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Precision of a dual energy X-ray absorptiometry device

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The standard method to diagnose and follow-up osteoporosis is the measurement of bone mineral density (BMD) using dual X-ray absorptiometry (DEXA). Manufacturers' manuals of DEXA devices state the intrascanner coefficient of variance is less than 0.01 g/cm^2. The aim of this study was to evaluate the in vivo coefficient of variance of a Lunar DPX scanner in male and female healthy adult subjects. Average BMD for females and males were 1.170±0.091 g/cm^2 and 1.272±0.115 g/cm^2, respectively. Monthly phantom measurements provided and controlled by the manufacturer were 1.243±0.008 g/cm^2 (range 1.222 to 1.257) and the coefficient of variance was 0.006. It is concluded that the in vivo coefficient of variance of DEXA devices can slightly be higher than that proposed by the manufacturer.

Introduction

Bone mineral density (BMD) in later adult life is determined by the peak bone mass (PBM) achieved in early adult life and the subsequent rate of bone loss.[1] Bone mass is affected by many factors including age, body size, gender[2–5] and ethnicity.[6–8] There is a progressive and continuous increase in fracture risk with diminishing bone mass.[9–11] Indeed, the clinical importance of osteoporosis lies in the fragility of fractures which occur and the consequent morbidity and mortality.[12,13] With an insufficient low bone mass, fracture at any skeletal site is possible, but those at the wrist, spine and hip are commonly associated with osteoporosis.[13]

The diagnosis of osteoporosis is usually based on the World Health Organizations (WHO) diagnostic criteria and BMD measurement using dual energy X-ray absorptiometry (DEXA) which is an integral part of this process.[13] Dual energy X-ray absorptiometry is the standard diagnosis method to osteoporosis and follow-up of the effectiveness of treatment in patients.[14] Bone mineral density is site-specific and is best predicted at the wrist, vertebral and hip measurements.[15]

The current problem of BMD measurements by DEXA scanners is the differences in the results that may occur between concurrent measurements even if the measurements are performed on the same person and same site, assuming that the DEXA equipment is calibrated properly. Discrepancies between DEXA scanners of different manufacturers[16] and even scanners of the same manufacturer were previously documented.[17] Intrascanner and interscanner precisions are only reported in the manufacturers' manuals. These manuals propose that the intrascanner coefficient of variances of DEXA scanners is less than 0.01 g/cm^2. This proposal is, however, not proved by independent scientific studies. It is hypothezed that the intrascanner coefficient of variance even of a single DEXA scanner may be different than that of the proposed coefficient of variance by the manufacturer. The aim of this study was to evaluate the in vivo coefficient variance of a Lunar-DPX scanner in healthy adult human subjects.

Experimental

AP spine scans of the L2-L4 level of 10 healthy subjects (5 female and 5 males) were studied. A total of 100 scans (10 scans of each subject) were made using the Lunar-DPX scanner at the Middle East Technical University Medical Center, Ankara, Turkey. One scan was obtained from each subject on each day and the study was completed in 10 days. All measurements were made within the ten-day period for all subjects. The same operator, who has five years experience made the scans to prevent users' technical errors. Patient positioning was carried out using the instructions and accessories provided by the manufacturer. Densitometry and densitometric analyses were performed according to the manufacturer's instructions. The Medical Center ensured the stability of the DEXA equipment by daily and monthly calibrations ($n = 21$) using a phantom provided by the manufacturer. The national distributor and technical service of the device controlled the accuracy of the system via the daily system test, peak test, air matrix test, limit switch test, machinery step control, static counter, beam distribution percentage, phantom measurements, standard error, hardware and software at every three months. The setting of the system on the daily system test was 76 kVp and 150.0 μA. The age, sex, body weight (kg) and height (cm) of the subjects were recorded. The mode of the measurements was medium.

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Table 1. Information about the subjects

	Males (n=5)							Females (n=5)						
	NT	IÇ	FK	MM	MU	Average	St. dev.	ZK	SB	GA	KS	SA	Average	St. dev.
Age, years	41	41	36	34	36	37.6	3.2	31	39	34	33	36	34.6	3.0
Weight, kg	84	61	83	85	76	77.8	10.0	65	60	52	58	53	57.6	5.3
Height, m	1.84	1.55	1.72	1.84	1.70	1.7	0.1	1.56	1.59	1.68	1.68	1.60	1.6	0.1
BMI, kg/m^2	24.8	25.4	28.0	25.1	26.3	25.9	1.3	26.8	23.7	20.3	20.6	20.7	22.0	0.1

Inclusion criteria of the subjects

The subjects were chosen among the staff of the Middle East Technical University Medical Center willing to participate in this study. Availability for measuring their BMD every consecutive day for 10 days was the major inclusion criterion. A physician consulted 25 candidates in order to determine their health status. Subjects with a history of chronic disease lasting longer than 3 months that may affect bone metabolism (i.e., renal, hepatic, gastrointestinal, thyroid diseases) were excluded. Other exclusion criteria were history of hormone supplementation (such as estrogen or corticosteroids), pregnancy or lactation, previous low energy fracture, prolonged immobilisation (>1 month), over-exposure to irradiation of long-term (over 1 month) and usage of any medication. Nineteen subjects remained (11 men and 8 women) and among them 5 women and 5 men subjects were chosen randomly. Information on the study and possible side effects was given to the candidates and a written consent was obtained. The expected highest radiation dose for each scan was 0.02 millirem and the total exposure to radiation of a subject at the end of the study was calculated as 0.2 millirem. Information about the subjects is given in Table 1.

Body mass index (BMI) of the subjects was suspected to affect the BMD measurements in this study. Statistical analyses were, therefore, conducted to evaluate possible interference of BMI with BMD. Firstly, the subjects were divided into two sub-groups according to Body Mass Index. The cut-off point was taken as 25 (low BMI<25≤high BMI). Independent *t*-test analysis was conducted to find significant differences between the high BMI and the low BMI groups in terms of BMD. The results of the analysis revealed that there was no significant difference between these two groups ($t_{value} = 0.54$, $df = 8$, $p = 0.6$). Body mass index of the subjects had no significant effect on BMD. The second analysis was conducted to confirm this result. At this time, group of subjects was divided into two, according to their coefficient of variance. The cut off point was taken as 0.01 (low coefficient variance group<0.01≤high coefficient of variance group). The group of subjects was taken as independent variable and BMI was taken as dependent variable. The result of the *t*-test analysis showed that there was no significant difference between high and low coefficient variance groups according to BMI ($t_{value} = -2.2$, $df = 8$, $p = 0.06$). Therefore, it was concluded that the BMI of the subjects did not affect BMD measurements.

Results

Average age of females and males were 34.6±3.0 (range 31 to 39) and 37.6±3.2 (range 34 to 41), respectively. Average BMD for females and males were 1.170±0.091 g/cm^2 (range 1.055 to 1.305) and 1.272±0.115 g/cm^2 (range 1.148 to 1.427), respectively. All measured values were in the two-standard deviation range (*T* score) for that age group defined by the manufacturer. Monthly phantom measurements ($n = 21$) provided and controlled by the manufacturer were 1.243±0.008 g/cm^2 (range 1.222 to 1.257) and the coefficient of variance was 0.006 g/cm^2. The coefficient of variances of three male (0.024 g/cm^2, 0.020 g/cm^2 and 0.014 g/cm^2) and one female (0.015 g/cm^2) subjects were more than 0.01 g/cm^2 that is usually necessary to utilize the system in a clinical setting for longitudinal observations (Table 2).

Table 2. Bone mineral density (in g/cm^2) of male and female subjects

Day	Males (n=5)					Females (n=5)				
	NT	IÇ	FK	MM	MU	ZK	SB	GA	KS	SA
1	1.343	1.240	1.478	1.204	1.155	1.195	1.057	1.138	1.309	1.151
2	1.340	1.242	1.402	1.184	1.159	1.210	1.062	1.138	1.310	1.158
3	1.343	1.242	1.419	1.174	1.155	1.189	1.063	1.136	1.322	1.158
4	1.321	1.251	1.420	1.175	1.164	1.180	1.060	1.138	1.285	1.161
5	1.333	1.232	1.426	1.174	1.148	1.183	1.042	1.136	1.299	1.158
6	1.355	1.246	1.426	1.174	1.136	1.176	1.051	1.134	1.310	1.159
7	1.326	1.269	1.430	1.204	1.136	1.218	1.047	1.145	1.302	1.159
8	1.323	1.258	1.412	1.206	1.144	1.183	1.052	1.146	1.302	1.153
9	1.386	1.252	1.431	1.196	1.138	1.177	1.059	1.132	1.308	1.156
10	1.387	1.248	1.430	1.190	1.143	1.176	1.057	1.139	1.306	1.158
Average:	1.346	1.248	1.427	1.188	1.148	1.189	1.055	1.138	1.305	1.157
St. dev.	0.024	0.010	0.020	0.014	0.010	0.015	0.007	0.004	0.010	0.003
RSD:	1.8	0.8	1.4	1.1	0.9	1.2	0.6	0.4	0.7	0.3

Discussion and conclusions

Calibration, precision, accuracy and intrascanner reliability are important aspects in DEXA measurements. Although standardization for proximal femur BMD measurement was well defined,[18] such standardization for the AP spine is not present. Sources of variability that could affect accuracy or reliability of serial measurements including the operator technique for patient positioning and scan analysis (exact correspondence of the region of interest), patient variability (metabolic changes over time, disease, dietary changes, radionuclide uptake, medical treatment) and presence of external sources of radiation. The same operator carried out the present study.

The subjects were healthy individuals with no disease and no metabolic change over time was expected. A relatively high coefficient of variance may also be seen in the AP spines of elderly subjects with sclerotic facets, scoliosis, calcified aorta, spondylolisthesis, vertebral fractures and arthritic changes. Such changes were not present in the measured subjects of this study. The coefficient of variance of the instrument with the phantom was 0.006 g/cm^2 even a larger standard deviation was expected over longer periods with the same instrument. The in vivo coefficient of variances of three male and one female subjects of this study were above 1%.

We have concluded that the in vivo coefficient of variance for DEXA measurements may be higher than that of the proposed 0.01 g/cm^2 level. The level of coefficient of variance should be considered as an important aspect either in the patient follow-up procedure or during the decision of the positive or negative effect of a treatment in a clinical setting. Such information may also be valuable in addressing the reasons for differences in concurrent BMD measurements and predicting the future trends in obtaining more accurate coefficient of variance of this instrument.

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