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Original Article

Prevalence and determinants of adolescent idiopathic scoliosis from school screening in Huangpu district, Shanghai, China

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Abstract: Objective: To identify the prevalence of adolescent idiopathic scoliosis (AIS) and potential disease-related factors in children aged 11 to 16 years in the Huangpu district, Shanghai, China. Methods: A total of 10,731 children (5,518 boys and 5,213 girls) were screened in the year of 2019. The screening process included a bending forward test and scoliometer measurements. The children who were deemed to be at risk for scoliosis from the screening were referred for a X-ray examination to confirm the diagnosis. Data from basic and clinical characteristics of the screened children were collected. Results: 214 children (138 girls and 76 boys, $P<0.05$) were diagnosed with scoliosis with a prevalence of 2.00%. The mean angel was 15.61°. The groups with the highest prevalence were girls aged 14 and boys aged 15. Conclusion: The prevalence of AIS in Huangpu district, Shanghai, China is 2.00% and is moderatley high, and it can occur more often in female children.

Keywords: Adolescent idiopathic scoliosis, school screening, Cobb angle, prevalence

Introduction

Adolescent idiopathic scoliosis (AIS) is the most common type of spinal deformity with a prevalence of 1-4% [1]. Since AIS is asymptomatic in its early stage, patients and their guardians often ignore it. Recently, the US Preventive Services Task Force (USPSTF) has shifted the recommendation for routine screening of asymptomatic adolescents for idiopathic scoliosis from negative to neutral [2]. Therefore, screening for scoliosis appears to be a valuable and an important way to identify patients with unrecognized scoliosis at an early stage [3]. They can receive early treatment (observation, exercise, bracing, and surgery) to avoid curve progression and adverse long-term health outcomes such as pulmonary disorders, disability, back pain, cosmetic issues, and reduced quality of life [4-7].

However, scoliosis screening is not popular in mainland China. According to the 2010 national population census, the population under the age of 15 in China is approximately 0.22 billion. The prevalence of scoliosis was 2.52% reported in Chongming [8] and 1.91% reported in Jing'an district [9]. Based on such a high incidence, it is estimated that there are about 4.20-5.54 million people under the age of 15 with scoliosis in China and more screening is necessary.

Therefore, we carried out this school scoliosis screening study in Huangpu district, Shanghai, to detect children with scoliosis and recommend corresponding treatments. In order to help clairify the relationship between prevalence and other factors.

Methods and materials

This was a cross-sectional study aimed at students aged 10-15 years of age (6th-8th grade) in Huangpu district, Shanghai, China. All 6th to 8th grade students in Huangpu district were enrolled without any restrictions or filtering process.

This study was approved by the Institution Review Board of the Second Affiliated Hospital

of Naval Medical University. All methods were carried out in accordance with relevant guidelines and regulations. All students and their legal guardians were well informed of comprehensive information about the screening process. Written informed consent was obtained from the legal guardians of all participating students.

Ten experienced orthopedists, 10 nurses, and 4 rehabilitation physicians from the Second Affiliated Hospital of Naval Medical University were well trained in the screening methods and criteria before the screening. The team members then informed the teachers and parents about the goals, importance and procedures of the school scoliosis screening study. Adam's forward bending test (FBT), visual inspection, and scoliometer measurements were used for scoliosis screening [10, 11]. The criteria to consider positivity of the tests included: (1) visual inspection: when shoulder asymmetries, scapula prominence, unequal waistline and lower limb length discrepancy appears; (2) FBT: bend forward with head bent and lower limbs extended. When the asymmetry of the trunk appears, this test is considered positive; (3) ATR: bend forward with head bent and lower limbs extended. Then the examiners measure the ATR using a scoliometer (Orthopedic Systems, Inc., CA, USA). If ATR is greater than 5°, this test is considered positive [12]. Once a child had at least one positive test, radiography was recommended to confirm the screening diagnosis and quantify the severity of the curve [2, 13].

SPSS version 21.0 (SPSS Inc., Chicago, IL, USA) was used to calculate all statistical analyses. Descriptive statistics in terms of frequencies, means, and standard deviations were provided in table for those screened positive. The overall prevalence, as well as the prevalence stratified by gender and age, was based on the cut-off point (a curve of 10° or more). The statistically significant differences in overall prevalence and Cobb angel distribution was calculated using the chi-squared test. The correlations between the quantitative variables of gender and age and the prevalence of AIS were identified by logistic regression analysis. $P<0.05$ was considered statistically significant.

Results

In the first phase of this school screening study, 462 (156 males and 306 females) out of 10,731 (4.31%) adolescents were found to be positive and need to receive a radiographic evaluation. Forty-four of them (24 males and 20 females) refused to undergo further examination, which meant that the response rate was 90.48%. Demographic information for these children is shown in **Table 1**. There are significant differences in gender. Students in grade 8 had the highest percentage of participation in radiography evaluation.

Among the children who received radiographic examination, 214 (76 males and 138 females) were confirmed with scoliosis by Cobb angels greater than 10° (51.20%), which meant the prevalence was 2.00%. The prevalence in females (2.65%) is significantly higher than in males (1.38%) ($P<0.001$) (**Table 2**). The prevalence of AIS and gender had a significant association using the logistic regression model ($P<0.05$). However, there were no significant differences by gender in Cobb angel ($P=0.36$) (**Figure 1**). The severity of the curve by age, gender, and grade is shown in **Table 3**.

Of the 214 patients with scoliosis, 182 had mild curves (10° to 19°), 23 patients had moderate curves (20° to 29°), and 9 patients had severe curves (>30°). Observation and professional exercises were recommended for 200 patients whose curves are 25° or less. Twelve patients with curves between 25° and 45° were advised with brace treatment. Also, 2 patients with curves greater than 45° who were Risser 2 were advised with surgical treatment. The distribution of curve magnitude by gender was not statistically significant.

Logistic regression analysis

By bivariate logistic regression analysis, being female, sitting more time, and dancing would significantly increase odds of being diagnosed. Age ($P=0.701$), bag type ($P=0.822$), bag weight ($P=0.295$), BMI ($P=0.101$), more time spent exercising ($P=0.150$), receiving milk supplementation (0.433), sleeping posture ($P=0.414$) and grade ($P=0.799$) were no longer significant in the present study. The bivariate odds ratios of the logistic regression models are shown in **Table 4**.

Discussion

In the present study of school screening for scoliosis, the prevalence rate in grade 6-8

Table 1. Demographic information of children identified in the first phase of screening

	Total (n=462)	Non-respondents (n=44)	Respondents (n=418)	*P*-value
Gender, n (%)				0.03
Male	153 (33.12)	21 (47.73)	132 (31.58)	
Female	309 (66.88)	23 (52.27)	286 (68.42)	
Age, years, mean (SD)	13.13 (0.93)	12.98 (1.09)	13.14 (0.91)	0.26
School grade, n (%)				0.37
6	151 (32.68)	18 (40.91)	133 (31.82)	
7	153 (33.12)	11 (25.00)	142 (33.97)	
8	158 (34.20)	15 (34.09)	143 (34.21)	
BMI, mean (SD)	19.92 (3.41)	19.49 (4.15)	19.96 (3.32)	0.39
Distance from home to school, mean (SD)	2.16 (1.10)	2.38 (1.11)	2.14 (1.10)	0.17
Schoolbag type, n (%)				0.35
Single-shoulder bag	7 (1.52)	1 (2.27)	6 (1.44)	
Backpack	417 (90.26)	37 (84.09)	380 (90.91)	
Trolley case	38 (8.23)	6 (13.64)	32 (7.66)	
Schoolbag weight mean (SD)	6.84 (3.25)	6.95 (2.84)	6.83 (3.29)	0.81
Exercise time, mean (SD)	1.91 (2.30)	1.96 (2.00)	1.80 (2.33)	0.65
No exercise, n (%)	156 (33.77)	10 (22.73)	146 (34.93)	0.10
Dancing time, mean (SD)	0.30 (1.03)	0.45 (0.76)	0.30 (1.03)	0.65
Sitting time, mean (SD)	10.42 (2.37)	9.87 (2.26)	10.49 (2.38)	0.10
Sleeping posture, n (%)				0.79
Supine	60 (12.99)	6 (13.64)	54 (12.92)	
Prone	45 (9.74)	3 (6.82)	42 (10.05)	
Lateral	357 (77.27)	35 (79.55)	322 (77.03)	
Calcium and milk supplement, n (%)	354 (76.62)	32 (72.73)	322 (77.03)	0.52
Family history, n (%)	26 (5.63)	1 (2.27)	25 (5.98)	0.31
Eutocia, n (%)	299 (64.72)	29 (65.91)	270 (64.59)	0.86

SD: standard deviation; BMI: body mass index.

schoolchildren in the Huangpu district, Shanghai, was 2.00%. In addition to regional and ethnic differences, the overall prevalence of scoliosis may be different because the methods and diagnostic criteria are not standardized in each screening study [14]. The prevalence of the present study is within the range of 0.13% to 3.26% as reported in previous studies from different countries [15-24] and similar to the prevalence of 2.52% reported in Chongming, China [8] and 1.91% reported in Jing' an district, Shanghai [9]. The percentage of students referred for radiographic evaluation is 4.31% (462 of 10731) and is within the range of 0.25%-19.79% that is similar in other reports [6, 14, 25-27].

In this study, we found that the prevalence of AIS was significantly higher among females. Several previous studies have confirmed the consensus of a higher prevalence of AIS in girls [16, 28, 29]. In the present study, the male/female ratio was 1:1.82, which is similar to that reported from Chongming (1:1.53), Shanghai, in 2016 [8] and Wuxi, Jiangsu Province, China (1:1.75) in 2016 [13]. Based on the publications of different countries (1:11.6 for Japan, 1:1 for Iran, 1:2.4 for Korea, 1:2.67 for Norwegian, 1:4.6 for Singapore) [16, 21, 28, 30-32], the male/female ratio in this study is higher than most of them, which indicates that the number of male patients aged 11-16 is greater in Huangpu district, Shanghai, China.

According to Raphael's study [32], ideally, screening for girls should be performed before menses and 1-2 years earlier than for boys. In their study, girls with Cobb angel >20° were all too mature to receive brace treatment. Although the present study did not count the radiological

Table 2. Clinical and radiological detected scoliosis in the adolescents according to grades and gender

Demographic variable	No. of students referred for X-ray	No. of students diagnosed positive	Prevalence of scoliosis (%)	Average Cobb angel (Degrees)
Gender				
Male	132	76	1.38	15.48
Female	286	138	2.65	15.67
Grade				
6th	133	66	1.86	15.09
7th	142	73	2.02	15.38
8th	143	75	2.10	16.28
Age				
11	5	3	1.39	12.67
12	112	57	1.80	14.79
13	138	69	1.99	15.94
14	146	76	2.27	16.00
15	15	9	1.83	15.78
16	2	0	/	/

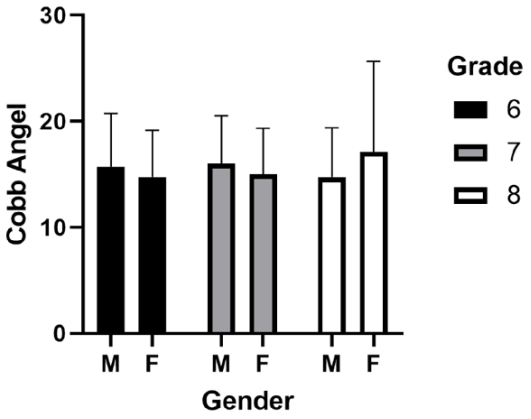

Figure 1. Comparison of mean Cobb angel between genders.

skeletal maturity of the students, the prevalence of scoliosis in girls before menses was significantly lower than in the others. In the present study, male and female patients had a similar prevalence with curve between 10°-20°, however, female patients were 1.5 times more likely than male patients to have curvature above 20°.

Cobb angels, 10° to 19°, were the most common in the present study (80%). Twenty-three patients (10 boys and 13 girls) had a moderate scoliosis curve and only 2 patients (2 girls) had a more severe curve. As shown in **Table 3**, the Cobb angel is positively related to the age of the patients, although there is no statistically significant correlation.

By logistic regression analysis, we found several predictors associated with the incidence of AIS. First, girls were more likely to be affected in the present screening, which was consistent with previous results. Second, we found that sitting more time and dancing were significantly associated with the incidence of AIS. In the present study, 68.69% (147 out of 214) of the students reported having a wrong sitting posture, which may influence the normal biomechanics of the spine. A cross-sectional study was designed to investigate the differences between the prevalence of AIS in ballet dancers and age-matched non-dancers [33]. In that study, about 30% of ballet dancers were tested positive while only 3% of non-dancers were tested positive. We concluded that adolescent dancers were at high risk of developing scoliosis compared to controls and dancers possessed characteristics such as hypermobility, low BMI, delayed menarche, which were associated with scoliosis.

Although the combination of FBT, the scoliometer test and Moiré topography had the highest sensitivity and specificity [11, 34, 35], the sensitivity cannot yet reach 100%. In Dalila's study, being positive for at least one examination (Adam's test, axial trunk rotation, and

Table 3. Curve magnitude by gender, grade and age among the 214 AIS patients

Demographic variable	No. of AIS patients with the curve magnitudes		
	Cobb Angel (10°-19°)	Cobb Angel (20°-30°)	Cobb Angel (>30°)
Gender			
Male	63	10	3
Female	119	13	5
Grade			
6th	57	7	2
7th	64	7	2
8th	61	9	5
Age			
11	3	/	/
12	48	6	2
13	60	8	2
14	64	7	5
15	7	2	/

Table 4. Odds rations and 95% CI for variables from bivariate logistic regression model

	OR	CI Lower bound	CI Upper bound	*P*-value
Gender	1.632	1.059	2.514	0.026
Sitting time	1.193	1.090	1.306	0.000
Dancing time	1.559	1.178	2.072	0.002

Plumb line) had the highest sensitivity (100%) and the lowest specificity (80.1%) [30]. In a 10-year follow-up program, the forward bending test produced 51 false negative results [36]. All this suggested that combining screening tests could optimize diagnostic sensitivity. With the popularity of the scoliometer APPs (ScolioTrack, Scoliosis Tools, Scoliometer, etc.) for the mobile phone, people with no medical background knowledge can determine whether scoliosis is present following the APPs' guidance and then consult a professional physician for further diagnosis and treatment. Therefore, we informed all students and their parents about these APPs to reduce the possibility of false negatives and monitor the Cobb angle of the patients. In this way, the entire screening study can be separated into three stages. However, the specificity of this method may be lower.

The present study has limitations. First, we only included schoolchildren in grades 6-8, but not all children between the ages of 11-16. Second, additional investigations should be done for the skeletal maturity of patients and a follow-up study of patients with scoliosis should also be performed after 6 or 12 months, which would collect more data on the long-term benefits and harms of scoliosis. Third, the lack of radiographic evaluation for some screened negative children made the calculation of false negative rates impossible.

Conclusion

In Shanghai, Huangpu District, the prevalence of AIS was 2.00% and within the range 0.13%-3.26% reported in previous studies. The highest prevalence of 2.95% was found in females aged 14 years, reminding researchers that future screening programs should focus on females. The present study provides evidence to support that the scoliosis screening study in annual school-based health screening programs (primary, junior and senior high schools) may be an effective way for early detection, which would allow young patients with potential issues to receive professional orthopedic and rehabilitation treatments.

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Disclosure of conflict of interest

None.

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References

[1] Cheng JC, Castelein RM, Chu WC, Danielsson AJ, Dobbs MB, Grivas TB, Gurnett CA, Luk KD, Moreau A, Newton PO, Stokes IA, Weinstein SL and Burwell RG. Adolescent idiopathic scoliosis. Nat Rev Dis Primers 2015; 1: 15030.

[2] US Preventive Services Task Force, Grossman DC, Curry SJ, Owens DK, Barry MJ, Davidson KW, Doubeni CA, Epling JW Jr, Kemper AR, Krist AH, Kurth AE, Landefeld CS, Mangione CM, Phipps MG, Silverstein M, Simon MA, Tseng CW. Screening for adolescent idiopathic scoliosis: US preventive services task force recommendation statement. JAMA 2018; 319: 165-172.

[3] Grivas TB, Vasiliadis ES, Rodopoulos G and Kovanis I. School screening as a research tool in epidemiology, natural history and aetiology of idiopathic scoliosis. Stud Health Technol Inform 2008; 135: 84-93.

[4] Grivas TB, Vasiliadis ES, Maziotou C and Savvidou OD. The direct cost of "Thriasio" school screening program. Scoliosis 2007; 2: 7.

[5] Thilagaratnam S. School-based screening for scoliosis: is it cost-effective? Singapore Med J 2007; 48: 1012-1017.

[6] Ugras AA, Yilmaz M, Sungur I, Kaya I, Koyuncu Y and Cetinus ME. Prevalence of scoliosis and cost-effectiveness of screening in schools in Turkey. J Back Musculoskelet Rehabil 2010; 23: 45-48.

[7] Lee CF, Fong DY, Cheung KM, Cheng JC, Ng BK, Lam TP, Mak KH, Yip PS and Luk KD. Costs of school scoliosis screening: a large, population-based study. Spine (Phila Pa 1976) 2010; 35: 2266-2272.

[8] Du Q, Zhou X, Negrini S, Chen N, Yang XY, Liang JP and Sun K. Scoliosis epidemiology is not similar all over the world: a study from a scoliosis school screening on Chongming Island (China). BMC Musculoskelet Disord 2016; 17: 303.

[9] Tang QR SY, Zhang J, Yu XY, Guo Y. Prevalence of adolescent idiopathic scoliosis (AIS) from school screening in Jing'an district, Shanghai, China [in Chinese]. International Journal of Orthopaedics 2017; 38.

[10] Hengwei F, Zifang H, Qifei W, Weiqing T, Nali D, Ping Y and Junlin Y. Prevalence of Idiopathic Scoliosis in Chinese schoolchildren: a large, population-based study. Spine (Phila Pa 1976) 2016; 41: 259-264.

[11] Luk KD, Lee CF, Cheung KM, Cheng JC, Ng BK, Lam TP, Mak KH, Yip PS and Fong DY. Clinical effectiveness of school screening for adolescent idiopathic scoliosis: a large population-based retrospective cohort study. Spine (Phila Pa 1976) 2010; 35: 1607-1614.

[12] Coelho DM, Bonagamba GH and Oliveira AS. Scoliometer measurements of patients with idiopathic scoliosis. Braz J Phys Ther 2013; 17: 179-184.

[13] Zheng Y, Wu XJ, Dang YN, Yang Y, Reinhardt JD and Dang YJ. Prevalence and determinants of idiopathic scoliosis in primary school children in Beitang district, Wuxi, China. J Rehabil Med 2016; 48: 547-553.

[14] Pin LH, Mo LY, Lin L, Hua LK, Hui HP, Hui DS, Chang BD, Chang YY and Yuan L. Early diagnosis of scoliosis based on school-screening. J Bone Joint Surg Am 1985; 67: 1202-1205.

[15] Daruwalla JS, Balasubramaniam P, Chay SO, Rajan U and Lee HP. Idiopathic scoliosis. Prevalence and ethnic distribution in Singapore schoolchildren. J Bone Joint Surg Br 1985; 67: 182-184.

[16] Wong HK, Hui JH, Rajan U and Chia HP. Idiopathic scoliosis in Singapore schoolchildren: a prevalence study 15 years into the screening program. Spine (Phila Pa 1976) 2005; 30: 1188-1196.

[17] Mittal RL, Aggerwal R and Sarwal AK. School screening for scoliosis in India. The evaluation of a scoliometer. Int Orthop 1987; 11: 335-338.

[18] Koukourakis I, Giaourakis G, Kouvidis G, Kivernitakis E, Blazos J and Koukourakis M. Screening school children for scoliosis on the island of Crete. J Spinal Disord 1997; 10: 527-531.

[19] Soucacos PN, Soucacos PK, Zacharis KC, Beris AE and Xenakis TA. School-screening for scoliosis. A prospective epidemiological study in northwestern and central Greece. J Bone Joint Surg Am 1997; 79: 1498-1503.

[20] Jenyo MS and Asekun-Olarinmoye EO. Prevalence of scoliosis in secondary school children in Osogbo, Osun State, Nigeria. Afr J Med Med Sci 2005; 34: 361-364.

[21] Suh SW, Modi HN, Yang JH and Hong JY. Idiopathic scoliosis in Korean schoolchildren: a prospective screening study of over 1 million children. Eur Spine J 2011; 20: 1087-1094.

[22] Chan A, Moller J, Vimpani G, Paterson D, Southwood R and Sutherland A. The case for scoliosis screening in Australian adolescents. Med J Aust 1986; 145: 379-383.

[23] Yong F, Wong HK and Chow KY. Prevalence of adolescent idiopathic scoliosis among female school children in Singapore. Ann Acad Med Singap 2009; 38: 1056-1063.

[24] Yilmaz H, Zateri C, Kusvuran Ozkan A, Kayalar G and Berk H. Prevalence of adolescent idiopathic scoliosis in Turkey: an epidemiological study. Spine J 2020; 20: 947-955.

[25] Lonstein JE, Bjorklund S, Wanninger MH and Nelson RP. Voluntary school screening for scoliosis in Minnesota. J Bone Joint Surg Am 1982; 64: 481-488.

[26] Randall FM and Denton TE. Scoliosis screening: a school survey. Ala J Med Sci 1983; 20: 395-396.

[27] Al-Arjani AM, Al-Sebai MW, Al-Khawashki HM and Saadeddin MF. Epidemiological patterns

of scoliosis in a spinal center in Saudi Arabia. Saudi Med J 2000; 21: 554-557.
[28] Ueno M, Takaso M, Nakazawa T, Imura T, Saito W, Shintani R, Uchida K, Fukuda M, Takahashi K, Ohtori S, Kotani T and Minami S. A 5-year epidemiological study on the prevalence rate of idiopathic scoliosis in Tokyo: school screening of more than 250,000 children. J Orthop Sci 2011; 16: 1-6.
[29] Yawn BP. School-screening for scoliosis. A prospective epidemiological study in northwestern and central Greece. J Bone Joint Surg Am 1998; 80: 1244.
[30] Scaturro D, de Sire A, Terrana P, Costantino C, Lauricella L, Sannasardo CE, Vitale F and Mauro GL. Adolescent idiopathic scoliosis screening: could a school-based assessment protocol be useful for an early diagnosis? J Back Musculoskelet Rehabil 2021; 34: 301-306.
[31] Moalej S, Asadabadi M, Hashemi R, Khedmat L, Tavacolizadeh R, Vahabi Z and Shariatpanahi G. Screening of scoliosis in school children in Tehran: the prevalence rate of idiopathic scoliosis. J Back Musculoskelet Rehabil 2018; 31: 767-774.
[32] Adobor RD, Rimeslatten S, Steen H and Brox JI. School screening and point prevalence of adolescent idiopathic scoliosis in 4000 Norwegian children aged 12 years. Scoliosis 2011; 6: 23.
[33] Longworth B, Fary R and Hopper D. Prevalence and predictors of adolescent idiopathic scoliosis in adolescent ballet dancers. Arch Phys Med Rehabil 2014; 95: 1725-1730.
[34] Lee CF, Fong DY, Cheung KM, Cheng JC, Ng BK, Lam TP, Mak KH, Yip PS and Luk KD. Referral criteria for school scoliosis screening: assessment and recommendations based on a large longitudinally followed cohort. Spine (Phila Pa 1976) 2010; 35: E1492-1498.
[35] Fong DY, Cheung KM, Wong YW, Wan YY, Lee CF, Lam TP, Cheng JC, Ng BK and Luk KD. A population-based cohort study of 394,401 children followed for 10 years exhibits sustained effectiveness of scoliosis screening. Spine J 2015; 15: 825-833.
[36] Karachalios T, Sofianos J, Roidis N, Sapkas G, Korres D and Nikolopoulos K. Ten-year follow-up evaluation of a school screening program for scoliosis. Is the forward-bending test an accurate diagnostic criterion for the screening of scoliosis? Spine (Phila Pa 1976) 1999; 24: 2318-2324.