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Utility of Heel Dual Energy X ray Absorptiometry in Diagnosing Osteoporosis

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Abstract

While peripheral dual energy X-ray absorptiometry (DXA) measurements have been found to predict fractures in population studies of Caucasians, little is known about their utility in other races and in patients with higher fracture risk. In a cross-sectional study of 874 women referred for bone mineral density (BMD) testing, we examined the utility of heel BMD in African-American (AA) compared to Caucasian (CA) women and in women using glucocorticoids. The ability of heel T-score to predict central osteoporosis was similar in AA and CA women (OR per 1 unit decrease in T-score of 2.79 [CI 2.16–3.60] and 3.15 [CI 2.53–3.92], respectively). The association between heel T-score and prevalent vertebral fractures was also similar in the two races (OR 1.46 [CI 1.15–1.85] in AA and 1.42 [CI 1.16–1.74] in CA). In women using glucocorticoids heel T-score was better than central T-score in predicting presence of vertebral fractures (OR 1.38 [CI 1.03–1.85] and 1.22 [CI 0.86–1.73], respectively). We conclude that in a multiracial referral population heel BMD predicts central osteoporosis and prevalent vertebral fractures equally well in AA as in CA women and may be better than central BMD in assessing fragility in glucocorticoid users.

INTRODUCTION

Bone mineral density (BMD) measurements at the lumbar spine and proximal femur are considered the gold standard for assessing fracture risk, diagnosing osteoporosis according to the criteria set by the World Health Organization, and selecting patients for therapy. Although measuring BMD using dual energy X-ray absorptiometry (DXA) has been associated with lower hip fracture rates (1), as few as 32% of patients with indications for osteoporosis screening undergo BMD testing (2). Even in high-risk populations, average BMD testing rates were 8% in patients with fractures and 9% in patients using oral glucocorticoids (3–5). Access to DXA scanners has been associated with increased likelihood of BMD ordering and testing (6–8). However, availability of central densitometers remains limited in many parts of the world, and in societies which have access reimbursement for central DXA testing has decreased, resulting in fewer physician offices providing this service (9). Thus, peripheral DXA scanners, which are cheaper, smaller, and

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more portable allowing for implementation in primary care settings, may serve as an attractive alternative to central DXA (10).

Several studies have shown that peripheral BMD measurements are useful for assessing fracture risk (11–15), selecting patients who should have BMD measured at central sites, and deciding which patients should be offered pharmacologic therapy for osteoporosis (16–19). Most of these studies were population-based and included predominantly Caucasians. It is not clear whether the same conclusions would apply to African-American patients or to patients who have higher fracture risk such as those referred for bone densitometry or patients taking glucocorticoids. To address these questions we studied a convenience sample of a multiracial population of patients referred for BMD measurement. We examined the association of anthropologic variables with heel and central BMD, the utility of heel BMD in diagnosing central osteoporosis in African-American (AA) as compared to Caucasian (CA) women, and the utility of heel BMD in evaluating bone fragility in patients with history of glucocorticoid use.

METHODOLOGY

Subjects

1075 ambulatory subjects were recruited over 7 years. This was a convenience sample; subjects were recruited when they presented for BMD measurement ordered for routine medical care. The densitometry facility performs all BMD testing at the University of Chicago; patients are referred by University of Chicago physicians and include primary and tertiary care patients. There were no specific inclusion criteria; patients were recruited if study personnel were present, the densitometry technologist had time to perform additional images, and the patients agreed to participate. The study was approved by the Institutional Review Board at University of Chicago, and all participants provided informed consent.

Measurements

Each subject completed a questionnaire which included information on personal and family history of fractures and their circumstances, young adult height, weight, medical history, medication use, and personal habits such as tobacco use, alcohol consumption, calcium intake, and activity level. Height and weight were measured using standard clinic equipment. The 10-year probability of having a major osteoporotic fracture was calculated using the web-based FRAX calculator (www.shef.ac.uk/FRAX).

BMD measurements of the lumbar spine and proximal femur and Vertebral Fracture Assessment (VFA) were obtained by two technologists certified by the International Society for Clinical Densitometry (ISCD) using the Prodigy densitometer (GE Medical Systems, Madison, Wisconsin). The precisions of BMD measurements were 1% for the lumbar spine and total hip and 1.5% for the femoral neck. NHANES III data was used to derive T-scores (gender-adjusted Caucasian norms) and Z-scores (age-, gender-, race-, and weight-adjusted norms). As recommended by ISCD (20), BMD of L1–L4 with elimination of artifact-laden vertebrae was used to derive lumbar spine T-score, and the lower BMD value was used for femoral neck and total hip T-scores. Heel BMD was obtained in duplicate using PIXI (Peripheral Instantaneous X-Ray Imager; GE Medical Systems, Madison, Wisconsin) with the mean of two measurements used for analyses. The precision of the heel BMD measurement was 1.8%.

All VFA images were evaluated by one ISCD-trained clinician (TJV) using the Genant semi-quantitative (SQ) approach (21), as recommended by ISCD (22, 23). Fractures were assigned a grade: grade 1 fracture represents a 20–25% reduction in vertebral height, grade 2 a 26–40% reduction, and grade 3 a >40% reduction. Only fractures with grade 2 or higher

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were considered for analyses as grade 1 fractures may be due to non-fracture deformities (24) and are not predictive of future fractures (25).

Definition of variables

Race was provided by the patient. Categories included AA, CA, Asian, and Hispanic. Vertebral fracture was a binary variable (yes or no) and referred to having at least a grade 2 fracture on VFA. Peripheral fracture was a binary variable and referred to a non-vertebral fragility fracture that occurred after the age of 50. Fragility fracture includes either vertebral fracture and/or peripheral fracture. Glucocorticoid use was a binary variable and defined as at least 5 mg/day of systemic prednisone use or its equivalent for at least 3 months (26). Osteoporosis treatment was defined as the patient receiving any of the following medications: estrogen (excluding vaginal preparations), raloxifene, tamoxifen, bisphosphonates, calcitonin, or teriparatide.

Statistical analysis

Differences between subgroups of patients were examined using t-tests for continuous and chi-square tests for categorical variables. The correlations between heel BMD and anthropometric variables were examined using Pearson correlation. The association between heel and central T-score was modeled using linear regression with heel T-score as the outcome, while the association of fractures and heel or central T-score was modeled using logistic regression with presence of fractures as a binary outcome. All analyses were performed using STATA 11 statistical software package.

RESULTS

Clinical characteristics

Among the 1075 subjects who consented to the study, results from 976 were available for analyses. Subjects were excluded if heel scans were not obtained, the positioning of the heel was poor, or the heel was too large to fit in the PIXI positioner. The clinical characteristics of the subjects included in the analyses are shown in Table 1. All mean Z-scores were significantly lower than zero ($p<0.0001$), indicating that this study population had lower BMD than the general population. Compared to females, male subjects had lower BMD Z-scores, higher prevalence of vertebral fractures, and higher prevalence of glucocorticoid use. In both genders heel T-scores were significantly higher than proximal femur sites ($p<0.0001$) but not higher than the spine, where degenerative changes likely artifactually increase BMD.

Relationship of BMD to anthropometric characteristics

The correlations between anthropometric variables and BMD of the heel and central sites are shown in Table 2. Heel BMD correlated significantly with BMD of the central sites, particularly of the total hip. Correlation between hip and heel BMD was stronger than between hip and lumbar spine BMD. There was no significant correlation between heel BMD and age for subjects under 50 years of age ($p=0.7$) but a significant negative correlation for those over 50 years of age ($p<0.0001$) (Figure 1). Heel BMD was positively correlated with weight across the continuum of body weight ($p<0.0001$) (Figure 2). Both heel and central BMD T-scores were higher in AA than in CA, even after controlling for age and weight ($p<0.001$).

We examined the association between anthropometric variables and BMD using multivariate regression analysis with age, weight, and race as predictors and heel or central T-score as the outcome (Table 3). This analysis was restricted to AA and CA subjects due to small numbers of subjects in other racial groups. In both women and men, anthropometric

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variables explained a greater proportion of the variability in the heel than central T-scores (R^2 of 35% vs. 24% for women, 29% vs. 21% for men). In women, heel and central BMD was associated with age, weight, and race with a T-score average of 0.4 units higher in AA than CA women, even when controlled for age and weight. In men, the association between BMD and either age or race was not statistically significant.

Because of small number of male subjects in our study, further analyses described below were performed in women. Among the 874 female subjects, 520 were CA and 300 were AA; 54 women of other races were excluded from the analyses of effect of race on utility of heel BMD due to small numbers.

Utility of heel BMD in African-American as compared to Caucasian women

The clinical characteristics of these subjects are shown in Table 4. CA patients were significantly younger, had lower weight and BMI, were less likely to use glucocorticoids, had lower T scores at all sites, had higher FRAX-derived 10-year probability of sustaining a major osteoporotic fracture, and accordingly more likely to be on treatment for osteoporosis, compared to AA patients. Although CA patients had significantly more peripheral fractures, prevalence of vertebral fractures was 18% for both races.

Heel T-score predicting osteoporosis at central site(s)—There was no significant difference between AA and CA women in the slope of the linear regressions relating heel T-scores to central T-scores (Figure 3). However, the intercept was higher in AA, indicating that relative to central T-score the average heel T-score was higher in AA by approximately 0.5 units (p=0.035). However, this difference disappeared when adjusted for weight. These relationships are described by the equations below with 95% confidence intervals given in parenthesis:

$$\mathbf{AA}:\text{Heel T}-\text{score}=\mathbf{0.88}(0.78-1.00)^{*}\text{Central T}-\text{score}+\mathbf{1.22}(1.0-1.4),\mathrm{R}^2=0.46$$
$$\mathbf{CA}:\text{Heel T}-\text{score}=\mathbf{0.75}(0.67-0.82)^{*}\text{Central T}-\text{score}+\mathbf{0.73}(0.5-0.9),\mathrm{R}^2=0.41$$

The ability of heel T-score to predict osteoporosis at central sites in the two racial groups was examined using logistic regression and sensitivity/specificity analyses. Heel T-score was found to predict central osteoporosis in both CA and AA women with similar areas under the receiver operating characteristic curves (AUCs) (Table 5). The odds of having osteoporosis at a central site expressed per 1 unit decrease in the heel T-score were slightly but not significantly higher in the CA than in AA women. In both races, the best ratio of sensitivity/specificity was at a heel T-score of −1 (Table 6). At lower levels of heel T-score (e.g. −2.2), the specificity was higher but the sensitivity was too low. Conversely, using a heel T-score of “0” as a cut-off improved the sensitivity to 92–95% but resulted in poor specificity.

Association between heel T-score and fragility fractures—We compared the association of heel or central T-score with presence of vertebral fractures on VFA, history of non-vertebral fractures, and any fragility fractures in CA and AA women (Table 7). Both heel and central T-scores were predictive of prevalent vertebral fractures with central T-score being the stronger predictor in both races. In CA women only the odds ratio was much higher for central than heel T-scores, resulting in significantly greater AUC for the central T-score (p=0.014). In contrast, there was no significant difference between the AUCs for central and peripheral T-scores in AA women. Additionally, while the odds ratio of having vertebral fractures based on central T-scores was higher in CA than in AA women, the odds ratios based on heel T-scores were similar in the two races.

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In both races central but not heel T-scores were significantly associated with a history of non-vertebral fractures. The significant association between heel T-score and any fragility fracture was likely driven by the association between heel T-score and vertebral fractures.

Utility of heel BMD in patients with history of glucocorticoid use

Heel T-score predicting vertebral fractures—134 women with history of glucocorticoid use had higher prevalence of vertebral fractures compared to 637 non-users (28% vs. 16%, p=0.001); the remainder of the women did not have a VFA performed or it was uninterpretable. Relationship between heel and central T-scores, described by the following equations, was not significantly different in glucocorticoid users and non-users:

$$\text{Glucocorticoid users: Heel T}-\text{score} = \mathbf{0.78}^{*}\text{Central T}-\text{score} + \mathbf{1.1}, \mathrm{R}^2 = 0.45$$
$$\text{Non}-\text{glucocorticoid users: Heel T}-\text{score} = \mathbf{0.83}^{*}\text{Central T}-\text{score} + \mathbf{1.0}, \mathrm{R}^2 = 0.50$$

In women not using glucocorticoids, both central and heel T-scores predicted the presence of prevalent vertebral fractures with central T-score being the stronger predictor (Table 8) and having a significantly greater AUC than heel T-score (p=0.005). In glucocorticoid users, only the heel T-score was significantly but weakly associated with presence of vertebral fractures, and AUC did not differ significantly from that of central T-score (p=0.1). The difference in the predictive value of heel BMD between glucocorticoid users and non-users is smaller than for central BMD.

DISCUSSION

Prior investigation has shown that peripheral DXA devices can predict fracture risk in population studies (11–15). In the National Osteoporosis Risk Assessment, heel BMD was associated with increased risk of fractures at the hip, spine, wrist, and rib (11). Furthermore, AUCs for heel and hip DXA in the prediction of hip fractures have been found to be similar and heel DXA outperformed spine DXA (12). However, most studies on heel DXA have enrolled healthy volunteers primarily of European descent. We examined the utility of heel BMD in a multiracial population of patients referred for bone densitometry, a population that would be expected to be more osteoporotic and have a higher fracture risk than the general population. We specifically wanted to determine whether heel BMD performs as well in AA as in CA patients and whether it is useful in patients using glucocorticoids.

We found that the relationship between heel and central BMD did not differ between the two races and that the ability of heel T-score to predict presence of vertebral fractures was as good in AA as in CA women. Furthermore, the heel T-score value that had the best sensitivity and specificity for detecting presence of osteoporosis at central sites was similar in the two races. Based on these findings we conclude that heel BMD is at least as useful in AA patients, in whom the utility of this methodology has not been previously examined, as it is in Caucasians.

The United Kingdom National Osteoporosis Society recommends the use of peripheral DXA as a screening tool to identify patients at high risk (who may be treated based on low peripheral BMD), medium risk (who would be referred for central DXA testing), and low risk (who would not need further testing) (27). The recommended approach is to define device-specific upper thresholds with 90% sensitivity and lower thresholds with 90% specificity for identifying patients with central osteoporosis. In prior studies in Caucasian women, 40–50% of patients did not require referral for central DXA testing (16–19).

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The utility of having upper and lower thresholds is not clearly accepted as Harrison and Adams have shown that although fewer patients require referral for central DXA testing the overall cost may be three times higher than utilizing central DXA alone (19). This is in part due to treating non-osteoporotic women with low peripheral BMD, resulting in increased cost of drug therapy and the risk of undesired side effects. The authors suggest that even these women should have central DXA to confirm presence of osteoporosis prior to commitment to pharmacologic therapy, and this would result in a 20% cost savings compared to use of central DXA alone (19). Furthermore, there is a lack of published data regarding use of peripheral DXA for monitoring response to treatment. Thus, it may be best to use peripheral DXA to reassure the women who have high heel BMD and lack risk factors for fractures and refer the medium and high risk patients for central DXA. Our results are consistent with this notion – although the best sensitivity/specificity ratio is afforded with a heel T-score of −1.0, using this cut-off value would fail to identify 20–25% of women who have osteoporosis at central sites. A higher T-score value of 0.0 would be a better solution, as it would primarily serve to assure women above this cut-off with a negative predictive value of 86–90%.

Patients treated with glucocorticoids are known to have increased bone fragility that is not entirely explained by a decrease in BMD (28). In accordance, we found no association between vertebral fractures and central BMD in glucocorticoid users. We did find a significant albeit weak association between vertebral fractures and heel BMD in glucocorticoid users, suggesting that heel BMD may be superior to central BMD in identifying patients with glucocorticoid-induced osteoporosis. This may be due to greater glucocorticoid-induced bone loss at the calcaneus, which has higher trabecular bone content compared to the proximal femur. Lack of a significant association between vertebral fractures and BMD of the lumbar spine, a site also rich in trabecular bone, is likely due to degenerative changes of the spine.

There are some limitations to our study. We used a convenience sample, and our subject population included an unknown percentage of tertiary care patients. This limits the applicability of our findings to primary care patients, a population which would more likely benefit from increased accessibility of peripheral DXA at physician offices. The number of men in our study was too small to examine for racial differences. Our analyses of racial differences were also limited to AA and CA subjects due to small numbers of Asian and Hispanic subjects. Also, our analyses did not take into account glucocorticoid dose or cumulative exposure. However, we were still able to find a significant association between heel BMD and glucocorticoid use. Because this was a cross-sectional study, we were not able to assess the utility of heel BMD in predicting incident fractures. Finally, the PIXI instrument that was used in our study is no longer commercially produced. However, many countries around the world still use refurbished instruments, and our findings add useful information about the utility of heel BMD testing in general.

Our study also has significant strengths. This is the first study to compare the use of peripheral DXA in AA and CA women and in glucocorticoid users and non-users. Also, our conclusions are likely to be applicable to other densitometry populations as we examined the use of peripheral DXA in patients referred for densitometry rather than the general population. Further studies are needed to determine how to best utilize peripheral skeletal measurements in a cost-effective manner.

In summary, our study indicates that in a multiracial referral population heel BMD correlates significantly with hip BMD and that the ability of heel BMD to predict central osteoporosis as well as presence of vertebral fractures is at least as good in AA as in CA

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women. Furthermore, heel BMD may be more useful than central BMD for identifying patients with glucocorticoid-induced osteoporosis.

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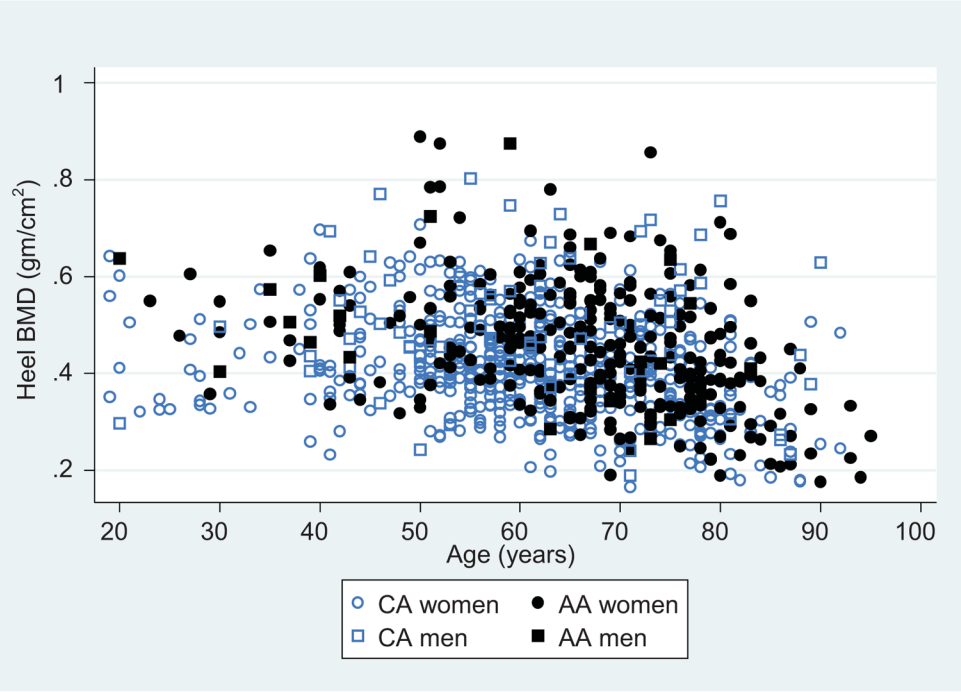

Figure 1.
Relationship of heel BMD to age in African-American (AA) and Caucasian (CA) subjects.

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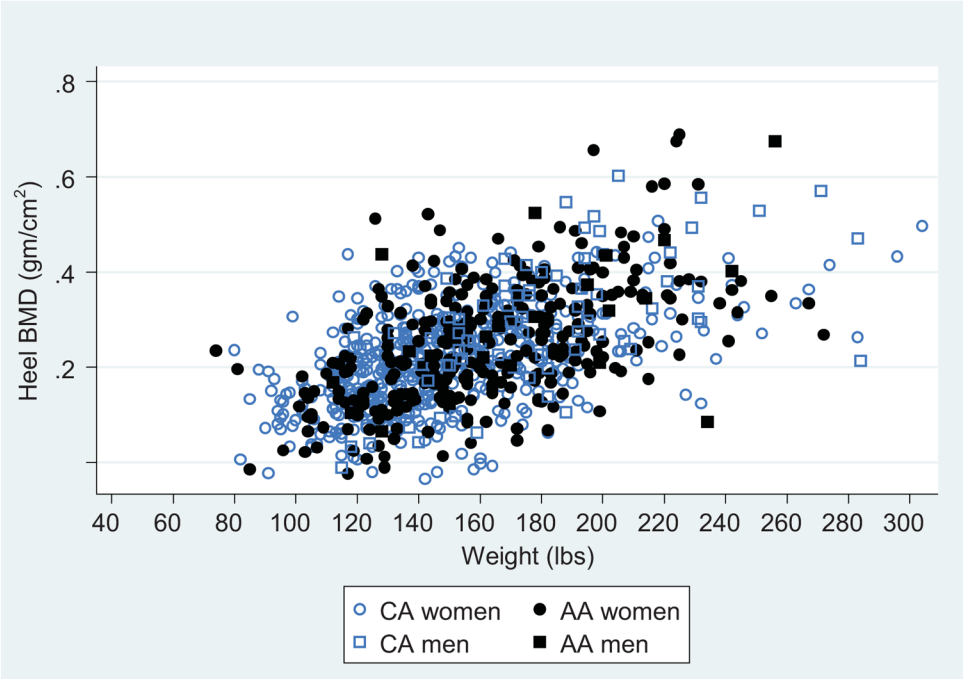

Figure 2.
Relationship of heel BMD to weight in AA and CA subjects.

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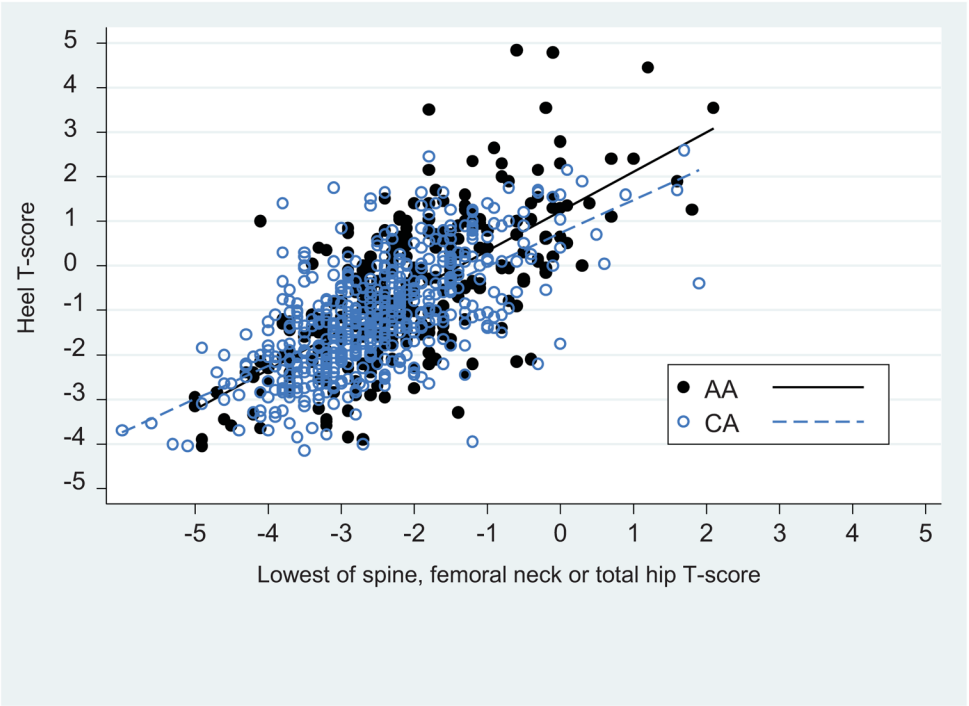

Figure 3.
Relationship between heel and central T-scores in AA and CA subjects.

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Table 1

Clinical characteristics of the study subjects given as mean±SD for continuous variables and counts (%) for categorical variables

	All subjects (976)	Females (874)	Males (102)
Age (years)	62.7±13.9	63.0±13.7	60.5±15.5
Race			
African-American	322 (33%)	300 (34%)	22 (22%)
Asian	38 (4%)	35 (4%)	3 (3%)
Caucasian	594(61%)	520 (60%)	74 (73%)
Hispanic	22 (2%)	19 (2%)	3 (3%)
Weight (lbs)[a]	154±37	151±36	177±37
Body Mass Index	27±6	27±6	27±5
Vertebral Fractures[a,b]	168 (19%)	139 (18%)	29 (38%)
Peripheral Fractures	249 (26%)	229 (26%)	20 (20%)
Fragility Fractures	353 (36%)	308 (35%)	45 (44%)
Glucocorticoid use[a]	186 (19%)	149 (17%)	37 (36%)
BMD T-score			
Lumbar spine	−1.6±1.5	−1.6±1.5	−1.6±1.6
Femoral neck	−2.1±1.1	− 2.1±1.2	−2.0±1.1
Total hip	−1.6±1.2	−1.5±1.3	−1.8±1.1
Lowest hip or spine	−2.3±1.2	−2.3±1.2	−2.4±1.1
Heel[a]	−1.0±1.4	−1.0±1.4	−1.3±1.5
BMD Z-score			
Lumbar spine[a]	−0.8±1.4	−0.7±1.4	−1.4±1.6
Femoral neck[a]	−1.0±1.0	−0.9±1.0	−1.4±1.0
Total hip[a]	−0.9±1.1	−0.9±1.1	−1.4±1.0
Lowest hip or spine[a]	−1.4±1.1	−1.4±1.1	−1.9±1.1
Heel[a]	−0.6±1.4	−0.6±1.3	−1.1±1.6
FRAX (%)[a,c]	10.2 ± 7.8	10.4 ± 8.1	7.9 ± 4.9
Osteoporosis Treatment	355 (36%)	322 (36%)	33 (32%)

[a] $p<0.05$ for gender differences.

[b] Vertebral fracture status was not available in 112 subjects who had uninterpretable or missing Vertebral Fracture Assessment.

[c] FRAX is reported as 10-year probability of sustaining a major osteoporotic fracture.

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Table 2

Correlation coefficients relating anthropometric variables to BMD of the heel, femoral neck (FN), total hip (TH) and lumbar spine (LS)

	Age	Weight	Height	Heel	FN	TH
Weight	−0.096					
Height	−0.269	0.393				
Heel	−0.288	0.543	0.330			
FN	−0.350	0.393	0.288	0.685		
TH	−0.306	0.428	0.225	0.707	0.913	
LS	−0.195	0.357	0.232	0.620	0.646	0.640

$p<0.0001$ for all correlations except age and weight ($p=0.003$).

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Table 3

Association of heel or central T-score[a] with anthropometric variables derived from multivariate linear regression analysis

	FEMALES (818)			MALES (96)			
	Predictor	**Coefficient (95% CI)**	**p-value**	**Predictor**	**Coefficient (95% CI)**	**p-value**	
Heel	**Age/year**	−0.03 (−0.04, −0.02)	<0.001	**Age/year**	−0.01 (−0.02, 0.01)	0.46	**Heel**
R^2=0.35	**Weight/lb**	0.02 (0.02, 0.02)	<0.001	**Weight/lb**	0.02 (0.02, 0.03)	<0.001	**R^2=0.29**
p<0.0001	**Race (AA vs. CA)**	0.37 (0.20, 0.54)	<0.001	**Race (AA vs. CA)**	0.05 (−0.59, 0.69)	0.87	**p<0.0001**
Central	**Age/year**	−0.03 (−0.03, −0.02)	<0.001	**Age/year**	−0.01 (−0.02, 0.01)	0.35	**Central**
R^2=0.24	**Weight/lb**	0.01 (0.01, 0.01)	<0.001	**Weight/lb**	0.01 (0.01, 0.02)	<0.001	**R^2=0.21**
p<0.0001	**Race (AA vs. CA)**	0.41 (0.26, 0.56)	<0.001	**Race (AA vs. CA)**	0.24 (−0.24, 0.71)	0.33	**p<0.0001**

[a] **Central T-score** is the lowest of hip (femoral neck or total hip) and spine T-scores.

R^2 is the regression coefficient squared (coefficient of determination); **95%CI** is the 95% confidence interval.

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Table 4

Clinical characteristics of female study subjects given as mean±SD for continuous variables and counts (%) for categorical variables

	All females (874)	Caucasian (520)	African-American (300)
Age (years)[a]	63.0±13.7	61.3±13.3	66.8±13.0
Weight (lbs) [a]	151±36	147±34	162±35
Body Mass Index [a]	27±6	26±6	29±6
Vertebral Fractures	139 (18%)	85 (18%)	46 (18%)
Peripheral Fractures [a]	229 (26%)	152 (29%)	62 (21%)
Fragility Fractures	308 (35%)	196 (38%)	93 (31%)
Glucocorticoid use [b]	149 (17%)	80 (15%)	63 (21%)
BMD T-score			
Lumbar spine [a]	−1.6±1.5	−1.8±1.4	−1.3±1.5
Femoral neck [a]	− 1.9±1.2	− 2.2±1.0	−1.9±1.2
Total hip [a]	−1.4±1.3	−1.7±1.1	−1.3±1.3
Lowest hip or spine [a]	−2.3±1.2	−2.5±1.1	−2.1±1.2
Heel [a]	−1.0±1.4	−1.1±1.3	−0.6±1.6
BMD Z-score			
Lumbar spine	−0.7±1.4	−0.7±1.4	−0.9±1.4
Femoral neck [a]	−0.8±1.0	−0.8±0.9	−1.3±1.1
Total hip [a]	−0.7±1.4	−0.8±1.0	−1.2±1.2
Lowest hip or spine [a]	−1.4±1.1	−1.2±1.0	−1.7±1.1
Heel	−0.6±1.3	−0.6±1.2	−0.6±1.5
FRAX (%)[a]	10.4 ± 8.1	13.1±8.7	6.2±4.1
Osteoporosis Treatment [a]	322 (36%)	227 (44%)	71 (24%)

[a] $p<0.01$,

[b] $p<0.05$ for racial differences.

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Table 5

Ability of heel T-score to predict presence of central osteoporosis in Caucasian (CA) and African-American (AA) women

Race	Predictor	OR (95% CI)	p-value	AUC
CA	Heel T-score	3.15 (2.53, 3.92)	<0.001	0.812
AA	Heel T-score	2.79 (2.16, 3.60)	<0.001	0.817

OR is the odds ratio of having osteoporosis at a central site expressed per 1 unit decrease in heel T-score; **95% CI** is the 95% confidence interval; **AUC** is the area under receiver operating characteristic curve.

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Table 6

Predicting osteoporosis (T-score≤−2.5) at central sites using different heel T-score threshold values

	Caucasian women			African-American women		
Heel T-score ≤	**−1**	**−2.2**	**0**	**−1**	**−2.2**	**0**
Sensitivity	**79.5%** (74.3, 84.1)	**34.2%** (28.6, 40.1)	**95.3%** (92.1, 97.5)	**73.9%** (65.1, 81.6)	**30.3%** (22.2, 39.3)	**91.6%** (85.1, 95.9)
Specificity	**66.5%** (60.2, 72.4)	**94.2%** (90.5, 96.8)	**35.5%** (29.5, 41.9)	**73.5%** (66.4, 79.8)	**95.6%** (91.5, 98.1)	**47%** (39.5, 54.5)
AUC	**0.73** (0.69, 0.77)	**0.64** (0.61, 0.67)	**0.65** (0.62, 0.69)	**0.74** (0.69, 0.79)	**0.63** (0.59, 0.67)	**0.69** (0.65, 0.74)
PPV	**73.2%** (67.8, 78.1)	**87.2%** (79.4, 92.8)	**62.9%** (58.1, 67.6)	**64.7%** (56.1, 72.7)	**81.8%** (67.3, 91.8)	**53.2%** (46.1, 60.2)
NPV	**73.9%** (67.5, 79.6)	**55.5%** (50.5, 60.3)	**86.9%** (78.6, 92.8)	**81.1%** (74.3, 86.8)	**67.6%** (61.5, 73.3)	**89.5%** (81.5, 94.8)

AUC is the area under receiver operating characteristic curve; **PPV** is the positive predictive value; **NPV** is the negative predictive value; 95% confidence interval is given in parenthesis.

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Table 7

Effect of race on association between heel BMD and prevalent vertebral fractures (A), history of non-vertebral fractures (B), and any fragility fracture (C)

Race	Predictor	OR (95% CI)	p-value	AUC (95% CI)
A				
CA	**Heel T-score**	**1.42** (1.16, 1.74)	**0.001**	**0.61** (0.54, 0.68)
	Central T-score	**1.98** (1.52, 2.59)	**<0.001**	**0.69** (0.62, 0.75)
AA	**Heel T-score**	**1.46** (1.15, 1.85)	**0.002**	**0.63** (0.54, 0.73)
	Central T-score	**1.61** (1.20, 2.16)	**0.002**	**0.64** (0.55, 0.73)
B				
CA	**Heel T-score**	**1.12** (0.96, 1.30)	**0.161**	**0.54** (0.49, 0.60)
	Central T-score	**1.48** (1.22, 1.80)	**<0.001**	**0.61** (0.56, 0.67)
AA	**Heel T-score**	**1.19** (0.99, 1.44)	**0.068**	**0.58** (0.50, 0.66)
	Central T-score	**1.60** (1.23, 2.08)	**0.001**	**0.65** (0.57, 0.72)
C				
CA	**Heel T-score**	**1.20** (1.03, 1.38)	**0.015**	**0.56** (0.51, 0.61)
	Central T-score	**1.75** (1.45, 2.13)	**<0.001**	**0.65** (0.31, 0.70)
AA	**Heel T-score**	**1.23** (1.04, 1.45)	**0.014**	**0.59** (0.51, 0.66)
	Central T-score	**1.59** (1.26, 2.00)	**<0.001**	**0.64** (0.54, 0.70)

OR is the odds ratio of having the specified fracture expressed per 1 unit decrease in T-score; **95%CI** is the 95% confidence interval; **AUC** is the area under receiver operating characteristic curve.

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Table 8

Effect of glucocorticoid (GC) use on utility of heel DXA: prediction of prevalent vertebral fractures using heel or central T-scores in 134 women with and 637 without history of glucocorticoid use.

GC use	Predictor	OR (95% CI)	p-value	AUC (95% CI)
NO (16%VFx)	**Heel T-score**	1.53 (1.28, 1.82)	<0.001	0.64 (0.58, 0.70)
	Central T-score	2.11 (1.68, 2.65)	<0.001	0.72 (0.66, 0.77)
YES (28%VFx)	**Heel T-score**	1.38 (1.03, 1.85)	0.032	0.62 (0.51, 0.74)
	Central T-score	1.22 (0.86, 1.73)	0.263	0.54 (0.42, 0.66)

OR is the odds ratio of having a prevalent VFx expressed per 1 unit decrease in T-score; **95%CI** is the 95% confidence interval; **AUC** is the area under receiver operating characteristic curve.