Clinical Utility of Calcaneal Quantitative Ultrasonometry and Thoracic Kyphosis Assessments in Identifying Vertebral Fractures in Community Settings

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ABSTRACT. *Objective.* Individuals with existing vertebral fractures may not be aware that they are at high risk of subsequent fractures. We investigated if calcaneal quantitative ultrasonometry (QUS) and assessment of thoracic kyphosis could discriminate a group of older women with prevalent vertebral fracture from those without.

Methods. One hundred four women (mean age 71.3 ± 5.8 yrs) underwent dual-energy x-ray absorptiometry (DEXA) bone mineral density (BMD; lumbar spine and hip), calcaneal QUS, and video rasterstereographic thoracic kyphosis measurements. They were dichotomized into a group with prevalent vertebral fracture (VF, n = 24) or without vertebral fracture (NVF, n = 80).

Results. Univariate variables associated with the VF group included broadband ultrasound attenuation (BUA; age-adjusted OR 1.96, 95% CI 1.12–3.42, p = 0.018); speed of sound (SOS; age-adjusted OR 2.01, 95% CI 1.09–3.70, p = 0.026); and thoracic kyphosis (age-adjusted OR 1.72, 95% CI 1.01–2.92, p = 0.049). A composite model (BUA and thoracic kyphosis) had higher area under the receiver-operating characteristic curve (AUC = 0.75) compared to lumbar spine DEXA BMD (AUC = 0.50, p = 0.0004) and total hip DEXA BMD (AUC = 0.60, p = 0.057).

Conclusion. Reduced calcaneal QUS values and greater thoracic kyphosis were found to be significantly associated with the group of women with prevalent vertebral fractures. A composite risk score (BUA and thoracic kyphosis) had better discriminatory power than the individual risk factor of (low) DEXA BMD. (First Release Jan 15 2008; J Rheumatol 2008;35:327–34)

Key Indexing Terms:
FRACTURE RISKS   OSTEOPOROSIS   QUANTITATIVE ULTRASOUND
THORACIC KYPHOSIS   VERTEBRAL FRACTURES

Low bone strength or poor bone quality and prevalent vertebral fractures may be asymptomatic and can often go undiagnosed[1,2]. Given that these factors significantly increase the risk of future osteoporotic fractures, the need for more cost-effective case-finding for individuals at high risk of fracture at an early timepoint of the disease is critical[3,4].

This is especially so as modifications to lifestyle and pharmacological interventions have been shown to reduce the risk of future fractures[3].

Although dual-energy x-ray absorptiometry (DEXA) assessment of bone mineral density (BMD) is a fundamental component of osteoporotic fracture risk assessment, proposal for its use in population screening depends on the sex and age of the population, plus the existence of risk factors for fragility fractures[3-6]. For example, the US Preventive Services Task Force (USPSTF) recommends "that women aged 65 and over be screened routinely for osteoporosis" and that this screening process begin at age 60 years for women known to be at increased risk of osteoporotic fractures[6]. The USPSTF considers that BMD measurements accurately predict the risk of fractures in the short term. With the aging population, there are concerns that unselective screening using DEXA may increase the financial burden on the healthcare system without delivering benefits commensurate with expenditure. The Australian Fracture Prevention Summit stated that a BMD measurement was "...not justified for screening a population of healthy people,

and should only be done...if the decision to treat (or not to treat) is influenced by the result of the test"[3]. There are also concerns about overreliance on this assessment, as there is evidence that a proportion of osteoporotic fractures are not identified by the conventional WHO threshold of BMD T-score < -2.5[7,8]. The consensus seems to be that if subpopulations at increased risk of fracture could be easily and economically identified, then BMD and possibly other clinic-based tests can be more justifiably applied to these groups, possibly at a younger age than would otherwise be recommended. Identification of a group with a high likelihood of subclinical vertebral fractures that should be monitored by DEXA would fit this view.

In the past decade, there has been increasing evidence to suggest the utility of calcaneal quantitative ultrasonometry (QUS) in fracture risk assessment[9-21]. However, findings from these studies are unable to conclusively support the use of QUS as a substitute for DEXA. At present, QUS is recommended to be used as a component of composite pre-screening for osteoporotic fracture risk[22-25] in some countries or in geographic areas where DEXA is not available[21].

Increased thoracic kyphosis is known to be an independent risk factor for future vertebral fractures[26-29]. It is also recognized as a potential risk factor for falling, as hyper-kyphotic women have greater postural sway[30,31]. It is therefore important to consider this fracture risk factor in older populations. To date, there are no reports on the discriminatory power of the combined use of calcaneal ultrasonometry and thoracic kyphosis assessments in identification of fracture risk.

In this cross-sectional study we investigated if a combination of QUS and thoracic kyphosis measurement was able to identify healthy, ambulant women with prevalent vertebral fractures, identified radiographically. We also aimed to compare the discriminatory power of these assessments with DEXA BMD evaluation.

MATERIALS AND METHODS

Of the 211 volunteers who responded to advertisements to participate, 104 met the inclusion criteria. These women were generally healthy and had no history of medical conditions (e.g., celiac disease, hyperthyroidism) or any neurological deficits, and were taking no medications (specifically hormone replacement therapy, thyroxin, corticosteroids for > 3 months before the study) that affected bone metabolism.

The ethics committees of The University of Western Australia, Royal Perth Hospital, and Sir Charles Gairdner Hospital approved the study. Written informed consent was obtained from all participants.

Participants underwent a series of assessments as follows.

DEXA BMD measurements. The lumbar spine (L1–L4) and the left proximal hip were scanned using a Hologic QDR1000W pencil-beam DEXA scanner (Hologic, Bedford, MA, USA).

Calcaneal quantitative ultrasound. Broadband ultrasound attenuation (BUA) and speed of sound (SOS) of the right calcaneum of each subject were assessed using the Sahara Clinical Bone Sonometer (Hologic). The short-term precision of the system used in this study had root-mean-square averages (CV_{RMS}%) of 2.2% for BUA and 0.1% for SOS.

Measurement of thoracic kyphosis. Thoracic curvature imaging was per-formed using the Jenoptik Formetric rasterstereography system (Aesculap Meditec GmbH, Heroldsberg, Germany) according to the protocol described by Goh, *et al*[32]. Rasterstereography is an optical imaging system that consists of a projector, video camera, and image processing software from which back surface curvature is derived[33]. Key features of the raster-stereographic analyses are illustrated in Figure 1. The principal merits of this assessment of spinal kyphosis are that it does not use ionizing radiation; it does not require manual landmark identification or any use of surface markers, thus reducing potential sources of error; the measurement is not affected by endplate deformities of the reference vertebra; and the unit used in this study has been shown to have excellent reliability [intraclass correlation coefficient (ICC) 0.98–0.99] and high accuracy (CV% 2.4%–3.0%) for repeat assessment[32].

Vertebral fracture determination. Standing-erect lateral thoracic and lumbar radiographs were taken according to the protocol for quantitative vertebral morphometry[34]. A single investigator (BKT) performed the morphometric measurements. Each subject's thoracolumbar radiograph was screened for spinal anomalies by an experienced radiologist (SS). No participant in the study had significant spinal anomalies (e.g., structural scoliosis). Vertebral fractures were determined using the composite approach described by Genant, *et al*[35]. The criterion of semiquantitative grade ≥ 1 was used to define a prevalent vertebral fracture. In addition, a vertebral body was considered fractured when at least one of the 3 vertebral height ratios fell 3 SD below the normal mean ratio for that vertebral body[36]. A prior intra-tester reliability study for measuring vertebral heights was conducted. ICC were high for all vertebral levels ($ICC_{(3,1)}$ ranged from 0.97 to 0.99), with measurement errors < 1 mm.

Statistical methods. The sample population was classified into 2 groups, one with prevalent vertebral fracture (VF), the other with no evidence of vertebral fracture (NVF). One-way ANOVA was used to test for any differences in mean scores of test variables between the 2 groups. The residuals of the ANOVA model were checked to ensure that they were normally distributed and random.

To determine which independent variables were most associated with the VF group, DEXA BMD (lumbar spine and total hip), SOS, BUA, and thoracic kyphosis variables were entered independently into the logistic regression analysis model with age included as a potential predictor. Stepwise multiple logistic regression analysis was also used to derive the composite variables that were most associated with the VF group.

Composite risk OR were derived to assess the simultaneous effect of the significant independent predictors on the increased risk of prevalent vertebral fracture using the formula:

$$\text{Risk OR} = \frac{\exp(a + bx + cy + ...)}{\exp(a + b[0] + c[0] + ...)} = \frac{\exp(a + bx + cy + ...)}{\exp(a)}$$

The intercept a and the beta coefficients b and c were derived from the final model of the stepwise multiple logistic regression analysis. The variables x and y represent 2 significant independent variables in this model, in units of Z-score (standard deviation units). A variable value of 0 in this case indicates that the subject is at the mean for the study population for that variable. In the determination of the composite risk OR, the simultaneous effect of the variables x and y were assessed in relation to the reference situation when both variables were at their mean value (Z-score = 0).

The composite variable Y, which best represents the combination of a QUS variable and thoracic kyphosis, is derived from the regression equation $Y = bz_x + cz_y$, where z_x represents the Z-score of the most significant QUS variable, z_y represents the Z-score of thoracic kyphosis, and b and c are beta coefficients from the stepwise multiple logistic regression equation of the respective variables.

Receiver-operating characteristic (ROC) curves were generated to compare the relationship between the diagnostic sensitivity and the specificity for the 4 separate groups of variables for discriminating the group with prevalent vertebral fractures, namely, total hip DEXA BMD; lumbar spine
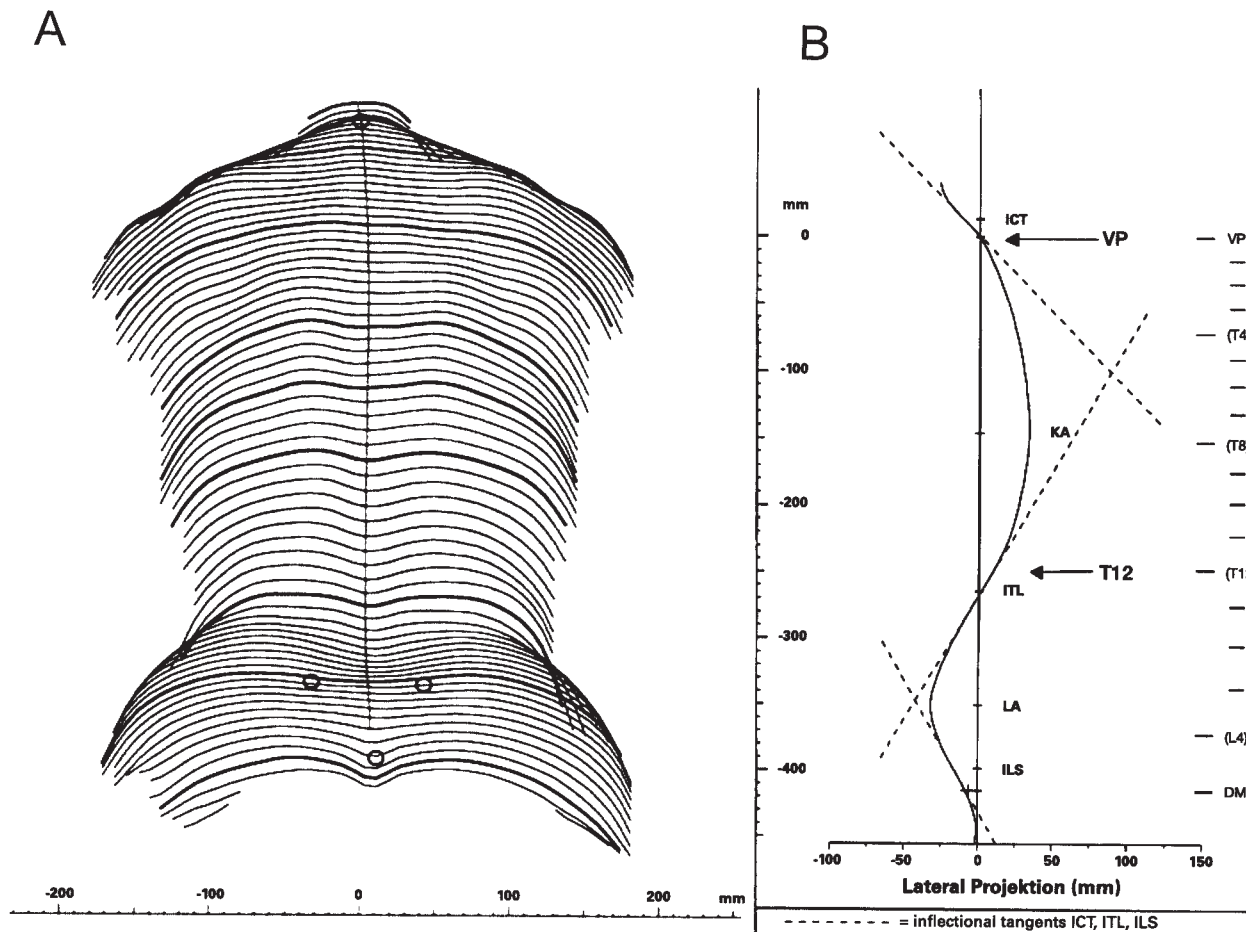
Figure 1. A. Transverse profile of a back image from the rasterstereographic evaluation. B. Kyphotic angle (KA) is defined between the tangents to the vertebral prominence (VP) and the 12th thoracic vertebra (T12; arrows).

DEXA BMD; the most significant QUS variable; and the composite model (combination of QUS variable and thoracic kyphosis).

The estimate of the area under the ROC curve (AUC) and its standard error (SE) were computed nonparametrically with the confidence interval set at 95%. Wilcoxon's nonparametric test was used to compare AUC using the method described by Hanley and McNeil[37]. Statistical significance was set at $p < 0.05$ for all analyses.

RESULTS
Twenty-four women with at least one prevalent vertebral fracture (VF) and 80 women who had no evidence of vertebral fracture (NVF) were identified. The NVF group were younger than the VF group but the groups were comparable in height and weight. Age-adjusted BMD at the proximal femur and lumbar spine were also comparable between groups; however, QUS values were lower and thoracic kyphosis greater in the VF group (Table 1).

Individual risk factors associated with prevalent vertebral fractures. The age-adjusted OR (per SD) for prevalent vertebral fractures were statistically significant for the QUS variables, BUA and SOS, and thoracic kyphosis (Table 2).

Composite risk factors associated with prevalent vertebral fractures. When DEXA BMD (lumbar spine and total hip), SOS, BUA, and thoracic kyphosis were entered into the stepwise multiple logistic regression model, BUA (OR 2.47, 95% CI 1.38 to 4.45, $p = 0.002$) and thoracic kyphosis (OR 2.54, 95% CI 1.44 to 4.50, $p = 0.001$) were found to be most significantly associated with prevalent vertebral fractures.

Composite risk OR calculations showed that an individual who had a decrease of 1 SD in BUA and a concomitant increase of 1 SD in thoracic kyphosis had a 6-fold increased risk of vertebral fracture compared with individuals who were not at risk (SD = 0 for both BUA and thoracic kyphosis; Table 3). The percentage of subjects in this study who fell within a quoted SD range for BUA, as well as that for thoracic kyphosis, is shown in Table 3.

Discriminators of prevalent vertebral fractures. ROC curves are presented in Figure 2. The composite model (BUA and thoracic kyphosis) had greater AUC compared to BUA alone, or to DEXA BMD of the total hip or the BMD of the lumbar spine (Table 4). The difference was statistically significant for the lumbar spine ($p = 0.0004$). At 70% sensitivity, the composite model had specificity of 68%, where-

Table 1. The mean, standard deviation (SD) of age, anthropometric variables, DEXA BMD, QUS variables, and thoracic kyphosis for the women with and without prevalent vertebral fractures and results of the ANOVA.

Variables	No Vertebral Fractures, n = 80, mean (SD)	Prevalent Vertebral Fractures, n = 24, mean (SD)	p	95% CI for Difference
Age, yrs	71 (5.4)	74 (6.3)	0.006	–6.3 to –1.1
Weight, kg	65.3 (11.4)	64.8 (8.5)	0.86	–4.5 to 5.4
Height, cm	159.8 (6.1)	159.6 (6.3)	0.90	–2.6 to 3.0
BMI, kg/m^2	25.5 (3.8)	25.4 (2.5)	0.90	–1.5 to 1.7
DEXA BMD, g/cm^2, adjusted by age				
Femoral neck	0.703 (0.10)	0.659 (0.14)	0.26	–0.02 to 0.08
Total hip	0.818 (0.11)	0.771 (0.13)	0.26	–0.02 to 0.08
Lumbar spine	0.901 (0.16)	0.903 (0.21)	0.91	–0.09 to 0.08
QUS variables, adjusted by age				
BUA, dB/MHz	67.8 (16.3)	58.0 (14.8)	0.02	1.9 to 17.3
SOS, m/s	1535.5 (27.9)	1519.8 (21.1)	0.03	1.8 to 27.3
Thoracic kyphosis, degrees	51.0 (9.9)	57.6 (10.2)	0.04	–9.6 to –0.29

BUA: broadband ultrasound attenuation; SOS: speed of sound.

Table 2. Univariate factors (derived from logistic regression) associated with prevalent vertebral fractures identified radiographically, after adjustment for age.

Variables	Vertebral Fracture Age-adjusted OR (95% CI)	p
Femoral neck BMD (per SD decrease)	1.39 (0.81–2.39)	0.24
Total hip BMD (per SD decrease)	1.35 (0.80–2.28)	0.26
Lumbar spine BMD (per SD decrease)	0.96 (0.60–1.54)	0.86
BUA (per SD decrease)	1.96 (1.12–3.42)	0.018
SOS (per SD decrease)	2.01 (1.09–3.70)	0.026
Thoracic kyphosis (per SD increase)	1.72 (1.01–2.92)	0.046

BUA: broadband ultrasound attenuation; SOS: speed of sound.

Table 3. The risk odds ratio (OR) for per-standard deviation decrease (SD) in BUA and per-SD increase in thoracic kyphosis. Percentage of subjects that fell within a quoted SD range for BUA* and thoracic kyphosis** is shown in parentheses.

Risk OR	BUA, SD 0	–1	–2
Thoracic kyphosis, SD			
0	1.0 (14)	2.5 (10)	6.5 (0)
+ 1	2.5 (12)	6.1 (10)	15.4 (1)
+ 2	5.7 (0)	14.4 (0)	36.6 (0)

* BUA: SD "0" included all subjects whose SD value for BUA was within 0.49 and –0.49; SD "–1" included subjects whose SD value was within –0.5 and –1.49; and SD "–2" included subjects whose SD value was within –1.5 and –2.49. ** Thoracic kyphosis: SD "0" included all subjects whose SD value for TK was within –0.49 and 0.49; SD "1" included subjects whose SD value was within 0.5 and 1.49; and SD "+2" included subjects whose SD value was within 1.5 and 2.49. Only 47% of the women fell within these criteria for both thoracic kyphosis and BUA. The other 53% (not accounted for in this table) had SD either ≥ 0.5 or ≤ –2.5 for BUA, and SD ≥ 2.5 and ≤ –0.5 for thoracic kyphosis.

as lumbar spine and total hip DEXA BMD had lower specificities of 23% and 43%, respectively. Table 5 presents 3 chosen levels of sensitivity (70%, 75%, and 80%), and for each level of sensitivity the respective specificity, positive predictive value, and negative predictive value are provided.

DISCUSSION
Despite the widespread use of DEXA in assessing status of skeletal fragility, there is interest in the use of quantitative ultrasonometry as an adjunctive method for estimating bone fragility. The main advantages of QUS are that it does not use ionizing radiation, and it is portable and less expensive than DEXA technologies[21,22,24,25]. We determined that calcaneal QUS and thoracic kyphosis, measured using portable and non-ionizing technologies, can significantly discriminate a group of postmenopausal women with prevalent vertebral fracture from those without.

The group with vertebral fractures had 14% lower BUA and 1% lower SOS measurements compared with the nonfracture group. There are more than 20 reports on the utility of QUS for vertebral fracture discrimination. Most studies observed that women with vertebral fractures had lower QUS measurements compared to the nonfracture controls[9-16,18,20,38-44]. The reported percentage differences ranged from 5.5% to 28.9% for BUA and 0.6% to 2.5% for SOS.

A recent metaanalysis of prospective studies suggests that QUS is a valid assessment of fracture risk especially for nonspinal sites[21]. Our results showed that QUS variables had higher and statistically significant age-adjusted OR compared to spinal or hip DEXA BMD measures. These findings are in agreement with 2 larger studies that used similar gel-coupled-contact QUS devices[11,15]. Hartl, et al[15] also demonstrated that the QUS variables had higher AUC compared to DEXA BMD in discriminating fractures. Results from these studies suggest that QUS variables deter-
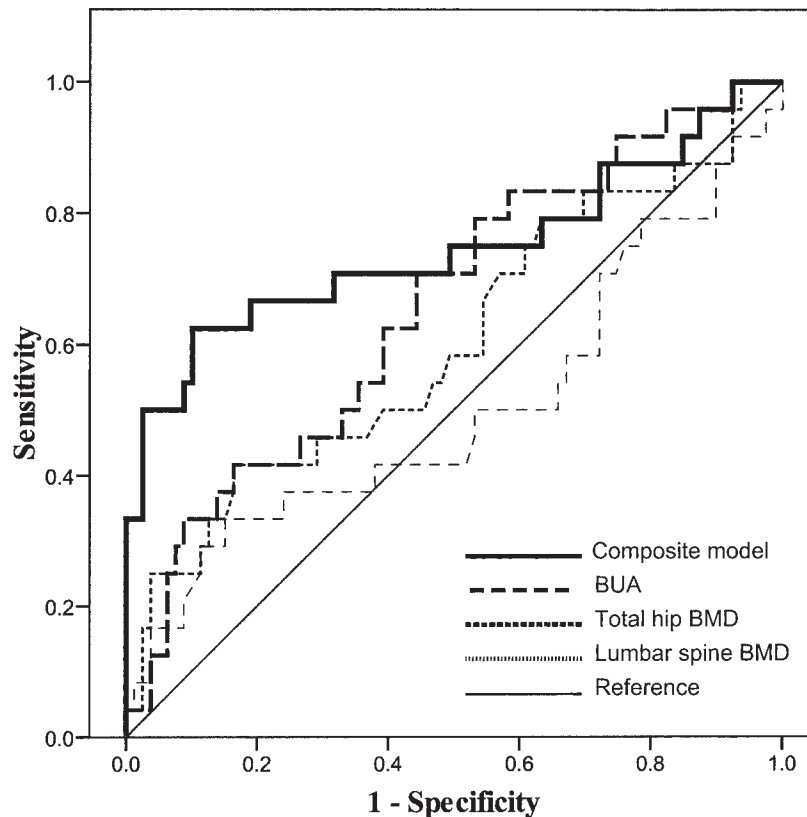
Figure 2. ROC curves for the composite model (BUA and thoracic kyphosis), BUA, total hip DEXA BMD, and lumbar spine DEXA BMD.

Table 4. Areas under the curve (AUC) and standard error (SE) for total hip bone mineral density (BMD), lumbar spine BMD, broadband ultrasound attenuation (BUA), and the composite model (BUA and thoracic kyphosis) in discriminating the group with prevalent vertebral fractures.

Variables	AUC	SE (95% CI)	p*
Total hip BMD	0.60	0.07 (0.47–0.74)	0.057
Lumbar spine BMD	0.50	0.08 (0.35–0.65)	0.0004
BUA	0.66	0.06 (0.53–0.78)	0.136
Composite (kyphosis + BUA)	0.75	0.07 (0.61–0.88)	

* Difference in AUC between individual variables and composite variable (BUA and kyphosis). Wilcoxon's nonparametric test used for comparing AUC.

mine bone fragility status in the spine better than DEXA BMD measurements. In addition, it has been postulated by Frost, *et al*[11] that the pain and disability associated with vertebral fractures may cause changes in mechanical loading on the calcaneum, contributing to the change in bone status at that site.

In our study BMD was not significantly associated with fracture. BMD at the lumbar spine was comparable between groups. Although there was a trend for BMD at the femoral neck and total hip to be lower in the fracture group, the differences were not statistically significant. While this may be

due to the relatively low number of fracture cases, it should be noted that this study had 80% power to detect a 10% difference in total hip BMD and a 12% difference in femoral neck BMD.

For a highly prevalent disease such as osteoporosis in the elderly, an ideal screening test should have high specificity to reduce the number of false-positive cases in order to minimize the cost associated with unnecessary followup assessments. Numerous studies have explored combining the assessments of DEXA BMD and calcaneal QUS in attempts to improve the specificity and the sensitivity of fracture risk identification. Data from 4698 women participating in a multicenter cohort study (the Study of Osteoporosis Fractures in the US) showed that QUS and BMD independently discriminated incident minimal trauma fracture cases from nonfracture cases[45]. Moreover, the study demonstrated that using a combination of BUA and femoral neck BMD can improve the specificity and sensitivity of fracture discrimination, especially at high levels of specificity (80%–95%).

Studies that have specifically used vertebral fracture as the outcome variable have, in general, found improved discriminatory power using a combined QUS and DEXA BMD model. However, most found only a modest increase that was not statistically significant[10,12,20,41]. It has been argued

Table 5. Comparison of 3 sensitivity levels (70%, 75%, 80%) and their respective specificities, positive predictive values (PPV), and negative predictive values (NPV) for separate predictive tests based on total hip BMD, lumbar spine BMD, broadband ultrasound attenuation (BUA), or the composite model (BUA and thoracic kyphosis).

Variable	Sensitivity, %	Specificity, %	PPV, %	NPV, %
Total hip BMD	70	43	28	80
	75	39	27	84
	80	30	27	86
Lumbar spine BMD	70	23	23	77
	75	24	23	77
	80	10	21	64
BUA	70	56	33	87
	75	47	30	86
	80	42	30	89
Composite	70	68	41	89
	75	51	31	87
	80	30	26	85

that the increased cost associated with using a combination of BMD and QUS assessment outweighs the modest improvement in the prediction of fracture risk[46]. However, using a decision-analytic model and data from the Study of Osteoporosis Fractures, Kraemer, et al[47] showed that the sequential use of QUS followed by DEXA would result in fewer women identified as needing treatment, plus lower total costs.

Our study is novel in that it included thoracic kyphosis, determined using video rasterstereography, in the assessment of fracture risk. At a sensitivity of 70%, the combination of BUA and thoracic kyphosis assessments had a relatively high level of specificity of almost 70% at discriminating subjects with vertebral fracture from those without. The discriminatory power of this composite model was better than using BMD of the hip or spine alone, where, at the same sensitivity, the specificity was only 43% and 23%, respectively (Table 5).

Although video rasterstereography has not been used widely in clinical practice or community health settings, its simplicity of use and lack of ionizing radiation recommend it as a screening application. Practice nurses or other community-based health professionals could quickly learn to use the equipment and interpret the results. Large numbers of subjects could be measured efficiently. However, this study addresses the general value of measuring thoracic kyphosis, rather than the choice of the most cost-effective method, which would require further studies. For example, the occiput-to-wall distance measures the magnitude of forward flexion of the head position[48,49]. In a future study it would be useful to compare the utility of this simple measurement with measures of thoracic kyphosis more directly addressing the spine, in the context of fracture prediction.

In our study, all but one of the 24 subjects with prevalent fractures had anterior wedge deformities. The finding that thoracic kyphosis was significantly associated with anterior wedge vertebral fractures is consistent with knowledge about the pathogenesis of thoracic hyperkyphosis[50,51]. These studies provide strong evidence that thoracic hyperkyphosis may be a useful clinical indicator for the presence of vertebral fractures. The clinical significance of thoracic hyperkyphosis is that it has been shown to be an independent risk factor of future spinal fracture[29,51]. In a prospective study by Shipp, et al[29] involving 3038 women (age range 55 to 81 yrs), thoracic kyphosis of greater than 36° (assessed using the Debruener Kyphometer) was shown to be linearly related to incident vertebral fracture (rate ratio 1.22), independent of age and BMD. This study confirmed the clinical significance of thoracic kyphosis as an indicator of future fracture risk[29].

The ability to successfully identify prevalent vertebral fracture has clinical importance as the presence of vertebral fractures increases the risk of future vertebral fractures, and also fractures at other skeletal sites, by up to 4-fold[26-28]. Early identification may allow at-risk individuals, especially those with asymptomatic vertebral fractures, to be followed up with appropriate interventions to reduce the risk of subsequent fractures, thereby reducing the morbidity and cost of osteoporotic fracture.

We have demonstrated that portable and non-ionizing tests could identify a group with prevalent vertebral fractures (including subclinical fractures) better than DEXA of either the hip or spine. This does not imply that DEXA should not play a central role in evaluation of individuals where risk (assessed by all available cost-effective means) is well established, either by DEXA itself, or by other measures. However, DEXA studies (with the necessity of operator and clinician training and licensing) are not universally available, particularly for those in poorer economies or in rural areas. Even the availability of DEXA does not guarantee that all relevant patients will benefit. Awareness of the need for comprehensive, continuing management of osteo-

porosis is currently deficient, and should be raised. Even when fractures are identified, a high proportion of patients remain untreated[52]. Prudent use of noninvasive community-based assessment tools does not require referrals from medical professionals, and is suited to those who do not seek medical help without marked symptoms. Enhancing the availability of testing will expand the public consciousness of the risk of osteoporosis, and involve at-risk individuals who would otherwise be underdiagnosed and undertreated. It will also highlight the need for better continuing management of identified disease.

Our results cannot be extrapolated to the less mobile, elderly women in nursing homes. We used a relatively novel assessment of thoracic kyphosis and thus comparison with previous studies is limited. Further studies are required to determine if other simpler measures of thoracic kyphosis, such as occiput-wall distance[48], are equally valid if employed in the current context. The role of disk disease in prediction of vertebral fractures has not been assessed in this study. Measurement of kyphosis using a nonradiologic technique does not allow for concurrent independent assessment of disk-space narrowing, which has been linked in a prospective study to increased risk of vertebral fractures[53].

The cross-sectional design of our study limits any attempt at identifying the causal directions of any associations identified. Additionally, the relatively small sample of vertebral fracture cases limited the statistical power of the study. Larger prospective studies are necessary to confirm these findings.

Our cross-sectional study demonstrated that reduced calcaneal QUS values and a greater thoracic kyphosis are significantly associated with prevalent vertebral fractures in women. The results also show that a composite risk score based on a combination of these fracture risk assessments (QUS and thoracic kyphosis) had better discriminatory power than the individual risk factor of (low) DEXA BMD. These findings suggest that there may be a role for such a composite model, which utilizes simple and easy to operate systems, as part of an osteoporosis service in the community to provide first-line screening for women at risk of future osteoporotic fractures. This study does not challenge the central role of DEXA BMD in the subsequent management of those patients.

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