



Fewer spine degenerations among Southeast Asians than among Southern Chinese suggests populations from a warmer climate have inherently better spine health

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Background: Compared with older Caucasians, older Chinese have remarkably lower prevalence and lower severity of spine degenerative changes. There have been few studies on Southeast East populations. This study aims to compare radiographic spine degeneration features among older Hong Kong (HK) Chinese, older Thais, and older Indonesians.

Methods: This study included 195 Thai women (mean: 73.6 years), 202 Thai men (mean: 73.7 years), 227 Indonesian women (mean: 70.5 years), and 174 Indonesian men (mean: 70.2 years), as well as same number of gender- and age-matched HK Chinese. The recruitment plan was that the participants would represent the general older population of their respective communities. With spine radiograph, spine hyper-kyphosis, osteoarthritic wedging (OAw), acquired short vertebrae (SVa), general osteophyte formation, lumbar disc space narrowing, and lumbar spondylolisthesis were assessed.

Results: Compared with Southeast Asians (Thais and Indonesian data together), Chinese women and men had a higher prevalence of hyper-kyphosis (24.9% *vs.* 16.4%), OAw (2.4% *vs.* 0.9%), general osteophyte formation (15.3% *vs.* 10.5%), lumbar 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 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%).

Conclusions: This study showed a lower prevalence of spine degeneration changes among older Thais and older Indonesians than among older Chinese. Indonesians, who inhabit an even warmer climate, show even fewer spine degeneration changes than Thais.

Keywords: Spine; vertebral deformities; degeneration; Chinese; Southeast Asians

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Submitted Jul 09, 2024. Accepted for publication Aug 06, 2024. Published online Aug 15, 2024.

doi: 10.21037/qims-24-1533

View this article at: <https://dx.doi.org/10.21037/qims-24-1533>

Introduction

Ethnic differences in a number of radiological features related to spine degeneration have been studied between Caucasians and East Asians. In a study comparing radiographic vertebral fragility fracture (FF) rates in age-matched Hong Kong (HK) Chinese women and Italian Caucasian women (mean: 74.1 years), endplate and/or vertebral cortex fracture prevalence was 26% for Chinese and 47% for Italian. Vertebral FF in Italian subjects were more likely to be multiple and generally more severe (1). The prevalence of clinical vertebral FF is also much higher among Caucasian men and women than among East Asian men and women (2-4). Yoshimura *et al.* (5) examined the radiographs of residents in the UK and residents in Japan (aged 60–79 years). British subjects were noted to be much more likely to have lumbar spine radiographs osteoarthritic changes graded as Kellgren-Lawrence 4 severity. In a paired analysis of spine radiographs of age-matched older HK Chinese women and older Italian Caucasian women (mean age: 73.6 years), Italian subjects were noted more likely to have thoracic spine hyper-kypnosis (53.4% *vs.* 25.6%), OA wedging (OA_w, 6.4% *vs.* 0.67%), Schmorl node (19.5% *vs.* 4.4%) (6). Italian Caucasian women were also noted to have higher scores for lumbar disc height loss (Italian, 3.6±2.8 *vs.* HK 2.5±2.1); lumbar antero/retrolisthesis (Italian 0.3±0.7 *vs.* HK 0.2±0.4); and end plate sclerosis (Italian 1.0±1.2 *vs.* HK 0.6±1.0) (7). Lumbar spondylolisthesis has also been noted to be relatively low among Japanese and Thais than among Caucasians (3). However, it was demonstrated that lumbar marrow fat content, which has been suggested to be associated with fragility, is not higher among older Italian women than among older Chinese women (8).

Compared with Caucasians, Chinese/Asians are known to have a lower incidence rate of back pain (9-12). From U.S. national surveys 2002, Deyo *et al.* (9) estimated back pain prevalence and clinics visit rates and showed that, among racial groups, Asian Americans had the lowest prevalence. Waterman *et al.* (10) queried National Electronic Injury Surveillance System (USA) for all cases of low back pain presenting to emergency departments between 2004 and 2008. They found that the per 1,000 person-years low back pain incident rates were 1.23 among whites, while only

0.20 among Asians. Mailis-Gagnon *et al.* (11) collected data on new patients over a three-year period at the Comprehensive Pain Program in downtown Toronto. They noted the East Asian group (primarily Chinese) was the most underrepresented (1.6% of the Comprehensive Pain Program population), despite that this group accounted for 9% of the population in Toronto and 6.01% of the Greater Toronto Area population. This lower back pain prevalence among Chinese/Asians is likely associated with the lower spine fracture prevalence and fewer and less severe spin degeneration changes.

There have been more studies conducted on East Asian populations, but few studies conducted on Southeast East populations. The primary aim of this study is to understand, whether the spine degeneration profile of Southeast East population is similar to Chinese population, and thus with a lower prevalence than that of Caucasian populations.

Methods

This is part of the Asian Vertebral Osteoporosis Study (AVOS), with the study protocol approved by the local institutional ethics committees. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The recruitment plans were designed so that the participants would represent the general elderly population in age and gender proportion of their respective communities. Data collection was conducted from Aug 15, 2001, to Dec 11, 2005. Written informed consent was obtained from all study participants.

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 Thai (for Thailand) or Indonesians (for Indonesia). Subjects were recruited in urban and rural area community centres (13). 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. Chinese data were from the Osteoporosis Fracture in Women (MsOS) and Osteoporosis Fracture in Men (MrOS) HK Study baseline data (14).

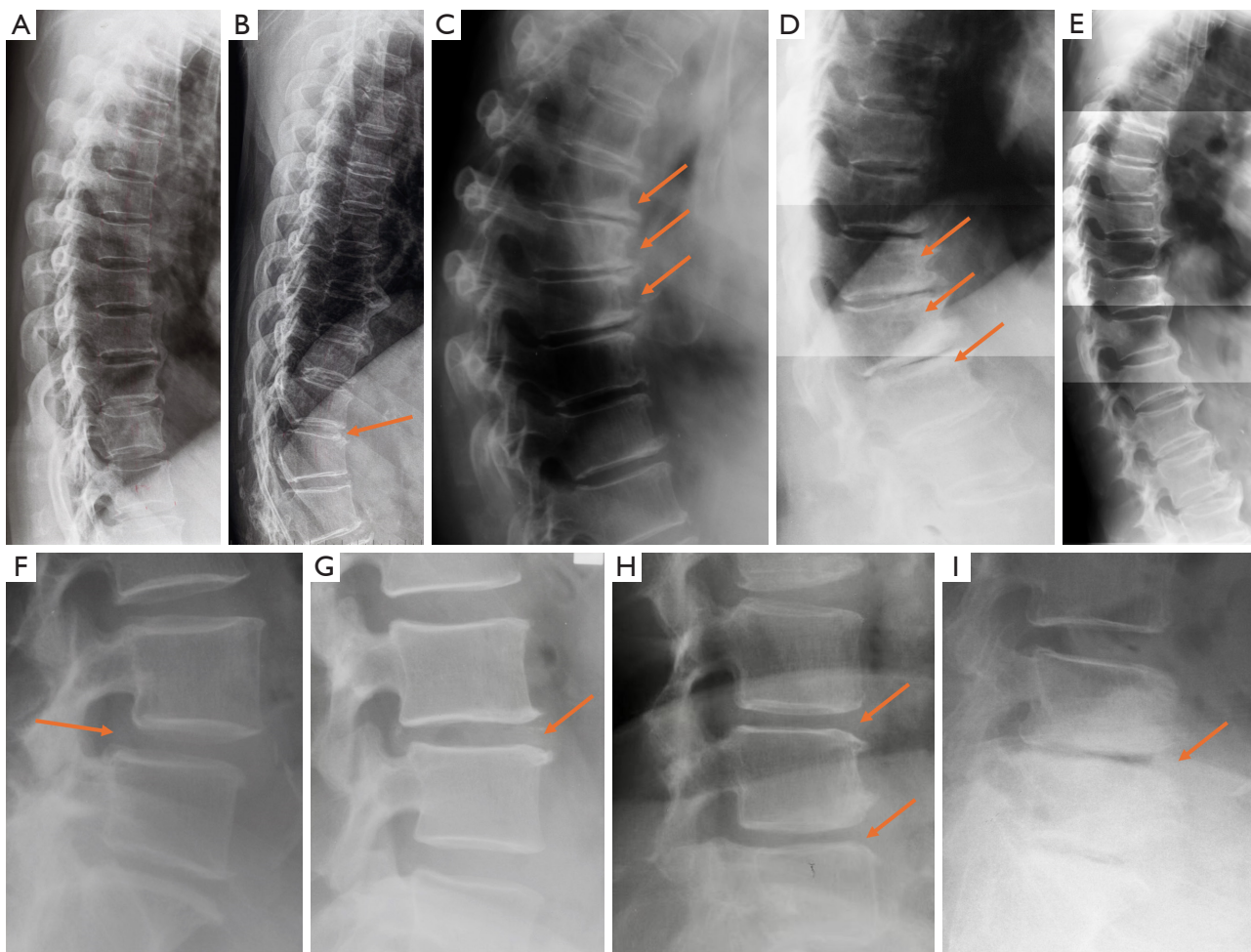


Figure 1 Examples of spine radiographic degenerative features. (A) A spine of normal morphology and physiological curve; (B) thoracolumbar junction hyper-kyphosis (arrow); (C) mid-thoracic spine osteoarthritic wedging (arrows) and hyper-kyphosis; (D) lower thoracic spine osteoarthritic wedging (arrows) and hyper-kyphosis; (E) a case with acquired short vertebrae and general osteophyte formation; (F) lumbar spondylolisthesis (grade 1 anterolisthesis, arrow); (G) lumbar disc space narrowing (grade 1, arrow). (H) Lumbar disc space narrowing (grade 2, arrows); (I) lumbar disc space narrowing (grade 3, arrow).

Aged-matched Chinese spine radiographs were randomly selected from the data pool of 2,000 female and 2,000 male participants. After excluding spine radiographs with insufficient image quality, included in the final analysis were 195 Thai women (mean: 73.6 ± 5.3 years), 202 Thai men (mean: 73.7 ± 6.0 years), 227 Indonesian women (mean: 70.5 ± 5.9 years), and 174 Indonesian men (mean: 70.2 ± 4.9 years). 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, the information of ‘*past longest occupation being a farmer*’ was also collected (13).

Spine radiographs from the three geographic regions were mixed, and images were jointly read by a radiology trainee (S.N.T.) and a specialist radiologist (Y.X.J.W.), with consensus all achieved. This study evaluated six radiographic features of spine degeneration, including kyphosis, OAw, acquired short vertebrae (SVa), general osteophyte formation, lumbar disc space narrowing, and lumbar spondylolisthesis (*Figure 1*). Subjectively evaluated hyper-kyphosis included both thoracic spine hyper-kyphosis and thoracolumbar junction hyper-kyphosis. OAw was diagnosed according to Abdel-Hamid Osman *et al.* (15), typically appearing as anterior wedging and with osteophyte

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

Categories	HK vs. Thai						HK vs. Indo					
	Female			Male			Female			Male		
	HK (n=195)	Thai (n=195)	P value	HK (n=202)	Thai (n=202)	P value	HK (n=227)	Indo (n=227)	P value	HK (n=174)	Indo (n=174)	P value
Age (years)	73.6±5.3			73.7±6.0			70.5±5.9			70.2±4.9		
SF-12 (physical)	47.4±8.3	43.6±11.6	0.010	50.4±8.5	46.1±10.9	<0.010	48.0±8.3	41.8±11.6	<0.010	51.3±7.3	47.2±10.4	0.001
SF-12 (mental)	54.9±7.0	52.8±9.2	0.146	55.6±6.3	53.2±8.6	0.019	55.0±7.0	52.3±8.2	<0.010	54.3±7.6	52.1±8.1	0.02
PASE score	93.5±47.6	76.4±44.9	<0.001	97.4±49.3	97.1±80	0.107	91.7±36.9	74.5±40.5	<0.001	103.0±50.9	104.3±66.8	0.675
Longest occupation	0	75 (38.5)	N/A	4 (2.0)	90 (44.6)	<0.001	0	11 (4.8)	N/A	0	19 (6.9)	N/A

Data are represented as mean ± standard deviation or positive cases (percentage). Longest occupation: past longest occupation being a farmer. PASE: physical activity screening for elderly. SF-12, 12-Item Short Form Survey; PASE, Physical Activity Screening for Elderly score; HK, Hong Kong; Thai, Thailand; Indo, Indonesians; N/A, not applicable.

and intervertebral disc space narrowing involving at least two adjacent vertebrae. SVa were vertebral deformity with middle vertebra height and anterior vertebra height reduced to a similar extent, and these vertebrae commonly had an anteroposteriorly elongated shape (16,17). SVa is assumed to be mostly associated with degenerative endplateitis (17). Generalized osteophyte formation had at least three adjacent inter-vertebral spaces, i.e., four vertebrae, involved while excluding ankylosing spondylitis. Lumbar disc space narrowing was evaluated from L1/L2 to L4/L5 disc space and was subdivided into three categories: grade 1 (<30% reduction in disc height), grade 2 (30–60% reduction in disc height), grade 3 (>60% reduction in disc height) (18). Lumbar spondylolisthesis was evaluated from L1/L2 to L5/S1 disc space, and the direction of spondylolisthesis (antero/retrolisthesis) was also recorded. The grading of spondylolisthesis was estimated using the Meyerding classification: grade 0, no slip; grade I, ≥5% and <25%; grade II, 26–50%; grade III, 51–75%; grade IV, 76–100%; and grade V, complete slippage.

Data analysis was processed using GraphPad Software (GraphPad Software Inc. San Diego, USA). Thais and Indonesians were both classified as Southeast Asians. Categorical variables were analysed by the chi-square test or Fisher exact test. Paired-samples Wilcoxon Signed Rank Test was used for the comparison of spine degeneration scores between age-matched populations. A 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, Thai, 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.

With HK data used as the reference, radiographic spine degeneration comparisons between three regions are summarized in *Figure 2*, *Table 2*. Pooling together the female data and male data, HK Chinese had a higher prevalence of hyper-kyphosis (Chinese: 24.9% vs. Southeast Asians 16.4%, P<0.001), a higher prevalence of OA_w (2.4% vs. 0.9%, P=0.018), a higher prevalence of general osteophyte formation (15.3%, vs. 10.5%, P=0.005), a higher prevalence of lumbar disc space narrowing (27.6% vs. 20.3%, P=0.001), a higher prevalence of lumbar spondylolisthesis (20.7% vs. 15.3%, P= 0.005). The trends were the same for the subgroup data analyses. However, there was no statistically significant difference in SVa prevalence among HK Chinese and Southeast Asians.

A further comparison was conducted between Thais and Indonesians, where Thai participants and Indonesian participants were age-matched with allowing + one year or -one year difference, and the results are shown in *Figure 3* and *Table 3*. For general osteophyte formation, lumbar disc space narrowing, and lumbar spondylolisthesis, an even

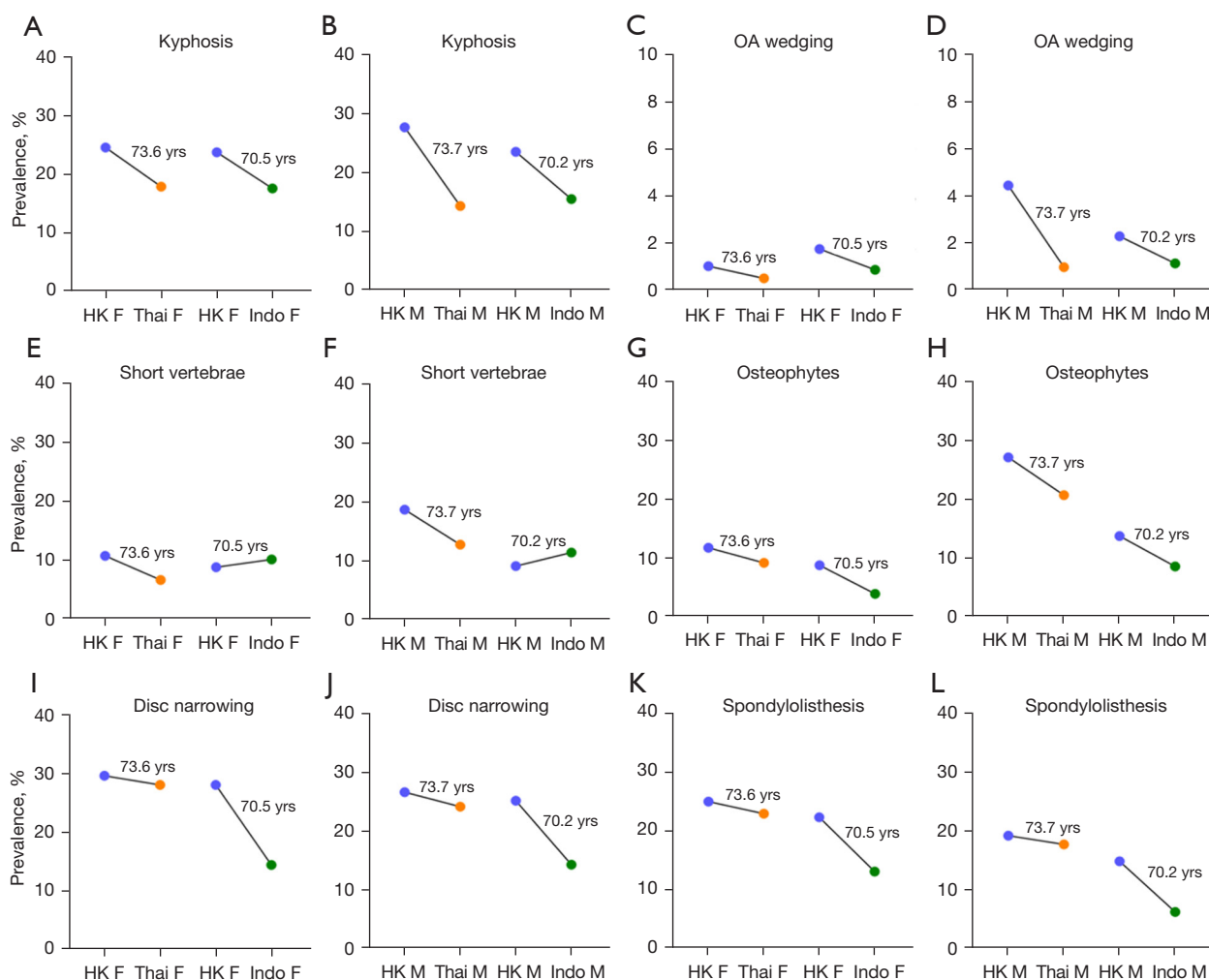


Figure 2 One-to-one matched subgroup comparison of six spine degenerative features. Except acquired short vertebrae (short vertebrae), HK Chinese show an overall higher prevalence of spine degenerative changes than Thais or Indo, both for F and M. HK, Hong Kong; F, women; Thai, Thailand; Indo, Indonesians; M, men; OA wedging, osteoarthritic wedging.

lower prevalence was noted among Indonesians than among Thais.

Lumbar disc space narrowing had the highest prevalence at the L4/L5 level (L1/S1 not evacuated), this was the same for Chinese and for Southeast Asians (Figure 4). The prevalence of lumbar disc space narrowing was higher among Chinese than among Indonesians at each vertebral level (Figure 4, Table 4). Lumbar spondylolisthesis had the highest prevalence at the L4/L5 level, this was the same for Chinese and for Southeast Asians (Figure 5). Anterolisthesis was the dominant lumbar vertebral spondylolisthesis among both Chinese and Southeast Asians, and the majority were grade I spondylolisthesis for all subgroups (Table 5). The

prevalence of lumbar spondylolisthesis was higher among Chinese than among Indonesians.

Discussion

Using HK Chinese as the reference and using Thais and Indonesians as examples for Southeast Asians, this study demonstrated that older Southeast Asians suffer fewer spine degenerations than Chinese. More interestingly, Indonesians who inhabit an even warmer climate than Thais, demonstrated even fewer spine degenerations than Thais in terms of general osteophyte formation, lumbar space narrowing, and lumbar spondylolisthesis. That consistent

Table 2 Comparison of prevalence of thoracolumbar spine degenerative features between female and male age-matched cases from Hong Kong and Southeast Asian countries

Categories	Chinese	Thai & Indo	P value
Total (mean age, 72.01 yrs) (n=798)			
Kyphosis	199 (24.94)	131 (16.42)	<0.001
OAw	19 (2.38)	7 (0.88)	0.018
SVa	95 (11.90)	82 (10.28)	0.3
General osteophyte formation	122 (15.29)	84 (10.53)	0.005
Lumber disc space narrowing	220 (27.57)	162 (20.30)	0.001
Lumbar spondylolisthesis	165 (20.68)	122 (15.29)	0.005
Women (mean age, 71.94 yrs) (n=422)			
Kyphosis	102 (24.17)	75 (17.77)	0.022
OAw	6 (1.42)	3 (0.71)	0.315
SVa	41 (9.72)	36 (8.53)	0.55
General osteophyte formation	43 (10.19)	27 (6.40)	0.046
Lumber disc space narrowing	122 (28.91)	88 (20.85)	0.007
Lumbar spondylolisthesis	100 (23.7)	75 (17.77)	0.034
Men (mean age, 72.09 yrs) (n=376)			
Kyphosis	97 (25.80)	56 (14.89)	<0.001
OAw	13 (3.46)	4 (1.06)	0.027
SVa	54 (14.36)	46 (12.23)	0.39
General osteophyte formation	79 (21.01)	57 (15.16)	0.037
Lumber disc space narrowing	98 (26.06)	74 (19.68)	0.037
Lumbar spondylolisthesis	65 (17.29)	47 (12.50)	0.065

Data are represented as positive cases (percentage). Thai, Thailand; Indo, Indonesians; yrs, years; OAw, osteoarthritic wedging; SVa, acquired short vertebrae.

Table 3 Comparison of spine degenerative features between Thailand and Indonesia based on age-matched cases (± 1 years).

Categories	All			Female			Male		
	Thai (n=290)	Indo (n=290)	P value	Thai (n=150)	Indo (n=150)	P value	Thai (n=140)	Indo (n=140)	P value
Age (years)	72.06 \pm 4.98	71.91 \pm 5.60		72.47 \pm 5.46	72.42 \pm 6.19		71.61 \pm 4.36	71.36 \pm 4.80	
General osteophyte formation	41 (14.14)	17 (5.86)	0.001	12 (8.00)	5 (3.33)	0.080	29 (20.71)	12 (8.57)	0.004
Lumber disc space narrowing	70 (24.14)	53 (18.28)	0.001	41 (27.33)	25 (16.67)	0.026	29 (20.71)	24 (17.14)	0.446
Lumbar spondylolisthesis	56 (19.31)	33 (11.38)	0.008	32 (21.33)	23 (15.33)	0.179	24 (17.14)	10 (7.14)	0.010

Data are represented as mean \pm standard deviation or positive cases (percentage). P values are calculated by comparing Thais and Indo. Thai, Thailand; Indo, Indonesians.

Table 4 Comparison of severity of lumbar disc space narrowing among Hong Kong Chinese, Thais, and Indonesians.

Grades	Total (n=798) (mean age 72.01 years)		Women (n=422) (mean age 71.94 years)		Men (n=376) (mean age 72.09 years)	
	HK	Thai + Indo	HK	Thai + Indo	HK	Thai + Indo
G1	102 (12.78)	69 (8.65)	66 (15.64)	44 (10.43)	36 (9.57)	25 (6.65)
G2	66 (8.27)	56 (7.02)	38 (9.00)	27 (6.40)	28 (7.45)	29 (7.71)
G3	75 (9.40)	67 (8.40)	33 (7.82)	36 (8.53)	42 (11.17)	31 (8.24)
∑G1–G3	220 (27.57)	162 (20.30)	122 (28.91)	88 (20.85)	98 (26.06)	74 (19.68)
∑G2–G3	129 (16.17)	113 (14.16)	61 (14.45)	60 (14.22)	68 (18.09)	53 (14.10)

Data are represented as positive cases (percentage). G, grade of lumbar disc space narrowing. HK, Hong Kong; Thai, Thailand; Indo, Indonesians.

Table 5 Comparison of severity of lumbar spondylolisthesis between Hong Kong Chinese, Thais, and Indonesians.

Spondylolisthesis	Total (n=798) (mean age 72.01 years)		Women (n=422) (mean age 71.94 years)		Men (n=376) (mean age 72.09 years)	
	HK	Thai + Indo	HK	Thai + Indo	HK	Thai + Indo
Prevalence	165 (20.68)	122 (15.29)	100 (23.70)	75 (17.77)	65 (17.29)	47 (12.50)
Grade I	161 (20.18)	118 (14.79)	98 (23.22)	72 (17.06)	63 (16.76)	46 (12.23)
Grade II	4 (0.50)	4 (0.50)	2 (0.47)	3 (0.71)	2 (0.53)	1 (0.27)
Anterolisthesis	140 (17.54)	115 (14.41)	88 (20.85)	73 (17.3)	52 (13.83)	42 (11.17)
Retrolisthesis	28 (3.51)	14 (1.75)	13 (3.08)	5 (1.18)	15 (3.99)	9 (2.39)

Data are represented as positive cases (percentage). HK, Hong Kong; Thai, Thailand; Indo, Indonesians.

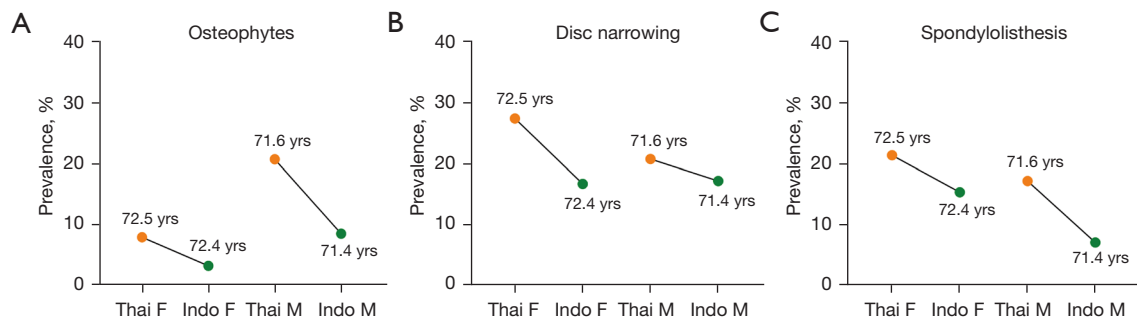


Figure 3 One-to-one matched comparison of general osteophyte formation (A), lumbar disc space narrowing (B), and lumbar spondylolisthesis (C) between Thais and Indo. Indonesians show a lower prevalence of these degenerative changes both for F and M. Thai, Thailand; F, women; Indo, Indonesians; M, men.

patterns were observed both for men and for women and there was a decreasing gradient from Chinese to Thais to Indonesians mitigate the possibility of sampling bias. It has been well acknowledged that populations originating from sub-Saharan African regions have stronger spine/bones (19–23). 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 (24,25). Lucas *et al.* (25) predicted that, the maximum hip fracture incidence rate (per 100,000 subjects)

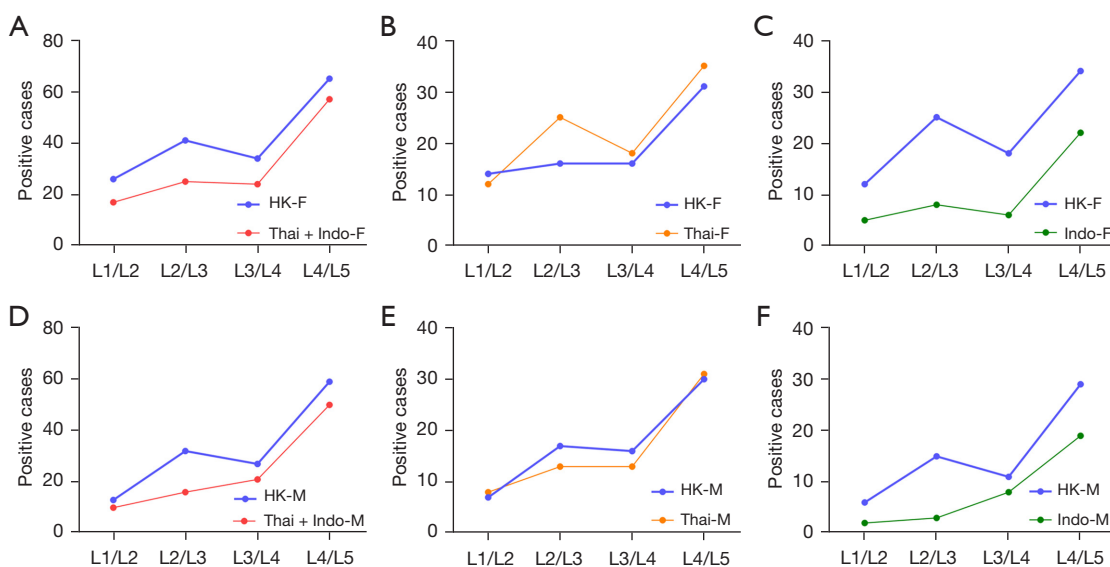


Figure 4 Lumbar disc space narrowing (all grades) at four-disc levels. The highest prevalence is noted at L4/L5 level. A higher prevalence of lumbar disc space narrowing is noted for HK Chinese than for Indo at the levels. However, the difference between HK Chinese and Thais is less notable. HK, Hong Kong; F, women; Thai, Thailand; Indo, Indonesians; M, men.

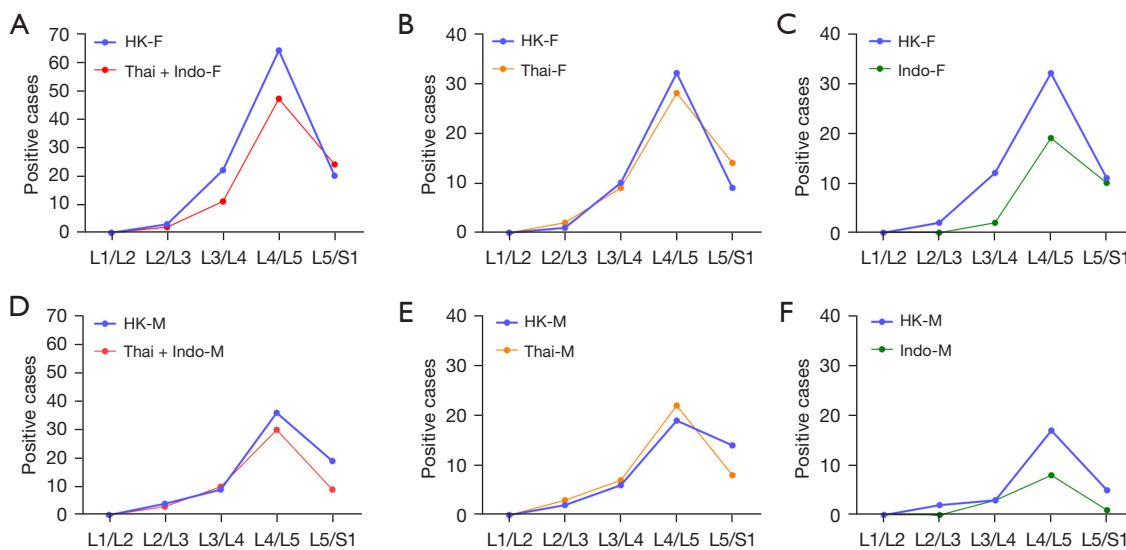


Figure 5 Lumbar spondylolisthesis (both antero- and retro-listhesis) at five-disc levels. The highest prevalence is at L4/L5 level. A higher prevalence of lumbar spondylolisthesis narrowing is noted for HK Chinese than for Indo, both for F and M. However, the difference between HK Chinese and Thais is minimal. HK, Hong Kong; F, women; Thai, Thailand; Indo, Indonesians; M, men.

is 1389.8 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.* (26) described that radiographic vertebral deformity prevalence was highest in the Scandinavian populations. In the European Prospective Osteoporosis Study (EPOS), Felsenberg *et al.* (27) described that age-standardized incidence of morphometric vertebral fracture

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. Taking the results from Europe and the results in this study together, we postulate that populations from a warmer climate have better spine health. Moreover, 'spine health' may not be a standalone phenomenon, instead, spine health is related to the overall general bone health of the population (28). For example, the ratio of spine FF risk to hip FF is consistent among East Asian populations and among Caucasian populations (29). Nevitt *et al.* (30) reported Chinese have a lower age-standardized prevalence of radiographic hip osteoarthritis, compared with Caucasians in the US. Zhang *et al.* (31) also reported a lower prevalence of hand osteoarthritis among Chinese, compared with Caucasians in the US.

The difference gradients are likely sharper for the Caucasians-Chinese comparison than for the Chinese-Southeast Asians comparison. Older Italian women and HK Chinese women had spine hyper-kyphosis prevalence of 53.4% and 25.6% respectively (6); while in this study HK Chinese women and Indonesian women had spine hyper-kyphosis prevalence of 23.8% and 17.6% respectively. The Study of Osteoporotic Fractures (SOF) for American women (mean age: 71.5 years) reported a spondylolisthesis prevalence of 43.1% while MsOS HK study for Chinese women reported spondylolisthesis prevalence of 25.0% (mean age: 72.6 years) (32,33). MrOS USA for American men (mean age: 74.0 years) reported a spondylolisthesis prevalence of 31% while MrOS HK for Chinese men reported spondylolisthesis prevalence of 19.1% (mean age: 72.4 years) (32-34). In this study, the spondylolisthesis prevalences among Thai women and men were similar to the HK Chinese. That Thai women have similar spondylolisthesis prevalence as those of Chinese women and Japanese women has been reported earlier (35,36).

Both Lumbar disc space narrowing and lumbar spondylolisthesis had the highest prevalence at the L4/L5 level for both Chinese and Southeast Asians. These are consistent with many earlier reports with various ethnic groups. Consistent with earlier reports (17), a trend was noted that SVa prevalence was higher among men than among women, this was the same for Chinese, Thais, and Indonesians. It was earlier noted that there was no difference in SVa prevalence between older Italian women and older HK Chinese women (6).

Spinal degeneration prevalence and severity differences observed between HK Chinese and Southeast Asians may be a result of racial or genetic factors related to ethnicity, as well

as other physical, social, cultural, and economic differences related to their place of residence. We further postulate that biological contributors (genetic factors) dominantly cause these differences between Chinese and Southeast Asians. Previous studies have demonstrated heritable genetic contributions to spine degeneration (37-39). In comparison with Caucasian women, Walker *et al.* (40) noted that postmenopausal Chinese women have a higher trabecular plate-to-rod ratio and greater whole bone stiffness, translating into a greater trabecular mechanical competence. Within the United States, a much lower hip fracture rate among older Asians than among older Caucasians has been consistently observed, while these comparisons were less affected by lifestyle differences. HK Chinese and Chinese in the United States both have a hip fracture prevalence of no more than half of that of Caucasians (22,41). Ross *et al.* (42) described that, although the lifestyle of the Hawaii Japanese is more westernized than Okinawa Japanese, the hip fracture rates of Hawaii Japanese and Okinawa Japanese are almost the same. Among Scandinavian countries, Lucas *et al.* (25) predicted that, the maximum hip fracture incidence rate (per 100,000 subjects) was 649.5 for Finn women (Finn men: 429.8), which is much lower than the rate of 1,389.8 for Swedish women (Swedish men: 742.4) and the rate of 1,089.7 for Danish women (Danish men: 551.1). It is assumed that Finish people (Finns) originated between the Volga, Oka, and Kama rivers in what is now Russia. They moved towards the Baltic Sea area in 1,250-1,000 BC. It has been well documented that Thais had an influx of population from southern China. Thais also on average tend to have fairer skin than Indonesians. '*That populations from a warmer climate have better spine health*' may be more of a result of evolutionary adaptation, rather than the direct result of a warmer environment and more sunshine.

There are a number of limitations to this study. The main limitation is the sample sizes are relatively small, with approximately 200 cases per ethnic and gender group. These sample sizes cannot detect small or subtle differences reliably, and this is further complicated by the subjectivities associated with radiographic sign assessment. Thus, while the trends were consistent for the majority of comparisons, in a few comparisons the trends were not consistent. Moreover, to achieve statistical significance in some aspects, we attempted to combine the male and female data together and also combine the Thai data and Indonesian data together. This study was conducted by subjectively determining the existence or absence of spine degenerative

features. It is possible the subjectivity associated with our results may not allow inter-study comparisons; however, we trust the results of intra-study comparisons remain valid. As noted above, that consistent patterns were observed both for men and for women and there was a decreasing gradient 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 for all the study participants. PASE score was higher among Chinese women. Both Thai women and men had a higher proportion with the past longest occupation being a farmer. 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. Actually, earlier studies suggest that manual labour activities increase the prevalence of spine degeneration (43,44). Another limitation is that, for Southeast Asia countries, we only studied Thais and Indonesians.

In conclusion, this study demonstrates that older Southeast Asians have a lower prevalence of spine degenerations than Chinese. Indonesians demonstrate an even lower prevalence of spine degenerations than Thais in general osteophyte formation, lumbar space narrowing, and lumbar spondylolisthesis. Our results suggest populations from a warmer climate have better spine health. The observed differences may reflect a foundational background influence of genetic predisposition that represents an important line of research for the future.

Acknowledgments

We thank the current and past staff at JC Centre for Osteoporosis Care and Control of the Chinese University of Hong Kong for their supports and thank Dr. Edith M. C. Lau for the pioneering work in osteoporosis research in Hong Kong.

Funding: None.

Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://qims.amegroups.com/article/view/10.21037/qims-24-1533/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. This is part of the Asian Vertebral Osteoporosis Study (AVOS), with the study protocol approved by the local institutional ethics committees. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Written informed consent was obtained from all study participants.

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Cite this article as: Tang SN, Li CY, Leung JCS, Kwok AWL, Kwok TCY, Wáng YXJ. Fewer spine degenerations among Southeast Asians than among Southern Chinese suggests populations from a warmer climate have inherently better spine health. *Quant Imaging Med Surg* 2024;14(9):6922-6933. doi: 10.21037/qims-24-1533