Table 6. Cont.

Country/Occupational Group	Activity[a]					
	Use keyboard >4 hours	Other repeated wrist/ hand movement >4 hours	Repeated elbow bending >1 hour	Hands above shoulder height >1 hr	Lifting ≥25 kg by hand	Kneeling/ squatting >1 hour
Sri Lanka						
Nurses	1.3	60.6	43.2	14.4	36.9	9.3
Office workers	100.0	94.7	72.4	11.8	25.7	17.1
Other workers (1)	0.0	95.6	95.6	95.6	0.0	0.0
Other workers (2)	0.7	86.1	60.9	25.2	4.6	29.1
Japan						
Nurses	23.5	23.8	72.8	12.5	66.9	48.5
Office workers	89.0	12.9	22.6	1.6	3.2	2.3
Other workers (1)	2.4	32.8	77.8	33.7	83.3	52.3
Other workers (2)	27.9	10.1	30.1	4.2	9.3	12.1
South Africa						
Nurses	11.3	76.1	85.0	53.4	80.2	26.3
Office workers	100.0	76.9	78.6	26.2	4.8	1.3
Australia						
Nurses	25.6	32.8	47.6	8.4	25.2	15.2
New Zealand						
Nurses	26.6	32.8	42.4	4.0	31.6	14.1
Office workers	91.7	40.0	44.8	0.7	2.1	0.0
Other workers	10.6	87.6	91.2	34.5	51.3	5.3

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To explore whether the two methods of answering the questionnaire might lead to systematic differences in answers, we therefore elected to interview a random subset of UK participants while collecting data from the remainder by self-administration. Comparison of responses using the two approaches (Table 10) suggests that no major bias will have occurred as a consequence using both interviews and self-administration. However, if appropriate, method of data collection can be taken into account in statistical analyses.

Participation rates among subjects eligible for study were mostly high, but were less than 50% in five occupational groups (Table 2). We have no reason to expect that those who elected to take part were importantly unrepresentative in the prevalence of pain and its associations with risk factors. However, in future work it may be appropriate to carry out sensitivity analyses, excluding the occupational groups with the lowest response rates. The incomplete response to the baseline questionnaire will be less of a concern in longitudinal analyses based on the follow-up questionnaire.

The numbers of participants by occupational group that were suitable for analysis ranged from 92 to 1018 with a mean of 264. At the outset, our aim was to recruit at least 200 subjects in each group, and this was for the most part achieved (only 7 groups provided fewer than 150 subjects). Furthermore, the occupational groups studied varied substantially in their employment conditions (Table 3), access to healthcare (Table 4), and prevalence of psychosocial risk factors (Tables 7, 8, and 9). When exploring possible reasons for differences in the prevalence of pain and disability between occupational groups, it will be important to investigate these group-level characteristics as well as individual-level risk factors such as mental health and somatising tendency. The heterogeneity in their distribution should enhance statistical power to address their impact.

As might be expected, the demographic constitution of occupational groups also varied. In particular, many of the samples of nurses were largely or completely female, whereas some groups of "other workers" were all men. This reflects the nature of the occupations of interest. However, it should not be a major problem in interpretation of comparisons since there were an adequate number of occupational groups with a fairly even distribution of sex and age. Moreover, the occurrence of common musculoskeletal complaints appears not to vary greatly between men and women or between older and younger adults of working age [13,23,24].

In summary, the CUPID study is a major resource for the investigation of cultural and psychological determinants of common musculoskeletal disorders and associated disability. Although the data collected have inevitable limitations, the large differences in psychosocial risk factors (including knowledge and beliefs about MSDs) between occupational groups carrying out similar physical tasks in different countries should allow the study hypothesis to be addressed effectively. It will also allow exploration of differences in patterns of musculoskeletal complaint between the three categories of occupation examined, and the consistency of these differences across countries.

Table 7. Psychosocial aspects of work – prevalence (%) by occupational group.

Country/Occupational Group	Incentives[a]	Time pressure[b]	Lack of choice[c]	Lack of support[d]	Job dissatisfaction[e]	Perceived job insecurity[f]
Brazil						
Nurses	25.4	65.4	13.5	4.9	7.6	20.0
Office workers	13.9	49.8	9.6	11.7	19.2	24.9
Other workers	100.0	96.8	96.8	2.2	5.4	90.3
Ecuador						
Nurses	29.2	69.4	39.7	51.6	1.8	30.1
Office workers	37.0	63.4	10.7	63.4	4.5	29.2
Other workers	45.8	65.2	52.0	63.4	11.5	50.7
Colombia						
Office workers	50.0	56.5	2.2	40.2	2.2	25.0
Costa Rica						
Nurses	48.2	92.7	24.5	36.8	12.7	17.7
Office workers	63.2	77.6	8.1	28.7	10.8	18.4
Other workers	67.8	77.6	50.7	29.3	17.1	26.3
Nicaragua						
Nurses	16.0	72.3	10.3	41.5	13.5	22.7
Office workers	26.0	80.0	19.3	43.2	9.5	23.2
Other workers	86.8	60.9	37.1	41.1	6.1	31.0
UK						
Nurses	6.2	75.1	9.7	10.1	14.8	17.9
Office workers	0.5	76.6	6.8	7.9	7.9	5.0
Other workers	19.2	79.5	37.8	17.4	15.5	35.8
Spain						
Nurses	21.0	80.1	19.9	77.7	12.0	16.5
Office workers	26.3	54.3	32.4	78.5	6.6	13.7
Italy						
Nurses	11.6	80.6	13.2	8.2	17.4	21.5
Other workers	19.4	82.7	53.2	34.5	51.8	41.7
Greece						
Nurses	6.3	97.3	8.9	14.7	33.9	29.0
Office workers	6.5	83.4	1.5	9.5	7.0	12.6
Other workers	2.1	97.9	15.0	40.7	18.6	17.9
Estonia						
Nurses	7.8	66.6	23.7	27.0	6.2	14.3
Office workers	4.0	64.4	2.0	8.4	5.9	23.3
Lebanon						
Nurses	81.0	95.1	6.0	6.5	20.1	38.6
Office workers	11.6	75.6	7.6	12.2	16.9	25.0
Other workers	75.9	76.6	29.9	6.6	16.8	41.6
Iran						
Nurses	28.9	90.2	24.8	23.6	29.3	54.9
Office workers	29.7	74.2	18.7	26.9	26.4	66.5
Pakistan						
Nurses	62.0	96.3	40.1	7.5	9.1	56.7
Office workers	68.3	96.1	45.6	7.8	7.8	53.9
Other workers	11.7	95.0	68.0	7.7	9.0	14.9
Sri Lanka						
Nurses	56.8	91.5	5.9	7.2	4.7	11.4
Office workers	18.4	87.5	10.5	5.3	8.6	43.4

Table 7. Cont.

Country/Occupational Group	Incentives[a]	Time pressure[b]	Lack of choice[c]	Lack of support[d]	Job dissatisfaction[e]	Perceived job insecurity[f]
Other workers (1)	100.0	100.0	0.0	0.0	2.8	1.6
Other workers (2)	95.4	94.0	17.2	11.9	4.0	33.8
Japan						
Nurses	4.4	63.0	20.9	5.7	44.4	41.2
Office workers	3.2	35.5	18.1	12.6	70.3	43.5
Other workers (1)	30.7	81.1	28.0	20.1	41.9	64.5
Other workers (2)	9.9	41.4	4.5	5.4	69.6	49.6
South Africa						
Nurses	21.1	80.2	23.1	13.8	34.8	29.6
Office workers	52	95.2	37.6	21.8	43.7	66.4
Australia						
Nurses	4.4	66.8	3.2	7.6	8.8	10.8
New Zealand						
Nurses	1.7	58.2	9.0	8.5	13.6	22.0
Office workers	2.1	58.6	4.8	18.6	8.3	17.9
Other workers	34.5	80.5	23.9	14.2	8.8	20.4

[a]Either a) piecework or b) payment of a bonus if more than an agreed number of articles/tasks are finished in a day.
[b]Either a) a target number of articles or tasks to be finished in the day or b) working under pressure to complete tasks by a fixed time.
[c]Choice seldom or never in all of: a) how work is done, b) what is done at work, and c) work timetable and breaks.
[d]Support from colleagues or supervisor/manager seldom or never.
[e]Dissatisfied or very dissatisfied overall.
[f]Feel job would be rather unsafe or very unsafe if off work for three months with significant illness.
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Table 8. Awareness of repetitive strain injury (RSI) work related upper limb disorder (WRULD) or cumulative trauma syndrome (CTS) – prevalence (%) by occupational group.

Country/Occupational Group	Proportion (%) of participants reporting awareness of				
	RSI, WRULD or CTS	Someone outside work with pain in past 12 months in			
		Low back	Neck	Upper limb	Knee
Brazil					
Nurses	94.6	62.7	49.2	53.0	55.1
Office workers	94.3	60.9	49.1	52.7	50.2
Other workers	0.0	60.2	12.9	36.6	14.0
Ecuador					
Nurses	52.1	42.9	34.7	30.1	42.5
Office workers	28.0	50.6	46.1	37.0	42.4
Other workers	24.2	48.0	27.3	39.2	32.2
Colombia					
Office workers	43.5	40.2	34.8	32.6	39.1
Costa Rica					
Nurses	54.1	55.9	43.6	42.7	46.4
Office workers	26.9	61.0	49.3	48.4	45.7
Other workers	36.1	74.6	65.9	65.9	61.5
Nicaragua					
Nurses	56.0	71.6	57.8	58.2	62.8
Office workers	34.0	60.4	54.0	51.2	48.8
Other workers	29.4	41.6	28.4	31.5	26.9
UK					
Nurses	76.3	59.1	30.0	35.0	41.2
Office workers	93.7	60	31.8	33.4	42.6
Other workers	47.9	42.5	21.0	26.7	35.0
Spain					
Nurses	67.9	82.6	73.1	49.8	55.9
Office workers	59.8	82.9	80.2	45.3	50.6
Italy					
Nurses	84.7	82.3	75.6	56.0	55.4
Other workers	77.0	69.8	66.9	54.0	51.1
Greece					
Nurses	21.4	82.6	62.5	56.3	50.4
Office workers	24.6	81.4	68.3	64.8	51.3
Other workers	15.7	70.7	50	43.6	36.4
Estonia					
Nurses	66.6	69.0	55.3	46.9	57.1
Office workers	49.5	65.8	59.4	47.0	51.5
Lebanon					
Nurses	67.9	70.1	58.2	39.1	57.6
Office workers	67.4	56.4	40.7	36.6	32.6
Other workers	34.3	38.7	27.7	16.1	29.2
Iran					
Nurses	45.5	76.8	53.3	59.3	69.5
Office workers	25.3	67.0	46.7	54.4	63.2
Pakistan					
Nurses	36.9	44.4	23.5	31.0	52.4
Office workers	17.8	39.4	15.0	20	41.1
Other workers	32.4	30.6	19.8	18.9	26.6

Table 8. Cont.

Country/Occupational Group	Proportion (%) of participants reporting awareness of				
	RSI, WRULD or CTS	Someone outside work with pain in past 12 months in			
		Low back	Neck	Upper limb	Knee
Sri Lanka					
Nurses	48.3	53.0	40.3	45.8	61.0
Office workers	51.3	45.4	36.8	37.5	47.4
Other workers (1)	82.4	57.2	27.6	36.0	57.2
Other workers (2)	36.4	37.1	20.5	25.2	45.0
Japan					
Nurses	72.3	59.5	27.4	35.8	33.6
Office workers	69.4	53.5	28.7	33.5	35.8
Other workers (1)	35.9	51.6	17.5	22.5	20.5
Other workers (2)	70.7	60.8	23.4	27.0	26.8
South Africa					
Nurses	47.0	51.4	36.4	34.8	53.8
Office workers	7.0	55.0	38.4	39.3	40.2
Australia					
Nurses	78.0	71.6	49.2	49.6	53.2
New Zealand					
Nurses	84.7	72.3	53.1	58.2	57.6
Office workers	95.9	64.1	44.8	47.6	54.5
Other workers	86.7	46.9	27.4	37.2	42.5

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Table 9. Adverse health beliefs regarding low back and arm pain – prevalence (%) by occupational group.

	Low back pain			Arm pain		
Country/ Occupational Group	**Commonly caused by people's work[a]**	**Physical activity is harmful[b]**	**Poor prognosis[c]**	**Commonly caused by people's work[a]**	**Physical activity is harmful[b]**	**Poor prognosis[c]**
Brazil						
Nurses	25.9	5.9	29.7	31.9	7.0	31.4
Office workers	32.7	7.5	31.3	42.7	6.0	31.0
Other workers	0.0	1.1	0.0	0.0	1.1	0.0
Ecuador						
Nurses	53.9	25.1	20.5	52.1	18.7	20.5
Office workers	37.9	18.9	10.7	33.7	16.0	9.9
Other workers	77.1	36.1	4.0	76.2	27.3	5.3
Colombia						
Office workers	12.0	1.1	13.0	13.0	1.1	13.0
Costa Rica						
Nurses	30.0	10.9	17.7	35.0	10.5	19.1
Office workers	13.9	4.0	24.2	11.7	2.7	22.0
Other workers	16.1	2.9	25.9	18.0	2.0	21.5
Nicaragua						
Nurses	36.2	23.8	15.2	35.5	21.3	14.5
Office workers	29.1	11.9	9.5	32.3	12.6	9.1
Other workers	38.1	22.3	10.7	36.5	16.8	8.6
UK						
Nurses	23.7	9.3	5.8	15.2	3.5	2.7
Office workers	9.2	2.9	4.7	10.8	1.3	3.2
Other workers	25.6	10.4	8.8	20.7	5.2	5.7
Spain						
Nurses	46.8	23.8	28.2	36.1	13.8	18.3
Office workers	22.4	15.5	22.1	19.6	9.6	15.3
Italy						
Nurses	34.1	3.2	6.9	24.1	0.9	4.5
Other workers	36.0	7.9	15.8	40.3	3.6	16.5
Greece						
Nurses	73.2	49.1	14.7	68.3	33.5	12.9
Office workers	40.2	31.2	10.6	44.2	18.6	12.6
Other workers	78.6	68.6	20.0	76.4	47.1	12.9
Estonia						
Nurses	27.5	9.2	7.5	25.9	5.9	5.9
Office workers	15.8	2.5	11.4	21.3	0.5	10.9
Lebanon						
Nurses	77.7	43.5	27.2	62.5	23.9	9.8
Office workers	36.6	24.4	15.1	36.0	11.0	7.6
Other workers	66.4	77.4	14.6	59.9	57.7	6.6
Iran						
Nurses	31.7	11	2.8	24.8	4.1	1.6
Office workers	24.2	12.1	4.9	22.0	2.7	1.6
Pakistan						
Nurses	51.9	50.3	5.9	47.1	26.2	4.8
Office workers	54.4	43.3	3.9	38.9	29.4	1.7
Other workers	40.5	31.5	5.9	36.9	28.4	6.3

Table 9. Cont.

	Low back pain			Arm pain		
Country/ Occupational Group	**Commonly caused by people's work**[a]	**Physical activity is harmful**[b]	**Poor prognosis**[c]	**Commonly caused by people's work**[a]	**Physical activity is harmful**[b]	**Poor prognosis**[c]
Sri Lanka						
Nurses	5.9	6.4	9.3	9.7	3.0	11.4
Office workers	13.8	10.5	4.6	19.7	4.6	3.9
Other workers (1)	4.0	36.0	10.4	3.6	11.2	8.0
Other workers (2)	20.5	9.9	7.3	20.5	6.0	6.0
Japan						
Nurses	46.6	14.7	18.2	24.3	5.7	9.3
Office workers	16.5	19.7	14.2	11.6	9.0	7.4
Other workers (1)	47.2	25.6	21.8	33.2	11.7	10.1
Other workers (2)	21.4	23.7	17.5	12.4	16.1	6.5
South Africa						
Nurses	37.7	5.3	7.7	36.0	3.6	6.1
Office workers	24.9	6.6	4.8	22.7	3.1	3.5
Australia						
Nurses	19.2	2.8	6.8	12.4	2.4	2.4
New Zealand						
Nurses	20.3	2.8	2.3	11.9	1.1	4.0
Office workers	6.2	2.1	2.8	9.0	2.1	4.1
Other workers	21.2	14.2	6.2	29.2	12.4	5.3

[a]Completely agree that such pain is commonly caused by people's work.
[b]Completely agree that for someone with such pain, a) physical activity should be avoided as it might cause harm, and b) rest is needed to get better.
[c]Completely agree that for someone with such pain, rest is needed to get better, and completely disagree that such problems usually get better within three months.
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Table 10. Comparison of UK participants who provided information by interview and by self-administered questionnaire.

	Nurses		Office workers		Other workers	
	Interview	**Self-administered questionnaire**	**Interview**	**Self-administered questionnaire**	**Interview**	**Self-administered questionnaire**
Number selected	190	500	200	851	240	1329
Number (%) participated	91 (48)	199 (40)	88 (44)	388 (46)	122 (51)	320 (24)
Number of subjects analysed	78	179	66	314	110	276
Prevalence (%) of activities in an average working day						
Use keyboard >4 hr	6.4	15.6	84.9	89.8	1.8	5.1
Other repeated wrist/hand movement >4 hr	46.2	43.0	22.7	32.8	86.4	80.1
Repeated elbow bending >1 hr	60.3	52.5	13.6	29.9	96.4	89.1
Hands above shoulder height >1 hr	7.7	9.5	1.5	1.3	55.5	50.4
Lifting ≥25 kg by hand	28.2	28.5	9.1	3.2	12.7	12.0
Kneeling/squatting >1 hr	21.8	17.3	1.5	0.3	15.5	7.6
Prevalence (%) of pain in past month						
Low back	26.9	36.3	28.8	26.8	34.6	34.4
Neck	14.1	20.1	21.2	22.9	20.9	20.7
Shoulder	9.0	21.8	21.2	20.7	33.6	31.2
Elbow	2.6	2.8	12.1	8.0	14.6	15.2
Wrist/hand	14.1	15.6	19.7	17.5	24.6	21.7
Knee	12.8	18.4	27.3	22.3	21.8	24.6

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Supporting Information

Appendix S1 Committees which provided ethical approval for the cupid study.
(DOCX)

Appendix S2 Baseline questionnaire.
(DOCX)

Appendix S3 Follow-up questionnaire.
(DOCX)

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Author Contributions

Conceived and designed the experiments: DC KTP. Performed the experiments: DC GN KTP KC VEF MHM LMS RH FH RF NH LHB MVM LAQ MR SAF DG EJSV ECH AC SVP CS JMM GD FGB MB MC MMF ACP ES LC PB MK EM KO TS RRH FS AS MMK SSPW RJPJ NS ARW KM NY BN DK MRS HLK VCWH DMU HH SD DM AG. Analyzed the data: GN DC. Wrote the paper: DC. Principal investigator Brazil: VEF. Principal investigator Ecuador: RH. Principal investigator Colombia: LHB. Principal Investigators Costa Rica and Nicaragua: SAF DG. Principal investigator UK: DC. Principal investigator Spain: SV-P. Principal investigator Italy: MB. Principal investigator Greece: ES. Principal investigator Estonia: EM. Principal investigator Lebanon: RRH. Principal investigator Iran: FS. Principal investigator Pakistan: MMK. Principal investigator Sri Lanka: SSPW. Principal investigator Japan: KM. Principal investigator South Africa: BN. Principal investigator Australia: MRS. Principal investigator New Zealand: HH. All authors reviewed the draft manuscript and contributed to its finalization.

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Original Research

Prevalence of vertebral fracture in Asian men and women: Comparison between Hong Kong, Thailand, Indonesia and Japan

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SUMMARY

Objectives: Little is known about the prevalence of vertebral fracture among Asians. This study investigated the prevalence of radiographically defined vertebral fracture, and identified associated risk factors in the aged population of four Asian countries.
Study design: In total, 1588 males and females aged ≥65 years were recruited from Hong Kong, Thailand, Indonesia and Japan.
Methods: Standard X-rays for the spine were taken and vertebral heights were measured. Vertebral fracture was defined as a reduction of >3 standard deviations in vertebral height ratio. Bone mineral density (BMD) of the hip was measured by dual energy X-ray absorptiometry, and anthropometric measurements were taken in Hong Kong and Japan. Other relevant data were entered in a standard questionnaire.
Results: The prevalence of vertebral fracture for both males and females was highest in Japan for younger (65–74 years) and older (≥75 years) age groups (36.6% and 37.6% for males; 18.8% and 28.7% for females). Lower hip BMD was associated with vertebral fracture in both sexes. Older age, lower quality of life score on Short Form-12 (physical), past longest occupation as a farmer, and history of cataract were significantly associated with vertebral fracture in females. However, smoking did not appear to be an important risk factor for vertebral fracture.
Conclusions: Radiographic assessments for vertebral fracture were performed in all four Asian countries. The prevalence of vertebral fracture was highest in Japan. Lower hip BMD, poorer physical condition and past longest occupation as a farmer were associated with vertebral fracture.

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Introduction

Osteoporosis is a condition characterized by low bone mass and micro-architectural deterioration of bone tissues causing increased bone fragility and susceptibility to fracture. The disease is becoming a major health problem in Asia where a rapidly increasing aged population will be accompanied by increasing incidence of hip fracture.[1] In Hong Kong, for instance, over the last two decades, the number of cases of hip fracture has increased two-fold due to the increase in the ageing population. Of every 1000 people who are aged ≥80 years, one man and two women will have a fractured hip each year.[2] The age-adjusted rate in Hong Kong is comparable to that in Singapore and higher than that in Japan. It has been projected that over half of all hip fractures in the world will occur in Asia by 2050.[1]

While there are many data on the prevalence and risk factors for hip fracture, little is known of the prevalence and risk factors for vertebral fracture in Asia. In a study by Lau *et al.*, the prevalence of vertebral fracture was estimated to be 29% in women in Hong Kong.[3] Vertebral deformity, back pain and psychological problems were associated symptoms in elderly Chinese women, and the use of analgesics was common in men. Overseas studies have demonstrated associations between vertebral fracture and back pain, disability and the need for healthcare support.[4–6] The survival rate of elderly people who had experienced a clinical vertebral fracture was found to be lower than that of elderly people who had not experienced a fracture.[7] Women with severe vertebral deformities were found to have a consistently higher risk of back pain and height loss. In addition, genetic and lifestyle factors may influence vertebral fracture. However, the risk factors for Asian men are still unclear.

The aim of this study was to investigate the prevalence of radiographically defined vertebral fracture, and to identify underlying risk factors associated with vertebral fracture in the aged population in four Asian countries (Hong Kong, Thailand, Indonesia and Japan). Existing data from Beijing, China were used for comparison.

Methods

Subjects

In total, 1588 subjects were recruited from Hong Kong, Thailand, Indonesia and Japan. Each country was required to recruit 400 ambulatory community-dwelling subjects (200 males and 200 females), half of whom were aged 65–74 years and the other half were aged ≥75 years. They all were ethnic Asians. Subjects were recruited in community centres (recreation centres for group activities, social support and public information) for the elderly. Recruitment notices were placed at these centres explaining the purpose and procedures of this study in different districts, including urban and rural areas. Moreover, community activities and community advertisements were used to enhance the representativeness of the whole region.

Radiographs and digitization

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 radiographs were evaluated by morphometry using a backlight translucent digitizing table (GTCO, Rockville, MD, USA) and cursor. Six points were marked on the radiographs with a wax pencil for each vertebral body T4–L4, and the X,Y co-ordinates for each point were recorded on an electronic grid with a resolution of 0.1 mm. In total, 120 and 68 subjects lacked T4 and T5, respectively. Standardized procedures were adopted. The six points corresponded to the four corners of the vertebral body and the midpoints of the end plates[8] (Fig. 1). Vertebral height ratios (VHR) were calculated [anterior to posterior (Ha/Hp), middle to posterior (Hm/Hp) and posterior above to posterior below (Hp/Hp−1 and Hp/Hp+1)]. Prevalent vertebral fracture was defined as a reduction of >3 standard deviations (SD) among any one of the VHRs.[6,8] Mean (SD) VHRs are shown in Table 1. X-ray films for Hong Kong, Thailand and Indonesia were measured in Hong Kong by three trained members of staff, all with >10 years of experience and trained by the radiologist-in-charge with standardized procedures. Fifteen films were selected at random for reliability analysis. Whereas X-ray films from Japan were measured in Japan, 30 were selected at random and sent to Hong Kong for reliability analysis. The analysis was performed by two members of staff (one from Hong Kong and one from Japan).

Questionnaire

Subjects were interviewed using a standardized and structured questionnaire in Hong Kong, Thailand and Indonesia by trained staff. Data collected included demographic information, Mini-Mental Status Examination score, medical history, fall history, smoking habit, alcohol consumption, Physical Activity Screening for Elderly score, quality of life,

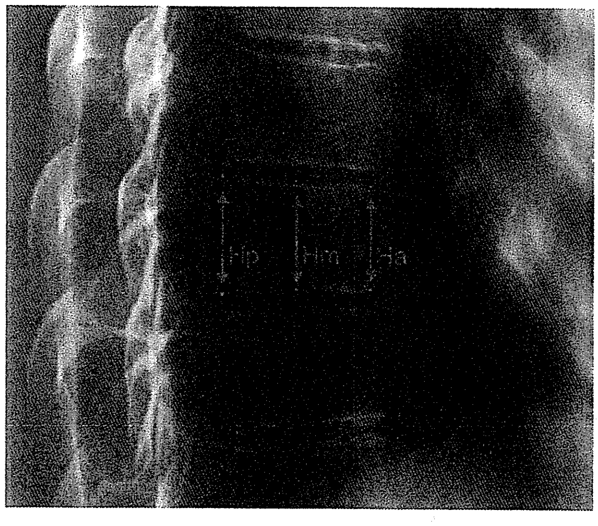

Fig. 1 – Measurement of vertebral height. Hp, posterior height; Hm, mid-body height; Ha, anterior height.

Table 1 – Adjusted means[a] and standard deviations (SD) of vertebral height ratios in Chinese male and female subjects.

Level	Ha/Hp		Hm/Hp		Hp/Hp−1		Hp/Hp+1	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male[b]								
T4	0.87	0.06	0.91	0.04	–	–	1.00	0.06
T5	0.87	0.07	0.92	0.04	1.00	0.06	0.98	0.06
T6	0.87	0.07	0.92	0.04	1.03	0.06	0.98	0.06
T7	0.86	0.07	0.92	0.04	1.02	0.06	1.00	0.06
T8	0.89	0.07	0.93	0.04	1.00	0.06	0.98	0.06
T9	0.91	0.07	0.94	0.04	1.02	0.06	0.95	0.06
T10	0.92	0.07	0.94	0.04	1.05	0.06	0.91	0.06
T11	0.86	0.08	0.91	0.05	1.10	0.07	0.93	0.05
T12	0.84	0.07	0.90	0.04	1.08	0.06	0.95	0.05
L1	0.84	0.06	0.89	0.04	1.06	0.05	1.01	0.04
L2	0.88	0.06	0.91	0.03	1.00	0.04	1.01	0.04
L3	0.92	0.06	0.94	0.04	0.99	0.04	1.06	0.05
L4	0.97	0.07	1.00	0.05	0.95	0.04	–	–
Female[c]								
T4	0.90	0.08	0.92	0.06	–	–	0.99	0.09
T5	0.88	0.08	0.91	0.06	1.03	0.09	0.99	0.07
T6	0.86	0.07	0.91	0.05	1.03	0.07	0.99	0.07
T7	0.86	0.08	0.91	0.05	1.02	0.07	0.99	0.06
T8	0.88	0.07	0.92	0.05	1.01	0.06	0.99	0.06
T9	0.92	0.08	0.94	0.05	1.01	0.06	0.97	0.06
T10	0.92	0.08	0.94	0.05	1.04	0.07	0.95	0.06
T11	0.87	0.08	0.91	0.05	1.06	0.07	0.94	0.06
T12	0.86	0.09	0.90	0.06	1.07	0.07	0.96	0.07
L1	0.87	0.08	0.89	0.05	1.05	0.08	1.00	0.05
L2	0.93	0.08	0.91	0.05	1.01	0.06	1.01	0.06
L3	0.98	0.08	0.95	0.06	0.99	0.06	1.04	0.07
L4	1.02	0.10	1.01	0.07	0.96	0.07	–	–

Ha/Hp, anterior height of vertebrae/posterior height of vertebrae; Hm/Hp, middle height of vertebrae/posterior height of vertebrae; Hp/Hp−1, posterior height of vertebrae/posterior height of vertebrae above; Hp/Hp+1, posterior height of vertebrae/posterior height of vertebrae below.

a Adjusted means were estimated as the mode on the log-frequency curve after trimming 5% of the values from each end of the distribution. The adjusted SDs were estimated by quantile–quantile plot after 10% of values were trimmed from each end of the distribution.

b Data used by Lau *et al.*[30]

c Data published by Lau *et al.*[3]

fracture history, back pain and musculoskeletal symptoms, medications, diet history, Geriatric Depression Scale score, and past longest occupation in their life.

Dual X-ray densitometry and anthropometric measurement

Bone mineral density (BMD), height and weight were measured in Hong Kong and Japan. Hip and spine BMD were measured by dual energy X-ray absorptiometry (DXA) using a Hologic QDR-4500W densitometer (Hologic, Waltham, MA, USA). The same type of DXA machine was used in both Hong Kong and Japan. The coefficient of variation (CV) in the laboratory was 0.7% and 0.9% for hip and spine, respectively. Height was measured using a Holtain Harpenden stadiometer (Holtain Ltd., Crosswell, UK), and weight was measured using the Physician Beam Balance Scale (Health-ometer, IL, USA) with subjects wearing a light gown.

Study flow

The study started in Hong Kong, Indonesia and Thailand. Radiographs and questionnaires were performed in these three countries. Japan joined the study at a later date; radiographs, BMD and anthropometric measurements were conducted but no questionnaire was used. As different information was collected from the four countries, the results are shown in three parts. First, the prevalence of vertebral fracture was compared between the four countries. Second, lifestyle and medical risk factors for vertebral fracture were analysed for Hong Kong, Indonesia and Thailand. Finally, anthropometric factors in Japan were compared with those for Hong Kong.

Statistical analysis

Inter-rater reliability of each parameter was assessed using the intraclass correlation coefficient (ICC). The prevalence of deformity was calculated based on the number of individuals with at least one vertebral deformity, and this was compared between countries using Chi-squared test. Data were analysed separately by sex. Continuous variables were compared between the countries using t-test or analysis of variance, while categorical variables were compared using Chi-squared test. Logistic regression (with adjustment for age) was used to calculate odds ratios (OR) and 95% confidence intervals (CI) of various lifestyle and anthropometric factors for definite vertebral deformity. Significant factors were collated to form the final models. All statistical analyses were performed using SAS Version 9.1 (SAS Institute, Inc., Cary, NC, USA). An α level of 5% was used as the level of significance.

Results

Inter-rater reliabilities of vertebral measurements were fair to good. ICC (3,1) ranged from 0.54 to 0.94 for anterior heights, from 0.70 to 0.96 for middle heights, and from 0.60 to 0.92 for posterior heights among 15 randomly selected subjects from Hong Kong, Thailand and Indonesia. ICC (3,1) ranged from 0.73 to 0.93 for anterior heights, from 0.69 to 0.93 for middle heights, and from 0.76 to 0.95 for posterior heights among 30 Japanese subjects.

Part 1: prevalence of vertebral fracture in four Asian countries

Seven hundred and seventy males (mean age 72.9 years) and 818 females (mean age 72.4 years) were recruited. The prevalence of vertebral fracture in Hong Kong, Indonesia, Thailand and Japan is shown in Table 2. Among males, the prevalence of fracture was highest in Japan (36.6% for age 65–74 years, 37.6% for age ≥75 years); the difference between Japan and the other three countries was significant. The prevalence of fracture was lowest in Hong Kong males (9.2%

Table 2 – Prevalence of vertebral fracture.

	Prevalence of vertebral fracture (%)				P-value of Chi-square
	Hong Kong (H)	Indonesia (I)	Thailand (T)	Japan (J)	
Male					
Age 65–74 years	(n = 98)	(n = 127)	(n = 105)	(n = 101)	
Radiological fracture					
Definite vertebral deformity, <mean – 3 SD	9.2	15.0	17.1	36.6[a,b,c]	<0.0001
Severe vertebral deformity, <mean – 4 SD	3.1	7.1	13.3[a]	20.8[a,b]	0.0003
Reported fracture	0.0	0.0	2.9	–	0.0402
Age ≥75 years	(n = 100)	(n = 40)	(n = 98)	(n = 101)	
Radiological fracture					
Definite vertebral deformity, <mean – 3 SD	18.0	20.0	24.5	37.6[a,b,c]	0.0102
Severe vertebral deformity, <mean – 4 SD	9.0	17.5	20.4[a]	20.8[a]	0.0926
Reported fracture	2.0	0.0	1.0	–	0.6125
Female					
Age 65–74 years	(n = 99)	(n = 170)	(n = 98)	(n = 101)	
Radiological fracture					
Definite vertebral deformity, <mean – 3 SD	2.0	7.6	8.2[a]	18.8[a,b,c]	0.0010
Severe vertebral deformity, <mean – 4 SD	1.0	5.9	6.1	10.9[a]	0.0338
Reported fracture	1.0	0.0	3.0	–	0.2930
Age ≥75 years	(n = 98)	(n = 54)	(n = 97)	(n = 101)	
Radiological fracture					
Definite vertebral deformity, <mean – 3 SD	15.3	13.0	17.5	28.7[a,b]	0.0727
Severe vertebral deformity, <mean – 4 SD	10.2	9.3	15.5	18.8	0.2312
Reported fracture	1.0	0.0	3.0	–	0.2930

SD, standard deviation.
Note: a higher number of reported fractures was significantly associated with a higher number of radiological fractures (Chi-squared = 7.078, P-value = 0.0078).
a P-value < 0.05 comparing Indonesia (I), Thailand (T) or Japan (J) with Hong Kong (H), by Chi-squared test.
b P-value < 0.05 comparing Thailand (T) or Japan (J) with Indonesia (I), by Chi-squared test.
c P-value < 0.05 comparing Japan (J) with Thailand (T), by Chi-squared test.

for age 65–74 years; 18% for age ≥75 years). In females, the prevalence of fracture was also highest in Japan (18.8% for age 65–74 years; 28.7% for age ≥75 years), and was lowest in Hong Kong and Indonesia (2% for age 65–74 years; 13% for age ≥75 years). The reported fracture rates ranged from 0 to 2.97%, which were much lower than radiological fracture rates (0–24.5%) (Table 2). More reported fractures were significantly associated with more radiological fractures (Chi-squared = 7.078, P-value = 0.0078).

Part 2: lifestyle and medical factors of vertebral fracture in Hong Kong, Indonesia and Thailand

Results for Hong Kong, Indonesia and Thailand are shown in Tables 3 and 4. Subjects' characteristics are shown in Table 3. Males and females in Hong Kong had significantly higher quality of life {Short Form[SF]-12 (mental)}; higher prevalence of hypertension, heart disease and myocardial infarction/angina; and lower levels of education compared with Indonesia and Thailand. The percentage of respondents who stated that their longest occupation had been as a farmer was highest in Thailand.

Risk factors of vertebral fracture are shown in Table 4. For males, older age, lower SF-12 (physical) score, and history of stroke were significantly associated with vertebral fracture. For females, older age, lower SF-12 (physical) score, history of cataract, and past longest occupation as a farmer were significantly associated with vertebral fracture. In logistic regression, a lower SF-12 (physical) score (OR 0.68, 95% CI 0.55–0.84) was associated with vertebral fracture among the males. Older age (OR 1.33, 95% CI 1.03–1.71), lower SF-12 (physical) score (OR 0.73, 95% CI 0.56–0.95), history of cataract (OR 2.86, 95% CI 1.48–5.53), and past longest occupation as a farmer (OR 2.47, 95% CI 1.07–5.72) were associated with vertebral fracture in females.

Part 3: anthropometric factors of vertebral fracture in Hong Kong and Japan

To investigate the difference in fracture rate between Japan and Hong Kong, 25 males and 27 females in Japan were selected at random as subsamples to obtain anthropometric factors: weight and height and bone density. Results are shown in Tables 5 and 6. Differences in characteristics between Hong Kong and Japan are shown in Table 5. Subjects in Hong Kong were heavier and taller (marginally in males but significantly in females). The body mass index of Hong Kong females was also significantly higher. Logistic regressions of vertebral fractures are shown in Table 6. Lower hip BMD (OR 1.47, 95% CI 1.001–2.17 per SD reduction) was associated with vertebral fracture in males, while in females, older age (OR 1.9, 95% CI 1.13–3.2), heavier weight (OR 1.6, 95% CI 1.1–2.3) and lower hip BMD (OR 3.23, 95% CI 1.72–6.25 per SD reduction) were associated with vertebral fracture.

Table 3 – Characteristics of subjects by country.

Variable	Male			P-value[a]	Female			P-value[a]
	Mean (SD)/%				Mean (SD)/%			
	Hong Kong ($n = 198$)	Indonesia ($n = 167$)	Thailand ($n = 203$)		Hong Kong ($n = 197$)	Indonesia ($n = 224$)	Thailand ($n = 195$)	
Age	73.7 (5.4)	70.3 (5.1)	73.8 (6.0)	0.9610	73.8 (5.5)	70.3 (5.8)	73.7 (5.5)	0.9078
SF-12 (physical)	49.7 (9.0)	47.2 (10.4)	46.0 (10.9)	**0.0003**	45.3 (9.0)	41.8 (11.6)	43.6 (11.6)	0.1085
SF-12 (mental)	56.4 (5.9)	52.1 (8.1)	53.1 (8.7)	**<0.0001**	55.7 (8.1)	52.3 (8.3)	52.7 (9.1)	**0.0005**
Physical activity (PASE score)	104.8 (49.8)	102.7 (67.9)	93.0 (80.8)	0.0880	81.3 (30.7)	70.8 (42.7)	70.5 (47.6)	**0.0081**
Marital status: married	84.1%	82.4%	81.3%	0.7564	57.7%	62.3%	50.5%	**0.0456**
Education				**<0.0001**				**<0.0001**
Primary or below	53.2%	41.9%	64.5%		76.6%	55.1%	72.9%	
Secondary	33.8%	43.8%	14.2%		18.9%	34.8%	15.1%	
Tertiary or above	12.9%	14.4%	21.3%		4.5%	10.1%	12.0%	
Demented (MMSE ≤ 24)	11.0%	13.4%	15.8%	0.3634	36.3%	22.9%	25.0%	**0.0046**
Diabetes	14.9%	10.5%	11.3%	0.3690	9.0%	14.2%	13.0%	0.2243
Reported osteoporosis	5.0%	1.7%	3.5%	0.2361	9.0%	11.6%	10.0%	0.6492
Stroke	6.0%	2.3%	4.4%	0.2263	3.5%	2.2%	2.0%	0.5768
Hypertension	39.3%	19.2%	22.7%	**<0.0001**	42.3%	26.7%	25.0%	**0.0002**
Heart disease	19.9%	2.3%	4.9%	**<0.0001**	14.4%	3.5%	4.5%	**<0.0001**
Myocardial infarction/ angina	18.4%	1.2%	4.9%	**<0.0001**	11.4%	4.3%	3.5%	**0.0014**
Congestive heart failure	2.5%	0.6%	2.5%	0.3150	3.5%	1.3%	1.0%	0.1328
Chronic obstructive pulmonary disease	15.9%	5.2%	3.0%	**<0.0001**	6.5%	4.3%	1.5%	**0.0424**
Cataracts	33.3%	18.6%	22.2%	**0.0024**	44.8%	23.3%	27.0%	**<0.0001**
Gastrectomy	9.0%	8.1%	11.3%	0.5425	4.0%	14.2%	7.0%	**0.0005**
Cancer	4.5%	0.6%	1.5%	**0.0268**	3.5%	2.2%	1.5%	0.4115
Fall in past 12 months	22.9%	4.1%	21.7%	**<0.0001**	20.9%	14.2%	31.5%	**<0.0001**
Smoker	9.5%	29.2%	19.4%	**<0.0001**	0.5%	1.4%	1.0%	0.6472
Use of alcohol at least 12 times in past 12 months	22.9%	5.5%	36.1%	**<0.0001**	0.5%	0.5%	6.5%	**<0.0001**
Fracture after 50 years of age	6.0%	5.5%	9.4%	0.2739	16.9%	5.6%	7.6%	**0.0002**
Past longest occupation as a farmer	1.0%	14.3%	44.8%	**<0.0001**	3.1%	5.7%	40.0%	**<0.0001**

SF-12, Short Form-12; PASE, physical activity screening for elderly; MMSE, Mini-Mental State Examination.
Bold: P-value < 0.05.
a P-value of Chi-squared for categorical variables or analysis of variance for continuous variables where appropriate.

Discussion

The occurrence of osteoporotic vertebral fracture is particularly common in older postmenopausal Asian women. The common sites involved are T12 and L1 as these levels are, biomechanically, the most vulnerable regiments of the thoracolumbar spine.[9] The first vertebral fracture is an important indicator for subsequent vertebral fracture, and possibly non-vertebral fracture including hip fracture.[10,11] Understanding the prevalence of vertebral fracture and deformity is critical for prevention.

Fracture identification can easily be affected by differences in radiographic methods. Fracture definition and methods of morphological assessment also affect the determination of fracture rates. Degenerative spondylosis and old asymptomatic spinal fractures may lead to spuriously high BMD at the site of involvement, thus diminishing the sensitivity in the prediction of fracture. In this study, all the radiographs were taken according a standardized protocol, and were analysed by trained and experienced assessors to minimize possible observer bias and to acquire more precise and accurate results. The number of reported vertebral fractures was generally lower in both males and females than the number of radiologically determined vertebral fractures in all four countries. As elsewhere, vertebral fractures were often under-reported. Vertebral fractures could also be overlooked when patients present with back pain arising from various spinal conditions.

This study found that the prevalence of vertebral fracture was significantly higher in Japan compared with Hong Kong, Thailand and Indonesia for both sexes. BMD is an important factor,[12,13] but in this study, no difference was noted between Hong Kong and Japan. This may be explained by the smaller body size of Japanese subjects. In a systematic review, Ruyssen-Witrand *et al.*[14] showed that vertebral size was an independent risk factor for vertebral fracture. After controlling for well-known confounding factors such as age, height,

Table 4 – Characteristics in subjects with vertebral fracture and control.

Variable	Unit	Male		Female	
		Age-adjusted model OR (95% CI)	Multivariate model OR (95% CI)	Age-adjusted model OR (95% CI)	Multivariate model OR (95% CI)
Age	5	**1.24 (1.03–1.49)[a]**	1.17 (0.96–1.44)	**1.48 (1.20–1.84)[a]**	**1.33 (1.03–1.71)**
Country					
Hong Kong	–	1	1	1	1
Indonesia	Indonesia/Hong Kong	1.44 (0.79–2.62)	1.28 (0.68–2.40)	1.36 (0.67–2.72)	1.20 (0.53–2.73)
Thailand	Thailand/Hong Kong	1.66 (0.97–2.82)	1.45 (0.84–2.51)	1.58 (0.82–3.05)	1.36 (0.61–2.99)
SF-12 – Physical	10	**0.65 (0.53–0.80)**	**0.68 (0.55–0.84)**	**0.67 (0.53–0.85)**	**0.73 (0.56–0.95)**
SF-12 – Mental	10	0.99 (0.75–1.32)		0.86 (0.64–1.17)	
Physical activity (PASE score)	50	1.00 (0.84–1.19)		0.72 (0.50–1.03)	
Marital status – married	Yes/no	1.78 (0.91–3.46)		0.68 (0.40–1.18)	
Education					
Primary or below	–	1		1	
Secondary	Secondary/primary	0.63 (0.36–1.11)		0.96 (0.48–1.91)	
Tertiary or above	Tertiary/primary	1.02 (0.55–1.90)		0.37 (0.09–1.57)	
Demented (MMSE<24)	Yes/no	1.36 (0.74–2.49)		1.34 (0.76–2.37)	
Diabetes	Yes/no	1.09 (0.56–2.14)		0.67 (0.26–1.75)	
Reported osteoporosis	Yes/no	1.26 (0.41–3.91)		2.01 (0.95–4.24)	
Stroke	Yes/no	**2.61 (1.08–6.31)**	2.32 (0.94–5.71)	1.43 (0.31–6.60)	
Hypertension	Yes/no	1.08 (0.66–1.77)		0.72 (0.39–1.31)	
Heart disease	Yes/no	0.80 (0.36–1.77)		0.94 (0.35–2.53)	
Myocardial infarction/angina	Yes/no	0.94 (0.42–2.08)		0.88 (0.29–2.60)	
Congestive heart failure	Yes/no	1.67 (0.43–6.47)		1.74 (0.37–8.26)	
Chronic obstructive pulmonary disease	Yes/no	1.02 (0.46–2.27)		–	
Cataracts	Yes/no	1.21 (0.73–1.98)		**1.80 (1.05–3.10)**	**2.86 (1.48–5.53)**
Gastrectomy	Yes/no	0.83 (0.38–1.83)		0.72 (0.25–2.09)	
Cancer	Yes/no	–		0.64 (0.08–5.04)	
Fall in past 12 months	Yes/no	0.90 (0.49–1.63)		1.39 (0.76–2.51)	
Smoker	Yes/no	0.62 (0.33–1.20)		–	
Use of alcohol at least 12 times in past 12 months	Yes/no	1.30 (0.78–2.17)		2.12 (0.45–9.95)	
Fracture after 50 years of age	Yes/no	2.00 (0.93–4.31)		1.36 (0.62–2.98)	
Past longest occupation as a farmer	Yes/no	1.19 (0.68–2.08)		2.14 (1.13–4.05)	**2.47 (1.07–5.72)**

SF-12, Short Form-12; PASE, Physical Activity Screening for Elderly; MMSE, Mini-Mental State Examination; OR, odds ratio; CI, confidence interval.
Bold: P-value < 0.05.
a Crude OR.

weight and BMD, small vertebral dimensions including area, cross-sectional area and volume were associated with vertebral fracture.[14–16] Moreover, there is a difference in the nutrient intake of these two populations; dietary calcium intake in the Japanese population is less than that of the Hong Kong population (550 mg/day in men and 519 mg/day in women vs 628 mg/day and 569 mg/day for people aged ≥65 years).[17,18] Kobayashi reported that the calcium content of river water in Japan was lower than that in most European countries.[19]

For Asian women, a review of vertebral fracture revealed that the prevalence of vertebral fracture increases steeply with age in Beijing: the prevalence of vertebral fracture in Chinese women aged 50–59 years was 3.9%, compared with 10.5%, 15% and 31.2% at ages 60–69, 70–79 and ≥80 years.[6,20,21] A similar trend has also been observed among Japanese women residing in Japan and Hawaii[22,23]; the rates were slightly higher for those living in Japan (8%, 25%, 38% and 43% for ages 65–70, 70–75, 75–80 and 80–85 years, compared with 5%, 15%, 25% and 27% for those living in Hawaii in 1996), suggesting that environmental factors are more influential than genetic factors.[24] Horikawa *et al.* reported a prevalence of 22.6% for Japanese women aged 65–92 years living in a fishing/farming village located in Nansei-cho in 2001.[25] Data for Japan in the present study showed similar rates. These data are similar to findings among Caucasian women in the USA, where the prevalence of vertebral fracture was 22% for women aged 70–79 years, and 34% for women aged ≥80 years. Hence, observations from the present study suggest that vertebral fracture is as prevalent in Asian women as in Caucasian women.[20]

The prevalence of vertebral fracture among Chinese women in 1996 in Hong Kong was 29% at age 70–79 years.[1,3] The current study found a prevalence of vertebral fracture of 2% at age 65–74 years and 15% at age ≥75 years among Hong Kong Chinese women. The prevalence of vertebral fracture appears to have decreased significantly over the years between these studies. This may reflect a proper

Table 5 – Comparison of characteristics between Hong Kong and Japan.

Variable	Mean (SD)		P-value[a]
	Hong Kong	Japan	
Male	$n = 198$	$n = 25$	
Age (years)	73.75 (5.40)	73.28 (4.31)	0.6784
Weight (kg)	61.86 (9.35)	58.34 (6.66)	0.0692
Height (cm)	162.64 (5.75)	160.50 (7.70)	0.0925
Body mass index (kg/m^2)	23.35 (3.13)	22.72 (2.73)	0.3315
Hip BMD (g/cm^2)	0.851 (0.129)	0.823 (0.105)	0.2956
Spine BMD (g/cm^2)	0.950 (0.183)	0.961 (0.151)	0.7742
Female	$n = 197$	$n = 27$	
Age (years)	73.76 (5.51)	72.33 (4.67)	0.2012
Weight (kg)	55.01 (9.01)	48.62 (7.98)	0.0006
Height (cm)	151.48 (4.99)	148.61 (6.23)	0.0072
Body mass index (kg/m^2)	23.93 (3.44)	21.98 (3.05)	0.0056
Hip BMD (g/cm^2)	0.697 (0.113)	0.691 (0.112)	0.7654
Spine BMD (g/cm^2)	0.757 (0.141)	0.787 (0.137)	0.3028

BMD, bone mineral density; SD, standard deviation.
a P-value of t-test for continuous or Chi-squared test for categorical variables.

osteoporosis prevention regime, health promotion and raised public awareness of osteoporosis in Hong Kong since 2001. The Hong Kong experience may set an example to other Asian countries for reference in combating osteoporosis.

Lau *et al.*[13] reported that the prevalence of vertebral fracture among Chinese men aged 70–79 years in 1998 in Hong Kong was 16%. The present study shows a similar result; 9.2% and 18% for men aged 65–74 and ≥75 years, respectively.

This study found that both male and female subjects aged ≥75 years with a lower hip BMD have more vertebral fractures. Most vertebral fractures are not caused by direct trauma[26] but are linked with low BMD.[10,12] Previous studies have shown that US women of African descent have the highest bone mass in the spine, while Caucasian women have intermediate values, and Asian women have the lowest values (unadjusted BMD values). An analysis and comparison of different ethnic populations residing in the USA suggested that the BMD of Asian women differed little from that of Caucasian women after adjustment for body size.[27] Unadjusted lumbar spine and femoral neck BMDs were 7–12% and 14–24% higher in African-American women compared with Caucasian, Japanese or Chinese women. Among women of comparable weight of <70 kg, there were no differences in lumbar spine BMD among African-American, Chinese and Japanese women, all of whom have higher BMDs than Caucasians.[20] This study also noted that there were no differences in lumbar spine and hip BMDs between Hong Kong and Japanese women or men. Kung reported that the pattern and magnitude of age-related bone loss in the lumbar spine was similar between female Asian and Caucasian populations.[20] Subjects with a spinal fracture had a spine or hip BMD that was 20–30% lower compared with normal healthy controls. After adjusting for age and body size, each SD reduction in bone density in the Hong Kong Chinese women increased the risk of vertebral fracture approximately two-fold for both spine and femoral neck measurements, whereas in Beijing Chinese women, each SD reduction in BMD at the spine or hip was associated with a 2.5-fold increased risk of vertebral fracture.[20] In the present study, among Hong Kong and Japanese women, each SD reduction in hip BMD was associated with a 3.2-fold increased risk of vertebral fracture after adjustment for age and body size, which is consistent with the previous finding. In men, each SD reduction had a 1.5-fold increased risk, showing less

Table 6 – Logistic regression of vertebral fracture.

Variable	Mean (SD)/frequency (%)		Unit	Adjusted OR (95% CI)
	Control	Vertebral fracture		
Male	$n = 187$	$n = 36$		
Age	73.57 (5.27)	74.61 (5.29)	5	1.15 (0.81–1.65)
Country				
Hong Kong	171 (91.4%)	27 (75.0%)	–	1
Japan	16 (8.6%)	9 (25.0%)	Japan/Hong Kong	**3.67 (1.42–9.49)**
Weight (kg)	61.48 (9.17)	60.94 (9.21)	5	1.27 (0.95–1.69)
Height (cm)	162.59 (5.77)	161.07 (7.14)	5	0.77 (0.55–1.09)
Hip BMD (g/cm^2)	0.855 (0.126)	0.816 (0.125)	−0.1	**1.47 (1.001–2.17)**
Female	$n = 201$	$n = 23$		
Age	73.09 (5.31)	77.43 (4.81)	5	**1.90 (1.13–3.20)**
Country				
Hong Kong	180 (89.6%)	17 (73.9%)	–	1
Japan	21 (10.5%)	6 (26.1%)	Japan/Hong Kong	**5.99 (1.58–22.68)**
Weight (kg)	54.45 (9.10)	53.42 (9.69)	5	**1.61 (1.11–2.33)**
Height (cm)	151.51 (5.01)	148.55 (6.39)	5	0.68 (0.39–1.17)
Hip BMD (g/cm^2)	0.707 (0.109)	0.608 (0.115)	−0.1	**3.23 (1.72–6.25)**

BMD, bone mineral density; SD, standard deviation; OR, odds ratio; CI, confidence interval.
Bold: P-value < 0.05.

influence than that in women. However, low BMD is still a causal factor of vertebral fracture.[12]

Lifestyle and medical factors are other important determinants of vertebral fracture. Women who had jobs involving heavy physical labour had a lower prevalence of vertebral fracture than women who had had more sedentary jobs. This suggests that strenuous physical activity during young adulthood is protective against vertebral fracture.[6] Gregg *et al.*[28] found that physical activity reduced the risk of hip fracture but not vertebral or wrist fractures. However, in this study, subjects with vertebral fracture had significantly lower SF-12 (physical) scores, which implies that poor physical strength may lead to more vertebral fractures. Stroke is another risk factor for vertebral fracture. Kim *et al.* reported that in the acute stages of stroke, bone loss progressed rapidly. Risks of osteoporosis and vertebral fracture were higher among subjects who had experienced a stroke.[29] People with cataracts were more likely to fall, which increases the risk of fracture.[30] The prevalence of vertebral fracture was higher in farmers. This may be explained by the lower intake of calcium. Kamiyama *et al.* performed a survey in various areas in Japan, and found that calcium intake in three farm villages was lower than that in the city (512, 532 and 601 mg vs 633 mg). The prevalence of osteoporosis was also higher in farm villages.[31]

Subjects from Hong Kong had the highest prevalence of hypertension, heart disease and myocardial infarction/angina, but the association with vertebral fracture was insignificant. This implies that hypertension, heart disease and myocardial infarction/angina are not direct risk factors for vertebral fracture. However, Lau *et al.*[32] reported that hypertension was associated with higher BMD; this may explain the fact that the lowest prevalence of vertebral fracture was seen in Hong Kong.

There were more male smokers in Indonesia. However, smoking in Indonesia did not appear to lead to adverse effects resulting in vertebral fracture. Grazio *et al.*[33] found that current smoking was a risk factor for vertebral fracture, but a study by Bensen *et al.*[34] did not. Similarly, the rate of falls was lowest in Indonesia, but this did not reflect on the prevalence of vertebral fracture, implying that falls are not a strong risk factor for vertebral fracture. This differed from hip fracture, which was always associated with falls and trauma[20] and 90% of cases resulted from falls.[35]

This study was a joint venture between Hong Kong, Thailand, Indonesia and Japan. Radiographic assessments of vertebral fractures were completed carefully in all four countries using the same methodology. As subjects were recruited using community activities and community advertisements, the subjects were members of the general population and hence the results are representative. The percentages of people who worked as farmers in Hong Kong, Indonesia and Thailand were 2.1%, 9.3% and 42.4% in this study, which is close to the population figures: 0.9%, 12.4% and 39%, respectively.[36–38] Unfortunately, the Indonesian and Thai collaborators in this study did not possess a DXA machine; otherwise data correlation between the groups could be more comprehensive. Likewise, the questionnaire was not used in Japan, which influenced the completeness of this study. Moreover, it would be more convincing if a study with a larger sample size was conducted. Despite the obvious limitations, this study provides useful data for prevention planning. Some of these data are similar to the results of previous studies, but some are unique (e.g. strong association between low SF-12 (physical) score and vertebral fracture among Asians; smoking habit was not an important risk factor for vertebral fracture).

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Ethical approval

The institutional review board at each centre approved the study protocol, and written informed consent was obtained from all participants.

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Conflict of interest

None declared.

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ORIGINAL ARTICLE

Radiographic features and risk of curve progression of de-novo degenerative lumbar scoliosis in the elderly: a 15-year follow-up study in a community-based cohort

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Abstract
Background Little information is available on the prevalence, incidence, and risk factors associated with curve progression in de-novo degenerative lumbar scoliosis (DNDLS) in the general population. Development of treatment guidelines requires further knowledge about the etiology and natural history of DNDLS in the elderly.
Methods To identify the cumulative incidence and radiographic features of DNDLS in the elderly, the authors reanalyzed the results of lumbar radiographic examinations from the Miyama study, which was originally conducted in a Japanese rural community to determine the prevalence of vertebral fractures in Japanese people. DNDLS was defined as a coronal curvature greater than 10° in the Cobb angle in the second survey and progression of greater than 5° compared with curve magnitude in the initial survey. The radiological features of the new curves were documented. The DNDLS group was recruited to compare the risk of curve progression with that in a control group of participants who had no scoliosis during a 15-year follow-up. Ten radiographic features were measured for statistical analysis to determine the prognostic factors of curve progression.
Results The cumulative incidence of DNDLS was 33/194 (17.0 %) in this cohort. There was a tendency for female predominance and frequency increased with age. However, the severity of these curves was relatively low and no curves developed a Cobb angle of greater than 30°, with most in the range 10°–20°. The 2 groups differed significantly in lateral spondylolisthesis and vertebral rotation only at the L3 level.
Conclusions The radiographic features of DNDLS revealed mild scoliosis with minimal rotatory deformity. Spinal decompensation by the upper lumbar segments of the asymmetric anatomical deformity in the lower lumbar segments may induce de-novo lumbar scoliosis. Rotatory deformity and lateral spondylolisthesis of the L3 vertebra may be a prognostic factor for DNDLS in the elderly.

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Introduction

Degenerative lumbar scoliosis (DLS) is one of the most prevalent disorders in the elderly population. DLS can become a leading cause of low back pain, radicular leg symptoms, and neurogenic claudication [1–3]. Increasing life expectancy and more active lifestyles among the elderly are likely to result in an increase in the number of elderly people requiring treatment for this disease, making DLS a possible major public health problem in an aging society.

Degenerative lumbar scoliosis is a multi-disease complex in the elderly involving lumbar progressive scoliosis, with or without a previous history of childhood scoliosis. Although the 2 forms of scoliosis are distinct clinical entities, determination of whether or not the curve represents a new scoliosis in an elderly person is difficult [4–7]. Hence, previous studies of DLS have been limited to curve progression in lumbar scoliosis detected in childhood after skeletal maturity. Lumbar curves with a Cobb angle of more than 30° have a high likelihood of progression even after skeletal maturity; surgery is usually recommended for such curves [8, 9].

In contrast, little information is available on the prevalence, incidence, and risk factors associated with curve progression in de-novo DLS (DNDLS) in the elderly. One cannot study disease prevention and treatment without knowing the disease's natural history. Therefore, the evidence available from the epidemiological database for this disease is crucial to discussions about the treatment of DNDLS in the elderly.

We conducted this study to assess results from lumbar radiographic examinations in a 15-year community-based cohort study to clarify the etiology and natural history of DNDLS in the elderly. The purpose of this study was to identify the radiographic features of DNDLS in the elderly and the risk factors for curve progression.

Materials and methods

The study sample comprised participants from the Miyama study who had lumbar radiographic examinations performed in 1990 and 2005. That population-based epidemiological study began in 1990 and was conducted in Miyama, a village located in a mountainous area in Wakayama Prefecture, Japan. A detailed profile of the Miyama cohort is available elsewhere [10–12], and is briefly summarized here. A list of all of the inhabitants born in this village between 1910 and 1949 (40–79 years old) was compiled from the register of residents at the end of 1989. A cohort of 1543 inhabitants (716 men, 827 women) was identified, all of whom completed a self-administered questionnaire covering daily activity such as dietary habits, smoking habits, alcohol consumption, and physical exercise (125 items). From the above cohort, a sub-cohort was recruited to examine prevention of bone and joint disorders. This sub-cohort consisted of 400 participants, divided into 4 groups of 50 men and 50 women each, and stratified by decade of birth (1910–1919, 1920–1929, 1930–1939, or 1940–1949) (Table 1). The sub-cohort was confirmed not to differ from the whole cohort with regard to the distribution of lifestyle details such as smoking, alcohol consumption, sleeping hours, exercise, walking, dietary habits, and stress, as measured by the initial questionnaire. An interviewer administered a second questionnaire, covering items of past history, family history, calcium intake, dietary habits, physical exercise, occupational activity, sun exposure, and reproductive variables in women, to these 400 participants. In addition to the interviewer-administered questionnaire, medical examinations and physical measurements were also performed for these participants. Radiographic examination of the spine was performed for all participants in 1990. Standing anteroposterior and lateral images of the thoracolumbar vertebrae, Th5-L5, were used for diagnosis (initial X-ray survey).

After 15 years, the second X-ray survey of the lumbar spine of the participants was repeated as part of the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) Study. The ROAD Study was a nationwide, prospective study of bone and joint diseases (with osteoarthritis and osteoporosis as the representative bone and joint diseases) in population-based cohorts established in several communities in Japan, including the Miyama cohort. A detailed profile of the ROAD Study has already been described elsewhere [13–16]. All participants provided written informed consent, and the study was conducted with the approval of the appropriate ethics committees.

In 2005, participants completed an interviewer-administered 400-item questionnaire, including lifestyle information, and also underwent anthropometric measurements and physical performance and radiographic examinations. The lumbar radiographic examinations in the second survey were also performed in a standing position. Among the participants of the ROAD Study, 81 men and 119 women who had the lumbar radiographic examinations in 1990 were identified, and their X-rays were used for evaluation in this study.

We defined DNDLS as a coronal curvature greater than 10° in the Cobb angle in the second survey and progression of greater than 5°, compared to the curve magnitude

Table 1 Number of study participants according to sex and age

Age	Male			Female		
	Inhabitants	Participants		Inhabitants	Participants	
		1st survey	2nd survey		1st survey	2nd survey
Total	716	200	81	827	200	119
40–49	130	50	25	135	50	34
50–59	252	50	30	254	50	45
60–69	224	50	23	276	50	34
70–79	110	50	3	162	50	6

measured in the initial survey. The curve magnitude, convexity of the curve, location of the apex, and rotation angle of the apex were documented by use of the images from the second survey. The DNDLS group (S-group) was recruited to compare the risk of curve progression with that for a control group (C-group) of participants who did not have scoliosis in either examination. In addition to the Cobb measurement of the main lumbar curve, the following radiographic features were measured by use of the images from the initial survey:

1 tilting angle of each vertebra (angle between the tangential line of the superior endplate of each vertebra and a horizontal line);
2 intervertebral disc angle (between the tangential lines of the inferior endplate of a vertebra and the superior endplate of the next);
3 lateral spondylolisthesis (the horizontal distance between 2 vertical lines which were drawn from the waist to the adjacent vertebra; more than 3 mm was accepted as being a significant difference);
4 axial rotation of each vertebra, based on Pedriolle [17] (more than 5° was accepted as significant);
5 lateral osteophyte differences for each intervertebral disc space using the method of Kobayashi [18];
6 coronal displacement of L1 (distance between the vertical line drawn from the center of the vertebral body of L1 and the center sacral vertical line);
7 sagittal displacement of L1, using the method of Kawakami [19] (distance between the vertical lines drawn from the center of the vertebral body of L1 and the superior-posterior corner of S1);
8 lumbar lordosis (distance from the upper endplate of L1 to the lower endplate of L5); and
9 pelvic tilt (the angle between the horizontal reference line and the intercrestal line; more than 2° was accepted as significant).

The same physician examined all radiographic features to prevent observer variability. To evaluate the intra-observer variability for this study, 100 randomly selected radiographs were measured by the same observer more than 1 month after the first reading. The intra-observer variability was evaluated by kappa analysis. As a result, the intra-observer variability was found to be sufficient for assessment (0.74).

The chi-squared test was used to examine differences between the prevalence of lateral spondylolisthesis, rotation deformities, and pelvic tilt abnormalities in the S and C-groups. To compare the differences in the other radiographic features between the 2 groups, non-paired t tests were used for statistical analysis. The level of significance was set at $p < 0.05$. The results are presented as mean ± standard error.

Results

Twelve participants had scoliosis of greater than 10° in the Cobb angle at the time of the initial survey in 1990. The prevalence of DLS in this cohort was 12/400 (3.0 %) at the beginning of the follow-up. Analysis of difference by sex indicated that prevalence was 1.0 in men and 5 % in women. All of the scoliosis curvatures identified were low-grade with the Cobb angle ranging between 10° and 12°, with minimal rotatory deformity. Six of the 12 participants with scoliosis participated in the second survey. Three curves were unchanged; the others had retrograded. When estimating the cumulative incidence of DNDLS, these 6 subjects were excluded from the study, leaving the X-ray films of 194 subjects (81 men, 113 women, with an average age of 69.8 years at the time of the initial survey) for radiographic evaluation. To avoid the effects of drop-out, cumulative incidence in this study was calculated by using the number who completed both of the radiographic examinations as the denominator. Thirty-three of the 194 subjects who had no scoliosis (Cobb angle <10°) in 1990 had DNDLS in 2005. The overall cumulative incidence of DNDLS in this cohort was, therefore, 33/194 (17.0 %).

Ten of the 81 men (12.3 %) and 23 of the 113 women (20.4 %) developed DNDLS. The male-to-female cumulative incidence ratio was approximately 1:2. The occurrence of DNDLS tended to increase with age. The cumulative incidence in each age stratum was: 4/57 (7.0 %) in the 40–49 year-group, 9/74 (12.2 %) in the 50–59 year-group, 15/55 (27.3 %) in the 60–69 year-group, and 5/8 (62.5 %) in the 70–79 year-group (Table 2).

The radiographic features of DNDLS in the study participants are summarized in Table 3. None of the scoliotic curvatures exceeded 30° in the Cobb angle, which ranged from 10° to 26°; the mean Cobb angle of DNDLS was 13.5 ± 4.4°. The convexity of scoliosis was to the left in 24 patients and to the right in 9 patients. The apexes were usually located at L3 or L4. None of the rotation angles exceeded 15° when measured by use of the Perdriolle method; the rotation angles ranged from 0–15°, and the mean rotation angle of DNDLS was 5.2° ± 3.3°.

The tilting angle was significantly larger in the S-group than in the C-group, at all levels. The intervertebral disc angles and lateral osteophyte differences were significantly larger in the S-group than in the C-group in the upper lumbar segments only, and these features did not differ between groups in the L4–5 and L5–S1 segments. The 2 groups differed significantly in lateral spondylolisthesis and vertebral rotation only at the L3 level. Pelvic tilt, lumbar scoliotic Cobb angle, coronal and sagittal spinal balance, and lumbar lordosis did not differ significantly between the S and C-groups (Table 4).