiometry Measurements

Karen M. Knapp,[*,1] *Joanne R. Welsman,*[1] *Susan J. Hopkins,*[1] *Andrew Shallcross,*[1] *Ignac Fogelman,*[2] *and Glen M. Blake*[2]

[1]*Medical Imaging, University of Exeter, Exeter, UK; and* [2]*Imaging Sciences, Guy's, King's and St Thomas' School of Medicine, King's College London, London, UK*

Abstract

Total body (TB) dual-energy X-ray absorptiometry (DXA) is increasingly being used to measure body composition in research and clinical settings. This study investigated the effect of body mass index (BMI) and body fat on precision errors for total and regional TB DXA measurements of bone mineral density, fat tissue, and lean tissue using the GE Lunar Prodigy (GE Healthcare, Bedford, UK). One hundred forty-four women with BMI's ranging from 18.5 to 45.9 kg/m^2 were recruited. Participants had duplicate DXA scans of the TB with repositioning between examinations. Participants were divided into 3 groups based on their BMI, and the root mean square standard deviation and the percentage coefficient of variation were calculated for each group. The root mean square standard deviation (percentage coefficient of variation) for the normal ($<$25 kg/m^2; n = 76), overweight (25−30 kg/m^2; n = 36), and obese ($>$30 kg/m^2; n = 32) BMI groups, respectively, were total BMD (g/cm^2): 0.009 (0.77%), 0.009 (0.69%), 0.011 (0.91%); total fat (g): 545 (2.98%), 486 (1.72%), 677 (1.55%); total lean (g): 551 (1.42%), 540 (1.34%), and 781 (1.68%). These results suggest that serial measurements in obese subjects should be treated with caution because the least significant change may be larger than anticipated.

Key Words: Bone mineral density; dual-energy X-ray absorptiometry; obesity; precision.

Introduction

Dual-energy X-ray absorptiometry (DXA) has been successfully used for around 25 yr for the diagnosis of osteoporosis and the prediction of fracture risk. In addition to the measurement of bone mineral density (BMD) at clinically significant fracture sites, DXA affords the ability to measure fat tissue and lean tissue body composition using total body (TB) scans. DXA scans of the spine and hip provide a low radiation burden, with negligible increase in lifetime cancer risk, and are therefore suitable for repeat measurements where clinical indications require this *(1)*. TB scans are acquired using the same low-dose technology and give a similarly small effective dose *(2)*. The precision errors of DXA measurements are important for characterizing the ability to detect longitudinal changes *(3)*, and changes in fat or lean tissue may be of interest in some clinical groups *(4)* and elite athletes *(5)*, particularly in decision making about their fat content and potential injury risk. Precision errors are partly dependent on quality assurance systems to detect scanner changes and on operators' training and experience *(3)*. The evaluation of precision errors involves repeated measurements, with the International Society of Clinical Densitometry recommending either duplicate scans of 30 subjects or triplicate scans of 15 subjects *(6,7)*. Precision errors may vary between individuals because of differences in bone status and biological variations, such as tissue inhomogeneity, and it is therefore important to measure a representative set of subjects *(8)*.

TB DXA measurements are used in a range of populations *(4,5)*, ranging from athletes with low body fat to patients suffering from a range of obesity and nonobesity-related conditions. The ability of TB DXA to accurately and precisely measure BMD, fat tissue, and lean tissue within these

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*Address correspondence to: Karen M. Knapp, PhD, Physics Building, Stocker Road, University of Exeter, Exeter, Devon EX4 4QL, UK. E-mail: K.M.Knapp@exeter.ac.uk

different populations is unlikely to be comparable (9), and a previous study demonstrated larger precision errors in spine, hip, and TB BMD in obese groups (10). As obesity becomes increasingly prevalent in the western world, DXA services are likely in future to see rising numbers of patients in the overweight and obese groups (11). It is estimated that by 2012, obesity levels in England will have risen to 31.2% and 31.0% in men and women, respectively (12).

Previous studies of TB DXA precision errors have investigated a range of participants, but the only other study in an obese population focused on a small number of obese women, with no direct comparison with their normal weight counterparts (9). To date, no well-powered study has been purposely designed to investigate TB DXA precision errors on the GE Lunar Prodigy (GE Healthcare, Bedford, UK). A previous study investigating spine and hip BMD precision errors demonstrated precision errors that increased with body mass index (BMI) and body fat, particularly at the spine (10). This was hypothesized to result from reduced signal-to-noise ratio and increased inhomogeneity in soft tissue composition. Increased soft tissue inhomogeneity is likely to occur from a greater and/or more variable amount of visceral fat surrounding the organs in overweight and obese patients.

This study investigated the effect of increasing BMI and percentage body fat on DXA precision errors at the TB for BMD, lean, and fat measurements of the TB and individual subregions using the GE Lunar Prodigy (GE Healthcare).

Materials and Methodology

Participants

The study consisted of 144 female volunteers aged between 18 and 75 yr recruited from the general population via poster advertisements. The participants were allocated to 1 of 3 BMI groups <25, 25−29.9, and ≥ 30 kg/m^2 representing optimal, overweight, and obese, respectively, based on the World Health Organization criteria for BMI classification (13). Participants were analyzed according to BMI groups determined from the measured height and weight at their DXA scan visit. The aim of the study was to perform duplicate TB DXA scans on a minimum of 30 participants in each BMI group, yielding a sufficiently robust study to determine differences between the groups with at least 30 degrees of freedom in each group. The exclusion criteria included aged younger than 18 yr or older than 75 yr, male, the presence of internal prosthetic implants, and the inability to lie flat and hold the position for the duration of the scan. The study was approved by the Devon and Torbay Research Ethics Committee, and all subjects gave written informed consent.

Methods

All participants had their height measured to the nearest 0.01 m using a stadiometer (Holtain, Crymych, Dyfed, UK) and body weight measured to the nearest 0.1 kg in minimal clothing using beam balance scales (Avery, Birmingham, UK), respectively, before their scan. BMI was calculated as weight (kg)/height^2 (m^2).

DXA scans were performed using the GE Lunar Prodigy (GE Healthcare, Little Chalfont, UK). The participants underwent duplicate TB DXA scans with repositioning, involving the participant getting off and back onto the table between the scans. The scan modes used (standard or thick) were selected automatically by the scanner software. Scans were analyzed using the GE Lunar Encore 2005 software, version 9.30.044 (GE Healthcare, Little Chalfont, UK).

Statistical Analysis

Descriptive statistics (means and standard deviations) were calculated for anthropometric variables, BMD, lean, and fat for the TB for participants by BMI group. Any differences between groups were tested using a 1-way analysis of variance using SPSS, version 21.0 (IBM, Hants, UK).

The participants were grouped into 3 BMI categories based on the World Health Organization criteria for BMI classification resulting in 3 groups of <25, 25−29.9, and ≥ 30 kg/m^2 representing optimal, overweight, and obese, respectively

Table 1
Descriptive Statistics (Mean [SD]) of Women by BMI Group

	Whole group	<25 kg/m^2	25−29.9 kg/m^2	≥ 30 kg/m^2
BMI group		Mean (SD)		
N	144	76	36	32
Age (yr)	41.0 (15.3)	37.2 (15.2)*	43.4 (15.6)*	47.6 (12.9)*
Height (m)	1.65 (0.07)	1.66 (0.06)	1.63 (0.07)	1.66 (0.07)
Weight (kg)	71.2 (16.5)	60.5 (6.5)**	72.5 (7.3)**	95.0 (15.3)**
BMI (kg/m^2)	26.1 (5.6)	22.1 (1.7)**	27.1 (1.4)**	34.5 (4.4)**
Total BMD (g/cm^2)	1.19 (0.09)	1.17 (0.08)**	1.20 (0.08)**	1.23 (0.08)**
Total fat (kg)	26.5 (11.9)	18.4 (5.4)**	28.4 (4.4)**	43.8 (9.0)**
Total lean (kg)	40.8 (5.6)	38.7 (4.2)**	40.2 (3.8)**	43.5 (6.6)**

Abbr: BMI, body mass index; BMD, bone mineral density; SD, standard deviation.
*$p \leq 0.05$; **$p \leq 0.001$: all intergroup comparisons significant.