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Original Article

Creation of an Age-Adjusted, Dual-Energy X-ray Absorptiometry–Derived Trabecular Bone Score Curve for the Lumbar Spine in Non-Hispanic US White Women

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Abstract

The trabecular bone score (TBS, Med-Imaps, Pessac, France) is an index of bone microarchitecture texture extracted from anteroposterior dual-energy X-ray absorptiometry images of the spine. Previous studies have documented the ability of TBS of the spine to differentiate between women with and without fractures among age- and areal bone mineral density (aBMD)-matched controls, as well as to predict future fractures. In this cross-sectional analysis of data collected from 3 geographically dispersed facilities in the United States, we investigated age-related changes in the microarchitecture of lumbar vertebrae as assessed by TBS in a cohort of non-Hispanic US white American women. All subjects were 30 yr of age and older and had an L1–L4aBMDZ-score within ±2 SD of the population mean. Individuals were excluded if they had fractures, were on any osteoporosis treatment, or had any illness that would be expected to impact bone metabolism. All data were extracted from Prodigy dual-energy X-ray absorptiometry devices (GE-Lunar, Madison, WI). Cross-calibrations between the 3 participating centers were performed for TBS and aBMD. aBMD and TBS were evaluated for spine L1–L4 but also for all other possible vertebral combinations. To validate the cohort, a comparison between the aBMD normative data of our cohort and US non-Hispanic white Lunar data provided by the manufacturer was performed. A database of 619 non-Hispanic US white women, ages 30–90 yr, was created. aBMD normative data obtained from this cohort were not statistically different from the non-Hispanic US white Lunar normative data provided by the manufacturer ($p = 0.30$). This outcome thereby indirectly validates our cohort. TBS values at L1–L4 were weakly inversely correlated with body mass index ($r = -0.17$) and weight ($r = -0.16$) and not correlated with height. TBS values for all lumbar vertebral combinations decreased significantly with age. There was a linear decrease of 16.0% (−2.47 T-score) in TBS at L1–L4 between 45 and 90 yr of age (vs. −2.34 for aBMD). Microarchitectural loss rate increased after age 65 by 50% (−0.004 to −0.006). Similar results were obtained for other combinations of lumbar vertebra. TBS, an index of bone microarchitectural texture, decreases with advancing age in non-Hispanic US white women. Little change in TBS is observed between ages 30 and 45. Thereafter, a progressive decrease is observed with advancing age. The changes we observed in these American women are similar to that previously reported for a French population of white women ($r^2 > 0.99$). This reference database will facilitate the use of TBS to assess bone microarchitectural deterioration in clinical practice.

Key Words: Bone microarchitecture; bone mineral density; non-Hispanic white US women; normative data; trabecular bone score.

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Introduction

Accounting for up to 9 million new fragility fractures worldwide each year *(1)*, osteoporosis is now considered the most common and most costly of all metabolic bone diseases

in the industrialized world *(2)*. Identification of individuals at risk for osteoporosis and the resultant prevention of fragility fractures are central to reducing the morbidity, increased risk of mortality, sometimes exceeding 20%, and the cost associated with these fractures *(3,4)*. However, to date, prediction of those in need of treatment remains imperfect. Although areal bone mineral density (aBMD), as measured by means of dual-energy X-ray absorptiometry (DXA), is still considered the gold standard for osteoporosis diagnosis in the absence of established fragility fractures *(5)*, it is now well-established that other bone characteristics also contribute significantly to bone strength and fracture risk. These characteristics include the microarchitecture of trabecular bone, which includes bone microdamage, mineralization, and turnover *(6–8)*, none of which is well represented by aBMD alone.

The trabecular bone score (TBS; Med-Imaps, Pessac, France) is a black-box algorithm that characterizes the gray-level amplitude variations in adjacent pixels of trabecular bone in standard DXA scans of the lumbar spine. On the basis of this approach, it has been shown that TBS correlates with trabecular bone connectivity, trabecular number, and space between trabeculae *(21,22)*. The technique has been evaluated in a variety of clinical settings. TBS is a strong and aBMD-independent predictor of current *(9–13)* and future osteoporotic fracture in adults *(14–17)* and provides aBMD-independent information when monitoring the effects of osteoporosis treatments *(18,19)*. Although derived from the same DXA scans from which aBMD is measured, TBS is not simply another index of aBMD. In large cohorts of subjects, the correlation between TBS and aBMD is weak to moderate ($0.01 \leq r^2 \leq 0.4$) *(9,10,14,15,17,20,23)*. Changes observed in TBS and aBMD caused by different therapeutic classes of osteoporosis agents are weakly to not correlated *(18,19)*. These observations suggest that TBS provides a different set of information about bone structure as well as bone strength *(27)* than do aBMD measurements. Combining aBMD and TBS measurements provides more accurate assessment of osteoporotic fracture risk than does either technique alone. In patients receiving glucocorticoids, TBS predicts vertebral fracture risk more accurately than does aBMD *(20,28)*.

Despite its clear promise, however, for the TBS to truly be useful in routine clinical practice, it is necessary that clinicians be able to compare single TBS values to age-adjusted reference data, as currently done for aBMD. To date, such data are limited with only one large national database in existence *(24)*.

The aims of the current study were: (1) to create a cohort of adult non-Hispanic US white women in the United States with TBS data across a broad range of ages to serve as a reference database for clinical use; (2) to identify trends in TBS values with age in this cohort; and (3) to compare these results against already-published, age-adjusted data to validate the sample and results.

Materials and Methods

Subjects

The subject sample consisted of adult non-Hispanic US white women whose DXA and demographic records were drawn from databases at 3 clinical centers across the United States, with all centers having similar densitometry systems in use (Prodigy, GE-LUNAR, Madison, WI). The 3 participating centers were selected to represent the eastern (Department of Medicine, University of Vermont College of Medicine, Burlington, VT); central (HealthEast Osteoporosis Care, Woodbury, MN) and western (Oregon Osteoporosis Center, Portland, OR) United States.

From these 3 centers, drawing on records dated between 2003 and 2012, a cohort of 619 non-Hispanic US white women was generated, including at least 70 subjects per decade of life via a predetermined normative data protocol. The sample population ranged from 30 to 90 yr of age. Subjects were then subdivided by decades of life: 30–39, 40–49, 50–59, 60–69, 70–79, and 80+. A wide range of body mass index (BMI) scores also were studied, spanning from 17.5 to 36.2 kg/m^2.

aBMD and TBS Assessments

Bone mineral density was evaluated for the spine using 3 DXA narrow fan-beam bone densitometers (Prodigy, GE-LUNAR, Madison, WI) via posteroanterior spine acquisitions. aBMD assessments were performed at L1–L4. Spinal TBS was evaluated using TBS iNsight (Med-Imaps, Pessac, France) over the same regions of measurement as those used for AP spine aBMD. TBS was calculated as the mean value of the individual measurements for each vertebra and their combinations from L1 through L4. A statistical procedure was used to cross-calibrate the three systems for aBMD and TBS measurements, using the following equations:

$$\mathrm{aBMD}_{center1\_cross-calibrated} = \mathrm{aBMD}_{center1} + \left(\frac{\sum_{Li=1}^{4} (\mathrm{aBMD}^{Li}_{reference\_center} - \mathrm{aBMD}^{Li}_{center1})}{4} \right)$$

$$\mathrm{TBS}_{center1\_cross-calibrated} = \mathrm{TBS}_{center1} + \left(\frac{\sum_{Li=1}^{4} (\mathrm{TBS}^{Li}_{reference\_center} - \mathrm{TBS}^{Li}_{center1})}{4} \right)$$

Where *reference_center* = the common center, *center1* = the center to be cross-calibrated, and *Li* = lumbar vertebra level *i* (*i* = 1 for *L1*).