JMM Journal of Menopausal Medicine
pISSN: 2288-6478, eISSN: 2288-6761
https://doi.org/10.6118/jmm.22011
J Menopausal Med 2022;28:112-120

ORIGINAL ARTICLE

Trabecular Bone Score as a Risk Factor of Major Osteoporotic Fracture in Postmenopausal Women: The First Study in Thailand

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Objectives: To compare the trabecular bone score (TBS) between Thai postmenopausal women with and without major osteoporotic fracture, and to determine whether TBS is associated with fracture risk.

Methods: All postmenopausal women sent for dual-energy X-ray absorptiometry (DXA) at the Police General Hospital were retrospectively recruited. The hospital's online database and radiographs were reviewed to collect information on underlying disease, medication, previous fractures, bone mineral density, and trabecular bone score. Patients with anti-osteoporotic medication use, skeletal malignancy, fracture from high-energy trauma, and uninterpretable DXA images were excluded.

Results: A total of 407 Thai postmenopausal women were enrolled. They were divided into 292 women without fractures and 115 women with major osteoporotic fractures. The fracture group was older (73.36 ± 9.95 vs. 66.00 ± 8.58, $P < 0.001$) and had lower serum 25-hydroxyvitamin D levels (23.28 ± 9.09 vs. 26.44 ± 9.20, $P = 0.023$). The mean TBS was lower in the fracture group, compared to the non-fracture group (1.244 ± 0.101 vs. 1.272 ± 0.099, $P = 0.011$). The subgroup analysis resulted in noticeably lower TBS in spine fracture, but not other fracture sites. The odds ratio of fracture was 1.355 ($P = 0.013$) for a decrease in one standard deviation of TBS.

Conclusions: TBS was significantly lower in postmenopausal women having fractures with an odd ratio of 1.355 ($P = 0.013$) per SD decrease in TBS. Categorizing by fracture sites, TBS was only found to be noticeably lower in the lumbar spine despite similar lumbar spine bone mineral density.

Key Words: Bone quality, Fracture risk, Fragility fracture, Osteoporosis, Trabecular bone score

INTRODUCTION

Osteoporosis is a disease characterized by diminished bone strength, contributed to both declined bone mass and deteriorating bone quality [1]. Generally known as a "silent disease", osteoporosis commonly shows no sign or symptom before it finally manifests as fragility fractures, inevitably leading to morbidity and mortality [2]. It has been estimated that over half of Thai elderly women have osteoporosis [3]. The prevalence of osteoporotic hip fracture in Thailand is approximately 253.5 per 100,000 citizens, leading to permanent disability and 1-year mortality of 18% [4], with the annual cost of treatment expected to reach 2 billion US dollar by 2050 [5]. It is also predicted that over 50% of global osteoporotic fractures will occur in Asia by 2050 [6].

Nowadays, bone mineral density (BMD) of the lumbar spine, hip and/or distal radius, measured by dual-energy X-ray absorptiometry (DXA), is widely used as a tool to predict fracture risk and to diagnose osteoporosis, as well as a treatment threshold [7-9]. However, a large proportion of osteoporotic fractures occur in osteopenic women, having BMD T-score between –1 and –2.5 standard deviation (SD), leading to an observation that

Received: March 26, 2022 **Revised:** November 25, 2022 **Accepted:** December 22, 2022
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BMD does not fully explain individual's risk of fracture [10,11]. Indeed, BMD can only capture 60%–70% of bone strength and does not provide information on bone quality, another important determinant of overall bone strength, and thus, fracture risk [12-14].

Trabecular bone score (TBS) has been introduced as a means to quantify bone 3-dimensional microarchitecture using variation in gray-level texture between adjacent pixels in 2-dimensional images obtained from any x-rays, including DXA [15]. Lower TBS reflects poorer bone quality despite equal BMD [16-18]. While computed tomography and magnetic resonance imaging also allow for determination of bone microarchitecture, it is not practical to determine bone quality using these methods due to the cost, radiation exposure, and limited availability [19,20]. TBS, on the other hand, can be calculated from the same set of images obtained during DXA scan using a plug-in of DXA software. Hence, there is no additional cost or radiation incurred to the patients. In the recent decade, TBS has been of growing interest, and research has been increasingly focusing on its capability to predict fracture risk [21-29]. While varying numerically, studies have shown an odd ratio of having a fragility fracture of as high as 3.8 (95% confidence interval [CI] 2.2–6.7) per a 1-SD decrease in TBS [29]. The largest study to date was conducted in Manitoba, prospectively following 29,407 postmenopausal women for 4.7 years on average [30]. It was found that a decrease in 1 SD of TBS results in more hip and major osteoporotic fractures (MOF) with a hazard ratio of 1.44 (95% CI 1.28–1.62) and 1.42 (95% CI 1.33–1.53), respectively. Studies in Asian population are scarcer. A prospective investigation in Chinese population revealed that, for a decline of 1 SD of TBS, a hazard ratio of suffering a MOF was 1.53 (95% CI 1.30–1.80) in elderly men and 1.40 (95% CI 1.22–1.61) in postmenopausal women [24].

Research on TBS in Thai population is even more uncommon, and there has been no study determining the relationship between TBS and fracture risk in Thai population. Therefore, our study aims to determine whether lower TBS value is associated with more MOF in Thai population. We also investigate the relationship between known clinical risk factors of osteoporosis and TBS.

MATERIALS AND METHODS

This retrospective cohort study design and a waiver of informed consent from participants were approved by Institutional Review Board of our hospital (The Ethical Committee of Police General Hospital [COA No. 121/2021]). All postmenopausal women with DXA performed were recruited, and later divided into the control and fracture groups. TBS was then compared between the two groups.

Participant selection

Our study is a retrospective cohort study performed in all postmenopausal women visiting Police General Hospital, Bangkok, Thailand, for BMD evaluation from July 1, 2019, to October 31, 2020, either for a routine check-up or after an osteoporotic fracture as a part of the hospital fracture liaison service (FLS). Eligible patients were postmenopausal women aged 50 or over with an interpretable DXA images. Since lumbar spine BMD (LS BMD) is subject to errors due to artifacts, degenerative changes, and vertebral compression fractures, we excluded fractured vertebrae and vertebrae with more than 1 SD difference in BMD from adjacent vertebrae to minimize these errors. If less than two interpretable vertebrae remained, the patient was excluded from the analysis. The fracture group was defined as participants with a history of MOF which was the fracture of the hip, vertebra, proximal humerus, and distal radius from a low-energy trauma. Patients with previous or current use of anti-osteoporotic medication, skeletal malignancy or metastasis, fracture of the hip, spine, humerus or wrist from high-energy trauma, previous spinal surgery including decompressive surgery, fixation, cement augmentation or intervertebral disc replacement were also excluded.

Data extraction

Participant's characteristics

Hospital database review was performed for each participant to obtain the following data: age, weight, height, detail of previous fracture, underlying diseases, alcohol use, cigarette smoking, age at menopause, and prescription of calcium and vitamin D supplement, and medication records (with an emphasis on drugs that cause skeletal harm, including anticonvulsants, antipsychotics, and chronic steroid defined as an equivalent dose of prednisolone 5 mg per day for three months or longer). If the required information was absent from the database, the patients were contacted via telephone calls to obtain the relevant information. Laboratory re-

sults including estimated glomerular filtration rate, and serum 25-hydroxyvitamin D level were also recorded.

Measurement of BMD

All DXA scans were performed using HORIZON A Hologic bone densitometry (Hologic Marlborough, MA, USA) in accordance with the recommendations from the International Society for Clinical Densitometry (ISCD) by ISCD-certified densitometer technologists. BMD measurements were obtained from the lumbar spine L1 to L4, total hip, and femoral neck. The lumbar spines with artifacts were excluded from analysis according to the aforementioned criteria.

Measurement of TBS

TBS was calculated by TBS iNsight version 3.0.2.0 (Medimaps Group, Geneva, Switzerland) using the lumbar spine DXA image with the same region of interest as LS BMD. An individual value for each vertebra was calculated, with each value subsequently combined to obtain a mean of the vertebrae in the region of interest. For analysis, we used the same levels of lumbar spines used for BMD calculation after excluding levels with artifact.

Ascertainment of fracture

History of fracture including fragility fracture of the hip, vertebra, proximal humerus, and distal radius, was obtained from medical records, plain radiographs of the affected part and vertebral fracture assessment (VFA) using DXA. Medical records of out-patient visits, in-patient admissions, and emergency department visits were reviewed to identify previous fragility fractures based on ICD-10 diagnosis and narrated medical records in the online database, to both confirm the diagnosis, and to exclude fractures from high energy trauma. Plain radiographs were reviewed to avoid misdiagnosis. When VFA images were available, a compression fracture of over 25% collapse was justified as a vertebral fracture.

Statistical analysis

The categorical variables were presented as frequency with percentages and compared between the control and fracture group using Pearson's Chi-square test or Fischer's exact test. Continuous variables were expressed as mean and SD. The differences between groups were calculated using Student's *t* test. The odd ratio of sustaining a MOF for an SD decrease of TBS was estimated using ordered logistic regression. All statistical analyses were performed using standard software package (Stata version. 13.0; StataCorp LLC, College Station, TX, USA).

RESULTS

A total of 407 Thai postmenopausal women were enrolled, consisting of 292 women without fractures and 115 women with MOF, divided into 35 hip fractures, 62 vertebral fractures, 2 humeral fractures, and 16 wrist fractures. A total number of female patients in FLS during the study period was 78, with 57 (73.1%) of them had their BMD measured. Ten of them had a history of previous anti-osteoporotic medication use and 4 had uninterpretable LS-BMD and were therefore excluded. The fracture group of remaining 43 patients recruited from FLS consisted of 27 hip fractures, 10 vertebral fractures and 6 distal radius fractures. The rest of the fractured patients were mainly identified from VFA (38 fractures, 52.78%), followed by plain radiographs (30 fractures (41.67%), and ICD-10 with confirming medical record (4 fractures, 5.56%). The mean age of the participants was 68.08 ± 0.47 years old. The fracture group was significantly older than the non-fracture group (66.00 ± 8.58 vs 73.36 ± 9.95, respectively, $P < 0.001$). The fractured patients identified from database search were significantly older than those from FLS ($P = 0.03$). Body mass index (BMI) was numerically lower in the fracture group, but the difference did not achieve statistical significance. The fracture group had lower serum 25-hydroxyvitamin D level (23.28 ± 9.09 vs 26.44 ± 9.20 ng/mL, $P = 0.023$). There were a significantly higher percentage of patients with type 2 diabetes mellitus and stage 3–5 chronic kidney disease in the fracture group. Type 2 diabetes mellitus was most prevalent in fractured patients from database searching. The use of steroid and other medications that cause skeletal harm did not significantly differ between groups. The characteristics of the non-fracture and fracture group in and out of LFS are shown in Table 1.

Comparison of TBS in fracture and non–fracture group

The mean TBS of the population was 1.264 ± 0.005. The fracture group had a mean TBS of 1.244 ± 0.101 which was significantly lesser than the non-fracture group's which was 1.272 ± 0.099 ($P < 0.01$). While patients with vertebral fractures had pronouncedly reduced TBS (1.239 ± 0.086, $P = 0.015$ compared to

non-fracture group), patients who suffered from hip, humerus and distal radius did not show statistically significant difference in TBS compared to non-fracture group. Patients with humeral fracture (n = 2), however, had numerically lowest TBS of 1.191 ± 0.086 (P = 0.250, compared to the non-fracture group). The TBS of non-fracture and fracture group categorized by fracture sites are demonstrated in Table 2. When only fracture patients from database search were considered, TBS was still lower in the fracture group (P = 0.012), and only vertebral fracture patients demonstrated lower TBS compared to non-fracture group (P = 0.038). Patients from FLS, in contrast, did not exhibit a difference in TBS compared to non-fracture patients. Vertebral fracture patients in FLS, however, showed numerically lower TBS than non-fracture group (P = 0.061). The TBS of fracture patients from database base search and from FLS are shown in Tables 3 and 4 respectively. Using ordered logistic regression, a decrease in 1 SD of TBS resulted in an odd ratio of 1.335 (P = 0.013) of having

Table 1. Characteristics of participants in each category

Characteristics of participants	Total	Without MOF[a]	MOF[a]	MOF[a] in FLS	MOF[a] not in FLS
Number of participants	407 (100)	292 (71.74)	115 (28.26)	43 (10.57)	72 (17.69)
Age (y)	68.08 ± 0.47	66.00 ± 8.58	73.36 ± 9.95***	75.95 (10.25)	71.55 ± 9.85*
Body mass index (kg/m^2)	24.17 ± 5.18	24.49 ± 5.50	23.37 ± 4.19*	22.90 ± 4.84	23.44 ± 3.77
25-hydroxy vitamin D level (ng/mL)	25.14 ± 9.24 (n = 184)	26.44 ± 9.20 (n = 109)	23.28 ± 9.09* (n = 75)	21.89 ± 8.78 (n = 43)	25.27 ± 9.08 (n = 32)
Dyslipidemia	71 (17.44)	48 (16.44)	23 (20)	6 (13.95)	17 (23.61)
Diabetes mellitus type 2	49 (12.04)	27 (9.25)	22 (19.13)**	7 (16.28)	15 (20.83)**
Stage 3–5 chronic kidney disease	76 (18.67)	39 (13.36)	37 (32.17)***	15 (34.88)	22 (30.55)***
Steroid use[b]	16 (3.93)	12 (4.11)	4 (3.48)	0 (0)	4 (5.56)
Anticonvulsant/ antidepressant/ antipsychotics use[c] (%)	17 (4.18)	10 (3.42)	7 (6.09)	3 (6.98)	4 (5.56)

Data are presented as number (%), mean ± SD or number only.
MOF: major osteoporotic fracture, FLS: fracture liaison service.
[a]MOF is defined as fracture of the hip, vertebra, proximal humerus, and distal radius from low-energy trauma. [b]Steroid use is defined as a use of an equivalent dose of 5 mg per day of prednisolone for three months or longer. [c]Anticonvulsant, antidepressant, or antipsychotics use is defined as a regular use of the aforementioned medication for three months or longer.
*P < 0.05, **P < 0.01, ***P < 0.001 compared to without MOF group.

Table 2. Trabecular bone score and bone mineral density of hip and spine in all participants, participants without fractures, and participants with fractures, categorized by site of fracture

Characteristics of participants	Total	Without MOF	MOF	Hip	Vertebra	Humerus	Distal radius
Number of participants	407 (100)	292 (71.74)	115 (28.26)	35 (8.59)	62 (15.23)	2 (0.49)	16 (3.93)
Trabecular bone score	1.264 ± 0.005	1.272 ± 0.099	1.244 ± 0.101**	1.258 ± 0.130	1.239 ± 0.086*	1.191 ± 0.086	1.242 ± 0.086
Lumbar spine BMD (g/cm^2)	0.868 ± 0.008	0.887 ± 0.159	0.817 ± 0.184***	0.775 ± 0.150***	0.847 ± 0.207	0.653 ± 0.042*	0.815 ± 0.140
Femoral neck BMD (g/cm^2)	0.638 ± 0.006	0.669 ± 0.112	0.558 ± 0.126***	0.522 ± 0.133***	0.574 ± 0.126***	0.48 ± 0.037*	0.581 ± 0.098**
Total hip BMD (g/cm^2)	0.763 ± 0.010	0.801 ± 0.188	0.665 ± 0.188***	0.653 ± 0.166***	0.685 ± 0.190***	0.574 ± 0.103	0.624 ± 0.233***

Data are presented as number (%) or mean ± SD.
MOF: major osteoporotic fracture, BMD: bone mineral density.
[a]MOF is defined as fracture of the hip, vertebra, proximal humerus, and distal radius from low-energy trauma.
*P < 0.05, **P < 0.01, ***P < 0.001 compared to without MOF group.

Table 3. Trabecular bone score and bone mineral density of hip and spine in participants without fractures, and participants with fractures not under fracture liaison service, categorized by site of fracture

Characteristics of participants	Without MOF[a]	MOF[a]	Hip	Vertebra	Humerus	Distal radius
Number of participants	292 (80.22)	72 (19.78)	8 (2.20)	52 (14.56)	2 (0.55)	10 (2.75)
Trabecular bone score	1.272 ± 0.099	1.239 ± 0.088*	1.264 ± 0.090	1.242 ± 0.087*	1.191 ± 0.086	1.222 ± 0.090
Lumbar spine BMD (g/cm^2)	0.887 ± 0.159	0.838 ± 0.194*	0.837 ± 0.105	0.853 ± 0.213	0.653 ± 0.042*	0.791 ± 0.101*
Femoral neck BMD (g/cm^2)	0.669 ± 0.112	0.571 ± 0.122***	0.610 ± 0.138	0.569 ± 0.126***	0.48 ± 0.037*	0.574 ± 0.094**
Total hip BMD (g/cm^2)	0.801 ± 0.188	0.674 ± 0.193***	0.690 ± 0.222	0.678 ± 0.194***	0.574 ± 0.103	0.646 ± 0.224**

Data are presented as number (%) or mean ± SD.
MOF: major osteoporotic fracture, BMD: bone mineral density.
[a]MOF is defined as fracture of the hip, vertebra, proximal humerus, and distal radius from low-energy trauma.
*P < 0.05, **P < 0.01, ***P < 0.001 compared to without MOF group.

Table 4. Trabecular bone score and bone mineral density of hip and spine in participants without fractures, and participants with fractures under fracture liaison service, categorized by site of fracture

Characteristics of participants	Without MOF[a]	MOF[a]	Hip	Vertebra	Humerus	Distal radius
Number of participants	292 (80.22)	43 (12.84)	27 (8.06)	10 (2.99)	0 (0)	6 (1.80)
Trabecular bone score	1.272 ± 0.099	1.256 ± 0.122	1.256 ± 0.141	1.222 ± 0.070	N/A	1.273 ± 0.054
Lumbar spine BMD (g/cm^2)	0.887 ± 0.159	0.783 ± 0.155***	0.756 ± 0.158***	0.745 ± 0.185***	N/A	0.853 ± 0.189
Femoral neck BMD (g/cm^2)	0.669 ± 0.112	0.527 ± 0.125***	0.496 ± 0.123***	0.468 ± 0.141***	N/A	0.601 ± 0.121
Total hip BMD (g/cm^2)	0.801 ± 0.188	0.639 ± 0.201***	0.642 ± 0.149***	0.621 ± 0.181***	N/A	0.588 ± 0.314**

Data are presented as number (%) or mean ± SD.
MOF: major osteoporotic fracture, BMD: bone mineral density, N/A: not applicable.
[a]MOF is defined as fracture of the hip, vertebra, proximal humerus, and distal radius from low-energy trauma.
**P < 0.01, ***P < 0.001 compared to without MOF group.

a MOF. Subgroup analysis showed that when patients from FLS were excluded, the odd ratio of sustaining a fracture increased to 1.49 (P = 0.014) per 1 SD decrease in TBS. However, when only FLS patients were taken into calculation, the odd ratio decreased to 1.18 and lost its statistical significance (P = 0.349).

Comparison of BMD in fracture and non-fracture group

Demonstrated in detail in Table 2, the mean LS BMD, FN BMD, and TH BMD were significantly lower in the fracture group, compared to non-fracture group (LS BMD 0.817 g/cm^2 ± 0.184 g/cm^2 vs 0.887 g/cm^2 ± 0.159 g/cm^2, P < 0.001; FN BMD 0.558 ± 0.126 g/cm^2 vs 0.669 ± 0.112 g/cm^2, P < 0.001; TH BMD 0.665 ± 0.188 g/cm^2 vs 0.801 ± 0.188 g/cm^2, P < 0.001). Patients with hip fracture had significantly lower BMD at all sites compared to non-fracture participants. Patients suffering from a vertebral fracture or distal radius fracture had lower FN BMD and TH BMD compared to non-fracture controls. LS BMD and TH BMD were lower in humeral fracture patients. Fracture patients who were not in FLS also had significantly lower BMD at all sites measured compared to non-fracture group. Categorized by site of fractures, vertebral fracture patients had significantly lower FN BMD and TH BMD, while humeral fracture patients had lower LS BMD and FN BMD. Distal radius fracture patients had lower BMD at all sites. Patients in FLS also had lower BMD at all sites. The same was found from subgroup of FLS patients with hip and vertebral fractures. Distal radius fracture patients in FLS only had lower TH BMD compared to non-fracture women. Site-specific BMD of both groups of fracture patients are listed in Tables 3 and 4.

Effect of supplement prescription on TBS

With regards to the prescription of supplements, 263 women were taking calcium carbonate supplement, 270 taking ergocalciferol supplement, and 238 taking both. The mean TBS of women receiving vitamin D supplement was significantly lower than those who were not prescribed vitamin D (1.256 ± 0.104 vs 1.280 ± 0.091, P = 0.02). The mean TBS however, was not different in women taking calcium supplements, or taking both

Table 5. The average TBS of participants taking calcium and/or vitamin D supplements

Supplement	Not prescribed`		Prescribed		*P* value
	Number of participants	TBS, mean ± SD	Number of participants	TBS, mean ± SD	
Calcium	144	1.269 ± 0.092	263	1.262 ± 0.105	0.516
Vitamin D	137	1.280 ± 0.091	270	1.256 ± 0.104	0.020
Calcium and vitamin D	169	1.274 ± 0.093	238	1.257 ± 0.105	0.104

TBS: trabecular bone score.

Table 6. Comparison of TBS in patients with diabetes mellitus type 2 or stage 3 chronic kidney disease or worse, with patients without the diseases

Underlying disease	No disease		With disease		*P* value
	Number of participants	TBS, mean ± SD	Number of participants	TBS, mean ± SD	
Type 2 diabetes mellitus	358	1.265 ± 0.005	49	1.261 ± 0.015	0.785
Stage 3–5 chronic kidney disease	331	1.266 ± 0.005	76	1.258 ± 0.013	0.526

TBS: trabecular bone score.

calcium and vitamin D, compared to those who were not taking them. The mean TBS of the participants who were taking and not taking supplements are shown in Table 5.

Effect of type 2 diabetes mellitus and chronic kidney disease on TBS

Among 407 participants enrolled, 49 (12.04%) had type 2 diabetes mellitus, and 76 (18.67%) had stage 3–5 chronic kidney disease. The mean TBS of patients with diabetes mellitus was lower but not significantly different from those without diabetes mellitus. Neither was the mean TBS of patients with chronic kidney disease. The mean TBS of patients with type 2 diabetes mellitus, and chronic kidney disease are shown in Table 6.

DISCUSSION

As delineated in the result, it is evident that there is differential accuracy of TBS in predicting fractures in postmenopausal women, with only vertebral fractures significantly associated with low TBS. We hypothesize that the ability of TBS to assess fracture risk might be site-specific, as TBS was derived from the DXA image of the lumbar spine, offering a more direct assessment of the bone quality of the vertebrae.

We found an odd ratio of MOF was 1.335 (P = 0.013) for a SD decrease in TBS. The results were in accordance with many previous studies. In a large retrospective cohort involving 29,407 women in Manitoba, Canada, the odd ratio (OR) of fracture for the lowest tertile of TBS compared with the middle tertile was 1.57 (95% CI 1.46–1.68); however, lower TBS value was found in both spine fracture and hip fracture patients [30]. A study in Asian population showed similar results. According to Su et al. [24] each SD decrease in TBS was associated with a hazard ratio of 1.40 (95% CI 1.22–1.61) of having a MOF in community-dwelling elderly Chinese women. A prospective cohort in 665 Japanese women reported a hazard ratio of sustaining a vertebral fracture per 1 SD decrease in TBS of 1.98 (95% CI 1.56–2.51) [23]. A meta-analysis consisting of 14 prospective population-based cohort found an adjusted gradient of risk of 1.44 (95% CI 1.35–1.53) of having a MOF per SD decrease in TBS [25]. When FLS patients were excluded from the calculation, we found a higher odd ratio of fractures for an SD decrease in TBS (OR = 1.49, P = 0.014). Again, this suggested the site specificity of TBS as the increase in odd ratio could be explained by higher percentage of vertebral fractures in this group in which vertebral fractures were mainly identified from VFA or plain radiographs and had significantly lower TBS. Meanwhile, only 10 patients from FLS had vertebral fracture. The TBS of vertebral fracture patients in the FLS were indeed considerably lower compared to control, but potentially due to its small sample size, did not achieve statistical significance.

Comparing the mean TBS value across studies of Asian

population, participants in our study had similar overall TBS value compared to community-dwelling Hong Kong population, but higher than Japanese women [23,24]. The non-fracture group in our study had higher mean TBS value than both studies, which might be explained by younger ages (66.00 ± 8.58). The fracture group also had higher mean TBS value (1.244 ± 0.101, 1.23 ± 0.08, and 1.132 ± 0.110 in our study, MsOs Hong Kong, and The Japanese Population-based Osteoporosis (JPOS), respectively) despite relatively similar or even older age (73.36 ± 9.95, 74.26 ± 5.27, and 68.2 ± 7.5 in our study, MsOs Hong Kong, and JPOS, respectively).

Rampersad et al. [31] recently discovered that TBS was lower in patients with stage 3–5 chronic kidney disease and that lower TBS score was associated with higher risk of MOF and hip fracture in patients with an estimated glomerular filtration rate ≥ 60 mL/min/1.73 m^2, but not in patients with lower estimated glomerular filtration rate. This finding was not reiterated our study, which only found a small numerical difference in TBS between patients with estimated glomerular filtration rate ≥ 60 and < 60 mL/min/1.73 m^2. Patients with type 2 diabetes mellitus had been found to have lower TBS and higher fracture risk compared to normal population, despite non-inferior BMD [32,33]. Our study however, did not find a significant difference between TBS in women with and without diabetes mellitus.

The majority of the patients in the FLS in our institute came for continuing follow-up visits at out hospital, allowing us to comprehensively study this group of patients. However, we found that a large proportion of vertebral fractures was identified from database searching, and was not referred to FLS or osteoporosis clinic for anti-osteoporotic treatment. Thus, the importance of asymptomatic vertebral fracture should be emphasized as these patients are inclined to suffer from future fractures [34].

Participants with history of vitamin D supplementation surprisingly had lower TBS compared to those who did not receive vitamin D in our study, which was seemingly contradicting preceding studies which showed that vitamin D deficiency was associated with lower TBS [35,36]. Participants with history of vitamin D supplementation in our study might indeed, had lower serum 25-hydroxyvitamin D level to begin with, and therefore, had vitamin D prescribed. Moreover, these participants possibly had osteopenia or clinically judged by physicians to be at higher risk of fractures, and was thus prescribed with vitamin D supplementation, contributing to lower TBS in participants with vitamin D supplementation in this study.

To date, this is the first study investigating the relationship between TBS and fracture risk in Thai population. It signifies the importance of TBS as an additional method of predicting a risk of MOF in Thai postmenopausal women. Therefore, we recommend incorporating TBS into the assessment of postmenopausal women with high risk of fracture. The strength of this study is in its comprehensive collection of all sites of central BMD, all of which were measured by the same technician using the same DXA scanner, minimizing inter-observer variability. Furthermore, the study included all postmenopausal women sent for DXA scan at our institute, partly representing the community sample in the area. The study is however limited by small sample size, especially the proximal humerus fracture group as patients with humeral fracture were not routinely referred to the hospital's FLS and thus did not have available data from DXA scan. Also, not all participants' serum 25-hydroxyvitamin D level was evaluated. Future research on site-specific TBS and risk of fracture with a larger sample size, and the role of TBS in initiating an anti-osteoporotic treatment will likely lead to an improvement in patient care.

TBS was significantly lower in postmenopausal women with MOF with an odd ratio of having a fracture of 1.355 (P = 0.013) per SD decrease in TBS. However, categorizing by fracture sites, TBS was only found to be significantly lower in the lumbar spine despite similar LS BMD, potentially driving the difference in the suggesting its site specificity.

ACKNOWLEDGEMENTS

We would like to thank Ms. Kamonchalat Apiromyanont for her contribution on DXA scans and TBS calculation and Athirat Janpanichjaroen, Pharm. D. and Lertkong Nitiwarangkul, MD for their assistance in statistical analysis. Lastly, we would like to thank Nacharin Phiphopthatsanee, MD for his assistance in final proofreading of the manuscript.

CONFILCT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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