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Estimating the Prevalence of Osteoporosis in Screening Eligible Women Based on the Thoracolumbar Hounsfield Unit (HU) Attenuation on Computed Tomography (CT)

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Abstract

Objective: The objective of this study was to determine the distribution of vertebral body trabecular attenuation on Computed Tomography (CT) in women who would be eligible for osteoporosis screening in order to create a framework to prioritize women for Dual Energy X-ray Absorptiometry (DXA) studies. **Methodology:** This retrospective study analyzed CT scans which included the T12 or L1 vertebral body performed between January 1, 2018 and July 31, 2023 in women between the ages of 65 - 75 who were members of our integrated healthcare system. For each CT scan, the mean attenuation of the trabecular bone of the L1 vertebral body was measured on three contiguous axial images centered at the mid-vertebral body. The T12 vertebral body was measured if the L1 vertebral body was not adequately visualized. The presence of vertebral body compression fractures was also noted. **Results:** The study comprised 1096 subjects with a mean (SD) age of 68.3 (3.2) years. Of these, 349 (31.8%) had a mean vertebral body HU value of 110 or less, and 478 (43.6%) had a mean vertebral body HU value of 120 or less. There was no statistical difference in the mean vertebral body HU between women of Asian/PI ethnicity and those who did not self-identify as being of Asian/PI ethnicity. **Conclusion:** We suggest that the opportunistic measurement of the CT attenuation of the L1 vertebral body can provide a framework to prioritize women 65 years or older for DXA studies and improve screening in at-risk populations. This method would lead to earlier diagnosis of osteoporosis, decreasing the negative impact on the individual, healthcare, and society.

Keywords

Osteoporosis, Computed Tomography, Bone Mineral Density, HU Attenuation

1. Introduction

Osteoporosis is described as low bone mass that leads to decreased bone strength and increased risk of low-trauma fracture [1], with subsequent large impact on healthcare and society [2]. The United States Preventive Services Task Force (USPSTF) recommends osteoporosis screening for all women 65 years and older, as well as post-menopausal women younger than 65 years who are at increased risk for osteoporosis. Many patients with osteoporosis are falling short of screening and treatment. For example, fewer than 1 in 4 women 65 years and older underwent Bone Mineral Density (BMD) measurement during 2008-2014 [3]. A previous descriptive analysis of individuals in the United States who sustained osteoporotic-related fractures demonstrated that diagnosis rates were low before the fractures occurred and improved, although they remained low, after the fractures occurred [4].

Computed Tomography (CT) studies are widely performed today for a broad number of indications. These studies often include a portion of the lumbar spine, providing valuable data. Prior studies have demonstrated that measurement of the Hounsfield Unit (HU) attenuation of the T12 or L1 vertebral central matrix is well correlated to BMD measured by Dual Energy X-ray Absorptiometry (DEXA) [5]-[10]. A study published by Vadera *et al.* [11] demonstrated the L1 attenuation measures were significantly different among females with osteoporosis, osteopenia, and normal body density in a British population, with increasing HU attenuation with increasing bone density. Another study published by Li *et al.* [8] found similar findings in a Chinese population.

Additional studies have suggested that CT studies obtained for other reasons, which include the lumbar spine, could be used to identify patients with osteoporosis by identifying subjects with low L1 vertebral body HU attenuation and by detecting vertebral compression fractures [11]-[14]. However, the diagnostic performance of different HU thresholds for detection or exclusion of osteoporosis is variable, with reported Area under the Curve (AUC) values ranging from 0.74 to 0.86 depending on the HU threshold and the study population [5]-[10].

Our integrated healthcare system serves a large number of members who are of Asian or Pacific Islander ethnicity. Prior studies have shown that these women have lower BMD values compared to non-Hispanic white women [15] [16]. It is not known if these women also have a different distribution of HU attenuation in their vertebra than those of other ethnicities.

Given the impact of osteoporosis and failure to meet current recommendations, there is a need for improvement in osteoporosis screening. One barrier to screen-

ing within our own integrated Healthcare System (IHS) is the number of available time slots for DXA studies due to shortages in trained technologists and available number of machines. One way to improve osteoporosis screening in the most at-risk population may be to triage eligible women to DXA studies based on their mean L1 attenuation on CT studies performed for other reasons, as well as those with vertebral compression fractures incidentally noted on CT.

The purposes of this study were: 1) to determine the distribution of HU attenuation of the L1 vertebral body on CT studies performed for other indications in women 65 years or older who are eligible for osteoporosis screening in order to develop a framework to prioritize women for DXA screening, 2) to compare the distribution of the HU values between women whose self-reported ethnicity was Asian or Pacific Islander (Asian/PI) to those women who were of other ethnicities, and 3) to estimate the prevalence of vertebral compression fractures in this older population of women who have not had a prior DXA study.

2. Materials and Methods

Subjects

This study was approved by the institutional review board with waiver of informed consent as this was a retrospective study with no direct patient interactions. Inclusion criteria were all women within our institution between the ages of 65 - 75 who had a CT scan of the chest, abdomen, or chest and abdomen, and therefore included the L1 or T12 vertebral body between January 1, 2018 and July 31, 2023. All women belonged to a geographically isolated Integrated Healthcare System (IHS) where all imaging and clinical data are stored in a common Electronic Medical Record (EMR). Exclusion criteria were women who had a DXA study after the age of 65, who had a diagnosis of osteoporosis, or were on antiresorptive or anabolic medications, such as bisphosphonates, as documented in the EMR. The self-reported ethnicity of these women was also recorded.

Computed Tomography

CT images were retrospectively analyzed on a standard radiology Picture Archiving and Communication system (PACS). All CT studies were performed on 32 or 64 detector array GE Optima CT660, Lightspeed VCT, Discovery or Revolution model scanners (GE Healthcare, Waukesha WI) with 120 kVp, 2.5 mm slice thickness and bone kernel. For each study, the mean attenuation of the trabecular bone of the L1 vertebral body was measured on three contiguous axial images centered at the mid vertebral body (**Figure 1**). The elliptical Regions of Interest (ROI) were manually drawn to be of approximately similar sizes in the three contiguous images and included as much of the medullary region as possible while excluding the cortex and osteophytes. The lowest value of the three measurements was recorded. Cortical bone, fractures, or focal lesions were avoided to prevent distortion of attenuation values. If the L1 vertebral body was not fully visualized (as may occur in some chest CT studies) or was fractured, then the T12 vertebral body was measured. If the T12 vertebra was also fractured or not fully visualized, the L2 vertebral body was measured. We assessed the presence of vertebral body

compression fractures using the sagittal reconstructions. Any vertebral body compression fracture of moderate or greater severity (>25% loss of body height) at any level was also noted. Reviewers were non-radiologists who were trained to obtain the previously described measurements by a radiologist who mentored each reviewer for a minimum of 25 studies. In addition, one or more radiologists reviewed approximately 25% of all the studies. All vertebral compression fractures were reviewed by the senior radiologist. Several different CT HU thresholds have been published depending on the study population and whether high sensitivity or specificity for osteoporosis is the desired outcome [10]-[12]. We chose 110 HU as an analysis of women within our IHS who had both a DXA study and CT within a 3-year period, which suggests a cutoff between 100 and 110 HU provided a reasonable combination of specificity and sensitivity for the detection of osteoporosis. We also chose a slightly higher HU threshold of 120 HU to determine what effect this would have on the number of subjects who would be referred for expedited DXA studies.

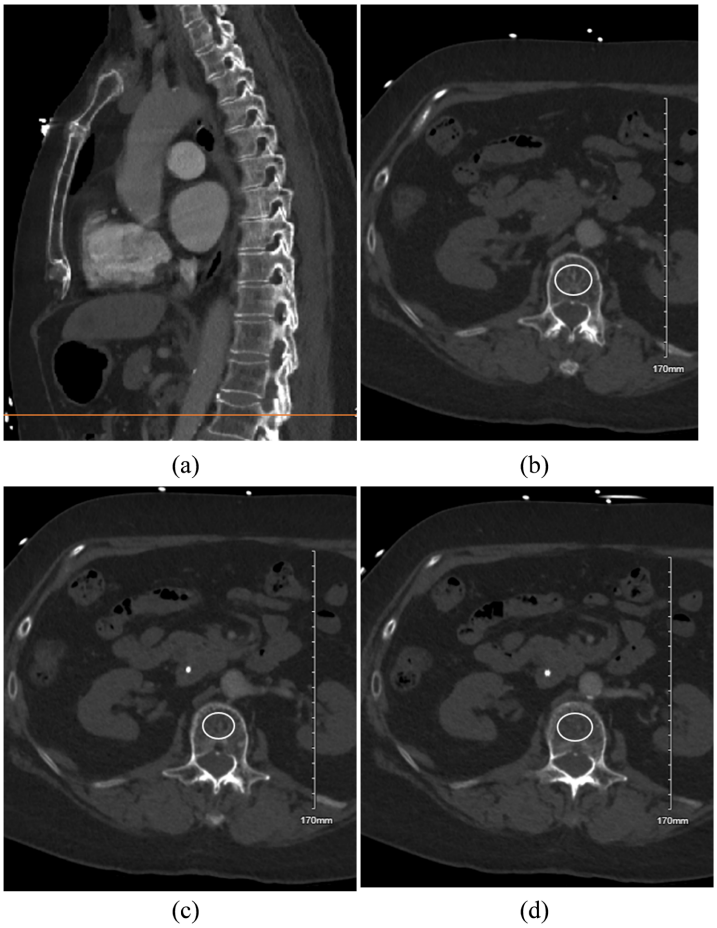

Figure 1. Example of mean attenuation of the L1 vertebral body measured on an axial image through the center of the mid vertebral body on a 71-year-old woman. (a) Sagittal slice through the spine which was used to find the mid-level of the L1 vertebral body (horizontal line). ((b) - (d)) HU measured on three contiguous axial images centered at the mid body of L1. The lowest HU measurement was recorded.

Statistical Analysis

Statistical analysis was performed using the online statistics calculator DATAtab. The Wilcoxon signed rank test was used to determine any significant difference in mean vertebral body HU between Asian/PI and non-Asian/PI. The independent t-test was used to evaluate for significant differences in age and HU in subjects with vertebral body compression fractures versus those without vertebral body compression fractures and between measurements of HU in the T12 and L1 vertebra. Scatterplot was used to describe the prevalence of subjects with mean vertebral body HU equal to or less than the thresholds of 110 and 120.

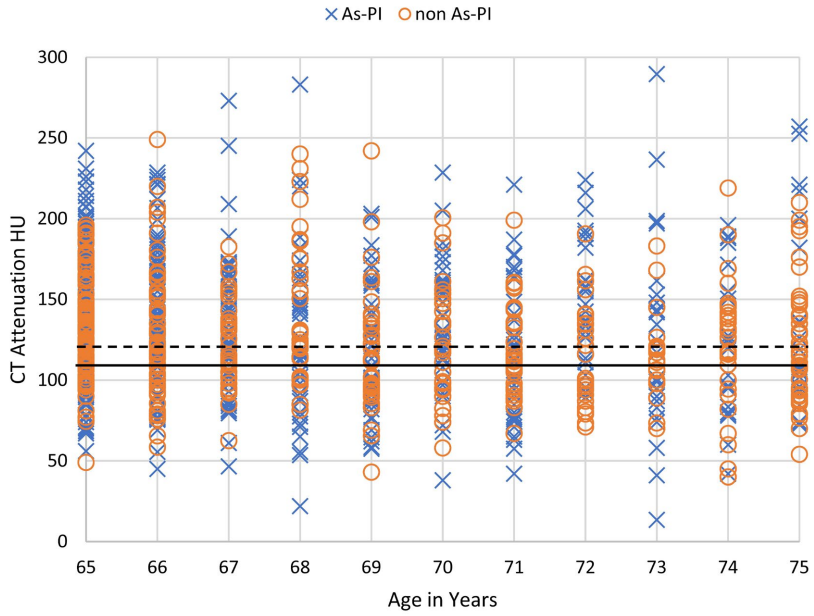

Figure 2. Mean vertebral body HU by age for women of Asian-PI ethnicity and women of non-Asian-PI ethnicity. Solid horizontal black line denotes the 110 HU threshold. Dotted horizontal black line denotes the 120 HU threshold.

3. Results

The study comprised of 1096 subjects with a mean (SD) age of 68.3 (3.2) years. Of these, 349 (31.8%) had a mean vertebral body HU value of 110 or less, and 478 (43.6%) had a mean vertebral body HU value of 120 or less (**Table 1** and **Figure 2**). The study was comprised of 643 (59%) women who self-identified as Asian/Pacific Islander (PI) ethnicity and 453 (41%) who did not self-identify as being of Asian/PI ethnicity. Wilcoxon signed-rank test indicated there was no significant difference ($Z = -0.3844$, $p = 0.70$) between the mean vertebral body HU for women of Asian/PI ethnicity and those who did not self-identify as being of Asian/PI ethnicity after controlling for the number of women in these categories (**Table 2**).

The L1 vertebra was used for HU measurement in 1036 subjects and the T12 vertebra in 59 subjects. Of the 59 subjects in whom the T12 vertebra was measured, 12 subjects had an L1 compression fracture. There was one subject with compres-

sion fractures of T12 and L1, in whom the L2 vertebra was measured. The mean HU attenuation measured at T12 was lower than at L1 (116.7 HU versus 131.5 HU, p = 0.006). However, when those subjects with vertebral compression fractures are excluded, the mean attenuation measured at T12 was not significantly different from that measured at L1 (125.0 HU versus 132.7 HU, p = 0.20).

Table 1. Prevalence of subjects with mean vertebral body HU value less than or equal to threshold value of 110 HU or 120 HU by age.

Age	HU ≤ 110 n (%)	HU ≤ 120 n (%)	Total Subjects n
65	73 (24)	107 (36)	301
66	48 (28)	67 (39)	173
67	28 (27)	43 (42)	102
68	21 (29)	32 (44)	73
69	44 (49)	51 (57)	90
70	20 (27)	29 (40)	73
71	30 (43)	41 (59)	70
72	17 (31)	21 (39)	54
73	20 (45)	27 (61)	44
74	19 (35)	27 (49)	55
75	29 (48)	33 (54)	61
Total	349 (32)	478 (44)	1096

Table 2. Distribution of mean vertebral body HU measurements in all subjects by Asian/PI ethnicity and non-Asian/PI ethnicity (Z = −0.3844, p = 0.70).

HU Range	Asian/PI n (%)	Non-Asian/PI n (%)	Total n
≤70	28 (62)	17 (38)	45
71 - 80	33 (70)	14 (30)	47
81 - 90	29 (53)	26 (47)	55
91 - 100	55 (50)	55 (50)	110
101 - 110	48 (52)	44 (48)	92
111 - 120	73 (57)	56 (43)	129
121 - 130	67 (57)	51 (43)	118
131 - 140	55 (56)	44 (44)	99
141 - 150	53 (58)	39 (42)	92
151 - 160	43 (60)	29 (40)	72
161 - 170	49 (65)	26 (35)	75
171 - 180	30 (70)	13 (30)	43
>180	80 (67)	39 (33)	119
Total	643 (59%)	453 (41%)	1096

There were 47 (4.3%) study subjects who had at least one moderate or greater severity compression fracture (defined as >25% loss of vertebral body height). The most common site of fracture was T12 which was seen in 15 subjects. The next most common site of fracture was L1 which was seen in 13 subjects. Ten of these patients had vertebral body HU value >120 HU, with the highest measuring of 192 HU in a 65-year-old. As expected, the mean attenuation of those who had a vertebral body compression fracture was much lower than those who did not have a vertebral body compression fracture (93.3 HU versus 132.4 HU, $p < 0.0001$). Women who had a vertebral body compression fracture were slightly older than those who did not have a fracture (69.5 years versus 68.2 years, $p = 0.01$).

4. Discussion

In this population of women over 65 years of age undergoing CT, almost 32% had a mean vertebral body attenuation equal to or less than 110 HU and almost 44% had a mean attenuation less than 120 HU. Depending on the number of CT studies performed on older women within our IHS, these high percentages could result in a large number of women being referred for expedited DXA studies. Therefore, the lower 110 HU threshold would be preferred initially to determine the effect on the number DXA studies generated by this screening methodology.

To our knowledge, this is one of the few studies with a high percentage of both Asian/PI women and non-Asian/PI women. According to the US census bureau, Asian and Pacific Islanders make up approximately 6% of the US population [17]. Osteoporosis as defined by t-score ≤ −2.5 from DXA studies is particularly common in Asian and non-Hispanic white women [18] [19]. However, we found no significant difference in the distribution of the mean vertebral attenuation value among Asian/PI women compared to other ethnicities. Going forward, it will be important to ascertain that if we apply the same CT attenuation threshold to all older women for expedited DXA studies, the prevalence of osteoporosis is more common in Asian/PI women than in other ethnicities.

Our study identified 47 subjects (4.3%) without a prior DXA study who demonstrated an incidental moderate or greater severity compression fracture on their CT study. This is less than what previous studies have reported. Pickhardt *et al.* [12] reported on 1867 subjects with CT and DXA performed within 6 months of each other and found that 6.4% had compression fractures. Although this study was comprised mostly of women (81%), the prevalence of compression fractures among women was not reported. Kim *et al.* [5] reported incidentally noted compression fractures in 18% of 154 Korean women who underwent CT and DXA studies within 30 days. Buckens *et al.* [7] reported on 204 Dutch women who had both CT and DXA studies within 90 days and found that 23% had at least one compression fracture. The low prevalence of compression fractures in this study population may be in part due to the exclusion of all subjects who had previously had a DXA study.

There are approximately 265,000 members in this IHS of whom almost 26,000 are women 65 years or older. This is consistent with the results of the 2019 census

data for the US which estimated approximately 10% of the total population to be women 65 years or older [20]. The USPSTF recommends osteoporosis screening with BMD testing for all women 65 years and older [21]. The current DXA testing capacity is limited to approximately 400 studies per month in this IHS. However, the capacity for routine screening studies for women 65 or older is much lower as many of these appointment slots are reserved for patients with specific risk factors such as those being imaged in follow up during antiresorptive or anabolic treatments for osteoporosis, cancer patients, and patients with recent major osteoporotic fractures. Therefore, the threshold for which to recommend patients for DXA studies will be determined by the regional capacity to perform these studies. Even the addition of a few studies based on CT results may affect the wait times for other patients. This must be weighed against the increased probability of documenting osteoporosis in patients referred because of a low vertebral HU.

There are limitations to this study. First, there may be selection bias by including only patients who had not previously undergone a DXA study. This population of patients could represent a healthier subset of patients, which may also explain the lower prevalence of vertebral body fractures and lack of difference in HU measurements between Asian/PI and non-Asian/PI women in our study. Second, both contrast and non-contrast studies were combined, which may affect the distribution of HU values. However, prior studies have shown no significant difference in pre and post contrast studies in determining optimal HU thresholds for osteoporosis [8] [12]. Since application of the study results will be applied to both contrast enhanced as well as unenhanced CT studies, we chose to include both in this analysis. Third, we excluded subjects who had a prior DXA study, so we cannot correlate the HU attenuation values to the presence or absence of osteoporosis as defined by a t-score ≤ -2.5. It will be important to demonstrate a higher prevalence of osteoporosis in those women who are given expedited referral for a DXA study based on their L1 HU attenuation than those women 65 years and older who undergo routine DXA screening. Finally, this study does not address reproducibility of HU measurements.

5. Conclusion

In conclusion, we suggest that the measurement of the CT attenuation of the L1 vertebral body can provide a novel framework to prioritize women 65 years or older for DXA studies. As many patients are falling short of osteoporosis screening and treatment, this framework would be extremely helpful to implement in a healthcare system that currently does not have enough resources to screen all eligible women.

Data Statement

The authors declare that they had full access to all of the data in this study and the authors take complete responsibility for the integrity of the data and the accuracy of the data analysis.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Cosman, F., de Beur, S.J., LeBoff, M.S., Lewiecki, E.M., Tanner, B., Randall, S., *et al.* (2014) Clinician's Guide to Prevention and Treatment of Osteoporosis. *Osteoporosis International*, **25**, 2359-2381. https://doi.org/10.1007/s00198-014-2794-2

[2] Hansen, D., Pelizzari, P. and Pyenson, B. (2021) The Clinical and Cost Burden of Fractures Associated with Osteoporosis. Milliman Research Report.

[3] Gillespie, C.W. and Morin, P.E. (2017) Trends and Disparities in Osteoporosis Screening among Women in the United States, 2008-2014. *The American Journal of Medicine*, **130**, 306-316. https://doi.org/10.1016/j.amjmed.2016.10.018

[4] Weaver, J., Sajjan, S., Lewiecki, E.M. and Harris, S.T. (2017) Diagnosis and Treatment of Osteoporosis before and after Fracture: A Side-by-Side Analysis of Commercially Insured and Medicare Advantage Osteoporosis Patients. *Journal of Managed Care & Specialty Pharmacy*, **23**, 735-744. https://doi.org/10.18553/jmcp.2017.23.7.735

[5] Kim, Y.W., Kim, J.H., Yoon, S.H., Lee, J.H., Lee, C.-H., Shin, C.S., *et al.* (2016) Vertebral Bone Attenuation on Low-Dose Chest CT: Quantitative Volumetric Analysis for Bone Fragility Assessment. *Osteoporosis International*, **28**, 329-338. https://doi.org/10.1007/s00198-016-3724-2

[6] Berger-Groch, J., Thiesen, D.M., Ntalos, D., Hennes, F. and Hartel, M.J. (2020) Assessment of Bone Quality at the Lumbar and Sacral Spine Using CT Scans: A Retrospective Feasibility Study in 50 Comparing CT and DXA Data. *European Spine Journal*, **29**, 1098-1104. https://doi.org/10.1007/s00586-020-06292-z

[7] Buckens, C.F., Dijkhuis, G., de Keizer, B., Verhaar, H.J. and de Jong, P.A. (2015) Opportunistic Screening for Osteoporosis on Routine Computed Tomography? An External Validation Study. *European Radiology*, **25**, 2074-2079. https://doi.org/10.1007/s00330-014-3584-0

[8] Li, Y., Wong, K., Law, M.W., Fang, B.X., Lau, V.W., Vardhanabuti, V.V., *et al.* (2018) Opportunistic Screening for Osteoporosis in Abdominal Computed Tomography for Chinese Population. *Archives of Osteoporosis*, **13**, Article No. 76. https://doi.org/10.1007/s11657-018-0492-y

[9] Zou, D., Li, W.S., Deng, C., Du, G.H. and Xu, N.F. (2018) The Use of CT Hounsfield Unit Values to Identify the Undiagnosed Spinal Osteoporosis in Patients with Lumbar Degenerative Diseases. *European Spine Journal*, **28**, 1758-1766. https://doi.org/10.1007/s00586-018-5776-9

[10] Ahern, D.P., McDonnell, J.M., Riffault, M., Evans, S., Wagner, S.C., Vaccaro, A.R., *et al.* (2021) A Meta-Analysis of the Diagnostic Accuracy of Hounsfield Units on Computed Topography Relative to Dual-Energy X-Ray Absorptiometry for the Diagnosis of Osteoporosis in the Spine Surgery Population. *The Spine Journal*, **21**, 1738-1749. https://doi.org/10.1016/j.spinee.2021.03.008

[11] Vadera, S., Osborne, T., Shah, V. and Stephenson, J.A. (2023) Opportunistic Screening for Osteoporosis by Abdominal CT in a British Population. *Insights into Imaging*, **14**, Article No. 57. https://doi.org/10.1186/s13244-023-01400-1

[12] Pickhardt, P.J., Pooler, B.D., Lauder, T., del Rio, A.M., Bruce, R.J. and Binkley, N. (2013) Opportunistic Screening for Osteoporosis Using Abdominal Computed Tomography Scans Obtained for Other Indications. *Annals of Internal Medicine*, **158**, 588-595. https://doi.org/10.7326/0003-4819-158-8-201304160-00003

[13] Jain, R.K., Lee, E., Mathai, C., Dako, F., Gogineni, P., Weiner, M.G., *et al.* (2020) Using Opportunistic Screening with Abdominal CT to Identify Osteoporosis and Osteopenia

in Patients with Diabetes. *Osteoporosis International*, **31**, 2189-2196. https://doi.org/10.1007/s00198-020-05521-x

[14] Alacreu, E., Moratal, D. and Arana, E. (2017) Opportunistic Screening for Osteoporosis by Routine CT in Southern Europe. *Osteoporosis International*, **28**, 983-990. https://doi.org/10.1007/s00198-016-3804-3

[15] Lo, J.C., Chandra, M., Yang, W., *et al.* (2024) Challenges of Fracture Risk Assessment in Asian and Black Women. *The American Journal of Managed Care*, **30**, 140-144. https://doi.org/10.37765/ajmc.2024.89515

[16] Donovan Walker, M., Babbar, R., Opotowsky, A.R., Rohira, A., Nabizadeh, F., Della Badia, M., *et al.* (2006) A Referent Bone Mineral Density Database for Chinese American Women. *Osteoporosis International*, **17**, 878-887. https://doi.org/10.1007/s00198-005-0059-9

[17] Monte, L.M. and Shin, H.B. (2023) 2022 20.6 Million People in the U.S. Identify as Asian, Native Hawaiian or Pacific Islander. https://www.census.gov/library/stories/2022/05/aanhpi-population-diverse-geographically-dispersed.html

[18] Gopinath, V. (2023) Osteoporosis. *Medical Clinics of North America*, **107**, 213-225. https://doi.org/10.1016/j.mcna.2022.10.013

[19] Leslie, W.D. (2023) Effect of Race/Ethnicity on United States FRAX Calculations and Treatment Qualification: A Registry-Based Study. *Journal of Bone and Mineral Research*, **38**, 1742-1748. https://doi.org/10.1002/jbmr.4896

[20] (2023) S0101: AGE AND SEX—Census Bureau Table, 2020. https://data.census.gov/table/ACSST1Y2019.S0101?q=age+and+gender+2019&t=Age+and+Sex&g=010XX00US

[21] Curry, S.J., Krist, A.H., Owens, D.K., Barry, M.J., Caughey, A.B., Davidson, K.W., *et al.* (2018) Screening for Osteoporosis to Prevent Fractures. *JAMA*, **319**, 2521-2531. https://doi.org/10.1001/jama.2018.7498