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Prevalence and risk factors of lumbar spondylolisthesis in elderly Chinese men and women

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Abstract

Objective A screening survey for osteoporotic fractures in men and women in Hong Kong represents the first large-scale prospective population-based study on bone health in elderly (≥65 years) Chinese men and women. This study aims to identify the prevalence and potential risk factors of lumbar spondylolisthesis in these subjects.

Methods The lateral lumbar radiographs of 1,994 male and 1,996 female patients were analysed using the Meyerding classification.

Results Amongst the men, 380 (19.1 %) had at least one spondylolisthesis and 43 (11.3 %) had slips at two or more levels; 283 had anterolisthesis, 85 had retrolisthesis, whereas 12 subjects had both anterolisthesis and retrolisthesis. Amongst the women, 499 (25.0 %) had at least one spondylolisthesis and 69 (13.8 %) had slips at two or more levels; 459 had anterolisthesis, 34 had retrolisthesis, whereas 6 subjects had both anterolisthesis and retrolisthesis. Advanced age, short height, higher body mass index (BMI), higher bone mineral density (BMD) and degenerative arthritis are associated with spondylolisthesis. Lower Physical Activity Scale for the Elderly (PASE) score was associated with spondylolisthesis in men; higher body weight, angina and lower grip strength were associated with spondylolisthesis in women.

Conclusion The male/female ratio of lumbar spondylolisthesis prevalence was 1:1.3 in elderly Chinese. Men are more likely to have retrolisthesis.

Key Points
• *The prevalence of spondylolisthesis is 19.1 % in elderly Chinese men.*
• *The prevalence of spondylolisthesis is 25.0 % in elderly Chinese women.*
• *Men are more likely to have retrolisthesis.*
• *Anterolisthesis is most commonly seen at the L4/L5 level.*
• *Retrolisthesis is most commonly seen at the L3/L4 level.*

Keywords Prevalence · Risk factors · Spondylolisthesis · Chinese · Vertebrae

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Introduction

Spondylolisthesis is defined as the anterior or posterior migration, or slip, of one vertebra in relation to the next caudal vertebra. It mostly occurs in the lumbar spine and is considered to have two main aetiologies, spondylolytic and degenerative [1]. Spondylolytic spondylolisthesis is distinguished by fracture of the pars interarticularis and is observed primarily during childhood or early adult life [2, 3]. Degenerative spondylolisthesis refers to slip without an associated defect in the posterior vertebral ring [4]. Although controversies regarding the pathogenesis of degenerative spondylolisthesis still exist, it is generally acknowledged that degenerative spondylolisthesis is seldom encountered in subjects less than 50 years of age. Degenerative spondylolisthesis is considered a classic example of spinal instability resulting from progressive degeneration of both the facet joints and the intervertebral discs with aging [5].

Although spondylolisthesis is usually asymptomatic, it can progress into spinal stenosis and result in neurogenic symptoms, such as leg pain, numbness, or weakness. Lumbar spondylolisthesis is considered to be a significant source of back pain and disability [6]. Over 300,000 lumbar spine fusions are performed in the USA each year and this number is increasing [7, 8]. Many of these fusions are performed to correct the instability associated with degenerative spondylolisthesis [9–12].

The prevalence of spondylolisthesis has been reported in symptomatic and asymptomatic subjects, and the results vary considerably. Most studies have focused on anatomical features associated with degenerative spondylolisthesis among symptomatic patients. Data from non-clinical, community-based populations are limited. Prevalence estimates among women range from 6 % in Taiwan [13], 8 % in Denmark [14], to 20–25 % in the USA [15–17], whereas among men estimates range from 3 % in Taiwan and Denmark to 4–31 % in the USA [13–18]. It has been suggested that women are about three times more likely to be affected by spondylolisthesis than men, and black women are about three times more frequently affected than white women [4, 18–20]. Until now, accurate precise data on spondylolisthesis prevalence among elderly Chinese subjects are lacking.

Using epidemiology data derived from 2,000 Chinese elderly men and 2,000 Chinese elderly women, this study aimed to estimate the prevalence of spondylolisthesis among community-dwelling elderly Chinese subjects, and determine whether certain demographic factors, lifestyle characteristics or medical conditions are associated with the prevalence of this condition. A clearer understanding of the epidemiology of spondylolisthesis is needed to allow a more in-depth patient discussion and to formulate evidence-based treatment plans.

Materials and methods

Two thousand Chinese men and two thousand Chinese women aged 65 years or above were recruited from the local communities by advertisements placed in housing estates and community centres for older people to take part in a prospective cohort study from August 2001 to March 2003. The recruitment criteria were established so that the study results from the cohort would be applicable to a broad population of similarly aged community-dwelling men and women. The project was designed primarily to examine the bone mineral density (BMD) of older Chinese adults prospectively for 4 years. All subjects were community dwelling, able to walk without assistance, had no bilateral hip replacement and had the potential to survive the duration of a primary study based on their general medical health. No subjects had a known malignancy or previous lumbar spine surgery. Subjects were invited to the research centre for interviews and physical examination. The study protocol was approved by the Chinese University of Hong Kong Ethics Committee. Written informed consent was obtained from all subjects. Data from the baseline evaluation were analysed in the current report.

The participants were interviewed using a structured standardised questionnaire. This questionnaire included demographic information, socioeconomic status, medical history related to osteoporosis, history of fracture, current medications (verified by direct inspection or medical record) and alcohol and tobacco consumption. Dietary intake was recorded using a modified Block Food Frequency questionnaire based on the data from the Hong Kong Adult Dietary Survey in 1995 [21]. Physical activity was measured by the Physical Activity Scale for the Elderly (PASE) questionnaire modified for use in older Chinese men and women in Hong Kong [22]. Height and weight of the subjects were measured with indoor clothing but without shoes. Height was measured using the Harpenden stadiometer (Holtain Ltd., Crosswell, UK). Body weight was measured using the physician beam balance scale (Healthometer, Alsip, IL, USA). Both readings were recorded to one decimal place. Grip strength on both hands was measured with a Preston grip dynamometer. Three tests on each hand were performed and the average of the second and third tests on each hand was used. Body mass index (BMI) was calculated using the formula of weight/height^2 (kilograms per square metre). BMD (grams per square centimetre) at the total hip and spine (L1–L4) was measured by QDR-4,500 W densitometers (Hologic, Inc., Waltham, MA, USA). The in vivo coefficient of variation of the system was 0.9 and 0.7 % at the lumbar spine and at the total hip, respectively.

Left lateral recumbent lumbar spine radiographs were obtained by adjusting exposure parameters according to participants' body weight and height. Only radiographs deemed suitable for accurate assessment of spondylolisthesis were

analysed. Spondylolisthesis was defined as a forward slip (anterolisthesis) or backward slip (retrolisthesis) of one vertebral body by at least 5 % in relation to the next most caudal vertebral body and assessed from L1 to S1. 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 [23]. All lumbar spine radiographs were interpreted and measured by two musculoskeletal radiologists in consensus. This study did not differentiate between spondylolisthesis and spondylolytic spondylolisthesis because only the lateral radiograph was obtained. Anterolisthesis and retrolisthesis are together termed spondylolisthesis. The test–retest reliability assessment conducted on a sample of 100 films indicated 100 % agreement on the presence of spondylolisthesis.

In this study, 24 factors were analysed according to their relationship with spondylolisthesis, including age (years), weight (kilograms), height (metres), BMI (kilograms per square metre), current smoking, current alcohol consumption, hypertension, angina, PASE score, chronic obstructive pulmonary disease (COPD), average left/right grip strength (kilograms), history of fracture, corticosteroid intake, self-reported degenerative arthritis (DA), lumbar spine BMD, hip BMD, low back pain, difficulty bending forward, dietary calcium intake, diabetes and longest occupation involving physical labour; for women number of children, age at menopause and any hormone replacement usage were also analysed. Statistical analyses were performed using the statistical package SAS, version 9.1.3 (SAS Institute, Inc., Cary, NC, USA). Characteristics of participants with and without lumbar spondylolisthesis were compared for the men and women separately. Two sample independent t tests were used for continuous variables, whereas Chi-squared tests were used for categorical variables. Logistic regression was performed for significant factors. All statistical tests were two-sided. An α level of 5 % was used as the level of significance.

Results

The radiographs of all 2,000 Chinese men (mean age 72.4 years, range 65–92 years) and 2,000 women (mean age 72.6 years, range 65–98 years) were obtained. There was no difference in age between the two sexes ($P = 0.25$). None of these subjects' spines were diagnosed as having pathological fractures or diseases other than degenerative or osteoporotic changes. The radiographs of 1,994 male subjects (99.7 %) and 1,996 female subjects (99.8 %) were deemed to be of suitable film quality for analysis of spondylolisthesis. Prevalence of spondylolisthesis for men from L1 to L5 is listed in Table 1. In male subjects 380 out of 1,994 subjects (19.1 %) had at least one level of spondylolisthesis. Of these 380 subjects, 43

Table 1 Number of lumbar vertebral spondylolisthesis in 1,994 male subjects

	Vertebral level					
	L1/2	L2/3	L3/4	L4/5	L5/S1	total
Anterolisthesis grade I	0	1	25	217	55	298
Anterolisthesis grade II	0	0	0	5	7	12
Anterolisthesis grade III	0	0	0	0	1	1
Total anterolisthesis	0	1	25	222	63	311
Retrolisthesis grade I	2	29	50	17	18	116
Spondylolisthesis grade I	2	30	75	234	73	414
Spondylolisthesis total	2	30	75	239	81	427

(11.3 %) had a slip at two or more levels, whereas the remaining 337 subjects (88.7 %) had a slip at only a single level. Anterolisthesis was seen in 283 (14.2 %) of the 1,994 subjects, whereas retrolisthesis was seen in 85 (4.3 %) of the 1,994 subjects. Twelve (0.6 %) of the 1,994 subjects had concurrent anterolisthesis and retrolisthesis. A total of 427 out of 9,970 levels (4.3 %) assessed in male subjects had some degree of listhesis. Of these 427 vertebral levels, 414 (97.0 %) were Meyerding grade I spondylolisthesis and 12 (2.8 %) were Meyerding grade II spondylolisthesis. Anterolisthesis was mainly grade I with a much smaller number of grade II and only one grade III (Table 1), whereas all retrolisthesis cases were grade I. Anterolisthesis was most commonly seen at the L4/5 level, whereas retrolisthesis was most commonly seen at the L3/4 level.

Prevalence of spondylolisthesis in women from L1 to L5 is listed in Table 2. In female subjects, 499 of the 1,996 subjects assessed (25.0 %) had at least one level of spondylolisthesis. Of these 499 subjects, 69 (13.8 %) had slips at two or more levels, whereas the remaining 430 (86.2 %) had a slip at a single level only. Of the 499 subjects with spondylolisthesis, anterolisthesis was seen in 459 subjects, whereas retrolisthesis was seen in 34 (1.7 %) subjects. Six (0.3 %) subjects had both anterolisthesis and retrolisthesis. A total of 575 out of 9,980 levels (5.8 %) assessed in female subjects had some degree of listhesis. Of these 575 vertebral levels, 545 (94.8 %) were Meyerding grade I spondylolisthesis and 30 (5.2 %) Meyerding grade II spondylolisthesis. All retrolisthesis cases were grade 1 (Table 2). Similar to male subjects, in female subjects anterolisthesis was most commonly seen at the L4/L5 level, whereas retrolisthesis was most commonly seen at the L3/L4 level.

Spondylolisthesis characteristics for men and women are shown in Table 3. The ratio of male to female spondylolisthesis prevalence was 1:1.3, whereas that for anterolisthesis was 1:1.6. Women had a higher prevalence of spondylolisthesis than men ($P < 0.001$). Women also had the tendency towards a greater prevalence of grade II spondylolisthesis ($P = 0.07$). Men were more likely to have retrolisthesis ($P < 0.001$).

Table 2 Number of lumbar vertebral spondylolisthesis in 1,996 female subjects

	Vertebral levels					
	L1/2	L2/3	L3/4	L4/5	L5/S1	Total
Anterolisthesis grade I	0	3	62	354	77	496
Anterolisthesis grade II	0	0	1	13	16	30
Total anterolisthesis	0	3	63	367	93	526
Retrolisthesis grade I	3	13	21	5	7	49
Spondylolisthesis grade I	3	16	83	359	84	545
Total spondylolisthesis	3	16	84	372	100	575

Age-specific prevalence of spondylolisthesis is shown in Table 4. Spondylolisthesis increased with age among both men ($P<0.0001$ for trend) and women ($P=0.014$ for trend).

Demographic and clinical data separated according to sex for subjects with and without spondylolisthesis are summarised in Table 5. For both men and women, advanced age, short height, higher BMI, higher spine and hip BMD, and clinical degenerative arthritis are associated with increased likelihood of spondylolisthesis. A lower PASE score was associated with increased likelihood of spondylolisthesis in men, whereas a higher body weight, angina and lower grip strength were associated with increased likelihood of spondylolisthesis in women. Spondylolisthesis was significantly associated with low back pain in men, whereas this association did not reach statistical significance in women. For both men and women, subjects with spondylolisthesis tended to have difficulty in bending forwards, but statistical significance was not reached. Factors including current smoking and alcohol consumption, COPD, history of fracture, corticosteroid intake, dietary calcium intake, diabetes, age at menopause, longest occupation involving physical labour, number of children and hormone replacement therapy were not associated with spondylolisthesis. Logistic regression analysis showed that advanced age and higher BMD at either the hip or spine were significant predictors of spondylolisthesis for both men and women. In addition, low back pain was a significant predictor of spondylolisthesis for men, whereas lower grip strength was a significant predictor of spondylolisthesis for women (Table 6).

Discussion

Despite the frequency of surgery performed for spondylolisthesis, the epidemiology of this condition remains unclear. One strength of this study is that we performed an investigation in both men and women from the same community-based population, and lateral lumbar spine radiographs were obtained in all subjects. The design of this study in Chinese subjects was the same as the Osteoporotic Fractures in Men (MrOS, USA) and Osteoporotic Fractures in Women (MsOS, USA) studies carried out on mainly Caucasian patients. Although the US studies on lumbar spondylolisthesis [15, 18] contained fewer subjects (295 men, 788 women), some insight into racial differences could be obtained by comparing these studies. In addition, prevalence of retrolisthesis was assessed in our cohort. There has been little previous research on the prevalence of retrolisthesis. However, retrolisthesis may be more strongly associated with low back pain and impaired lumbar function [15]. The present study found a prevalence of lumbar spondylolisthesis of 19.1 % in elderly Chinese men and 25.0 % in elderly Chinese women.

Compared with the MrOS (USA) study, our male cohort had a lower anterolisthesis prevalence (19.1 % versus 31 %) [18], more Meyerding grade II anterolisthesis (2.8 % vs. 1 %) and slightly more subjects with more than one level of anterolisthesis (5.1 % vs. 4 %) [18]. For women, in the MsOS (USA) study Vogt et al. used greater than 3 mm as the threshold of spondylolisthesis and measured at the lower lumbar level (L3 to S1) [15]. The anterolisthesis prevalence was 28.9 % and that of retrolisthesis was 14.2 %. When the cut-off point is increased to 5 mm, the prevalence decreases to 14.2 % and 3.2 % respectively [15]. Vogt et al.'s results have been considered to be similar to those of a population-based radiographic survey conducted in 1982 in the Netherlands [24]. Similar to our study, 73 % of anterolisthesis in the MsOS (USA) study involved the L4–L5 level, and retrolisthesis involved primarily the L3–L4 or L5–S1 levels instead of L4/5 [15].

No similar studies in community-dwelling subjects have been performed in Asian populations. In one study of Japanese subjects with low back pain, 8.7 % patients showed degenerative spondylolisthesis (defined as a slippage of >3 mm, including both anterolisthesis and retrolisthesis, but excluding spondylolytic spondylolisthesis [25]. Chen et al.

Table 3 Comparison of spondylolisthesis characteristics among male and female subjects

	Total subjects with spondylolisthesis	Subjects with grade II spondylolisthesis	Retrolisthesis subjects: anterolisthesis subjects	Subjects with both antero- and retrolisthesis
Male	380 (19.1 %)	12 (2.8 %)	85/283=30 %	12
Female	499 (25.0 %)	30 (5.2 %)	34/459=7 %	6
	$P<0.001$	$P=0.07$	$P<0.001$	$P=0.17$

Table 4 Prevalence of spondylolisthesis for different age and sex cohorts

	Prevalence: % (subjects)				
	65–69 years	70–74 years	75–79 years	>80 years	*P* for trend
Male	14.7 % (97)	18.5 % (131)	23.4 % (104)	26.6 % (49)	<0.0001
Female	21.1 % (141)	27.1 % (180)	26.6 % (119)	28.4 % (61)	0.0136

reported that among Taiwanese taxi drivers over 45 years old with low back pain, the degenerative spondylolisthesis prevalence was 8.9 % [13].

The aetiology of spondylolisthesis is multifactorial. Disc and facet joint degeneration are generally considered the most likely causes [5, 26, 27], although increased sagittal orientation of the facet joints, loss of paraspinal muscle bulk [28–31], increasing age [17, 26], strength of the iliolumbar ligaments, increased pelvic inclination or reclination, and increased L1–S1 angulation have all been considered to be potential causes to varying degrees in cadaver and radiological studies [18].

The present study confirmed previous reports that women are more susceptive to spondylolisthesis than men. The male to female ratio of 1:1.3 (or 1:1.6 for anterolisthesis) in this study is, however, considerably lower than in previous population-based studies on Caucasian subjects [4, 18, 19]. In the Danish study, Jacobsen et al. reported a male to female ratio of 1:6.4 [14]. Pregnancy [32], generalised joint laxity [33] and oophorectomy [34] are thought to be predisposing systemic factors in spondylolisthesis as well as a postmenopausal status [14]. Wang et al. recently demonstrated that elderly women had more severe disc narrowing than their male age-matched counterparts [35–37]. The higher severity of disc degeneration in elderly women may partially be responsible for the higher prevalence of degenerative spondylolisthesis in women than in men. Our results suggested that higher hip

Table 5 Clinical characteristics between subjects with and without lumbar spondylolisthesis

	Male (*n*=1,994)			Female (*n*=1,996)		
	Slip (*n*=380)	No slip (*n*=1,613)	*P*	Slip (*n*=499)	No slip (*n*=1,495)	*P*
Age (years)	73.61±5.30	72.12±4.89	<0.001	73.13±5.38	72.38±5.33	0.007
Weight (kg)	62.49±8.97	62.42±9.50	0.896	55.55±8.39	54.19±8.51	0.002
Height (m)	1.62±0.06	1.63±0.06	0.001	1.50±0.05	1.51±0.05	0.001
BMI (kg/m^2)	23.73±3.04	23.38±3.15	0.047	24.59±3.44	23.70±3.42	<0.001
Current smoker	41 (10.8 %)	197 (12.2 %)	0.432	7 (1.4 %)	30 (2.0 %)	0.381
Current alcohol consumption	87 (22.8 %)	384 (23.8 %)	0.688	10 (2.0 %)	41 (2.7 %)	0.358
Hypertension	161 (42.3 %)	671 (41.6 %)	0.815	231 (46.1 %)	638 (42.7 %)	0.180
Angina	38 (10.0 %)	166 (10.3 %)	0.854	50 (10.0 %)	97 (6.5 %)	0.010
PASE	92.66±46.21	98.14±50.95	0.042	84.15±31.76	85.82±33.63	0.329
COPD	41 (10.8 %)	190 (11.8 %)	0.577	31 (6.2 %)	69 (4.6 %)	0.163
Grip strength (kg)	31.41±7.42	32.13±6.88	0.072	20.45±4.36	21.05±4.59	0.010
History of fracture	25 (6.6 %)	126 (7.8 %)	0.407	91 (18.2 %)	246 (16.5 %)	0.377
Corticosteroid intake	5 (1.3 %)	23 (1.4 %)	0.865	7 (1.4 %)	14 (0.9 %)	0.382
DA	39 (10.2 %)	115 (7.1 %)	0.041	78 (15.6 %)	166 (11.1 %)	0.008
Spine BMD (g/cm^2)	0.99±0.18	0.94±0.18	<0.001	0.79±0.16	0.74±0.14	<0.001
Hip BMD (g/cm^2)	0.88±0.12	0.86±0.13	0.003	0.72±0.12	0.70±0.12	0.001
Low back pain	134 (35.2 %)	477 (29.6 %)	0.033	261 (52.1 %)	801 (53.6 %)	0.565
Difficulty bending forward	32 (8.4 %)	116 (7.2 %)	0.419	61 (12.2 %)	144 (9.6 %)	0.105
Dietary Calcium intake (mg)	645.26±314.64	624.04±293.25	0.211	584.38±273.99	565.29±264.73	0.167
Diabetes	61 (16.0 %)	230 (14.3 %)	0.384	66 (13.2 %)	218 (14.6 %)	0.435
Longest occupation involving physical labour	39 (10.2 %)	138 (8.6 %)	0.301	16 (3.3 %)	45 (3.2 %)	0.879
Number of children born	–	–	–	3.61±2.23	3.52±2.10	0.436
Age at menopause	–	–	–	49.23±5.04	48.79±4.96	0.096
Hormone replacement therapy	–	–	–	13 (2.6 %)	51 (3.4 %)	0.369

PASE Physical Activity Scale for the Elderly, *DA* degenerative arthritis, *COPD* chronic obstructive pulmonary disease

Table 6 Logistic regression of variables related to lumbar spondylolisthesis

	Male			Female		
	OR (95 % CI)			OR (95 % CI)		
	Unit	Model 1: Hip BMD	Model 2: Spine BMD	Unit	Model 1: Hip BMD	Model 2: Spine BMD
Age (years)	5.0	1.37 (1.23, 1.54)*	1.33 (1.19, 1.49)*	5.0	1.18 (1.07, 1.31)*	1.14 (1.03, 1.26)*
BMI (kg/m^2)	3.13	1.05 (0.92, 1.20)	1.06 (0.94, 1.20)	3.45	1.22 (1.09, 1.37)	1.16 (1.03, 1.29)
Hip/spine BMD†	0.13	1.23 (1.08, 1.40)*	1.19 (1.09, 1.30)*	0.12	1.18 (1.04, 1.33)*	1.29 (1.18, 1.41)*
DA	Yes/No	1.43 (0.97, 2.12)	1.40 (0.94, 2.08)	Yes/No	1.33 (0.99, 1.79)	1.29 (0.95, 1.74)
PASE	−50.3	1.07 (0.95, 1.20)	1.07 (0.95, 1.21)	–	–	–
Low back pain	Yes/No	1.28 (1.004, 1.63)*	1.26 (0.98, 1.60)	–	–	–
Grip strength (kg)	–	–	–	−4.55	1.14 (1.03, 1.28)*	1.18 (1.05, 1.31)*
Angina	–	–	–	Yes/No	1.45 (1.01, 2.09)	1.36 (0.94, 1.97)
AUC		0.608	0.620		0.610	0.630

PASE Physical Activity Scale for the Elderly, *DA* degenerative arthritis, *AUC* area under the curve, *OR* odds ratio, *Unit* SD of the variable

† Hip BMD for model 1 and spine BMD for model 2; *$P<0.05$

BMD and spine BMD are associated with higher prevalence of spondylolisthesis. We have previously suggested that higher BMD is associated with more severe disc degeneration [35, 37]. It is likely that higher BMD leads to more severe disc degeneration, and in turn leads to higher degenerative spondylolisthesis prevalence.

In our study low back pain was significantly associated with spondylolisthesis in men, whereas Jacobsen et al. found no relationship between low back pain and degenerative spondylolisthesis [14]. This study further confirmed that the prevalence of spondylolisthesis increased with age in both men and women. Unsurprisingly, a history of self-reported degenerative arthritis is associated with a higher prevalence of spondylolisthesis because these subjects are more likely to have symptomatic or severe degenerative arthritis. Greater physical activity and frequent exercise could result in a higher prevalence of degenerative spondylolisthesis owing to increased loads upon the lumbar spine [3, 13, 23, 38, 39]. However, no association between spondylolisthesis and occupational exposure with repeated daily lifting was observed in the Copenhagen cohort [14]. Our results suggested that longest occupation involving physical labour was not associated with higher prevalence of spondylolisthesis. On the other hand, PASE score was significantly higher in male subjects without spondylolisthesis than in those with spondylolisthesis, whereas grip strength was significantly greater in female subjects without spondylolisthesis than in those with spondylolisthesis. Physical activity and greater grip strength may play a protecting role via stronger muscles to maintain the stability of the spine.

Similar to previous reports [13, 14], our study showed higher BMI in men and women, and greater weight in women with spondylolisthesis. Biomechanically both the compression force

and the axial load on lumbar facet joints are increased as the body mass increases [40]. Our elderly male and female subjects with spondylolisthesis were all shorter; this is probably because subjects with spondylolisthesis are more likely to have narrowed disc spaces [15]. Lifestyles, such as alcohol consumption and cigarette smoking, can affect bone health [41]. Others suggested that diabetes and atherosclerotic disease may be associated with degenerative spondylolisthesis [42]. In our study angina is significantly associated with spondylolisthesis in women, whereas dietary calcium intake, diabetes, history of fracture, smoking, alcohol consumption, corticosteroid intake and COPD were not associated with spondylolisthesis in either men or women. Age at menopause, hormone replacement therapy and number of children born was not associated with spondylolisthesis in women.

A limitation of the current study is that only relatively healthy subjects with a high likelihood of surviving the study duration were enrolled. This could have led to a selection bias in favour of relatively healthy participants. However, this may be an inevitable feature of medium to long-term prospective cohort studies. The study questionnaire was designed with a view to determining risk factors for osteoporosis and was not specifically designed to characterise risk factors for spondylolisthesis. Therefore the variables associated with spondylolisthesis could not be explored in greater depth. As in previous studies [5, 13, 15], recumbent lateral radiographs were used to assess spondylolisthesis in this study. Vertebral displacement resulting from spondylolisthesis measured on radiographs could decrease as the subjects' posture changed from upright to supine position; therefore, recumbent lateral radiographs may underestimate the prevalence and the degree of spondylolisthesis. It has been suggested that a portion of spondylolisthetic lesions can only be seen by a standing lateral

radiograph [19]. However, in one experiment, mean slip distances observed among 125 patients with spondylolysis were not significantly different on recumbent and standing radiographs, being 12.0 mm (±8.8) on recumbent and 12.3 mm (±8.6) respectively [43]. In this study it was not possible to differentiate degenerative spondylolisthesis from spondylolytic spondylolisthesis. However, in elderly subjects, spondylolytic spondylolisthesis made up only a very small portion of total spondylolistheses [44]. Additionally, because the frontal view of the lumbar spine was not obtained, disc and facet joint degeneration could not be fully assessed.

In conclusion, this large-scale study on community-based populations demonstrated that the prevalence of spondylolisthesis was 19.1 % in elderly Chinese men and 25.0 % in elderly Chinese women. Anterolisthesis was most commonly seen at the L4/L5 level, whereas retrolisthesis was most commonly seen at the L3/L4 level, both for men and women. The prevalence of spondylolisthesis in elderly Chinese is broadly similar to that of the MsOS (USA) study, but lower than the MrOS (USA) study. The overall male to female ratio in Chinese subjects was 1:1.3 which is lower than reports for Caucasian subjects. Women tended to have more Meyerding grade II spondylolisthesis than men. On the other hand, men were more likely to have retrolisthesis than women. Higher physical activity and grip strength may protect against the occurrence of spondylolisthesis, whereas higher hip BMD and higher spine BMD, and self-reported degenerative arthritis were associated with a higher prevalence of spondylolisthesis. Our study also reinforced some of the previous studies in which advanced age and higher BMI were associated with a higher prevalence of spondylolisthesis.

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