Bone Mineral Density Assessment in Pre- and Postmenopausal Women: Comparison Between T-Scores by Heel QUS and DXA in HRPZII

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SUMMARY

This short-term study which was carried out in a small group of pre- and postmenopausal women at Hospital Raja Perempuan Zainab II (HRPZII) aims to compare between T-scores detected by heel Quantitative Ultrasound (QUS) and by Dual X-ray Absorptiometry (DXA) of the hip and spine. The prevalence of osteoporosis by heel QUS was 63.3% and up to 16.7% by DXA. Insufficient or weak agreement exists between T-score measurements by heel QUS and axial DXA. Significant correlations were found between measurements of T-scores by both methods, with r values from 0.364 to 0.91. Although some correlation was found, significant discrepancy in the frequency of osteoporosis using different methods and sites is substantial.

KEY WORDS:
T-scores, Heel QUS, DXA, BMD, Osteoporosis

INTRODUCTION

Osteoporosis is one of the major public health concerns worldwide. It is a systemic bone disease characterized by reduced mineralization and microarchitecture changes of the bone, resulting in increased bone fragility and susceptibility to fracture with considerable morbidity and mortality. The most serious consequence of osteoporosis is hip fracture, where women with hip fractures are 2 – 4 times more likely to die within 12 months of the event as compared to women of the same age without fracture in the general population [1]. One of the important factors influencing the risk of fracture is bone mineral density (BMD). Studies have shown that a decrease in the femoral BMD to one standard deviation will give rise to a two to three fold increase of fracture risk [2].

According to the World Health Organization (WHO) report, normalization of measurements of bone mineral content (BMC) and bone mineral density (BMD) can be achieved by calculating T-score, which is a gender-specific normalization using the skeletal status of young normal adults as the "gold standard". Based on the WHO criteria (3), osteoporosis is determined by T-score value of bone mineral > 2.5 SD below the mean for young healthy normal adult women (T-score < -2.5). Patients with BMD values between 1 and 2.5 SD below the mean for young adults (T-score between -1.0 and -2.5) are classified as having osteopenia.

Dual X-ray Absorptiometry (DXA) is the gold standard method for the diagnosis of osteoporosis due to its ability to measure BMD at a variety of sites [4]. With the increase in the aging population and incidence of osteoporosis, more and more new medical technologies are emerging for the use in the field of bone mineral density assessment such as single photon absorptiometry (SPA), single X-ray absorptiometry (SXA), quantitative computed tomography (QCT) and quantitative ultrasound (QUS). QUS of the peripheral bone uses imperceptible sound waves that are passed through the bone.

Although DXA has long been accepted worldwide as the method of choice for evaluating BMD, other factors (other than bone mineral density) such as elasticity and biomechanical characteristics of bone could not be assessed by DXA. QUS has the ability to assess such characteristics, and has the advantage of being more readily available, portable, cheaper as well as radiation-free; which makes it a more favourable tool for mass (community-based) screening of the high risk population [5, 6]. As majority of the calcaneum is mainly composed of trabecular bone, it has been extensively studied for the assessment of BMD. Several studies have shown that the relative risk of all fractures estimated from heel BMD measurements is similar to that from DXA measurements of the hip and lumbar spine [5-7].

However, other studies have shown questionable results and insufficient agreement between QUS and DXA [8], and that the precision of QUS is generally poor, and changes at the heel may not reflect changes at the spine or hip. Furthermore the frequency of osteoporosis has been shown to differ significantly when examined at different sites and using different machines [9].

Studies on peripheral QUS in assessing BMD in the local setting are scarce. This study was done primarily to compare between T-scores by QUS with T-scores by the gold standard DXA, to find a cut-off point of this method for osteoporosis diagnosis and to establish any other possible factors associated with calcaneal BMD in the local population.

MATERIALS AND METHODS

Subjects

A total of thirty women aged 48 to 77 years (mean 58.1 ± 7.3 years) who underwent calcaneal (heel) QUS in a local health education fair at the hospital were included in this study upon detection of abnormal T-score levels during the screening programme. Five of 30 (5/30, 16.7%) women were

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premenopausal whilst the rest (25/30, 83.3%) were in their menopausal state. These patients were then subjected to a DXA examination of the lumbar spine and hip. Written consent was obtained from each patient prior to the examination. Table I summarizes the demographic characteristics.

Measurements
Calcaneal QUS was evaluated with a Sahara clinical bone sonometer (Hologic). Each subject was seated with the right foot positioned and secured in the Sahara system using a positioning aide. A pair of silicone rubber pads were secured and brought into contact with both sides of the foot by means of a motorized caliper mechanism. Using Sahara ultrasound coupling gel, each silicone pad was acoustically coupled to the heel and to a sound transducer. Upon transmission of ultrasound waves (0.6 MHz) through the calcaneus by one of the sound transducer, the waves are received by the opposite transducer. The output from the sonometer is expressed as an estimate of the BMD as a T-score.

DXA (Hologic, Discovery W) was used to measure T-scores for lumbar spine and proximal femur. In the lumbar spine, the T-score was calculated as an average of bone mineral density in L1 – L4 whereas for the proximal femur, bone mineral densities were calculated from different sites (femoral neck, intertrochanteric area and Ward's area). Total T-score of the proximal femur was calculated as an average value of bone mineral density for the femur sites.

All subjects had their weight (kilograms) and height (meters) measured and the body mass index (BMI) calculated as follows: weight/ (height)^2. A questionnaire regarding the patient's medical, surgical and drug history and other relevant information such as duration of menopause, family history of osteoporosis, previous history of hysterectomy, drug history for calcium, steroids, or hormone replacement therapy, consumption of caffeine, gaseous drinks, exercise and smoking status were filled in by each patient and registered.

Statistical Analyses
Statistical analysis was done using SPSS software for Windows version 15.0. The socio-demographic data was analyzed using descriptive statistics. Events and non-events were defined by T-scores of DXA (events defined as "osteoporosis", non-events defined as "normal or osteopenia"). The agreement between T-scores from QUS and DXA at different sites were done using Kappa Statistics. Spearman's nonparametric correlation test was performed for correlation tests. When the variables are numerical, Pearson's test was used. Chi-square test and linear regression were used to test for relationship and statistical analyses. For all the tests, a p value of less than 0.05 was taken as significant. Results were expressed as mean ± standard deviation (SD).

RESULTS

Out of the 30 women, none had any history of hysterectomy or was on hormone replacement therapy. A regular drug history was observed only in 2 women (6.7%), who were on steroids therapy. Seven (23%) women were on calcium supplement prior to the study. Caffeinated and gaseous drinks consumption were present in 17 (56.7%) and 3 (10%) subjects respectively. A family history of osteoporosis was present in 7 (23.3%) women. Only one person (3.3%) admitted to smoking, whereas 11 (36.7%) women practiced regular exercise.

According to the WHO definitions, osteoporosis was found in 6.7 – 16.7% of cases with DXA method (16.7% in L1 – L4 spine, and 6.7% each in femoral neck and total hip/ femur). Using calcaneal US, the prevalence of osteoporosis was found to be 63.3% with the average T-score of -2.52 [95% confidence interval (-2.76, -2.78)] (Table II). Kappa agreement between the two modalities in detecting osteoporosis ranges from 0.079 to 0.208 (Table III). There was a correlation found between T-score measurements of the spine and the femoral neck, between the spine and total hip, and between the femoral neck and total hip. Osteoporotic diagnosis by heel QUS did not correlate absolutely with those of DXA. T-scores in each measurement correlated with each other at r from 0.36 to 0.91, with the highest values when in DXA (Table IV). Using the ROC curve for defining the cut-off point of QUS T-score for osteoporosis diagnosis, 95% CI of area under curve for diagnosis of osteoporosis in neck and total hip contained diagonal line ($p>0.05$ for both), so further analysis on the cut-off were not done. No significant correlation or relationship was found between heel QUS and all other parameters. As such, further statistical analysis with linear regression test was not carried out. For DXA Spine, Neck and Total Hip, significant correlations and relationships were found for age, duration of menopause, weight and smoking respectively (Table V).

DISCUSSION

For the past few decades, ultrasound densitometry has gained much attention and popularity in the assessment of bone mineral density and osteoporosis, mainly due to its low cost, radiation-free and easy availability as compared to the more expensive and less widely available DXA. Studies on the role of QUS in assessing osteoporosis have shown variable results. While some data suggests that heel QUS may have a role in screening osteoporosis [5-7, 10], other studies did not seem to find significant agreement between these two methods, with relatively poor precision [8, 9].

Based on previous reports, the prevalence of osteoporosis (T-score ≤ -2.5) by DXA was 55%, and the same threshold for QUS yielded a lower prevalence of osteoporosis (10%) (11). On the contrary, this study had shown a lower prevalence rate of osteoporosis by DXA method as compared to heel QUS (16.7% vs. 63.3%). This is most likely due to the small sample size as well as the highly selective patient selection, where all the patients who underwent DXA had T-score values less than -1.5 (osteopenic or osteoporotic) and none had absolutely normal T-score by heel QUS.

In assessing the agreement between different methods and sites, a recent study by Larijani et al. on heel QUS showed insufficient agreement of 0.317 for DXA spine and 0.036-0.068 for femoral regions [8]. This study has shown comparable results where the agreement (Kappa Score) between heel QUS

Table I: Descriptive statistics on demographic data

Variables	Mean	± Standard Deviation (SD)
Age in years	58.1	7.3
Age of Menopause	52.2	3.0
Duration of Menopause	7.6	7.3
Height in meters	1.52	0.08
Weight in kg	60.82	12.3
BMI (kg/m^2)	26.5	5.2

Table II: Prevalence of osteoporosis in different regions with different methods

Regions	N (%)	Mean T-score ± SD	95% Confidence Interval (CI)
DXA			
Spine (L1 – L4)	5 (16.7)	-1.25 ± 1.28	-1.73, -0.78
Neck	2 (6.7)	-1.18 ± 1.05	-1.58, -0.79
Total Hip/ Femur	2 (6.7)	-0.44 ± 1.05	-0.85, -0.02
QUS Calcaneus	19 (63.3)	-2.52 ± 0.65	-2.76, -2.78

Table III: Agreement (Kappa) between Calcaneal QUS and DXA at different sites

Kappa	Spine T-Score	Neck T-score	Total Hip T-score
Heel QUS	0.208	0.079	0.079

Table IV: Correlations of T-score measurements between Heel QUS and DXA

	DXA Spine		DXA Neck		DXA Total Hip	
	r	p	r	p	r	p
Heel QUS	0.39	0.03	0.38	0.04	0.36	0.05
DXA Spine		0.76	0.00	0.80	0.00	
DXA Neck	0.76	0.00		0.91	0.00	

Table V: Correlation between QUS, DXA and demographic data/ risk factors

	Heel QUS		DXA Spine		DXA Neck & Total Hip	
Variables	r	p	r	p	r	p
Age in years	0.20	0.30	0.64	0.00	0.69	0.00
Age of Menopause	0.01	0.95	-0.16	0.44	0.29	0.17
Duration of Menopause	0.20	0.33	0.67	0.00	0.57	0.00
Menopausal State	0.03	0.87	0.20	0.29	0.12	0.53
Height meters	-0.16	0.40	-0.31	0.10	-0.32	0.05
Weight in kg	-0.18	0.35	-0.41	0.03	-0.43	0.02
BMI (kg/m2)	-0.09	0.63	-0.29	0.12	-0.32	0.09
Caffeinated Drink	0.17	0.36	0.21	0.26	0.23	0.21
Gaseous Drink	0.23	0.90	-0.15	0.43	-0.09	0.64
Steroids	0.20	0.28	-0.12	0.53	-0.07	0.71
Calcium Supplement	-0.23	0.21	-0.04	0.85	-0.15	0.44
Exercise	0.15	0.43	0.03	0.87	-0.20	0.28
Smoking	0.14	0.46	0.42	0.02	0.70	0.00
Family History of Osteoporosis	-0.23	0.21	-0.04	0.85	-0.15	0.44

and DXA Spine was 0.208, and 0.79 for DXA femur; indicating only slight agreement. Similarly, previous studies have shown that the correlations between these two methods were a little beyond the critical ones. In a recent study, the T-score in each measurement correlated with each other at r from 0.453 to 0.905, with the highest values when in DXA (9). In this study, almost similar results were obtained, where the highest correlation was found between methods by DXA (0.76 – 0.91) whilst heel QUS and DXA at various sites correlated at r from 0.26 to 0.39 only.

The sensitivity and specificity of heel QUS in diagnosing osteoporosis varies from 78% to 87.5% depending on the site of the DXA [8]. Another study showed that QUS can conclusively confirm the presence of osteoporosis in only about one-fifth of cases with 61.1% sensitivity and 65.3% specificity for the best QUS parameter [11]. In this study, analysis on the sensitivity and specificity of heel QUS were not done as the ROC curve generated to determine the cut-off point was not statistically significant for all DXA methods.

In evaluating the possible association between calcaneal bone density by QUS and demographic characteristics and other risk factors, a previous study has shown that age and consumption of cheese were found to have an effect on calcaneal bone density whereas other factors such as weight,

BMI did not have any significant effect [12]. However, in this study, no significant relationship was found between QUS T-scores and any of the assessed parameters. This can be explained by the very small sample size used and biasness of patient selection.

In conclusion, comparison between heel QUS and DXA to diagnose osteoporosis revealed only slight or weak agreement. Although some correlation was found between both methods, the frequency of osteoporosis diagnosis differs significantly, depending on the method and site examined. This paper supports other previous observations on the limited role of QUS in the diagnosis of osteoporosis. Further evaluation on a larger scale and proper patient selection is needed to work out other possible diagnostic criteria for heel ultrasound.

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