Degenerative lumbar scoliosis in Chinese Han population: prevalence and relationship to age, gender, bone mineral density, and body mass index

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Received: 20 August 2012 / Revised: 14 December 2012 / Accepted: 16 January 2013 / Published online: 30 January 2013
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Abstract

Purpose To investigate the prevalence of degenerative lumbar scoliosis (DLS) in Chinese Han population, as well as its correlation with age, gender, bone mineral density (BMD), and body mass index (BMI); and to determine factors that might affect the curve severity.

Methods A prospective study was performed on adults visiting the dual-energy X-ray absorption clinics for physical examination from January 2011 to March 2012. 2,395 subjects aged older than 40 years and having no history of previous spinal trauma, surgeries or scoliosis, were enrolled in this study. A logistic regression analysis was performed to determine the independent variables related to the presence of scoliosis. Besides, the relationship between curve severity and these variables was also analyzed with partial linear correlation analysis.

Results The prevalence of DLS was approximately 13.3 %. The logistic regression analysis showed that age, *T* score, and gender all had remarkable correlation with the occurrence of DLS, with the odd ratios being 4.2, 1.5, and 1.6, respectively. According to the receiver operating characteristics curve, the best dividing point for age and *T* score of female subjects was 65 and -2.0 , respectively. Partial linear correlation analysis indicated that there existed no obvious correlation between the above variables and the severity of scoliosis.

Conclusion The prevalence of DLS in Chinese Han population aged older than 40 years was approximately

13.3 %, which had a significant correlation with age, gender, and BMD. Osteopenia, gender of female, and aged older than 65 years could contribute to the presence of DLS. The curve severity was not associated with age, gender, BMI, or BMD.

Keywords Degenerative lumbar scoliosis · Prevalence · Osteopenia · Curve severity

Introduction

Degenerative lumbar scoliosis (DLS) is defined as a lumbar scoliosis developing during adulthood without previous history of scoliosis [1–5]. In recent years, increasing attention has been paid to the diagnoses and management of DLS with the population aging worldwide. It has been well documented that DLS could be initiated from asymmetrical collapse of the inter-vertebra disk along with associated incompetence and hypertrophy of the facet joints [6, 7]. If not treated appropriately, patients with DLS may present with severe pain in the back and leg, thus having a considerable influence on their daily life. It is now becoming a public health care concern to investigate factors that are associated with the presence and the progression of DLS.

An accurate understanding of the prevalence of DLS is important in determining the impact of this disorder on the patients' quality of life. To date, a number of studies have reported the prevalence and related factors of scoliosis in adult population [8–13]. Yet, as a result of differences in definitions of scoliosis, sample size, and screening tools, these studies reported a variety of prevalence rates ranging from 1.4 to 68 % [8–13]. Kobayashi et al. [14] screened the development of DLS in a group of 60 elder normal subjects through a 12-years follow-up, and they found a DLS

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incidence of 36.3 %. The study of Schwab et al. [15], who investigated 75 subjects aged more than 60 years old, showed that the prevalence of DLS was 68 %. For epidemiological studies, a sufficient number of cases are warranted for a sound conclusion [16]. However, to our knowledge, there are few large-scale studies specifically addressing the prevalence of DLS. Also, there was a lack of consensus in terms of factors that may be correlated with the curve severity.

The primary purpose of this prospective study was to ascertain the prevalence of DLS in Chinese Han population. In addition, we also investigated the possible influence of age, gender, bone mineral density (BMD), and body mass index (BMI) on the presence and the progression of DLS.

Methods

Subjects

A cohort of subjects from Chinese Han ethnic population voluntarily participated in a public benefit health program screening bone loss of elder population, which had been approved by institutional review board. All the subjects were recruited randomly from the local communities regardless of their level of mobility between January 2011 and March 2012. As the primary sponsor of this program, we thus collected the data of these subjects who underwent Dual energetic X-ray absorption (DEXA) examination in our hospital. The inclusion criteria for this study were as follows: aged older than 40 years, no history of scoliosis or spinal trauma, and no prior spine surgery. A total of 2,395 subjects, including 701 males and 1,694 females, met the inclusion criteria, and were enrolled in the current study.

Data collection

The general information including age and gender were recorded when the subjects came to the clinics. The subjects' weight was measured to the nearest 0.1 kg in normal indoor clothing without shoes. Standing height was recorded without shoes on a wall-mounted stadiometer to the nearest 0.1 cm. BMI was then calculated by dividing the weight (in kg) with the height (in meter) squared. *T* score in the lumbar spine and in left femoral neck were also recorded to determine the BMD of the subjects. The lumbar curve magnitude was measured on the coronal plane of the DEXA image using the Cobb method. We measured the Cobb angle digitally on a Laptop monitor using the Image Pro Plus (Media Cybernetics, Inc.). A diagnosis of DLS was determined in case that the Cobb angle was more than 10° [14]. Subjects without scoliosis were considered as

controls. Two of the authors (L. X. and X. S.) completed the measurement together. In addition, 100 scoliosis patients were randomly selected to determine the intra- and inter-observer variability of the measurement. The curve magnitude of the selected patients were measured by the authors and then repeated twice. Reliability was assessed using intra-class correlation coefficients. Reliability was high for all comparisons: 0.902 among raters and 0.934 for each of the two independent raters. Therefore, the method of digitally measuring the Cobb angles was confirmed to be acceptable, and the measured data were highly reliable.

Patients diagnosed as DLS were suggested to undergo standing radiographic examinations of the whole spine. Several radiological parameters were recorded, including thoracic kyphosis, lumbar lordosis, pelvic incidence, apex translation, and the relationship between the inter-crest line and the L5 vertebra. Apex translation was defined as the distance from the center of the sacral line to the apical vertebra. A low L5 vertebra was defined as at a level below the inter-crest line [9]. Besides, to evaluate the effect of curve severity on patients' health status, visual analog pain scale (VAS) assessment evaluating low back pain were assigned to patients with DLS. The VAS assessment was marked with the degree of pain on a horizontal 10 cm line, with the left start-line 0 indicating no pain. Each patient's mark was transferred into VAS score according to its ratio to the full length of the line.

Statistical analyses

The prevalence of scoliosis was calculated as the ratio of the number of scoliosis patients to the total number of the cohort. In several previous studies that investigated the prevalence of adult scoliosis [9, 10, 13], a 10-years value for age-span was used to stratify the subjects into different age categories. Thus, in current study, the subjects were stratified into five groups according to their age, namely, Group 1 from 41 to 50 years old, Group 2 from 51 to 60 years old, Group 3 from 61 to 70 years old, Group 4 from 71 to 80 years old, and Group 5 from 81 to 90 years old. The prevalence of DLS in each group was calculated, respectively, and the difference of prevalence was analyzed using Chi square test. A student's *t* test between scoliosis patients and controls was carried out to determine the differences in terms of age, BMI, and BMD. A logistic regression analysis was performed to determine the impact of independent variables on the presence of scoliosis, including age, gender, *T* score of femoral neck and of spine, and BMI. Then the receiver operating characteristics curve (ROC) was used to identify the best dividing point of each significant variable.

To investigate variables that influence the curve severity, a two-group comparison was carried out with the

dividing point of Cobb angle set at 20° , which was in line with prior studies that used 20° as the cutoff value to split patients with different curve severity [9, 13]. Namely, patients with Cobb angle less than 20° were assigned to Group A, and the other patients were assigned to Group B. Variables including age, BMI, and BMD were compared between the two groups using student's *t* test. Furthermore, we investigated the correlation between age, BMI, BMD, and the curve severity using the partial correlation analysis. For patients undergoing standing radiographic examinations of the whole spine, thoracic kyphosis, lumbar lordosis, pelvic incidence, apex translation, and the relationship between the inter-crest line and the L5 vertebra were compared between the two curve severity groups. As for the relationship between curve severity and VAS assessment, a comparison between the above two groups and a Pearson correlation analysis were performed, respectively. A $p < 0.05$ was considered to be statistically significant. All data were analyzed with SPSS version 16.0.

Results

Among the 2,395 subjects of the current study, 318 subjects were found to have a lumbar scoliosis. The prevalence of DLS in Han population was approximately 13.3 %. About 15.1 % of female subjects were found to have DLS, while this proportion in male subjects was about 8.8 % ($p = 0.018$).

The mean age of subjects with scoliosis was significantly older than that of control subjects (71.9 ± 10.2 vs. 64.2 ± 11.6 , $p < 0.001$). As shown in Table 1, the prevalence of DLS increased almost linearly from the Group 1 to Group 5. For subjects in Group 5 with a age between 81 and 90 years old, the prevalence of DLS was about 27.5 %, significantly higher than in any other group ($p < 0.001$). In scoliosis patients, the lumbar spine *T* score (L1–L4) and the

femoral neck *T* score were both significantly lower than those in control subjects (-2.1 ± 1.3 vs. -1.7 ± 1.6 , $p = 0.02$; -2.2 ± 1.1 vs. -1.6 ± 1.3 , $p = 0.01$). In terms of BMI, we did not find any significant difference between DLS patients and controls (24.1 ± 3.6 vs. 24.0 ± 3.5 , $p = 0.92$) (Table 2).

Logistic regression analysis showed that three variables, i.e., age, *T* score, and gender, had remarkable association with the presence of DLS, with the odd ratios calculated to be 4.2, 1.5, and 1.6, respectively. According to the ROC curve, the best dividing point for age and *T* score were 65 and -2.0 , respectively, at which the diagnostic ability reached the optimal balance between sensitivity and specificity.

Among the 318 patients who had scoliosis, 273 cases (85.8 %) had lumbar curves between 10 and 20° , 32 cases (10.1 %) between 21 and 30° , 8 cases (2.5 %) between 31 and 40° , and 5 cases (1.6 %) more than 40° . That is, there were 273 cases with lumbar curve less than 20° in Group A, and the remaining 45 cases were in Group B. Group A consisted of 228 female and 45 male patients, while Group B consisted of 37 female and 8 male patients. There was no significant difference between the two groups in terms of the ratio of female-to-male (5.06:1 vs. 4.62:1, $p = 0.42$). The inter-group comparison showed that patients in Group A had significantly higher *T* scores at both lumbar spine and femoral neck than patients in Group B (-2.0 ± 0.9 vs. -2.4 ± 1.5 , $p = 0.01$; -1.9 ± 1.1 vs. -2.3 ± 0.8 , $p = 0.01$). With respect to age and BMI, we found no significant differences between the two groups. The mean values of these variables are shown in Table 3. The partial correlation analyses, as shown in Table 4, revealed no remarkable correlation between the curve severity and variables including age, BMI, and BMD.

The standing X-ray films of the whole spine were obtained from 63 DLS patients. For the 48 patients initially assigned to Group A, the incidence of low L5 vertebra was significantly higher than that of the other 15 patients who were initially assigned to Group B (87.5 vs. 60.0 %, $p = 0.028$). As for thoracic kyphosis, lumbar lordosis, pelvic incidence, and apex translation, as shown in Table 5,

Table 1 Prevalence of degenerative lumbar scoliosis in different age groups and gender groups

Group	Number of scoliosis patients	Number of total group subjects	Prevalence of scoliosis (%)	Statistical value (<i>p</i>)
Age				
41–50	10	259	3.9	
51–60	34	553	6.4	
61–70	58	654	8.9	
71–80	136	639	21.3	
81–90	80	290	27.5	<0.001
Gender				
Male	62	701	8.8	
Female	256	1,694	15.1	0.018

Table 2 Comparison of age, BMI, and *T* score of both spine and femoral neck between scoliosis patients and normal subjects

Group	Age	BMI	<i>T</i> score of spine	<i>T</i> score of femoral neck
Scoliosis patients (<i>n</i> = 318)	71.9 ± 10.2	24.1 ± 3.6	-2.1 ± 1.3	-2.2 ± 1.1
Normal subjects (<i>n</i> = 2,077)	64.2 ± 11.6	24.0 ± 3.5	-1.7 ± 1.6	-1.6 ± 1.3
Statistical value (<i>p</i>)	<0.001	0.92	0.02	0.01

Table 3 Comparison in terms of age, BMI, and *T* score of both spine and femoral neck between the two groups classified by curve magnitude

Group	Age	BMI	<i>T</i> score of spine	<i>T</i> score of femoral neck
Group A (<i>n</i> = 273)	71.3 ± 9.5	24.2 ± 1.7	−2.0 ± 0.9	−1.9 ± 1.1
Group B (<i>n</i> = 45)	72.1 ± 11.2	24.1 ± 2.3	−2.4 ± 1.5	−2.3 ± 0.8
Statistical value (<i>p</i>)	0.55	0.63	0.01	0.01

Table 4 Correlations among curve severity, age, BMI, and *T* score of spine and femoral neck in scoliosis patients

	Partial correlation coefficient (<i>r</i>)			
	Age	BMI	<i>T</i> score of spine	<i>T</i> score of femoral neck
Curve severity	0.021	0.015	0.028	0.024
Statistical value (<i>p</i>)	0.12	0.34	0.09	0.10

Table 5 Comparison in terms of thoracic kyphosis, lumbar lordosis, pelvic incidence, and apex translation between the two groups classified by curve magnitude

Group	Thoracic kyphosis	Lumbar lordosis	Pelvic incidence	Apex translation (mm)
Subgroup A (<i>n</i> = 48)	30.3 ± 12.5	43.8 ± 8.8	44.5 ± 13.2	21.5 ± 3.9
Subgroup B (<i>n</i> = 15)	31.2 ± 13.1	42.9 ± 10.4	43.7 ± 16.8	22.6 ± 3.7
Statistical value (<i>p</i>)	0.58	0.73	0.85	0.36

there was no significant difference between the two curve severity groups.

The mean value of VAS scores was 2.3 ± 0.8 . Although patients in Group B had higher VAS score than those in Group A, the difference was not statistically significant (2.3 ± 0.4 vs. 2.2 ± 1.2 , $p = 0.59$). The correlation analysis between curve severity and VAS scores revealed no significant correlation across the entire cohort of scoliosis patients ($r = 0.253$, $p = 0.63$).

Discussion

Degenerative scoliosis is becoming an issue of great concern with the aging of the population worldwide [17]. Besides the cosmetic considerations, it also brings about significant pain and disability [2, 3]. However, there is still a lack of agreement on the etiology and prevalence of DLS [6, 7]. Therefore, it is important to understand the epidemiology of DLS and the influencing factors of the curve

severity, which could in turn help predict the curve progression and determine optimal timing of surgical intervention [18, 19].

To date, several studies have been carried out in different regions or ethnic groups to investigate the prevalence of lumbar scoliosis in the general adult population, which was reported to range from 1.4 to 68 % [8–13]. Recently, two large-scale prevalence studies of adult lumbar scoliosis, which have enrolled over two thousand subjects, reported a scoliosis rate of 8.85 [10] and 8.3 % [8], respectively. However, both studies failed to differentiate DLS from adult scoliosis of adolescent onset (ASA) in their cohort, leaving the prevalence of DLS still obscure. In the current study, we specifically investigated the prevalence of DLS in a cohort of 2,395 adults aged more than 40 years old, and found that 13.3 % of the cohort population had DLS. A prevalence of 13.3 % was mostly comparable to the results of several earlier studies that reported the prevalence of adult scoliosis in elder population. Urrutia et al. [13] found a 12.9 % prevalence of lumbar scoliosis in postmenopausal women aged 50 years. Although Hong et al. [9] reported a relatively higher adult scoliosis prevalence of 35.5 % in Korean population, we believed that this variation could be attributed to different inclusion criteria. In the study of Hong et al. [9], subjects aged more than 60 years were included, while the current study included patients aged more than 40 years. When stratifying these subjects into different age groups, we found a remarkable increase in the prevalence of DLS with the age increasing. In the group of subjects older than 80 years, there was a prevalence up to 27.1 %, significantly higher than in any other age group. Besides, the comparison of prevalence between genders revealed that female subjects had an obviously higher incidence of lumbar scoliosis than male subjects. Moreover, we also found that the BMD at lumbar spine and femoral neck of scoliosis patients were both significantly decreased when compared with control subjects.

Based on the above findings, we speculated that age, gender and BMD could have an influence on the development of DLS. Vanderpool et al. [20] reported that the incidence of DLS in patients with osteoporosis was sixfold higher than in age- and sex-matched controls. Bridwell et al. [21] reviewed 48 female DLS patients between the ages of 40 and 80 years, among which 38 were noted to be osteopenic. In our study, the regression analysis showed that age, gender, and BMD were all independent risk factors of adult scoliosis, with the odd ratios calculated to be 4.2, 1.5, and 1.6, respectively. Namely, elder and osteopenic female patients might be more susceptible to the development of adult scoliosis. Using ROC analysis, we found that the age of 65 years old and the spine *T* score −2.0 could serve as the optimal dividing points. Hence, for

female patients aged more than 65 years old and with a spine T score <-2.0 , a standing X-ray examination should be proposed for the screening of adult scoliosis, especially when they are asymptomatic and not knowing any spinal deformity of themselves.

Although related to the development of DLS, age, gender, and BMD were not found to have influence on the curve progression in our study. As indicated by the partial correlation analyses, there was a lack of correlation between curve severity and three continuous variables (i.e., age, BMI, and BMD). It is noteworthy that, in the inter-groups comparison analysis patients with larger curve magnitude were shown to have significantly lower T score of spine. However, we still hold the view that BMD might have no effect on the progression of curve magnitude, considering that partial correlation analysis could better control potential interactions among variables. From earlier studies, it appeared that radiological parameters might serve as significant predictors of the progression of DLS. Pritchett et al. [4] reported that apical rotation, lateral vertebral translation of 6 mm or more, and the prominence of L5 in relation to the inter-crest line were important factors in predicting curve progression of DLS. In a recent study by Seo et al. [22], the relationship between the inter-crest line and the L5 vertebra was demonstrated to significantly affect the progression of DLS. Comparably, we also found that the level of L5 vertebra was remarkably associated with curve severity. Herein, we believed that radiological factors could offer better prediction of the progression of DLS, when compared with aging, female gender and lower BMD.

In the current study, we also preliminarily investigated the relationship between curve severity and healthy status by using VAS questionnaires. We found that low back pain of a varied degree did exist in DLS patients, while the pain itself had no relation with curve severity. This finding was partly consistent with the study of Schwab et al. [15], who reported no statistically significant correlation between degrees of adult scoliosis and VAS scores. Thus, it seemed that coronal deformity in DLS might have a less influence on the symptoms. Glassman et al. [23] investigated the curve pattern, curve magnitude, the coronal balance, the sagittal balance and apical rotation in 298 adults with scoliosis, and he concluded that sagittal balance was the most reliable predictor of symptoms. In a previous study which investigated predictors for self-reported pain level in adult scoliosis [24], Cobb angle was not a significant predictor, while lateral listhesis between adjacent lumbar vertebrae and lumbar lordosis were significant parameters, which could reflect pathologic loading of spinal elements and regional instability. Therefore, to clarify the influencing factors of DLS patients' symptoms, more radiological parameters of the sagittal profiles need to be further evaluated in patients with enough sample size.

Some limitations still exist in our study. As a non-invasive examination of bone density, DEXA has been routinely used to screen bone mass loss, which made it a convenient method for the epidemiology study of lumbar scoliosis [10, 13]. However, the curve magnitude measured in the image of DEXA might be a bit different, which was always smaller, from that measured on the standing X-ray film, with the body position shifting from supine to standing upright. Besides, as an inherent limitation of such prevalence study, it should be noted that some patients with disease or discomfort will be more inclined to participate in the program, thus leading to a bias in the data collection. More strict inclusion criteria and larger sample size might be helpful to obviate such bias. Third, our primary purpose was to investigate the prevalence of DLS, but, it has always been difficult to discern the two types of adult scoliosis, including ASA and DLS. In current study, we have attempted to avoid such a bias by inquiring the subjects whether they had a history of scoliosis before. However, it was very likely that some ASA patients were still taken as DLS patients, since these patients might have been unaware of their spinal deformity until DEXA examination, especially when having small curve magnitude and negligible anomaly of body appearance. Out of this limitation, the prevalence of DLS in this study could be a bit higher than the virtual one. We believed that only relying on the improvement in the understanding of etiology and diagnosis of DLS can such a bias be solved.

Conclusion

The prevalence of DLS in Chinese Han population was approximately 13.3 %, which had a significant relationship with age, gender and BMD. Osteopenia, gender of female, and age older than 65 years could significantly contribute to the presence of adult scoliosis. The curve severity was not associated with age, gender, BMI, or BMD.

Acknowledgments This work was supported by the National Public Health Benefit Research Foundation, China (Grant No. 201002018).

Conflict of interest No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

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