Editorial

More evidence to support a lower quantitative computed tomography (QCT) lumbar spine bone mineral density (BMD) cutpoint value for classifying osteoporosis among older East Asian women than for Caucasians

Yì Xiáng J. Wáng[1]^, Wei Yu[2], Jason C. S. Leung[3], James F. Griffith[1], Ben-Heng Xiao[1], Daniele Diacinti[4], Ali Guermazi[5], Wing P. Chan[6,7], Glen M. Blake[8]

[1]Department of Imaging and Interventional Radiology, Faculty of Medicine, The Chinese University of Hong Kong, Shatin, Hong Kong SAR, China; [2]Department of Radiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China; [3]Jockey Club Centre for Osteoporosis Care and Control, Faculty of Medicine, The Chinese University of Hong Kong, Shatin, Hong Kong SAR, China; [4]Department of Radiological Sciences, Oncology, and Pathology, Sapienza University of Rome, Rome, Italy; [5]Department of Radiology, VA Boston Healthcare System, Boston University School of Medicine, Boston, MA, USA; [6]Department of Radiology, Wan Fang Hospital, Taipei Medical University, Taipei; [7]Department of Radiology, School of Medicine, College of Medicine, Taipei Medical University, Taipei; [8]School of Biomedical Engineering and Imaging Sciences, King's College London, St Thomas' Hospital, London, UK

Correspondence to: Yì Xiáng J. Wáng, MMed, PhD. Department of Imaging and Interventional Radiology, Faculty of Medicine, The Chinese University of Hong Kong, 30-32 Ngan Shing Street, Shatin, New Territories, Hong Kong SAR, China. Email: yixiang_wang@cuhk.edu.hk.

Submitted Mar 05, 2024. Accepted for publication Mar 25, 2024. Published online Apr 10, 2024.
doi: 10.21037/qims-24-429
View this article at: https://dx.doi.org/10.21037/qims-24-429

Introduction

Quantitative computed tomography (QCT) for bone mineral density (BMD) measurement can be performed on any CT scanner with the use of a calibration phantom. Calibration phantoms are required to transform the attenuation measured in Hounsfield units into a BMD value in units of mg/mL. It is expected that the application of QCT for spine BMD will increase, particularly in the setting of opportunistic screening. The most common form of QCT provides a trabecular bone measurement (1-4). Numerous studies have demonstrated that the skeleton of East Asians has microstructural and mechanical advantages (5,6). For example, Walker *et al.* (7,8) reported that postmenopausal Chinese women have a higher trabecular plate-to-rod ratio and greater whole bone stiffness, translating into greater trabecular mechanical competence despite smaller bone size compared to Caucasian women. For the spine, compared with older Caucasian women, older Chinese women are less likely to have disc space narrowing, thoracic spine hyper-kyphosis, vertebral osteoarthritic wedging, Schmorl nodes defect, and degenerative spondylolisthesis (9,10). Almost all of the published results comparing East Asians and Caucasians show nearly all fragility fracture prevalences, including hip fracture, vertebral fracture, humerus fracture, and wrist fracture, are no more than half that of older Caucasians, both for men and women [reviewed in (11,12)].

For Caucasian women (and men), the recommended QCT lumbar spine (LS) trabecular BMD cutoff value for osteoporosis is 80 mg/mL (13,14). The same QCT criterion has also been commonly applied to East Asian populations (15-23), despite earlier reports that East Asian women suffer from vertebral fragility fracture at a lower LS QCT BMD than Caucasian women (24,25). Considering the different bone properties and the much lower incidence of fragility fractures in East Asian women compared with Caucasians

^ ORCID: 0000-0001-5697-0717.

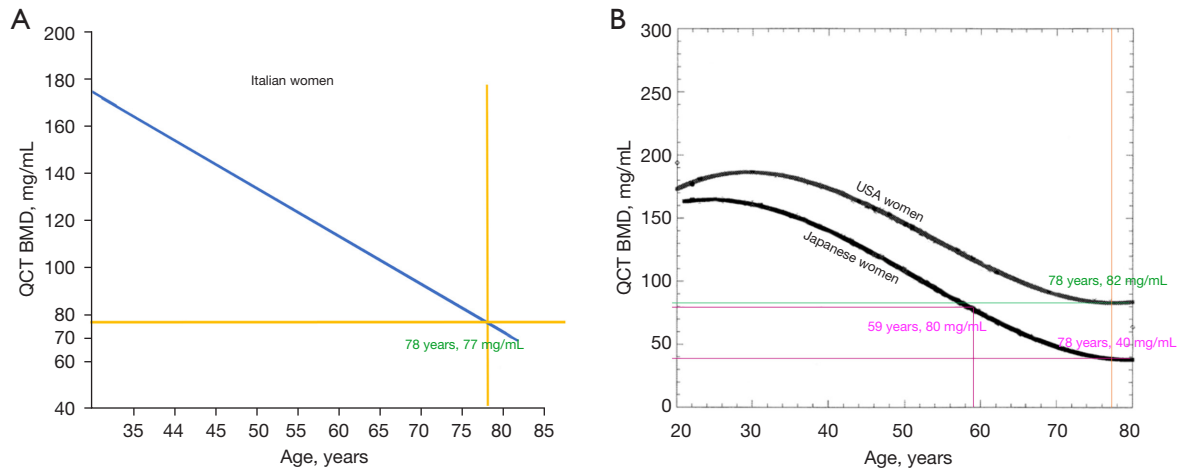

Figure 1 Women's population mean LS QCT BMD decreases during aging. (A) For Italian women at the age of 78 years, the mean LS BMD decreases to around 77 mg/mL. (B) For USA women at the age of 78 years, the mean LS BMD decreases to around 82 mg/mL. For Japanese women at the age of 78 years, the mean LS BMD decreases to around 40 mg/mL, while for a mean BMD value of 80 mg/mL, the corresponding age is 59 years. Data in (A) from Guglielmi *et al.* (33); Japanese data in (B) from Ito *et al.* (25); US women's data (assumed predominantly Caucasians) from Block *et al.* (31) and Ito *et al.* (25). The values in (B) for US subjects and for Japanese subjects had been cross-validated. QCT, quantitative computed tomography; BMD, bone mineral density; LS, lumbar spine.

(26-28), based on literature evidence, we recently argued that the QCT LS BMD equivalent to the older Caucasian women's threshold of 80 mg/mL is about 45–50 mg/mL for East Asian women (29). To strengthen that argument, in this article, we list more evidence.

East Asian women have a lower QCT LS BMD with aging than Caucasians

We have previously noted that, for US Caucasian women aged 78 years, based on the data of Looker *et al.* (30) and Block *et al.* (31), the population mean LS dual-energy X-ray absorptiometry (DXA) T-score is –2.5 and QCT BMD is around 80 mg/mL (29). Therefore, on the assumption that BMD measurements are normally distributed, half of them will have densitometric osteoporosis. At the same age, the LS average DXA T-score for Chinese women is –3.7, which is the recommended threshold to diagnose osteoporosis in Chinese women (28,32). For Chinese and Japanese women at the same age, the QCT LS BMD decreases to an average of around 50 mg/mL, according to the data of Li *et al.* (16) and Fujii *et al.* (24). According to these latter studies, if a QCT LS BMD of 80 mg/mL is used as the cutpoint value to classify osteoporosis, then around half of the Chinese and Japanese female population will be classified as osteoporotic at the age of around 65 years, leading to serious overdiagnosis (12,28,29).

In this article, we list more literature data to support this observation. *Figure 1A* shows that, for Italian women at the age of 78 years, the mean QCT LS BMD has decreased to around 77 mg/mL (33), which is consistent with the data of Block *et al.* (31). This conclusion is supported by many other reports for Caucasian women, including Compston *et al.* (34), Sandor *et al.* (35), and Karantanas *et al.* (36), and Manisal *et al.* (37). *Figure 1B* compares data of US women by Block *et al.* (31) and Japanese women by Ito *et al.* (25). For Japanese women at the age of 78 years, the mean QCT LS BMD has decreased to around 40 mg/mL, which is consistent with the data of Fujii *et al.* (24). For a BMD value of 80 mg/mL, according to the same study, for Japanese women, the corresponding age would be less than 60 years. *Figure 2A* shows that, for Korean women at the age of 78 years, the mean QCT LS BMD decreases to around 50 mg/mL, while for a mean BMD value of 80 mg/mL, the corresponding age is around 67 years (38). *Figure 2B* shows that, for Thai women at the age of 78 years, the mean QCT LS BMD decreases to less than 45 mg/mL, while for a BMD value of 80 mg/mL, the corresponding age is around 67 years (39). These QCT LS BMD results for older East Asian women are consistent with many other studies conducted on Chinese women (40-43). For example, Zhang *et al.* (40) reported a study of healthy subjects in which the

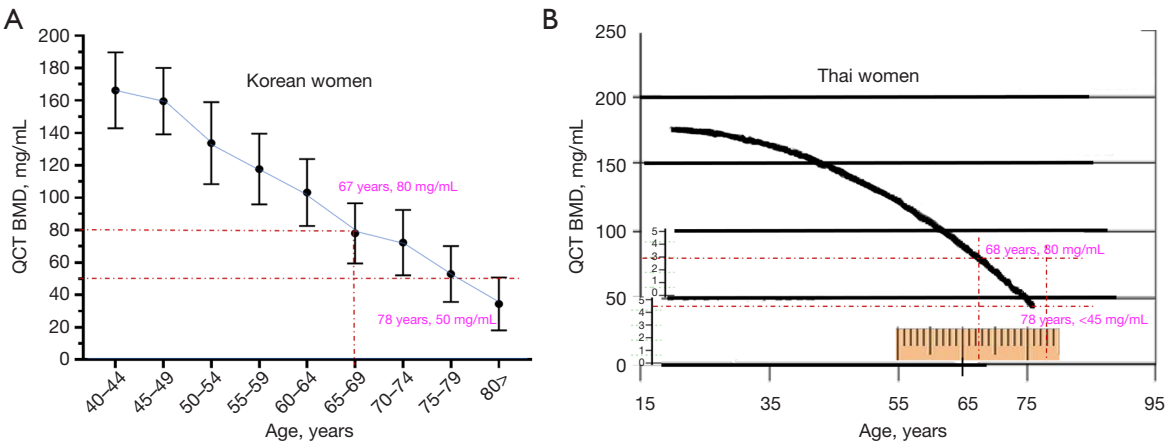

Figure 2 During aging of Korean (A) and Thai (B) women, the population mean LS QCT BMD decreased. (A) For Korean women at the age of 78 years, the mean LS BMD decreases to around 50 mg/mL, while for a BMD value of 80 mg/mL, the corresponding age is around 67 years. (B) For Thai women at the age of 78 years, the mean LS BMD decreased to less than 45 mg/mL, while for a BMD value of 80 mg/mL, the corresponding age is around 68 years. Data in (A) is from Youn and Kim (38). Data in (B) is from Hoonpongsimanon *et al.* (39). QCT, quantitative computed tomography; BMD, bone mineral density; LS, lumbar spine.

mean QCT LS BMD was 82.39±27.45 mg/mL for females aged 60–69 years and 63.78±30.59 mg/mL for females aged ≥70 years. In a group of healthcheck women, Xuan *et al.* (41) reported that the mean QCT LS MBD was 63.9±29.7 mg/mL for older participants (>60 years). Similarly, in a group of BMD examinees (excluding those with disorders or medication histories that can affect bone metabolism), Wang *et al.* (42) reported that the mean QCT LS MBD was 62.4±28.3 mg/mL for older female participants (>60 years). Hsu *et al.* (43) studied abdominal CT scan examinees (excluding those with disorders or medication histories that can affect bone metabolism). At the age of 63 years, the mean QCT LS MBD was around 80 mg/mL for their female participants. Moreover, Melton *et al.* (44) reported that, at the age of 62 years, the mean QCT LS BMD of Vietnamese women in the US was 26 mg/mL less than that of US Caucasian women.

It is also well established that peak LS BMD is lower among East Asian women than Caucasian women (12,24,25,45).

Note that, at the age of 78 years, the fragility fracture risk of Chinese and Japanese women is still lower than that of Caucasian women of the same age. Therefore, the data in *Figures 1,2* support the conclusion that, for older East Asian women, the threshold for the QCT LS BMD definition of osteoporosis equivalent to the Caucasian women's threshold of 80 mg/mL is no more than 50 mg/mL.

Older Chinese women experience vertebral fracture at a lower QCT LS BMD than Italian women: a comparison with spine fracture severity as the reference

Among Caucasian women, the lifetime risk of hip fracture at the age of 50 years is considered to be around 16%. According to the WHO criteria, the T-score is defined as: $(BMD_{patient} - BMD_{young\ normal\ mean})/SD_{young\ normal\ population}$. In Caucasian women aged ≥50 years, a cutpoint value of femoral neck BMD 2.5 SD below $BMD_{young\ normal\ mean}$ results in a prevalence of densitometrically defined osteoporosis of about 16.2%, similar to the lifetime risk of hip fragility fracture. Following a line of thinking similar to the WHO definition of osteoporosis, we performed a study to determine what proportion of older community women with what severity of radiographic osteoporotic vertebral fracture correspond to what low T-score status (46). All the data are from the "Osteoporotic Fracture in Women (Hong Kong)" study and the "Roman Osteoporosis Prevention Project". The recruitment plan was designed so that the participants would represent the older general population in the correct proportion by age. For the current analysis, we included 301 Italian women with a mean age of 73.6±6.1 years, and 512 Chinese women with a mean age of 74.0±7.2 years. The T4–L5 vertebrae were evaluated with an extended version of the semi-quantitative criteria (eSQ) (47).

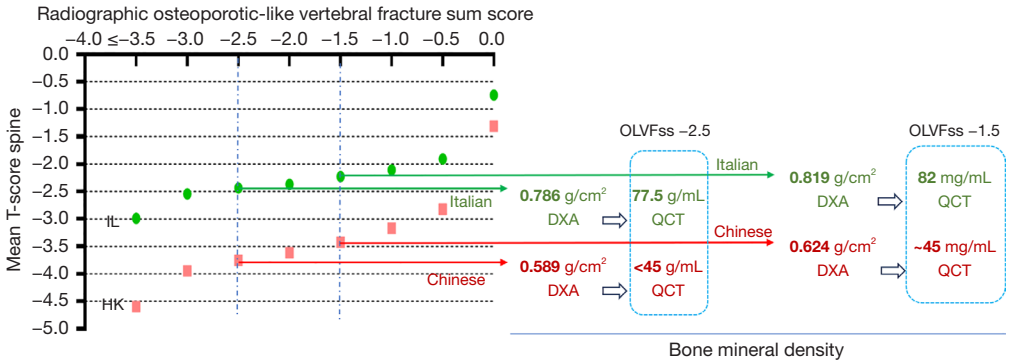

Figure 3 Relationship between OLVF severity and BMD for Caucasian Italian women (IL, age: 73.6±6.1 years) and Hong Kong Chinese women (HK, 74.0±7.2 years). Each vertebra on a spine radiograph was assigned a score of 0, −0.5, −1, −1.5, −2, −2.5, or −3 for no radiographic OLVF or OLVFs of <20%, 20–25%, ≥25%–1/3, ≥1/3–40%, ≥40%–2/3, and ≥2/3 vertebral height loss, respectively. OLVFss for each subject was calculated by summing the scores of all vertebrae from T4 to L5. Counting each study case, the OVFss and lumbar T-score were ranked from the smallest negative value to the largest value and plotted on the X- and Y-axes, respectively. When the OLVF is −1.5 and −2.5, for Italian women, the corresponding lumbar spine DXA BMD is 0.819 and 0.786 g/cm^2, and the corresponding QCT BMD is 82 and 77.5 mg/mL QCT, respectively. For Chinese women, the corresponding lumbar spine DXA BMD is 0.624 and 0.589 g/cm^2, and the QCT BMD is around 45 and <45 mg/mL QCT, respectively. OLVFss, OLVF sum score; DXA, dual-energy X-ray absorptiometry; QCT, quantitative computed tomography; OLVF, osteoporotic-like vertebral fracture; BMD, bone mineral density.

For each vertebra in women, a score of 0, −0.5, −1, −1.5, −2, −2.5, or −3 was assigned for no osteoporotic-like vertebral fracture (OLVF) or OLVF of <20%, ≥20–25%, ≥25%–1/3, ≥1/3–40%, ≥40%–2/3, and ≥2/3 vertebral height loss, respectively. The term OLVF is used because based on a radiograph it is not always possible to diagnose with certainty a vertebral fracture being of osteoporotic cause. An OLVF sum score (OLVFss), which sums the scores of the T4–L5 vertebrae, was calculated for each study subject (46). Hong Kong local BMD reference data and BMD reference values collected in NHANES 2005–2010 were used for the T-score calculation for Chinese and Italians, respectively.

Counting each study case, the OLVFss and lumbar T-score were ranked from the smallest negative value to the largest value and plotted on the X- and Y-axes, respectively (*Figure 3*). When the OLVF is −1.5, statistically, the corresponding LS T-score is −2.23 for Italian and −3.42 for Chinese women. Based on the original data, the corresponding LS DXA BMDs are 0.819 and 0.624 g/cm^2, respectively. When the OLVF is −2.5, the corresponding LS T-score is −2.44 for Italian and −3.75 for Chinese women, and the corresponding LS DXA BMDs are 0.786 and 0.589 g/cm^2, respectively. For Italian women, DXA LS BMDs of 0.819 and 0.786 g/cm^2 are equivalent to QCT LS BMDs of around 82 and 77.5 mg/mL, respectively (48-51). Based on the data of Lin *et al.* (17) and Yu *et al.* (52) and supported by the data of Uemura *et al.* (22), for Chinese women, a DXA LS BMD of 0.624 g/cm^2 is equivalent to a QCT value of around 45 mg/mL, and 0.589 g/cm^2 is equivalent to less than 45 mg/mL QCT value [see *Figure 3* in reference (29)].

To achieve the detection sensitivity of 78% for patients with radiographic OLVF, 90 mg/mL QCT LS BMD for Caucasian women is equivalent to around 60 mg/mL for East Asian women

In addition to *Figure 4* presented in reference (29), in this article, we list more data to support our contention that a QCT LS BMD of 80 mg/mL in Caucasian women is equivalent to 45–50 mg/mL in East Asian women. We calculated the QCT LS BMD threshold to achieve a sensitivity of 78% for detecting radiographic OLVF in Caucasian and East Asian women, and the results are shown in *Table 1* (17,25,38,48,53-58). The calculations in *Table 1* assumed that the respective BMD values are normally distributed. For Caucasian women, the goal was to

Table 1 Caucasian women and East Asian women QCT lumbar spine BMD to detect radiographic OLVF with a sensitivity of around 78%

Authors	Non-OLVF		OLVF		QCT BMD (mg/mL)	Sensitivity (%)*
	n	Age (years)	n	Age (years)		
Caucasian women						
Jergas *et al.* (53)	56	68.0±6.1	55	67.9±6.5	<95.0	78.2
Lang *et al.* (48)	45	71.5±4.4	26	76.1±6.5	<84.7	76.9
Duboeuf *et al.* (54)	83	63.6	29	66.6	<89.5	79.3
Cann *et al.* (55)	20	57.1±10.1	91	62.8±8.0	<87.5	78.0
Andresen *et al.* (56)	229 women, 17 men, 57.4 (33–87)				<101.9	77.9
East Asian women						
Ito *et al.* (25)	118	64.3±2.6	67	64.9±6.9	<63.5	77.3
Youn *et al.* (38)	290	61.9±6.3	34	70.4±7.1	<59.9	76.5
Lin *et al.* (17)	296[†]	65.4±9	205[‡]	72.5±9.7	<62.9	77.6
Qin *et al.* (57)	80	50–70	80	50–70	<48.1	77.5
Mao *et al.* (58)	198	68 (61–75)	198	68 (61–75)	<50.6	77.8
Mao *et al.* (58)	198	68 (61–75)	198	68 (61–75)	<55.6[§]	75.3[§]

Age data are represented as mean ± standard deviation or mean and range. *, simulated results assuming normal distribution of QCT BMD data; [†], 74.3% female; [‡], 85.4% female; [§], calculated with actual data. Results of Cann *et al.* were based on *Fig. 6* in reference (55) (Cann *et al.*). QCT, quantitative computed tomography; BMD, bone mineral density; OLVF, osteoporotic-like vertebral fracture.

use data other than those listed in *Figure 4* of reference (29). For East Asians, only limited data has been published. Besides the data of Mao *et al.* (58), which are already listed in *Figure 4* of reference (29), we additionally included the data of Lin *et al.* (17), Ito *et al.* (25), Youn *et al.* (38), and Qin *et al.* (57). Despite the subjectivity of classifying OLVF, the small size of almost all the studies, and the likely deviation of the data from a normal distribution, the results in *Table 1* are remarkably consistent across studies. Note that the study participants in the study of Andresen *et al.* (56) were younger than those of the other authors. Overall, for an OLVF detection sensitivity of around 78%, for Caucasian women the QCT LS BMD threshold is around 90 mg/mL, while it is around 60 mg/mL for East Asian women. *Table 2* further shows that, when the Caucasian women QCT LS BMD threshold is 80 mg/mL, the OLVF detection sensitivity is around 60%, while for East Asian women the corresponding threshold is around 50 mg/mL.

The data in *Table 1* and *Table 2* are supported by other reports that, for East Asian women, vertebral fragility fractures occur at a lower BMD than is typical for Caucasian women. For example, Jiang *et al.* (59) described their QCT LS BMD results for postmenopausal women with radiographic OLVF. For a wedge type of OLVF, mean QCT LS BMD was 45.1±23.8 mg/mL (n=36, age: 70.3± 8.0 years); while for the biconcave type of OLVF, mean QCT LS BMD was 32.1±24.51 mg/mL (n=40, age: 70.9± 7.8 years). In a study of mixed-sex older Chinese patients (>50 years), Xie *et al.* (60) reported that their spine fracture group (n=58) had QCT LS BMDs that ranged from 21 to 65 mg/mL, while the nonfracture group (n=62) had BMD values ranging from 55 to 121 mg/mL. On the other hand, for Caucasian women, spine fractures typically occur at a higher QCT LS BMD (around 70 mg/mL) (25,48,51,53-55,61).

In conclusion, this article provides further evidence that for East Asian women, a QCT LS BMD threshold of 80 mg/mg is too high for classifying osteoporosis (29). While hereby we are not arguing 45–50 mg/mL is the most suitable threshold for classifying osteoporosis in East Asian women, we argue that for East Asian women, the QCT LS BMD value equivalent to the Caucasian women's threshold of 80 mg/mL is about 45–50 mg/mL.

Table 2 Radiographic OLVF detection sensitivity when QCT lumbar spine BMD is <80 mg/mL for Caucasian women and <45–50 mg/mL for East Asian women

Authors	Non-OLVF		OLVF		QCT BMD* (mg/mL)	Sensitivity (%)
	n	Age (years)	n	Age (years)		
Caucasian women data						
Jergas *et al.* (53)	56	68.0±6.1	55	67.9±6.5	<80.0	52.7
Lang *et al.* (48)	45	71.5±4.4	26	76.1±6.5	<80.0	65.4
Duboeuf *et al.* (54)	83	63.6	29	66.6	<80.9	69.0
Cann *et al.* (55)	20	57.1±10.1	91	62.8±8.0	<80.0	71.4
Andresen *et al.* (56)	229 women, 17 men, 57.4 (33–87)				<80.6	56.5
East Asian women data						
Ito *et al.* (25)	118	64.3±2.6	67	64.9±6.9	<50.7	51.5
Youn *et al.* (38)	290	61.9±6.3	34	70.4±7.1	<51.2	55.9
Lin *et al.* (17)	296†	65.4±9	205‡	72.5±9.7	<50.1	55.6
Qin *et al.* (57)	80	50–70	80	50–70	<46.4	70.0
Mao *et al.* (58)	198	68 (61–75)	198	68 (61–75)	<45.1	66.7

Age data are represented as mean ± standard deviation or mean and range. *, simulated results assuming normal distribution of QCT BMD data; †, 74.3% female; ‡, 85.4% female. Results of Cann *et al.* were based on *Fig. 6* in reference 55 (Cann *et al.*). OLVF, osteoporotic-like vertebral fracture; QCT, quantitative computed tomography; BMD, bone mineral density.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the editorial office, *Quantitative Imaging in Medicine and Surgery*. The article has undergone external peer review.

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-429/coif). Y.X.J.W. serves as the Editor-in-Chief of *Quantitative Imaging in Medicine and Surgery*. J.F.G. and A.G. serve as unpaid editorial board members of *Quantitative Imaging in Medicine and Surgery*. A.G. is shareholder of BICL and LLC and consultant to Pfizer, TissueGene, Novartis, ICM, Coval, Medipost and TrialSpark. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Link TM, Lang TF. Axial QCT: clinical applications and new developments. J Clin Densitom 2014;17:438-48.
2. Engelke K, Chaudry O, Bartenschlager S. Opportunistic Screening Techniques for Analysis of CT Scans. Curr Osteoporos Rep 2023;21:65-76.
3. Löffler MT, Jacob A, Valentinitsch A, Rienmüller A, Zimmer C, Ryang YM, Baum T, Kirschke JS. Improved prediction of incident vertebral fractures using opportunistic QCT compared to DXA. Eur Radiol 2019;29:4980-9.
4. Leonhardt Y, May P, Gordijenko O, Koeppen-Ursic VA, Brandhorst H, Zimmer C, Makowski MR, Baum T,

Kirschke JS, Gersing AS, Seifert-Klauss V, Schwaiger BJ. Opportunistic QCT Bone Mineral Density Measurements Predicting Osteoporotic Fractures: A Use Case in a Prospective Clinical Cohort. Front Endocrinol (Lausanne) 2020;11:586352.
5. Cong E, Walker MD. The Chinese skeleton: insights into microstructure that help to explain the epidemiology of fracture. Bone Res 2014;2:14009.
6. Himič V, Syrmos N, Ligarotti GKI, Kato S, Fehlings MG, Ganau M. The role of genetic and epigenetic factors in determining the risk of spinal fragility fractures: new insights in the management of spinal osteoporosis. Quant Imaging Med Surg 2023;13:7632-45.
7. Walker MD, Liu XS, Zhou B, Agarwal S, Liu G, McMahon DJ, Bilezikian JP, Guo XE. Premenopausal and postmenopausal differences in bone microstructure and mechanical competence in Chinese-American and white women. J Bone Miner Res 2013;28:1308-18.
8. Walker MD, Shi S, Russo JJ, Liu XS, Zhou B, Zhang C, Liu G, McMahon DJ, Bilezikian JP, Guo XE. A trabecular plate-like phenotype is overrepresented in Chinese-American versus Caucasian women. Osteoporos Int 2014;25:2787-95.
9. Wáng YXJ, Deng M, Griffith JF, Kwok AWL, Leung JCS, Lam PMS, Yu BWM, Leung PC, Kwok TCY. 'Healthier Chinese spine': an update of osteoporotic fractures in men (MrOS) and in women (MsOS) Hong Kong spine radiograph studies. Quant Imaging Med Surg 2022;12:2090-105.
10. Wáng YXJ, Diacinti D, Iannacone A, Kripa E, Leung JCS, Kwok TCY, Diacinti D. A comparison of radiographic degeneration features of older Chinese women and older Italian Caucasian women with a focus on thoracic spine. Aging Clin Exp Res 2023;35:2583-91.
11. Wáng YXJ. Fragility fracture prevalence among elderly Chinese is no more than half of that of elderly Caucasians. Quant Imaging Med Surg 2022;12:874-81.
12. Wáng YXJ, Xiao BH. Estimations of bone mineral density defined osteoporosis prevalence and cutpoint T-score for defining osteoporosis among older Chinese population: a framework based on relative fragility fracture risks. Quant Imaging Med Surg 2022;12:4346-60.
13. Engelke K, Adams JE, Armbrecht G, Augat P, Bogado CE, Bouxsein ML, Felsenberg D, Ito M, Prevrhal S, Hans DB, Lewiecki EM. Clinical use of quantitative computed tomography and peripheral quantitative computed tomography in the management of osteoporosis in adults: the 2007 ISCD Official Positions. J Clin Densitom 2008;11:123-62.
14. Expert Panel on Musculoskeletal Imaging; Yu JS, Krishna NG, Fox MG, Blankenbaker DG, Frick MA, Jawetz ST, Li G, Reitman C, Said N, Stensby JD, Subhas N, Tulchinsky M, Walker EA, Beaman FD. ACR Appropriateness Criteria® Osteoporosis and Bone Mineral Density: 2022 Update. J Am Coll Radiol 2022;19:S417-32.
15. Cheng X, Wang L, Zeng Q, Wu J. Chinese guideline for the diagnosis of osteoporosis with quantitative computed tomography (2018). Chin J Health Manage 2019; 13:195-200.
16. Li K, Chen J, Zhao L, Chen Y, Zhou J, Shao J, et al. The establishment of QCT spinal vBMD reference database and the validation of the diagnosis criteria of osteoporosis with QCT for Chinese. Chin J Osteopros 2019;25:1257-72.
17. Lin W, He C, Xie F, Chen T, Zheng G, Yin H, Chen H, Wang Z. Quantitative CT screening improved lumbar BMD evaluation in older patients compared to dual-energy X-ray absorptiometry. BMC Geriatr 2023;23:231.
18. Nam KH, Seo I, Kim DH, Lee JI, Choi BK, Han IH. Machine Learning Model to Predict Osteoporotic Spine with Hounsfield Units on Lumbar Computed Tomography. J Korean Neurosurg Soc 2019;62:442-9.
19. Lee JS, Kim K, Jeon YK, Kim J, Jung DH, Kim SH, Shin MJ, Shin YB. Effects of Traction on Interpretation of Lumbar Bone Mineral Density in Patients with Duchenne Muscular Dystrophy: A New Measurement Method and Diagnostic Criteria Based on Comparison of Dual-Energy X-Ray Absorptiometry and Quantitative Computed Tomography. J Clin Densitom 2020;23:53-62.
20. Kim K, Kim IJ, Pak K, Kim SJ, Shin S, Kim BH, Kim SS, Lee BJ, Jeon YK. Evaluation of Bone Mineral Density Using DXA and cQCT in Postmenopausal Patients Under Thyrotropin Suppressive Therapy. J Clin Endocrinol Metab 2018;103:4232-40.
21. Kim K, Song SH, Kim IJ, Jeon YK. Is dual-energy absorptiometry accurate in the assessment of bone status of patients with chronic kidney disease? Osteoporos Int 2021;32:1859-68.
22. Uemura K, Fujimori T, Otake Y, Shimomoto Y, Kono S, Takashima K, Hamada H, Takenaka S, Kaito T, Sato Y, Sugano N, Okada S. Development of a system to assess the two- and three-dimensional bone mineral density of the lumbar vertebrae from clinical quantitative CT images. Arch Osteoporos 2023;18:22.
23. Song QS, Tang FB, Wang XH, Zhang JL, Li ZF, Rao YS, Wu L, Tai ZH, Qin HB. Xu JW. Relationship between

the lumbar quantitative computed tomography values and contrast agent dispersion in osteoporotic thoracolumbar fractures. Chinese Journal of Tissue Engineering Research 2017;21:3051-6.
24. Fujii Y, Tsutsumi M, Tsunenari T, Fukase M, Yoshimoto Y, Fujita T, Genant HK. Quantitative computed tomography of lumbar vertebrae in Japanese patients with osteoporosis. Bone Miner 1989;6:87-94.
25. Ito M, Lang TF, Jergas M, Ohki M, Takada M, Nakamura T, Hayashi K, Genant HK. Spinal trabecular bone loss and fracture in American and Japanese women. Calcif Tissue Int 1997;61:123-8.
26. Wáng YXJ, Blake GM, Xiao BH, Guglielmi G, Su Y, Jiang Y, Guermazi A, Kwok TCY, Griffith JF. East Asians' T-scores for the diagnosis of osteoporosis should be calculated using ethnicity- and gender-specific BMD reference ranges: justifications. Skeletal Radiol 2024;53:409-17.
27. Wáng YXJ, Guglielmi G, Guermazi A, Kwok TCY, Griffith JF. Much lower prevalence and severity of spine degenerative changes among older Chinese women than among older Caucasian women and its implication for the interpretation of lumbar spine BMD T-score for Chinese women. Skeletal Radiol 2024;53:247-51.
28. Wáng YXJ, Griffith JF, Blake GM, Diacinti D, Xiao BH, Yu W, Su Y, Jiang Y, Guglielmi G, Guermazi A, Kwok TCY. Revision of the 1994 World Health Organization T-score definition of osteoporosis for use in older East Asian women and men to reconcile it with their lifetime risk of fragility fracture. Skeletal Radiol 2024;53:609-25.
29. Wáng YXJ, Blake GM, Tang SN, Guermazi A, Griffith JF. Quantitative CT lumbar spine BMD cutpoint value for classifying osteoporosis among older East Asian women should be lower than the value for Caucasians. Skeletal Radiol 2024. [Epub ahead of print]. doi: 10.1007/s00256-024-04632-4.
30. Looker AC, Borrud LG, Hughes JP, Fan B, Shepherd JA, Melton LJ 3rd. Lumbar spine and proximal femur bone mineral density, bone mineral content, and bone area: United States, 2005-2008. Vital Health Stat 11 2012;(251):1-132.
31. Block JE, Smith R, Glueer CC, Steiger P, Ettinger B, Genant HK. Models of spinal trabecular bone loss as determined by quantitative computed tomography. J Bone Miner Res 1989;4:249-57.
32. Wu XP, Liao EY, Huang G, Dai RC, Zhang H. A comparison study of the reference curves of bone mineral density at different skeletal sites in native Chinese, Japanese, and American Caucasian women. Calcif Tissue Int 2003;73:122-32.
33. Guglielmi G, Giannatempo GM, Blunt BA, Grampp S, Glüer CC, M. Cammisa M, Genant HK. Spinal bone mineral density by quantitative CT in a normal Italian population. Eur Radiol 1995;5:269-75.
34. Compston JE, Evans WD, Crawley EO, Evans C. Bone mineral content in normal UK subjects. Br J Radiol 1988;61:631-6.
35. Sandor T, Felsenberg D, Kalender WA, Clain A, Brown E. Compact and trabecular components of the spine using quantitative computed tomography. Calcif Tissue Int 1992;50:502-6.
36. Karantanas AH, Kalef-Ezra JA, Glaros DC. Quantitative computed tomography for bone mineral measurement: technical aspects, dosimetry, normal data and clinical applications. Br J Radiol 1991;64:298-304.
37. Manisal M, Ozaksoy D, Kabakç N. Quantitative computed tomography BMD reference values in women of Izmir, Turkey. Clin Orthop Relat Res 2006;443:109-12.
38. Youn TH, Kim JS. The Assessment of Bone Mineral Density in The Lumbar Vertebra Using Quantitative Computed Tomography. J Korean Soc Spine Surg 2006;13:255-61.
39. Hoonpongsimanon S, Santipapmonthon M, Chuntana M. Spinal bone mineral density by quantitative computed tomography in Thais compared with Westerners. J Med Assoc Thai 2005;88:1666-73.
40. Zhang W, Ma X, Xue P, Gao Y, Wu X, Zhao J, Wang Y, Li S. Associations between fat distribution and volumetric bone mineral density in Chinese adults. Endocrine 2014;47:862-8.
41. Xuan SX, Zhang ZG, Jia SQ. Analysis of correlation between lumbar bone mineral density and abdominal fat in women of different ages and different physiological period base on quantitative CT. Fang She Xue Shi Jian (Radiol Practice) 2021;36:642-7.
42. Wang S, Chen J, Cao B, Li P, Guo M, Yang H. Quantitative CT analysis of bone mineral density of the lumbar vertebra in Miyun. Chin J Osteopros 2015;21:179-82.
43. Hsu PC, Luzhbin D, Shih TY, Wu J. Diagnosis of Osteoporosis by Quantifying Volumetric Bone Mineral Density of Lumbar Vertebrae Using Abdominal CT Images and Two-Compartment Model. Healthcare (Basel) 2023;11:556.
44. Melton LJ 3rd, Marquez MA, McCready LK, Achenbach SJ, Riggs BL, Amin S, Khosla S. Trabecular bone deficits among Vietnamese immigrants. Osteoporos Int

2011;22:1627-31.
45. Davis JW, Novotny R, Ross PD, Wasnich RD. The peak bone mass of Hawaiian, Filipino, Japanese, and white women living in Hawaii. Calcif Tissue Int 1994;55:249-52.
46. Wáng YXJ, Diacinti D, Leung JCS, Iannacone A, Kripa E, Kwok TCY, Diacinti D. Conversion of osteoporotic vertebral fracture severity score to osteoporosis T-score equivalent status: a framework and a comparative study of Hong Kong Chinese and Rome Caucasian older women. Arch Osteoporos 2022;18:1.
47. Wáng YXJ, Diacinti D, Yu W, Cheng XG, Nogueira-Barbosa MH, Che-Nordin N, Guglielmi G, Ruiz Santiago F. Semi-quantitative grading and extended semi-quantitative grading for osteoporotic vertebral deformity: a radiographic image database for education and calibration. Ann Transl Med 2020;8:398.
48. Lang TF, Guglielmi G, van Kuijk C, De Serio A, Cammisa M, Genant HK. Measurement of bone mineral density at the spine and proximal femur by volumetric quantitative computed tomography and dual-energy X-ray absorptiometry in elderly women with and without vertebral fractures. Bone 2002;30:247-50.
49. Milisic L, Vegar-Zubovic S, Valjevac A, Hasanovic-Vučković S. Bone Mineral Density Assessment by DXA vs. QCT in Postmenopausal Females with Central Obesity. Curr Aging Sci 2020;13:153-61.
50. Rehman Q, Lang T, Modin G, Lane NE. Quantitative computed tomography of the lumbar spine, not dual x-ray absorptiometry, is an independent predictor of prevalent vertebral fractures in postmenopausal women with osteopenia receiving long-term glucocorticoid and hormone-replacement therapy. Arthritis Rheum 2002;46:1292-7.
51. Paggiosi MA, Debono M, Walsh JS, Peel NFA, Eastell R. Quantitative computed tomography discriminates between postmenopausal women with low spine bone mineral density with vertebral fractures and those with low spine bone mineral density only: the SHATTER study. Osteoporos Int 2020;31:667-75.
52. Yu W, Qin M, Xu L, van Kuijk C, Meng X, Xing X, Cao J, Genant HK. Normal changes in spinal bone mineral density in a Chinese population: assessment by quantitative computed tomography and dual-energy X-ray absorptiometry. Osteoporos Int 1999;9:179-87.
53. Jergas M, Breitenseher M, Glüer CC, Yu W, Genant HK. Estimates of volumetric bone density from projectional measurements improve the discriminatory capability of dual X-ray absorptiometry. J Bone Miner Res 1995;10:1101-10.
54. Duboeuf F, Jergas M, Schott AM, Wu CY, Glüer CC, Genant HK. A comparison of bone densitometry measurements of the central skeleton in post-menopausal women with and without vertebral fracture. Br J Radiol 1995;68:747-53.
55. Cann CE, Genant HK, Kolb FO, Ettinger B. Quantitative computed tomography for prediction of vertebral fracture risk. Bone 1985;6:1-7.
56. Andresen R, Radmer S, Banzer D. Bone mineral density and spongiosa architecture in correlation to vertebral body insufficiency fractures. Acta Radiol 1998;39:538-42.
57. Qin H, Qin H, Li Z, Fu S, Deng D, Tang Y, Zhong Y. A study on correlation between bone mineral density measured by quantitative CT and fragile fracture of osteoporotic spine in postmenopausal women. Chin Youjiang Med J 2019;47:423-6.
58. Mao YF, Zhang Y, Li K, Wang L, Ma YM, Xiao WL, Chen WL, Zhang JF, Yuan Q, Le N, Shi XL, Yu AH, Hu Z, Hao J, Cheng XG. Discrimination of vertebral fragility fracture with lumbar spine bone mineral density measured by quantitative computed tomography. J Orthop Translat 2019;16:33-9.
59. Jiang W, Li X, Cheng K, Wang C, Cheng X. Study of the types of osteoporotic vertebral fractures and the difference of volumetric BMD detected using QCT. Chin J Osteopros 2014;20:1273-5.
60. Xie LJ, Hou ZL, Wen CH, Li JL, Zhang YP, Yang H. Value of 64-row 128-slice spiral CT for bone density measuring in vertebral osteoporotic fractures. China Medical Equipment 2013;10:53-5.
61. Sollmann N, Löffler MT, El Husseini M, Sekuboyina A, Dieckmeyer M, Rühling S, Zimmer C, Menze B, Joseph GB, Baum T, Kirschke JS. Automated Opportunistic Osteoporosis Screening in Routine Computed Tomography of the Spine: Comparison With Dedicated Quantitative CT. J Bone Miner Res 2022;37:1287-96.

Cite this article as: Wáng YXJ, Yu W, Leung JCS, Griffith JF, Xiao BH, Diacinti D, Guermazi A, Chan WP, Blake GM. More evidence to support a lower quantitative computed tomography (QCT) lumbar spine bone mineral density (BMD) cutpoint value for classifying osteoporosis among older East Asian women than for Caucasians. Quant Imaging Med Surg 2024;14(5):3239-3247. doi: 10.21037/qims-24-429

