Original Article

Lower osteoporotic-like vertebral fractural deformity (OLVF) prevalence and severity among older Thais and Indonesians than among older Chinese

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Background: Chinese are known to have a lower vertebral fragility fracture risk than Caucasians. This study evaluates radiographic osteoporotic-like vertebral fractural deformity (OLVF) prevalence and severity among Chinese, Thai, Indonesian women and men.

Methods: In an epidemiological study with community subjects, spine radiographs (T4–L5) were sampled for 195 Thai women (mean: 73.6 years), 202 Thai men (mean: 73.7 years), 236 Indonesian women (mean: 70.4 years), and 174 Indonesian men (mean: 70.2 years). Spine radiographs of age-matched subjects were also sampled for Chinese. OLVF classification included no OLVF (grade 0), and OLVFs with <20% (grade 0.5, minimal grade), ≥20–25% (grade 1, mild grade), ≥25%–1/3 (grade 1.5, moderate grade), ≥1/3–40% (grade 2, marked grade), ≥40%–2/3 (grade 2.5, severe grade), and ≥2/3 height loss (grade 3, collapsed grade). OLVF sum score (OLVFss) was calculated with each vertebra assigned a score of 0, –0.5, –1, –1.5, –2, –2.5, and –3 for no OLVF or OLVF grades 0.5–3. Osteoporosis prevalences were estimated based on OLVFss. For a woman, OLVFss ≤–1.0 and OLVFss ≤–1.5 were the thresholds to classify the case being osteoporotic according to the lowest T-score or femoral neck T-score respectively. For men, these thresholds were OLVFss ≤–2.5 and OLVFss ≤–3.0.

Results: Compared with Southeast Asians, Chinese had overall higher prevalences of all-inclusive OLVF, apparent OLVF, and OLVF among Chinese were more likely to be multiple. A trend was noted that Chinese women were more likely to have severe and collapsed grades OLVFs than Southeast Asian women, while such a trend was not noted for Chinese men *vs.* Southeast Asian men comparison. For men, the Chinese *vs.* Southeast Asians difference was that Chinese had a higher prevalence of milder OLVFs. For the Thais *vs.* Indonesians comparison, OLVFss (mean ± standard deviation) was –0.62±1.43 for Thai men, –0.47±0.98 for Indonesian men, –0.82±2.39 for Thai women, and –0.76±2.18 for Indonesian women. The lowest T-score based osteoporosis prevalence and femoral neck T-score based osteoporosis prevalence was 9.4% and 6.9% respectively for Thai men, and 6.9% and 2.9% for respectively Indonesian men; 19.5% and 14.9%

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respectively for Thai women, 18.9% and 14.5% respectively for Indonesian women.

Conclusions: The prevalence and severity of radiographic OLVF show a weak trend of 'Chinese > Thais > Indonesians', both for older women and for older men. The results of the current study support the notion that 'populations from a warmer climate have better spine health'.

Keywords: Osteoporotic vertebral fracture; osteoporosis; Chinese; Thais; Indonesians

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Introduction

Fragility fractures (FFs) may occur in almost all skeletal segments, but the preferential locations are the vertebral column, the proximal ends of the femur and humerus, and the distal end of the radius (Colles's fracture). The bone composition of the spine, which is predominantly trabecular bone, is more prone to the thinning and microarchitectural changes associated with osteoporosis than regions of the hip that are richer in cortical bone. Assessment of vertebral FF status, in addition to bone mineral density (BMD), provides relevant clinical information to aid in predicting fracture risk in the elderly population (1-6).

There have been more studies on the prevalence and severity of vertebral FF among Caucasians and East Asians, but studies on Southeast populations remain limited. As compared with Caucasians, much lower prevalence and severity of radiological and clinical vertebral FFs among Chinese and Japanese have been noted (7-9). As the majority of vertebral FFs are independent of falls and clinically silent, identification of true osteoporotic vertebral fractures (VFs) on radiograph remains a challenge. As a part of the Asian Osteoporosis Study (AOV), Kwok *et al.* (10) reported the prevalence of radiographic VF in the aged population in four Asian regions (Hong Kong, Thailand, Indonesia, and Japan). However, there were a number of limitations to that study. Kwok *et al.* used morphometric methods to define VF. Morphometric methods are likely to classify X-ray projection artifacts, short vertebrae, and degenerative wedging as VF (11,12). Much of the reported VF prevalence differences among different studies is expected to be due to the inconsistency of VF assessment (13,14). International Society of Clinical Densitometry doesn't recommend vertebral morphometry alone for VF diagnosis. Instead, vertebral morphometry is useful for the evaluation of fracture severity and for follow-up. In the report of Kwok *et al.*, while the participants of four Asian regions were distributed in similar age groups, the participants' ages were not one-to-one age matched. Moreover, the results of Kwok *et al.* did not describe the severity of VFs.

In the current study, by re-using the spine radiograph data of Kwok *et al.* (10), we apply a detailed eSQ (extended semi-quantitative) scheme, which combines the features of both radiological assessment and quantitative measurement, to evaluate radiographic osteoporotic-like vertebral fractural deformity (OLVF) among older Hong Kong Chinese, Thais, and Indonesians. The participants of the three Asian regions will be one-to-one age matched. Severity of the radiographic VF will also be recorded. Spine radiographs of Japanese subjects are not available to us, thus not evaluated in this new study. We were particularly interested in whether the OLVF profile of Southeast Asians is more similar to that of Chinese who are known to have relatively low FF risk as compared with Caucasians, or maybe Southeast Asians have an even lower prevalence and severity of radiographic OLVF than Chinese. In addition to lower OLVF prevalence among Chinese than among Caucasians, older Chinese also have less prevalence and severity of other spine degenerative changes, such as spine hyper-kyphosis, osteoarthritic wedging, disc height loss, lumbar antero/retrolisthesis; and end plate sclerosis (7,15,16). Interestingly, using the spine radiograph data of Kwok *et al.* (10), we recently noted that, compared with Southeast Asians (i.e., Thais and Indonesians in this article), Chinese had a higher prevalence of hyper-kyphosis, osteoarthritic wedging, general osteophyte formation, lumber disc space narrowing, and lumbar spondylolisthesis (17). An even lower prevalence was noted among Indonesian women and men than among Thais in general osteophyte formation, lumbar disc space narrowing, and lumbar spondylolisthesis (17).

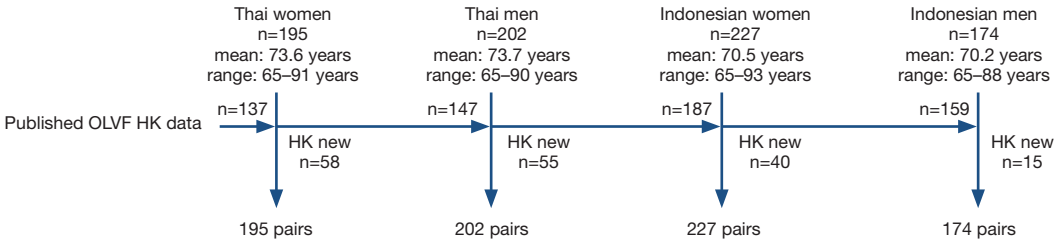

Figure 1 Study participant information. Published HK data were from Wáng *et al.* (18-21). There was one Indonesian woman aged 93 years, there was no subject among Chinese women aged 93 years, thus a Chinese woman aged 94 years was used to pair this Indonesian woman. For Thai and Indonesian subjects without age-matched subjects in the published articles (18-21), cases were in addition randomly selected from the MrOS and MsOS (Hong Kong) baseline study database [Kwok *et al.* (22), marked as 'HK new']. The Chinese cases to pair Thais and the Chinese cases to pair Indonesians are mutually exclusive. Compared with the cases used in (17), 22 Chinese women and 55 Chinese men are different. OLVF, osteoporotic-like vertebral fractural deformity; HK, Hong Kong Chinese; MrOS, osteoporotic fractures in men; MsOS, osteoporotic fractures in women.

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the Ethics Committees of the Chinese University of Hong Kong (CREC Ref. No.: 2003.102). Data collection was conducted from Aug 15, 2001, to Dec 11, 2005. Written informed consent was obtained from all subjects. The recruitment plans were designed so that the participants would represent the general elderly population in age and gender proportion.

According to the initial plan, both Thailand and Indonesia were required to recruit 400 ambulatory community-dwelling subjects (200 males and 200 females), half of whom would be aged 65–74 years and the other half would be aged ≥75 years. Participants were all ethnic Thais (for Thailand) or Indonesians (for Indonesia). Subjects were recruited in urban and rural area community centres for the elderly (10). For the study participants, radiographic films of the lateral thoracic and lumbar spine were taken with a tube-to-film distance of 100 cm, with thoracic films centred at T8 and lumbar films centred at L3. The participant data finally included for analysis with spine radiographs of satisfactory quality are shown in *Figure 1*. Chinese data were from the MrOS and MsOS (Hong Kong) baseline studies conducted from August 2001 to March 2003 (22). In the Hong Kong studies, at baseline all subjects were required to be able to walk without assistance, without bilateral hip replacement, and have the potential to survive the duration of primary study for at least 4 years as judged by their pre-existing medical status. For the Hong Kong data, to allow better comparisons with published results, we re-used the radiograph eSQ reading in the four published articles (18-21). For cases without age matched subjects with eSQ reading in the published articles, Chinese cases were in addition randomly selected from the MrOS and MrOS (Hong Kong) baseline study database, and spine radiographs were additionally read during this study. The Chinese cases to pair Thais and the Chinese cases to pair Indonesians were mutually exclusive. Questionnaires of physical and mental 12-Item Short Form Survey (SF-12) as well as Physical Activity Screening for Elderly score (PASE) were administered to all study participants. In addition, information on 'past longest occupation being a farmer' was also collected (10).

All the spine radiographs were digitized. Thoracic and lumbar vertebrae were evaluated with eSQ criteria (23,24): (I) minimal grade refers to radiological OLVF with <20% height loss, which would be theoretically equivalent to Genant SQ grade 0.5, and the diagnosis of this grade rely on a distinct fracture-like change of a vertebra's morphology (as compared with its expected shape consideration those of the neighbouring vertebrae); (II) mild grade OLVF is the same as Genant mild grade (≥20–25% height loss); (III) Genant moderate grade OLVF is divided into two subgrades: ≥25%–1/3 height loss (moderate grade) and ≥1/3–40% height loss (marked grade); (IV) Genant severe grade OLVF is divided into two subgrades: ≥40%–2/3 height loss (severe grade) and with >2/3 height loss (collapsed grade). The vertebral height loss estimation was primarily based on measurement, by comparing the vertebral heights of neighbouring vertebrae of normal shape (23). Vertebrae with radiographic endplate and/or cortex fracture while without notable height loss were also classified as minimal grade. Non-fractural changes/

Table 1 SF-12 physical and mental, PASE, and longest occupation characteristics of study participants

Characteristics	Chinese *vs.* Thais				Chinese *vs.* Indonesians			
	Chin F (n=195)	Thai F (n=195)	Chin M (n=202)	Thai M (n=202)	Chin F (n=227)	Indon F (n=227)	Chin M (n=174)	Indon M (n=174)
Age (years)	73.6 years	73.6 years	73.7 years	73.7 years	70.5 years	70.5 years	70.2 years	70.2 years
SF-12 (physical)	47.0±8.9[A]	43.6±11.7[A]	49.7±8.5[E]	46.1±10.9[E]	47.8±8.4[I]	42.1±11.6[I]	51.3±7.3[M]	47.2±10.4[M]
SF-12 (mental)	55.3±7.9[B]	52.8±9.2[B]	56.6±6.2[F]	53.2±8.6[F]	55.1±7.2[J]	52.4±8.1[J]	54.3±7.7[N]	52.1±8.1[N]
PASE score	89.4±35.9[C]	76.4±45.1[C]	100.3±53.0[G]	97.1±80.2[G]	91.3±36.8[K]	74.4±40.5[K]	103.0±51.0[O]	104.3±67.0[O]
Longest occupation	0.5% [1][D]	38.5% [75][D]	2.0% [4][H]	44.6% [90][H]	0[L]	4.7% [11][L]	0[P]	6.9% [19][P]

Data are presented as mean ± SD or percentage [positive cases]. [A], P=0.016; [B], P=0.032; [C], P<0.001; [D], P<0.001; [E], P=0.004; [F], P<0.001; [G], P=0.052; [H], P<0.001; [I], P<0.001; [J], P<0.001; [K], P<0.001; [L], P<0.001; [M], P=0.001; [N], P=0.020; [O], P=0.675; [P], P<0.001. Longest occupation, past longest occupation being a farmer; SF-12, 12-Item Short Form Survey; PASE score, Physical Activity Screening for Elderly score; Chin, Chinese; Indon, Indonesians; F, women; M, men; SD, standard deviation.

deformities of the vertebrae shape were differentiated from OLVF as much as possible (13,14,25,26). The radiograph reading in the current study was double-read by two trained readers (Y.X.J.W. and C.Y.L.), with consensus all reached. In this study, the term 'OLVF' is further used, as only based on spine radiograph it is not possible to diagnose a vertebral deformity as osteoporotic VF with certainty in every case, particularly for milder deformities (14,27,28). OLVF might also include those of osteopenic VF.

An OLVF sum score (OLVFss), which describes the overall number and severity of osteoporotic fracture status of the thoracic and lumbar spine, was calculated for each study subject. For each vertebra in a subject, a score of 0, –0.5, –1, –1.5, –2, –2.5, and –3 was assigned for no OLVF or OLVF of <20% (grade-0.5), ≥20–25% (grade-1), ≥25%~1/3 (grade-1.5), ≥1/3–40% (grade-2), ≥40%–2/3 (grade-2.5), and ≥2/3 vertebral height loss (grade-3), respectively. However, two adjacent minimal OLVFs were assigned as –0.5. Three adjacent minimal OLVFs are generally rare and were assumed to be –1 (14,24). OLVFss was calculated by summing up the scores of vertebrae T4 to L5. T1–T3 are not always shown very well on spine radiograph, and osteoporotic vertebral fracture at T1–T3 levels are rare. However, in cases an OLVF was seen at T1–T3 level, it was counted for OLVFss calculation as well. Following earlier reports (14,20,24), osteoporosis prevalences in the study populations were estimated using OLVFss in statistical terms. For women, thresholds of OLVFss ≤–1 and ≤–1.5 were used to estimate osteoporosis prevalence equivalent to the lowest T-score (of femoral neck, total hip, and lumbar spine) and the T-score of femoral neck, respectively. For men, thresholds of OLVFss ≤–2.5 and ≤3.0 were used to estimate osteoporosis prevalence equivalent to the lowest T-score (of femoral neck, total hip, and lumbar spine) and the T-score of femoral neck, respectively. Among older subjects and after excluding known osteoporotic vertebral fracture mimics, if OLVFss achieve these thresholds then the OLVF are most probably osteoporotic fracture in statistical terms (14,24). Note that it is well known that non-osteoporotic vertebral deformities are more common in men than in women (14).

For the comparison between Thais and Indonesians, 140 pairs for men and 150 pairs for women were age-matched with allowing +/– one year's age differences.

All statistical analyses were performed using GraphPad Software (GraphPad Software Inc., San Diego, CA, USA). Continuous variables were tested by Wilcoxon signed-rank test, and categorical variables were analysed by the chi-square test. All statistical tests were two-sided. P value <0.05 was considered statistically significant, >0.1 as not significant, and between 0.05 and 0.1 as with a trend of significance.

Results

The general physical and mental health survey results, and the former occupation history are shown in *Table 1*. There was no apparent difference in SF-12 physical and mental scores among Chinese, Thais, and Indonesians, both for women and for men. PASE score was higher among Chinese women, but there was no apparent difference among men. Both Thai women and men had a higher proportion with the past longest occupation being a farmer.

The prevalence and severity results of OLVF are shown

Table 2 Comparison of OLVF between age matched Chinese and Southeast Asians

Categories	Hong Kong (n=798)	Thailand & Indonesia (n=798)	P value
Total (mean age, 72.01 years)			
All-inclusive OLVF*	50.00% [399]	40.35% [322]	<0.001
Minimal OLVF	26.19% [209]	24.56% [196]	0.455
Apparent OLVF*	23.81% [190]	15.79% [126]	<0.001
Severe OLVF#	7.02% [56]	5.89% [47]	0.359
Collapsed OLVF	4.51% [36]	3.38% [27]	0.247
Multiple OLVF¶*	20.18% [161]	15.16% [121]	0.009
OLVFss*	−0.84±1.85	−0.70±2.08	<0.001
Men n=376 (mean age, 72.09 years)			
All-inclusive OLVF*	59.57% [224]	45.48% [171]	<0.001
Minimal OLVF	34.31% [129]	30.05% [113]	0.212
Apparent OLVF*	25.27% [95]	15.43% [58]	0.001
Severe OLVF#	5.59% [21]	5.59% [21]	1.00
Collapsed OLVF	3.19% [12]	3.19% [12]	1.00
Multiple OLVF*¶	24.20% [91]	17.02% [64]	0.015
OLVFss*	−0.85±1.53	−0.58±1.18	<0.001
Women n=422 (mean age, 71.94 years)			
All-inclusive OLVF*	41.47% [175]	35.78% [151]	0.090
Minimal OLVF	18.96% [80]	19.67% [83]	0.794
Apparent OLVF*	22.51% [95]	16.11% [68]	0.019
Severe OLVF#	8.29% [35]	6.16% [26]	0.232
Collapsed OLVF	5.69% [24]	3.55% [15]	0.140
Multiple OLVF¶	16.59% [70]	13.51% [57]	0.211
OLVFss*	−0.83±2.09	−0.81±2.62	0.056

Data are presented as percentage [positive cases] or mean ± SD. *, P<0.1; #, severe OLVFs inclusive of collapsed OLVF; ¶, more than one vertebra involved. Apparent OLVF, OLVF with ≥20% vertebral height loss. OLVF, osteoporotic-like vertebral fractural deformity; SD, standard deviation.

in *Tables 2-5*. Overall, compared with Southeast Asians, Chinese had higher prevalences of all-inclusive OLVF, apparent OLVF, and OLVF in among Chinese were more likely to be multiple. A trend was noted that Chinese women were more likely to have severe and collapsed grade OLVF than Southeast Asian women (statistical significance not achieved), while such a trend was not noted for Chinese men *vs.* Southeast Asian men comparison (probably due to men overall are less likely to have severe and collapsed grade OLVF). A comparison between Thais and Indonesians showed Thais tended to have higher overall OLVF prevalence and lower mean OLVFss values, though statistical significance was not achieved for most of the comparisons. For men, the Chinese *vs.* Southeast Asian difference was more on the higher prevalence of milder OLVF among Chinese. For women, the Chinese *vs.* Southeast Asian difference was more on that the severity of OLVF among Chinese was higher (*Figure 2*).

Among Chinese, Thais, and Indonesians, a consistent pattern was noted men were more likely to have milder grades of OLVF, while in proportion women were more likely to have ≥ moderate grade OLVF (with ≥25% vertebral

Table 3 Comparison of OLVF between age matched Chinese and Thai subjects

Categories	Hong Kong (n=397)	Thailand (n=397)	P value
Total (mean age, 73.65 years)			
All-inclusive OLVF*	58.69% [233]	47.61% [189]	0.002
Minimal OLVF	30.23% [120]	30.23% [120]	1.000
Apparent OLVF*	28.46% [113]	17.38% [69]	<0.001
Severe OLVF#	9.07% [36]	6.80% [27]	0.237
Collapsed OLVF	5.79% [23]	3.53% [14]	0.130
Multiple OLVF*¶	24.94% [99]	17.13% [68]	0.007
OLVFss*	−1.00±1.80	−0.80±2.24	<0.001
Men n=202 (mean age, 73.73 years)			
All-inclusive OLVF*	74.75% [151]	52.48% [106]	<0.001
Minimal OLVF*	43.07% [87]	34.16% [69]	0.066
Apparent OLVF*	31.68% [64]	18.32% [37]	0.002
Severe OLVF#	6.93% [14]	6.93% [14]	1.000
Collapsed OLVF	3.47% [7]	3.47% [7]	1.000
Multiple OLVF*¶	32.18% [65]	20.30% [41]	0.007
OLVFss*	−1.08±1.67	−0.70±1.35	<0.001
Women n=195 (mean age, 73.56 years)			
All-inclusive OLVF	42.05% [82]	42.56% [83]	0.918
Minimal OLVF*	16.92% [33]	26.15% [51]	0.027
Apparent OLVF*	25.13% [49]	16.41% [32]	0.034
Severe OLVF#	11.28% [22]	6.67% [13]	0.111
Collapsed OLVF*	8.21% [16]	3.59% [7]	0.053
Multiple OLVF¶	17.44% [34]	13.85% [27]	0.329
OLVFss	−0.92±1.93	−0.89±2.89	0.498

Data are presented as percentage [positive cases] or mean ± SD. *, P<0.1; #, severe OLVFs inclusive of collapsed OLVF; ¶, more than one vertebra involved. Apparent OLVF, OLVF with ≥20% vertebral height loss. OLVF, osteoporotic-like vertebral fractural deformity; SD, standard deviation.

height loss) (*Figure 3*).

The distribution of OLVFs at different vertebral levels is shown in *Figure 4*. There was no difference in distribution pattern between Chinese, Thais, and Indonesians, with the highest prevalence at thoracolumbar junction (T11–L1 levels) followed by mid-thoracic spine (T7–T9 levels). A trend was noted that, compared to those of women, OLVF of men were more likely to concentrate in thoracolumbar junction; and compared to those of men and in relative terms, OLVF of women had a higher proportion of distribution at the mid-thoracic spine level.

Percentage of cases with OLVFss ≤−1, ≤−1.5 or ≤−2 for women, and with OLVFss ≤−2, ≤−2.5 or ≤−3 for men are shown in *Table 6*. Except for men OLVFss ≤−3 category, for all other comparisons, the percentage of cases below various OLVFss thresholds was higher for Chinese than for Southeast Asians. For men of the OLVFss ≤−3 category, the percentage of cases was lowest for Indonesians.

Discussion

With Thais and Indonesians as examples of Southeast

Table 4 Comparison of OLVF between age matched Chinese and Indonesian subjects

Categories	Hong Kong (n=401]	Indonesia (n=401]	P value
Total (mean age, 70.39 years)			
All-inclusive OLVF*	41.40% [166]	33.17% [133]	0.016
Minimal OLVF	22.19% [89]	18.95% [76]	0.256
Apparent OLVF*	19.20% [77]	14.21% [57]	0.058
Severe OLVF #	6.73% [27]	6.73% [27]	1.000
Collapsed OLVF	3.74% [15]	3.74% [15]	1.000
Multiple OLVF¶	14.96% [60]	13.22% [53]	0.477
OLVFss*	−0.68±1.88	−0.61±1.90	0.022
Men n=174 (mean age, 70.18 years)			
All-inclusive OLVF	41.95% [73]	37.36% [65]	0.381
Minimal OLVF	24.14% [42]	25.29% [44]	0.804
Apparent OLVF	17.82% [31]	12.07% [21]	0.133
Severe OLVF#	6.93% [14]	6.93% [14]	1.000
Collapsed OLVF	4.02% [7]	4.02% [7]	1.000
Multiple OLVF¶	14.94% [26]	13.22% [23]	0.644
OLVFss	−0.58±1.29	−0.44±0.94	0.274
Women n=227 (mean age, 70.54 years)			
All-inclusive OLVF*	40.97% [93]	29.96% [68]	0.014
Minimal OLVF*	20.70% [47]	14.10% [32]	0.063
Apparent OLVF	20.26% [46]	15.86% [36]	0.222
Severe OLVF #	5.73% [13]	5.73% [13]	1.000
Collapsed OLVF	3.52% [8]	3.52% [8]	1.000
Multiple OLVF¶	15.86% [36]	13.22% [30]	0.424
OLVFss*	−0.76±2.22	−0.74±2.38	0.037

Data are presented as percentage [positive cases] or mean ± SD. *, P<0.1; #, severe OLVFs inclusive of collapsed OLVF; ¶, more than one vertebra involved. Note that, subjects in this table were on average younger than the subjects in *Table 3*, while >70 years is the age period when OLVF severity develop rapidly. Apparent OLVF: OLVF with ≥20% vertebral height loss. OLVF, osteoporotic-like vertebral fractural deformity; SD, standard deviation.

Asians, this study demonstrated that, Chinese had overall higher prevalences of all-inclusive OLVF, apparent OLVF, and OLVF among Chinese were more likely to be multiple. A weak trend was also noted that severity of OLVF might be even milder among Indonesians than among Thais. OLVFss was −0.62±1.43 for Thai men, −0.47±0.98 for Indonesian men, −0.82±2.39 for Thai women, and −0.76±2.18 for Indonesian women. Using the same spine data of Thais and Indonesians and age-matched largely similar Hong Kong Chinese cases (*Figure 1*), we analysed the prevalence of spine hyper-kyphosis, osteoarthritic wedging, acquired short vertebrae, general osteophyte formation, lumbar disc space narrowing, and lumbar spondylolisthesis (17). We noted that, compared with Southeast Asians, Chinese (women and men data grouped together) had a higher prevalence of hyper-kyphosis (24.9% *vs.* 16.4%), osteoarthritic wedging (2.4% *vs.* 0.9%), general osteophyte formation (15.3% *vs.* 10.5%), lumber disc space narrowing (27.6% *vs.* 20.3%), and lumbar spondylolisthesis (20.7% *vs.* 15.3%). The trends were also consistent for sub-group data analyses. An even

Table 5 Comparison of OLVF between Thais and Indonesians with on age matched cases while allowing ±1 years during the matching

Categories	Thailand (n=290)	Indonesia (n=290)	Thailand M (n=140)	Indonesia M (n=140)	Thailand F (n=150)	Indonesia F (n=150)
Mean age	72.06 years	71.91 years	71.6 years	71.3 years	72.47 years	72.42 years
All-inclusive OLVF	42.76% [124][a]	36.55% [106][a]	47.86% [67][d]	41.43% [58][d]	38.00% [57][g]	32.00% [48][g]
Minimal OLVF	28.62% [83][b*]	21.72% [63][b*]	34.29% [48][e]	29.29% [41][e]	23.33% [35][h*]	14.67% [22][h*]
Apparent OLVF	14.14% [41]	14.83% [43]	13.57% [19]	12.14% [17]	14.67% [22]	17.33% [26]
Severe OLVF[#]	5.52% [16]	5.52% [16]	5.00% [7]	4.29% [6]	6.00% [9]	6.67% [10]
Collapsed OLVF	3.10% [9]	3.79% [11]	2.86% [4]	3.57% [5]	3.33% [5]	4.00% [6]
Multiple OLVF[¶]	16.55% [48]	14.48% [42]	19.29% [27]	14.29% [20]	14.00% [21]	14.67% [22]
OLVFss	−0.72±1.98[c*]	−0.62±1.71[c*]	−0.62±1.43[f]	−0.47±0.98[f]	−0.82±2.39[i]	−0.76±2.18[i]

Data are presented as percentage [positive cases] or mean ± SD. [a], P=0.127; [b], P=0.056; [c], P=0.097; [d], P=0.279; [e], P=0.369; [f], P=0.359; [g], P=0.276; [h], P=0.056; [i], P=0.162; *, P<0.1. OLVF, osteoporotic-like vertebral fractural deformity; M, men; F, women; SD, standard deviation.

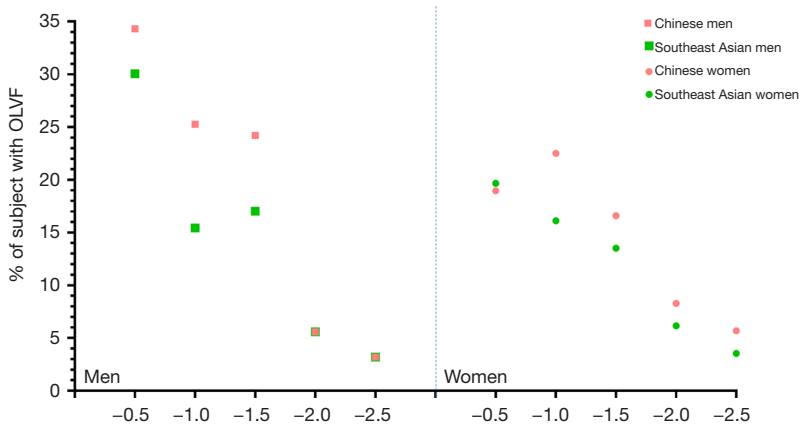

Figure 2 Chinese men have higher prevalence of milder OLVF than Southeast Asian men, and OLVF among Chinese women are more severe than OLVF among Southeast Asian women. In X-axis, −0.5, −1, −1.5, −2, and −2.5 represent OLVF of <20%, ≥20–25%, ≥25%– 1/3, ≥1/3–40%, ≥40% vertebral height loss, respectively. OLVF, osteoporotic-like vertebral fractural deformity.

lower prevalence was noted among Indonesian women and men than among Thais in general osteophyte formation (5.9% *vs.* 14.1%), lumbar disc space narrowing (18.3% *vs.* 24.1%), and lumbar spondylolisthesis (11.4% *vs.* 19.3%). Thus, Indonesians who inhabit an even warmer climate than Thais, demonstrated even fewer OLVF and spine degenerations than Thais. While the differences in OLVF among Chinese, Thais, and Indonesians follow the trends of spine degeneration differences among these three ethnic groups, it is noted the magnitudes of differences were larger for spine degenerations than for OLVF.

In Europe, it has been well noted that Mediterranean Europeans have better overall bone health than northern Europeans. The hip fracture incidence rates are the highest in the Scandinavian countries particularly those of Norway, Denmark, Sweden, and Iceland, while lower among Southern Europeans (29,30). Lucas *et al.* (30) predicted that, the maximum hip fracture incidence rate (per 100,000 subjects) is 1,389.8 for Swedish women and 1,089.7 for Danish women (742.4 for Swedish men, 551.1 for Danish men), 376.0 for Portuguese women and 420.0 for Spanish women (156.9 for Portuguese men, and 195.0 for Spanish men). With the European Vertebral Osteoporosis Study (EVOS) data, O'Neill *et al.* (31) described that radiographic vertebral deformity prevalence was highest in the Scandinavian populations. In the European Prospective

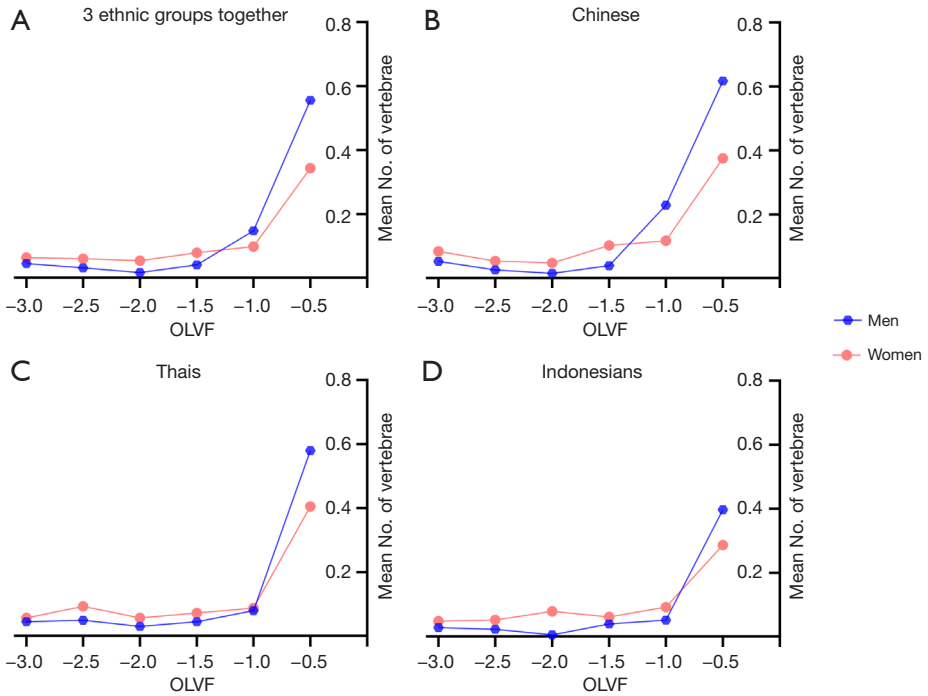

Figure 3 Men are more likely to have milder grades of OLVF, while in proportion women are more likely to have ≥ moderate grade OLVF (with ≥25% vertebral height loss). X-axis is OLVF grading. In X-axis, –0.5, –1, –1.5, –2, –2.5, and –3 represent OLVF of <20%, ≥20–25%, ≥25%–1/3, ≥1/3–40%, ≥40%–2/3, and ≥2/3 vertebral height loss, respectively. OLVF, osteoporotic-like vertebral fractural deformity.

Osteoporosis Study (EPOS), Felsenberg *et al.* (32) described that age-standardized incidence of morphometric VF was 17.7 and 7.3 per 1,000 person-years for older Scandinavia women and men, and 10.2 and 3.6 per 1,000 person-years for older Southern Europeans. The OLVF difference gradients are likely sharper for the Caucasians *vs* Chinese comparison than for the Chinese *vs.* Southeast Asians comparison. In our study comparing OLVF rates in age-matched Hong Kong Chinese women (n=200, from MsOS Hong Kong study) and Italian Caucasian community women (mean age: 74.1 years), endplate and/or cortex fracture (ECF) prevalence was 26% for Chinese and 47% for Italian. OLVF with ≥40% vertebral height loss was recorded among 9.5% of the Chinese subjects while among 26% of the Italian subjects. OLVFs in Italian subjects were more likely to be multiple and generally severer. Taking the results from Europe and our results in comparison of Chinese and Southeast Asians together, we postulated that populations from a warmer climate have better spine health (17). We further postulated '*That populations from a warmer climate have better spine health*' may be more of a result of evolutional adaptation, rather than the direct result of a warmer environment and more sunshine (17,33). Moreover, 'spine health' may not be a standalone phenomenon, instead, spine health is related to the overall general bone health of the population. For example, the ratio of spine FF risk to hip FF is consistent among East Asian populations and among Caucasian populations (9). Nevitt *et al.* (34) reported Chinese have a lower age-standardized prevalence of radiographic hip osteoarthritis, compared with Caucasians in the US. Zhang *et al.* (35) also reported a lower prevalence of hand osteoarthritis among Chinese, compared with Caucasians in the US.

A trend was noted that, compared with those of women and in relative term, OLVF in men were more likely to concentrate in thoracolumbar junction; and compared with those of men, OLVF in women had a higher proportion of distribution at the mid-thoracic spine level. Such a phenomenon has been noted by us earlier (*Figure 5*) (36,37). This could be due to that OLVF in men are more likely associated with a greater biomechanical stress (and thus with an increased possibility of OLVFs being mixed with osteopenic VF or VF of normal BMD) (14), as the middle thoracic spine is protected by the rib cage. The OLVF in the mid-thoracic region may be more clinically relevant than those in the thoracolumbar junction.

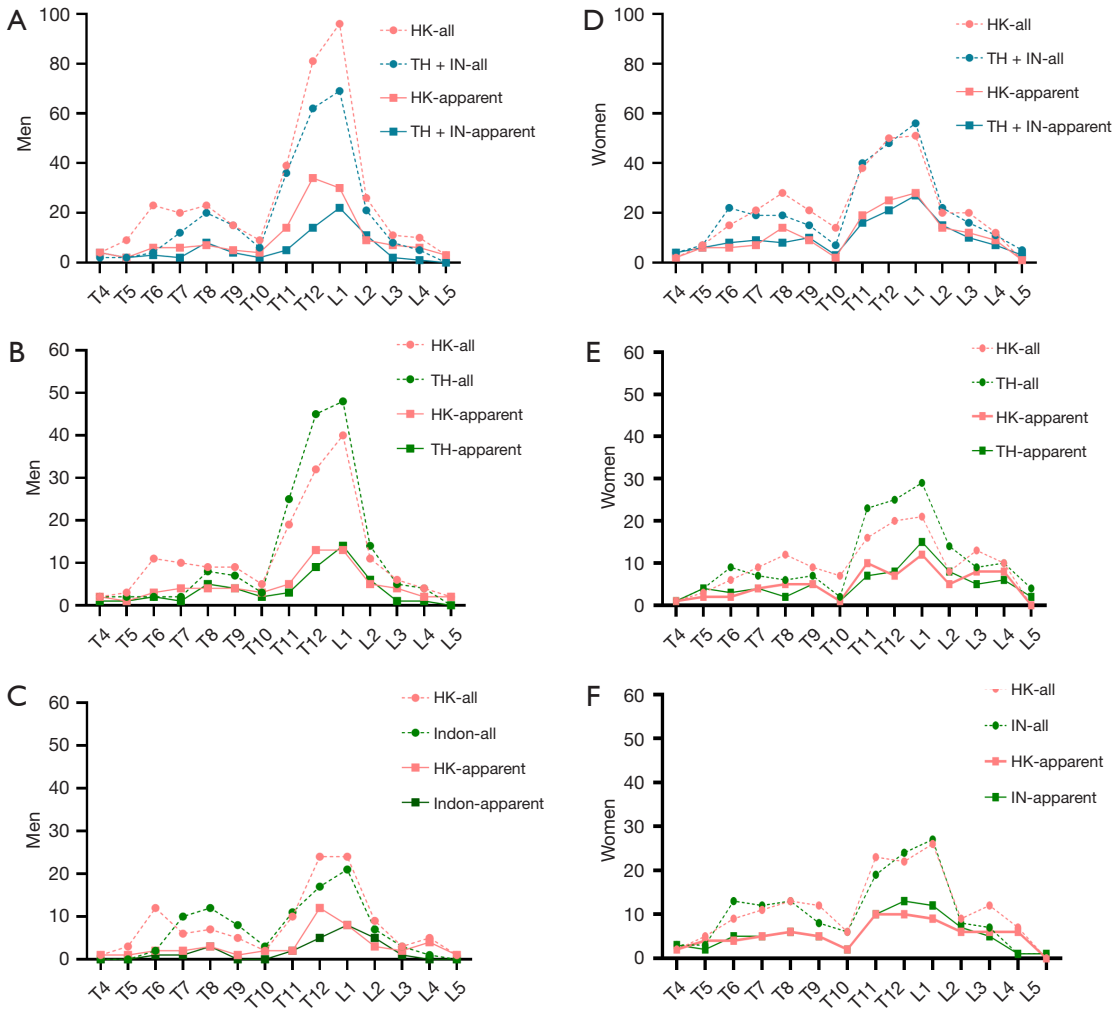

Figure 4 Vertebral level distribution of OLVF deformity. Thin dotted lines indicate all-inclusive OLVF (all), and thick solid lines indicate OLVF with ≥20% vertebral height loss (apparent). HK, Hong Kong Chinese; TH, Thais; Indon or IN, Indonesian; OLVF, osteoporotic-like vertebral fractural deformity.

Table 6 Comparisons of lower OLVFss proportion of subjects among Chinese, Thais, and Indonesians

Categories	Chinese	Thais	Indonesians	P value[a]	P value[b]	P value[c]
Women (mean age, 72.09 years)	n=422	n=195	n=227			
OLVFss ≤−1	24.88% [105]	19.49% [38]	18.94% [43]	0.140	0.085	0.887
OLVFss ≤−1.5	19.67% [83]	14.87% [29]	14.54% [33]	0.151	0.104	0.923
OLVFss ≤−2	13.75% [58]	11.28% [22]	10.57% [24]	0.002	0.246	0.816
Men (mean age, 71.94 years)	n=376	n=202	n=174			
OLVFss ≤−2	14.63% [55]	12.87% [26]	8.05% [14]	0.562	0.030	0.130
OLVFss ≤−2.5	11.17% [42]	9.41% [19]	6.90% [12]	0.510	0.117	0.378
OLVFss ≤−3	6.91% [26]	6.93% [14]	2.87% [5]	0.994	0.056	0.073

Data are presented as percentage [positive cases]. P value[a] compares the difference between Chinese and Thais. P value[b] compares the difference between Chinese and Indonesians. P value[c] compares the difference between Thais and Indonesians. OLVFss, OLVF sum score; OLVF, osteoporotic-like vertebral fractural deformity.

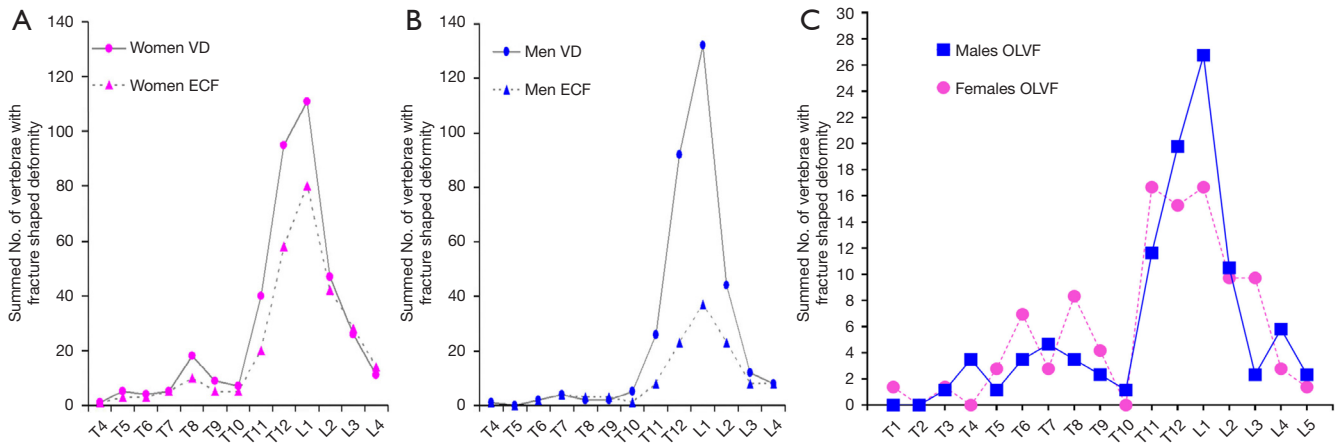

Figure 5 In relative term, OLVF deformities in older men are more concentrated in thoracolumbar junction. X-axis: the vertebral level of OLVF distribution. For A (MsOS Hong Kong study for women baseline) and B (MrOS Hong Kong study for men baseline), the radiographs of 1,953 elderly Chinese women (mean: 72.5 years) and 1,954 elderly Chinese men (mean: 72.3 years) were evaluated according to Genant's VD criteria and ECF criteria. The distribution of VD is highest at T12 and L1, second highest at T11 and L2. A higher VF rate is also seen at T8 in women (A), but less so in men (B). For (C), at year-14 follow-up of MsOS and MrOS Hong Kong studies. Two hundred seventy-one men and 150 women participants were included. The mean age was 82.8±3.6 years for men and 82.0±4.29 years for women. Reproduced with permission from Deng *et al.* (36) and Wáng *et al.* (37). VD, vertebral deformity; ECF, endplate and/or cortex fracture; OLVF, osteoporotic-like vertebral fractural deformity; MsOS, osteoporotic fractures in women; MrOS, osteoporotic fractures in men.

For older Chinese women, subjects with OLVF of less than 20% vertebral height loss have a further incident VF risk higher than the subjects without any baseline OLVF (14,19). On the other hand, for older Chinese men, subjects with VF of less than 20% vertebral height loss do not have a further incident VF risk higher than the subjects without any baseline VF (14,19). Among Chinese, Thais, and Indonesians, a consistent pattern was noted that men were more likely to have milder grades OLVF, while women have a higher proportion of more ≥ moderate grade OLVF (with ≥25% vertebral height loss). It is possible that the OLVF difference between Chinese women and Southeast women would be more clinically relevant than the OLVF difference between Chinese men and Southeast men. It had been suggested that VF is more common in the older Thai population (38). However, some of the earlier reports on Thai population were based on morphometric methods (10,39,40). In a study of 1,062 postmenopausal Thai women by Pongchaiyakul *et al.* (41), women <50 years, 50 to 59 years, and 60 to 69 years had asymptomatic radiographic 'VF' rates of 25.0% (21/84), 25.8% (123/447), and 34.8% (111/340), respectively. Although there was an increased 'VF' rate among the age 60 to 69 group, there was no difference in 'VF' rate between the <50 years group and the 50 to 59 years group. It is likely that the 25.0% 'VF' prevalence for the <50 years group is close to that of 'baseline noise' vertebral deformities, with the increase of postmenopausal OLVF prevalence beginning in the 60 to 69 years group (14,28,41).

Table 2 in this study shows older men had a much lower osteoporosis prevalence than aged-matched women, this is consistent with that osteoporotic fracture is much less common among older men (42-45). The osteoporosis prevalence of Thai women estimated from OLVFss in the current study show a lower osteoporosis prevalence than a few earlier dual-energy X-ray absorptiometry (DXA) BMD-based reports on Thais. Limpaphayom *et al.* (46) reported the age-adjusted prevalence of osteoporosis of the femoral neck in Thai women at the age of 70–74 years was 46.9% for urban women and 53.5% for rural women. Asavamongkolkul *et al.* (47) reported the osteoporosis prevalence (lowest of femoral neck, total hip, and lumbar T-score) in Thai women and men at the age of 71–75 years was 47.0% and 17.8% respectively. It is noted that the proportion of US women with femoral neck or lumbar BMD based osteoporosis is estimated to be 6.8%, 12.3%, 25.6%, and 34.9%, for the age bands of 50–59, 60–69, 70–79, ≥80 years, respectively (48). The proportion of US men with femoral neck or lumbar BMD based osteoporosis is estimated to be 3.4%, 5.0%, and 10.9%, for

the age bands of 50–69, 70–79, ≥80 years, respectively (48). The hip FF prevalences among Thai populations are not higher than Hong Kong Chinese (actually, maybe lower than Hong Kong Chinese) (49), and the current study also showed OLVF prevalences among Thai populations are likely lower than Hong Kong Chinese. Chinese has an FF prevalence of approximately half of those of US Caucasians, both for men and for women (44,45,50). Following the 1994 World Health Organization (WHO) definition, densitometric osteoporosis prevalence among a specific population should be in proportion to its relative osteoporotic fracture risk with Caucasian data as reference (51). The osteoporosis prevalence in the reports of Limpaphayom *et al.* (46) and Asavamongkolkul *et al.* (47) were highly likely over-estimated.

There are a number of limitations to this study. The main limitation is the sample sizes were relatively small, with approximately 200 cases per ethnic and gender group. These sample sizes will not detect small or subtle differences with sufficient statistical power. Thus in a few comparisons the trends were not consistent. To achieve statistical significance, we attempted to combine the men's and women's data together and also combine the Thai data and Indonesian data together. That consistent patterns were observed both for men and for women and there was a decreasing gradient in OLVF prevalence/severity from Chinese to Thais to Indonesians mitigate the possibility of sampling bias. Though we used population based and age-match pairs, not all factors were well matched in the subjects. PASE score was higher among Chinese women. Both Thai women and men had a higher proportion with the past longest occupation being a farmer (*Table 1*). Few HK Chinese in this study had an occupation being a farmer. These factors might not have majorly affected the results of the current study. Earlier studies suggest that manual labour activities increase the prevalence of vertebral fractural deformity (27,28), while in this study Hong Kong Chinese still had a higher mean OVLFss than that of Thais. Another limitation is that, for Southeast Asia countries, we only studied Thais and Indonesians.

Conclusions

In conclusion, the prevalence and severity of radiographic OLVF show a weak trend of '*Chinese* > *Thais* > *Indonesians*', both for older men and for older women. The differences between Chinese men and Southeast Asian men were mainly on overall prevalence, while the differences between Chinese women and Southeast Asian women were mainly on severity. The results of the current study further support the notion that '*populations from a warmer climate have better spine health*'.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-430/coif). Y.X.J.W. serves as the Editor-in-Chief of *Quantitative Imaging in Medicine and Surgery*. 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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the Ethics Committees of the Chinese University of Hong Kong (CREC Ref. No.: 2003.102). Written informed consent was obtained from all subjects.

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