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ORIGINAL STUDY

Spine trabecular bone scores and bone mineral density of postmenopausal Taiwanese women

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Abstract

Objectives: The aims of the study were to determine the mean trabecular bone score (TBS) of postmenopausal Taiwanese women and to analyze the value of TBS in predicting osteoporosis.

Methods: A total of 1,915 postmenopausal women with lumbar spine and hip bone mineral density (BMD) and spine TBS were enrolled from a single medical center into this study. The women's BMD and TBS were measured using dual x-ray absorptiometry (Discovery Wi; Hologic, Bedford, Mass) and iNsight software (Med-Imaps SASU, Merignac, France), respectively. The women's demographic characteristics; lumbar spine, total hip, and femoral neck BMD; and lumbar spine TBS were recorded, and correlations among the parameters were identified using a 2-tailed Pearson test, in which a *P* value less than 0.05 was considered statistically significant. We developed simple linear regression models to represent changes related to TBS and performed an analysis of variance on the selected variables.

Results: The average age of the women was 62.5 ± 9.1 years (range, 25.7-93.7 years). The mean TBS was 1.300 ± 0.086 (range, 1.015-1.596). The TBS was weakly and negatively correlated with body mass index ($r = -0.078$) and moderately and positively correlated with the lumbar spine BMD ($r = 0.619$). The patients' lowest BMD values among those measured at multiple sites revealed a higher rate of osteoporosis (32.5%) than those measured at individual sites. Degraded TBS were noted in 21.2% of the participants, and a combination of BMD and TBS results predicted more individuals (7.8%) at a high risk of fracture than did the BMD result only. The rates of both osteoporosis and degraded TBS increased with age.

Conclusions: Bone mineral density and TBS can be used in combination to predict osteoporosis in a greater number of postmenopausal Taiwanese women. Because the incidence of osteoporosis is the highest among older women, clinicians should pay careful attention to TBS degradation among older patients without low BMD.

Key Words: Bone mineral density – DXA – Osteoporosis – Postmenopausal – Trabecular bone score.

Osteoporosis is defined as systemic osteopenia, which destroys bone microarchitecture and leads to bone fragility and increased bone fracture risk.[1-4] With the increase in the human life span, osteoporosis has become a widespread epidemic second in prevalence to cardiovascular disease.[5] Because osteoporosis is a major cause of fractures that leads to increased mortality risk in older adults, the diagnosis and prevention of osteoporosis are a key public health concern. Records from Taiwan's

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National Health Insurance Research Database between 1999 and 2001 revealed an increase in the estimated prevalence of osteoporosis and underestimation of the diagnoses of osteoporosis in adults older than 50 years in Taiwan, which was consistent with the global trend.[6] In a following study of the results of the Nutrition and Health Survey in Taiwan between 2005 and 2008, the prevalence rates of osteoporosis were 23.9% and 38.3% for men and women older than 50 years, respectively.

Currently, bone mineral density (BMD), measured through dual-energy x-ray absorptiometry (DXA), is the criterion standard for diagnosing osteoporosis and is used to assess fracture risk.[4,7,8] The World Health Organization (WHO) recommends diagnosing osteoporosis based on the *T* score at the femoral neck (FN),[9] whereas the International Society for Clinical Densitometry (ISCD) suggests using the lowest *T* score among those measured at the lumbar spine (L1-L4), FN, or total hip.[10] However, approximately half of patients with bone fractures exhibit normal bone density or low bone mass according to the *T* score of BMD.[11] The risk of bone fracture depends on the strength of the bone, including its mass and quality (eg, microarchitecture). The risk of osteoporosis in these patients was underestimated because BMD can be used to assess only bone mass and not bone quality.[12-14]

The trabecular bone score (TBS) is a new tool to measure bone microarchitecture by analyzing changes in the gray level of pixels in standard lumbar spine BMD images. It also provides indirect indicators of trabecular bone microarchitecture and bone texture derived from bone quality.[5,11-19] The TBS can be used as an auxiliary measure of BMD and as an assessment tool for osteoporotic fracture risk.[19-21] Studies have demonstrated the effectiveness of TBS in predicting osteoporosis[19,22-24] and have indicated that the combination of BMD and TBS can predict the risk of osteoporosis and fracture more effectively than BMD alone.[8,14,21,24] However, these studies have focused mainly on White women, and a similar study involving a sample of patients from the Asian population has not yet been conducted.

The purposes of this study are to determine the mean TBS of postmenopausal Taiwanese women in different age groups, to analyze the association between TBS, demographic characteristics, and BMD, and to assess the value of TBS in predicting osteoporosis.

METHODS

This retrospective study was approved by the institutional review board of our hospital. Because the images and clinical data were deidentified and the patients remained anonymous, the requirement for informed consent was waived.

Research Design and Participants

This study was conducted at a single medical center and involved a cohort of postmenopausal women from southern Taiwan. The medical records of 4,977 patients with BMD and TBS data from June 2018 to June 2020 were retrieved. The inclusion criteria were (1) being postmenopausal, (2) having qualified BMD through a DXA scan for at least 2 body parts (lumbar spine and hip), (3) having no history of compression fracture, and (4) having a body mass index (BMI) between 15 and 35 kg/m^2. In addition, patients with TBS limitations and those whose spines could not be analyzed were excluded. After 3,061 patients were excluded, a total of 1,915 patients remained (Figure 1).

Measurement of BMD

Bone mineral density at the lumbar spine (L1-4) and hip regions were obtained using a central DXA (Discovery Wi; Hologic, Bedford, Mass) with the software supplied by the manufacturer (version 13.3.5.2). The scan parameters were 140/100-kVp dual energy with an average of 2.5 mA, and the scan mode was a 41-second fast array at 60 Hz. Before examinations, the factory-provided prosthesis (calibration standard) was used for daily calibration. The precision error of the instrument was 0.27% (percentage of the coefficient of variation). The scan was performed by a radiographer, and the precision error was 0.70% for the lumbar spine, 1.23% for the FN, and 0.77% for the total hip. According to WHO criteria, a *T* score of ≥ -1 indicates normal bone density; $-2.5 < T$ score < -1 indicates low bone mass; *T* score ≤ -2.5 indicates osteoporosis. The *T* scores were calculated using the The Third National Health and Nutrition Examination Survey-corrected reference range for young White women provided by the manufacturer.

Trabecular Bone Score Assessment

The TBS at the lumbar spine was analyzed using the lumbar spine (L1-L4) DXA scan data and TBS iNsight software (version 3.0); the precision error was 1.33%. The reference curve was divided into 3 sections to represent TBS values for Asian populations: TBS $\geq$ 1.310 indicates normal bone microarchitecture, 1.230 < TBS < 1.310 indicates partially degraded bone microarchitecture, and TBS $\leq$ 1.230 indicates degraded bone microarchitecture.

Inconsistent Selection Conditions Between TBS and BMD

This study divided inconsistencies between BMD and TBS into 3 groups: (1) normal BMD with partially degraded TBS, (2) normal BMD with degraded TBS, and (3) low bone mass with degraded TBS. An analysis was performed on four age groups, namely, younger than 50, 50 to 59, 60 to 69, and 70 years or older.

Statistical Analysis

The descriptive statistics were age, height, weight, BMI, TBS, and BMD. Each patient's BMI was calculated by dividing their weight by the square of their height (in kilograms per square meter). The correlations among the parameters were determined using a Pearson 2-tailed test; a *P* value less than 0.05 was considered statistically significant. The χ^2 test was performed to determine consistency between osteoporosis BMD and TBS in predicting osteoporosis. Differences in the rates of osteoporosis diagnosed according to lowest BMD and according to the combination of lowest BMD and TBS in the different age groups were determined through 1-way analysis of variance with a Tukey-Kramer post hoc test, in which a *P* value less than 0.0125 (0.05/4) was considered statistically significant. The regression standardization of Pearson 1-tailed test was used to predict TBS, with significance at a *P* value less than 0.05. We performed a regression

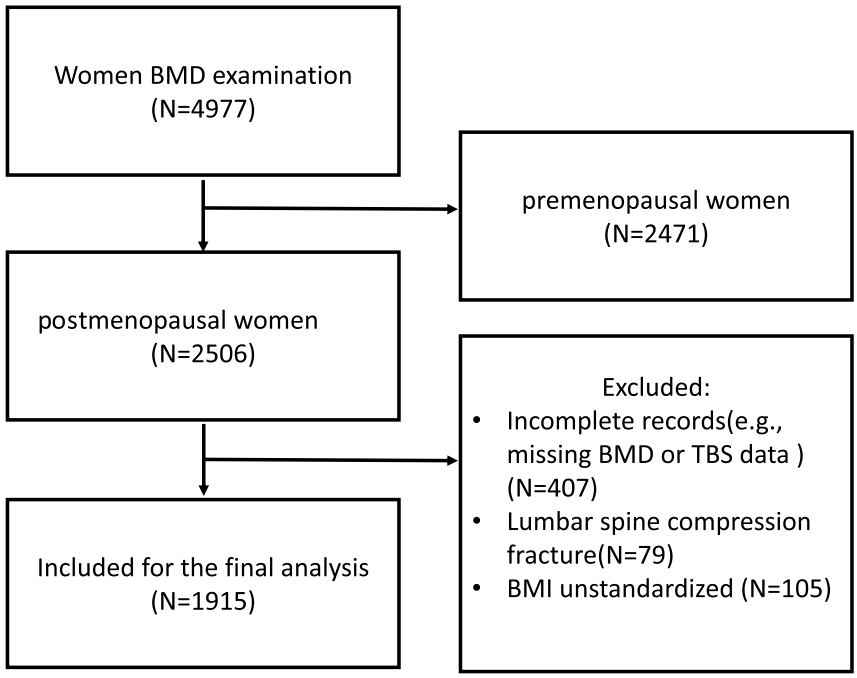

FIG. 1. Flowchart of participant inclusion in bone mineral density examination at a single medical center. BMD, bone mineral density; BMI, body mass index; TBS, trabecular bone score.

analysis to explore the relationship between BMD and TBS to establish a regression model for TBS prediction. After analyzing the variables, we established regression models for the relationships between TBS and age, height, weight, BMI, lumbar spine BMD, total hip BMD, and FN BMD.

RESULTS

Basic Characteristics

The 1,915 postmenopausal Taiwanese women enrolled in this study had a mean age of 62.5 ± 9.1 years, a mean BMI of 23.5 ± 3.6 kg/m^2, a mean lumbar spine BMD of 0.837 ± 0.142 g/cm^2, a mean FN BMD of 0.622 ± 0.110 g/cm^2, a total hip BMD of 0.764 ± 0.124 g/cm^2, and a mean spine TBS of 1.300 ± 0.086 (Table 1).

The spine TBS was moderately and positively correlated with lumbar spine BMD (r = 0.619, P < 0.001), total hip BMD (r = 0.535, P < 0.001), and FN BMD (r = 0.545, P < 0.001); moderately and negatively correlated with age (r = −0.505, P < 0.001); and weakly and negatively correlated with BMI (r = −0.078, P = 0.001). Bone mineral density was positively correlated with all variables except age, which was negatively correlated with BMD. Lumbar spine (L1-L4) BMD was moderately and positively correlated with total hip BMD and FN BMD (r = 0.696, P < 0.001; r = 0.670, P < 0.001); weakly and positively correlated with height, weight, and BMI (r = 0.211, P < 0.001; r = 0.396, P < 0.001; r = 0.307, P < 0.001); and weakly and negatively correlated with age (r = −0.274, P < 0.001). Total hip BMD was strongly and positively correlated with FN BMD (r = 0.905, P < 0.001); weakly to moderately correlated with height, weight, and BMI (r = 0.244, P < 0.001; r = 0.405, P < 0.001; r = 0.292, P < 0.001); and weakly and negatively correlated with age (r = −0.367, P < 0.001). Femoral neck BMD was weakly and positively correlated with height, weight, and BMI (r = 0.300, P < 0.001; r = 0.362, P < 0.001; r = 0.220, P < 0.001) and moderately and negatively correlated with age (r = −0.400, P < 0.001).

Diagnosis of Osteoporosis According to BMD Assessment at Different Sites and Combined Multiple Sites

Table 2 lists the numbers of patients at high risk of fracture (T score ≤ −2.5) in different age groups according to the assessments of BMD at different sites. In the BMD analysis of individual sites, 22.1%, 22.0%, and 5.3% of the patients received a BMD T score ≤ −2.5 at the lumbar spine, FN, and total hip, respectively, and these percentages increased with age. When the lowest T score among those measured at each of these sites was used, in accordance with the ISCD standard, the ratio of patients with a lowest BMD T score of −2.5 or lower (approximately 32.5%) was higher than that of the patients with BMD T scores of −2.5 or lower at each of the individual sites, and the ratio increased with age.

Combined Assessment of BMD and TBS

When the lowest T score at any of these sites was used according to the ISCD standard, 330 of the patients had normal bone density, 963 had low bone mass, and 622 had osteoporosis. According to the TBS assessment, 406 of the patients had degraded TBS, and 658 had partially degraded TBS. In the combined assessment of BMD and TBS, only 256 of the patients had both osteoporosis and degraded TBS. Among the patients without osteoporosis, 3.3% (11/330) of those with normal bone density and 14.4% (139/963) of those with low bone mass had degraded TBS (Figure 2). After the degraded TBS assessment was combined with the BMD assessment, the prediction rate for osteoporosis increased from 32.5% to 40.3%.

TABLE 1. *Baseline demographic characteristics of different age groups of participants (Taiwanese postmenopausal women)*

	Total (N = 1,915)	<50 y (n = 88)	50-59 y (n = 761)	60-69 y (n = 683)	≧70 y (n = 383)
Age, y	62.5 ± 9.1 (25.7-93.7)	46.6 ± 4.2 (25.7-49.9)	55.6 ± 2.6 (50.0-59.9)	64.6 ± 2.9 (60-69.9)	76.3 ± 5.3 (70.0-93.7)
Height, m	1.55 ± 0.1 (1.29-1.78)	1.60 ± 0.1 (1.49-1.68)	1.57 ± 0.1 (1.40-1.77)	1.54 ± 0.1 (1.29-1.77)	1.52 ± 0.1 (1.29-1.67)
Weight, kg	56.9 ± 9.3 (31.8-93.5)	57.8 ± 10.2 (42.0-90.0)	57.0 ± 9.0 (35.8-93.5)	57.1 ± 9.2 (32.1-88.0)	56.4 ± 9.7 (31.8-86.5)
BMI, kg/m^2	23.5 ± 3.6 (15.2-36.3)	22.6 ± 3.8 (16.4-33.1)	22.9 ± 3.4 (15.6-36.3)	23.8 ± 3.5 (15.2-35.1)	24.3 ± 3.8 (15.4-35.0)
Spine BMD, g/cm^2	0.837 ± 0.142 (0.360-1.379)	0.925 ± 0.146 (0.590-1.379)	0.871 ± 0.133 (0.520-1.373)	0.813 ± 0.134 (0.409-1.305)	0.790 ± 0.144 (0.360-1.263)
FN BMD, g/cm^2	0.622 ± 0.110 (0.234-1.043)	0.696 ± 0.116 (0.479-0.996)	0.656 ± 0.105 (0.352-1.043)	0.612 ± 0.095 (0.345-0.921)	0.556 ± 0.106 (0.234-0.982)
Total hip BMD, g/cm^2	0.764 ± 0.124 (0.234-1.129)	0.705 ± 0.121 (0.482-1.054)	0.660 ± 0.109 (0.352-1.129)	0.616 ± 0.100 (0.343-1.004)	0.559 ± 0.108 (0.234-0.982)
Spine TBS	1.300 ± 0.086 (1.015-1.596)	1.379 ± 0.078 (1.144-1.543)	1.341 ± 0.077 (1.100-1.596)	1.276 ± 0.074 (1.067-1.596)	1.241 ± 0.071 (1.015-1.468)

BMD, bone mineral density; BMI, body mass index; FN, femoral neck; TBS, trabecular bone score.

Effect of Age on the Assessment of BMD and TBS

Table 2 presents the distribution of patients of different age groups at high risk of fracture according to the BMD (*T* score ≦ −2.5) at different sites, TBS, and combined assessment of BMD and TBS. The ratios of patients with BMD *T* scores of −2.5 or lower at different sites and across all of the designated measurement sites increased with age. The ratios of patients with degraded TBS also increased with age. Figure 2 presents the distribution of BMD and TBS assessments in different age groups. Among the patients without osteoporosis, 150 had degraded TBS, and the ratios of patients with degraded TBS increased with age not only in the low bone mass group but also in the normal bone density group. In our analysis of the different ages in the prediction rate for osteoporosis when using a combination of the lowest BMD and degraded TBS, the percent increase among the women 70 years or older was the highest (14.4%) and was significantly higher than those among the women younger than 50 years (0.0%, $P < 0.001$) and 50 to 59 years (3.0%, $P < 0.001$). The percent increase among the women aged 60 to 69 years (10.5%) was also significantly higher than those among the women younger than 50 years (0.0%, $P = 0.003$) and 50 to 59 years (3.0%, $P < 0.001$). The percent increase among the women aged 60 to 69 years did not differ significantly from that among the women 70 years or older ($P = 0.108$).

Regression Models for TBS

After the variables were analyzed, this study established various regression models after analyzing the variables. Visual depictions of the relationship between TBS and each of the continuous variables are presented in Table 3. Of note, in the regression models, TBS exhibited significant positive correlations with lumber spine, total hip, and FN BMD ($r = 0.619$, 0.535, and 0.545; all $P < 0.001$) and significant positive but weaker associations with height and weight ($r = 0.298$ and 0.081, respectively; both $P < 0.001$). Trabecular bone score also exhibited a significant moderate negative correlation with age ($r = 0.505$, $P < 0.001$) and a significant negative but weaker association with BMI ($r = 0.078$, $P < 0.001$).

DISCUSSION

We retrospectively reviewed the patients' demographic records and BMD and TBS data based on DXA scans and analyzed the correlations between these variables. Both BMD and TBS were negatively correlated with age in our results. The patients' lowest BMD values among those measured at the multiple designated sites revealed a higher rate of osteoporosis (32.5% or 622/1,915 participants) than did those measured at individual sites. Degraded TBS were observed in 21.20% of the patients (406/1,915), and the combination of BMD and TBS results identified more patients (7.8%) at high risk of fracture than did the BMD result alone. The ratios of both osteoporosis and degraded TBS increased with age, and the ratio of degraded TBS in patients without osteoporosis also increased with age.

Studies have explored the negative correlation between TBS and age not only in White women but also in women from other ethnic groups.[25–29] In this study, a moderate negative correlation ($r = -0.505$) was identified between TBS and age in postmenopausal Taiwanese women, which was similar to the results reported in studies involving patients of different ethnic groups. The results suggested that older adults exhibit lower bone quality that, in turn, affects bone strength. Studies have demonstrated that TBS was negatively correlated with age for 53 healthy postmenopausal Turkish women and 4,907 French postmenopausal women aged 20 to 90 years.[27,29] In addition, the TBS of non-Hispanic

TABLE 2. *Numbers of participants at high risk of fracture for different age groups according to assessments of BMD (T* score ≦ −2.5*) and TBS (TBS ≦ 1.230)*

	T score of BMD ≦ −2.5				TBS ≦ 1.230				
	Spine	FN	Total hip	Lowest[a]	Normal bone density	Low bone density	Osteoporosis	All participants	Combined lowest BMD and TBS[b]
All (N = 1,915)	423 (22.1%)	421 (22.0%)	101 (5.3%)	622 (32.5%)	11 (3.3%)	139 (14.4%)	256 (41.2%)	406 (21.2%)	772 (40.3%)
<50 y/o (n = 88)	8 (9.1%)	8 (9.1%)	4 (4.6%)	12 (13.6%)	0 (0.0%)	0 (0.0%)	4 (100.0%)	4 (4.6%)	12 (13.6%)
50-59 y/o (n = 761)	110 (14.5%)	96 (12.6%)	18 (2.4%)	161 (21.2%)	2 (3.3%)	21 (35.0%)	37 (61.7%)	60 (7.9%)	184 (24.2%)
60-69 y/o (n = 683)	182 (26.7%)	140 (20.5%)	23 (3.4%)	242 (35.4%)	2 (1.1%)	70 (39.5%)	105 (59.3%)	177 (25.9%)	314 (46.0%)
>70 y/o (n = 383)	123 (32.1%)	177 (46.2%)	56 (14.6%)	207 (54.1%)	7 (4.2%)	48 (29.1%)	110 (66.7%)	165 (43.1%)	262 (68.4%)

BMD, bone mineral density; FN, Femoral neck; TBS, trabecular bone score.
[a]Lowest: participants with a lowest *T* score of ≦ − 2.5 at any of the three sites (spine, FN, or total hip).
[b]Combined lowest (BMD and TBS): participants with a lowest *T* score of ≦ − 2.5 at any bone site and or a spine TBS of ≦1.230.

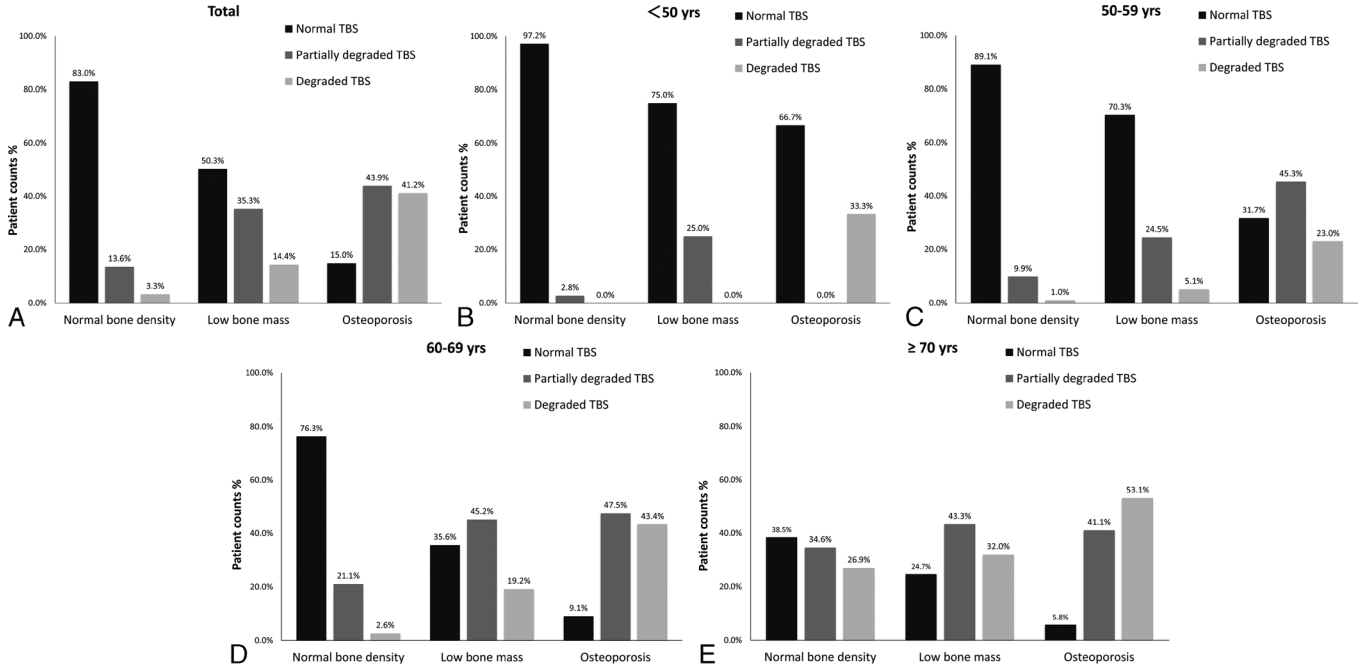

FIG. 2. Distributions of the normal, partially degraded, and degraded TBS tertiles in the lowest BMD category of postmenopausal women: (**A**) total, (**B**) <50 years old, (**C**) 50 to 59 years old, (**C**) 60 to 69 years old, and (**E**) ≥70 years old. BMD, bone mineral density; TBS, trabecular bone score.

White American women aged 30 to 90 years decreases significantly with age.[28] Studies involving patients of other ethnic groups have yielded similar results, indicating that TBS generally decreases with age regardless of ethnicity. In our study, the mean TBS was 1.300 ± 0.086, which indicated partial degradation and is consistent with the findings of the studies involving Canadian and South Korean women. However, the mean TBS in the previous study of postmenopausal Turkish women (1.35 ± 0.11) was higher than those in our study and the other studies. This difference may be attributable to the mean age of the participants in the Turkish study being lower than those of the participants in the other studies. These findings are consistent with the trend of older adults exhibiting lower TBS than younger adults. Therefore, although TBS of older adults are similar across different ethnic populations, the effect of the age of the participants should be considered in the interpretation of TBS results.

TABLE 3. *Simple linear regression models of the relationships among TBS and age, height, weight, BMI, spine BMD, total hip BMD, and FN BMD of Taiwanese postmenopausal women*

Dependent variable: spine TBS				
		ANOVA		
Independent variable	*r*	*F*	*P*	Linear Regression
Age	−0.505	654.447	<0.000	$y = 1.599–0.005x$
Height	0.298	186.515	<0.000	$y = 0.593 + 0.005x$
Weight	0.081	12.661	<0.000	$y = 1.257 + 0.001x$
BMI	−0.078	11.577	0.001	$y = 1.343–0.002x$
Spine BMD	0.619	1190.69	<0.000	$y = 0.984 + 0.378x$
Total hip BMD	0.535	765.865	<0.000	$y = 1.016 + 0.372x$
FN BMD	0.545	808.302	<0.000	$y = 1.033 + 0.428x$

ANOVA, analysis of variance; BMD, bone mineral density; BMI, body mass index; FN, Femoral neck; TBS, trabecular bone score.

To assess a patient's risk of osteoporosis, the WHO recommends using the FN BMD,[30] but the ISCD suggests using the lowest *T* score at the lumbar spine, FN, or total hip.[31] In our study, when we used the lowest *T* score across multiple sites instead of the FN data alone, the prevalence of osteoporosis increased from 22.0% to 32.5% and increased across all age groups. The results of our study, which involved a population from southern Taiwan, are similar to those reported in a previous study involving a population in northern Taiwan,[32] in which the authors concluded that using the lowest *T* score across multiple sites, in accordance with the official ISCD position, enables the identification of more Taiwanese women with osteoporosis. In our study, according to the DXA measurements collected as part of the BMD assessment, 32.5% of the participants (622/1915) had osteoporosis.

The mean BMD of our study is similar to those reported in studies involving patients from other Asian countries (South Korea, Thailand, and Japan)[33–35] but was lower than those reported in studies involving White women.[27,36] Differences in BMD across different ethnic groups were also noted in a previous study that reported similar average FN BMDs among Filipino, Chinese, and Japanese women but higher BMD in White women.[35] The lower average BMD of the Asian study populations may be due to smaller average bone size among Asian populations because DXA accounts for area BMD but not for volumetric BMD.[37,38] The influence of small bone size on BMD may result in overestimation of fracture risk. Trabecular bone score is reportedly associated with volumetric BMD, but not area BMD, and is not influenced by bone size.[39–41] In the previous TBS studies involving White women in early menopause (<60 years old), the mean TBS was 1.343-1.374, and our value fell within this range.[42,43] Our value

also fell within the range of mean TBS reported in studies involving White menopausal women of any age (1.240-1.341).[42,44,45] According to these results, TBS is a useful clinical tool for the evaluation of bone health in Asian women.

In our study, the BMD assessment results indicated that 32.5% of the participants (622/1915) had osteoporosis. This rate increased by 7.8% when the patients' risk of osteoporosis was evaluated using a combination of the BMD assessment and TBS. Among the patients exhibiting degraded TBS, 3.3% (11/330) and 14.4% (139/963) had normal bone density and low bone mass, respectively. Our results are similar to those of a previous South Korean study that reported a 10.1% higher risk of osteoporosis after incorporating TBS into osteoporosis risk assessment.[46] Therefore, TBS are helpful for identifying patients with poor bone quality, but not those with reduced bone density. According to the results of our age analysis, higher rates of degraded TBS in the patients without osteoporosis were noted in older age groups, and the rates of degraded and partially degraded TBS were 26.9% (7/26) and 34.6% (9/26), respectively, in the subgroup of patients older than 70 years with normal bone density. Our findings suggest that a combination TBS and BMD assessments can be used to identify a higher number of postmenopausal Taiwanese women at risk of osteoporosis than BMD assessment alone and that a higher rate of poor bone quality, determined according to degraded TBS, was noted in older women without low BMD.

Several studies have examined the effects of BMI on BMD and TBS in various ethnic groups.[8,46-50] In our study, BMD was positively correlated with BMI; this finding is consistent with the results of studies involving not only White women but also Asian women.[6,46,48,50] However, our results indicated that TBS was weakly and negatively correlated with BMI. Studies involving South Korean, Thai, Japanese, and Chinese participants[25,33,34,48] have reported similar results, but the correlation between BMI and TBS in studies involving White women was uncertain.[27-29] The conflicting findings regarding the effect of BMI on TBS and BMD are similar to those regarding the role of obesity (as a protective or risk factor) in the prevalence of fracture.[51] Nevertheless, the weak negative correlation between BMI and TBS may imply that some patients with high BMIs may exhibit acceptable bone mass but poor bone quality. For these patients, TBS may be more influential than BMD in the prediction of fracture risk.

This study has several limitations. First, several clinical risk factors for osteoporosis were not considered, such as lifestyle, family history, and medical history. Second, this study was a retrospective study conducted in a single hospital, and the study population may not adequately represent the entire community. Third, the sample size was small; larger TBS data sets may be required to develop an accurate regression model to predict fracture risk. Fourth, this study was cross-sectional, and no follow-up data on the incidence of fracture were available. Finally, this study developed a model to predict osteoporosis risk that may be applied in studies using the same DXA scanner; however, the applicability of this model in studies using other DXA scanners requires further evaluation.

CONCLUSIONS

This study revealed that the combination of BMD and TBS can be used to predict osteoporosis in a greater number of patients and that older postmenopausal Taiwanese women present with degraded TBS more often than do their younger counterparts. Clinicians should carefully monitor TBS degradation in older patients without low BMD.

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