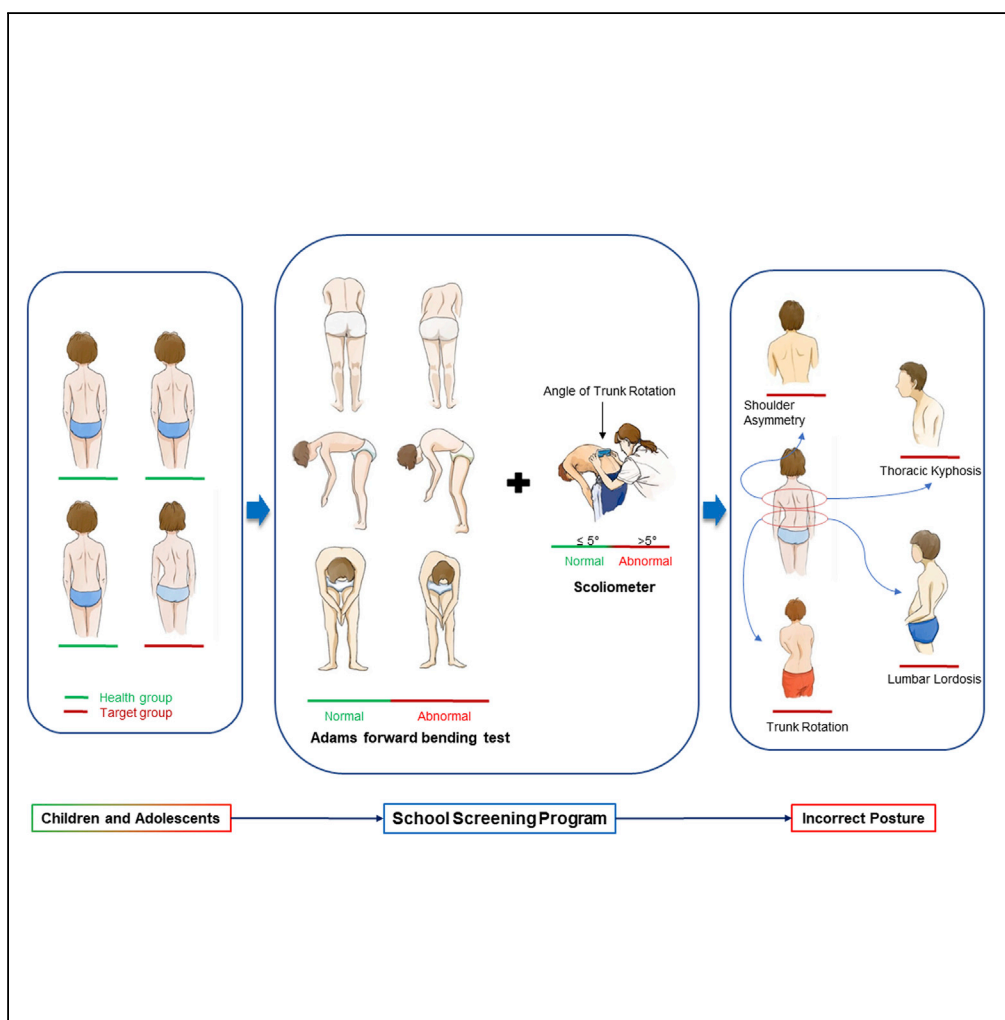


Article

Prevalence of Incorrect Posture among Children and Adolescents: Finding from a Large Population-Based Study in China

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Yang et al., iScience 23, 101043
May 22, 2020 © 2020 The Author(s).
<https://doi.org/10.1016/j.isci.2020.101043>



Article

Prevalence of Incorrect Posture among Children and Adolescents: Finding from a Large Population-Based Study in China

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SUMMARY

Evidence showed that bad posture in adulthood is often formed from the childhood, and individuals with severe incorrect posture may be associated with the progress of scoliosis. We aimed to estimate the prevalence of incorrect posture in Chinese children and adolescents and to describe the epidemiological findings stratified by the demographic characteristics. A total of 595,057 students were screened; the overall prevalence of incorrect posture in children and adolescents was 65.3%, and around 3.7% of the students were referred to radiography. Girls had a higher prevalence of incorrect posture than boys, students aged >10 years accounted for a higher rate of incorrect posture than students aged <10 years. We found that Chinese children and adolescents had a high prevalence of incorrect posture, with girls and older students being an especially high-risk group. Early interventions targeted for students with incorrect posture are urgently needed.

INTRODUCTION

Incorrect posture refers to an abnormal body state in which the body cannot maintain a stable state and the normal function of tissues and organs in an upright state (Dolphens et al., 2012). Previous studies have shown that the bad posture in adulthood is often formed from the childhood (Louw et al., 2007). Severe incorrect posture in children and adolescents with may be associated with progress to adolescent idiopathic scoliosis (Nissinen et al., 1993; Nault et al., 2002). Moreover, untreated incorrect posture was shown to be associated with the reduction in cardiorespiratory efficiency, decreased vital capacity of lungs, low back pains, and the displacement of internal organs (Yu et al., 2002). Understanding the current prevalence of incorrect posture of children and adolescents will help to identify high-risk population and formulate targeted interventions.

Previous studies showed that 34%–50% children and adolescents have different degrees of incorrect posture (Motylewski et al., 2016; Mahlknecht, 2007); less than a fifth of children and adolescents have a correct body posture (Kamal, 2008); most of the children have certain incorrect posture problems (e.g., shoulder asymmetry, thoracic kyphosis, or scapula tilt). Furthermore, some researchers suggested that compared with children of the same age who have not received school education, students who have received school education have more serious body posture problems (Macialczyk-paprocka et al., 2017; Kasten et al., 2017).

To the best of our knowledge, previous evidence mainly comes from the Western or developed countries. In China, only one school screening program conducted in Beijing showed that nearly 80% children and adolescents were reported to have at least one sign of incorrect postures (Xing, 2018). However, there is still a lack of population-based epidemiological evidence in the prevalence of adolescent incorrect posture.

Therefore, we conducted this large-scale cross-sectional study in south China to estimate the prevalence of incorrect posture among children and adolescents, to describe the epidemiological findings stratified by the demographic characteristics, which will provide data support to find out high-risk population and develop targeted interventions.

RESULTS

Demographic Characteristics of Chinese Children and Adolescents

The sample demographic information is shown in Table 1. A total of 595,057 Chinese children and adolescents were screened, among which 54.6% were boys and 45.4% were girls, yielding a male-to-female ratio of 1.2:1, and the mean (SD) age of the students was 12.8 ± 2.0 years. Primary school, junior high school, and senior high school students account for 38.0%, 42.7%, and 19.3%, respectively.

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<https://doi.org/10.1016/j.isci.2020.101043>



Variables	N (%)	
Gender		
Boy	3,24,932 (54.6)	
Girl	2,70,125 (45.4)	
Age (year, mean \pm SD)	12.8 \pm 2.0	
Ethnic group		
Han	5,77,205 (97.0)	
Minority	17,852 (3.0)	
School category		
Primary school	2,26,121 (38.0)	
Junior high school	2,54,089 (42.7)	
Senior high school	1,14,847 (19.3)	
Grade (age [years], mean \pm SD)		
Grade 1 (7.26 \pm 1.09)	1,190 (0.2)	
Grade 2 (8.11 \pm 0.98)	1,785 (0.3)	
Grade 3 (9.35 \pm 1.12)	1,796 (0.3)	
Grade 4 (10.44 \pm 0.89)	1,856 (0.3)	
Grade 5 (11.40 \pm 0.56)	1,13,060 (19.0)	
Grade 6 (12.37 \pm 0.44)	1,06,515 (17.9)	
Grade 7 (13.30 \pm 0.39)	91,638 (15.4)	
Grade 8 (14.29 \pm 0.45)	89,258 (15.0)	
Grade 9 (15.32 \pm 0.37)	72,596 (12.2)	
Grade 10 (16.24 \pm 0.42)	59,505 (10.0)	
Grade 11 (17.28 \pm 0.51)	53,555 (9.0)	
Grade 12 (18.24 \pm 0.79)	2,303 (0.4)	

Table 1. Demographic Characteristics of Chinese Children and Adolescents (N = 595,057)

N, number; SD, standard deviation.

Prevalence of Incorrect Posture of Chinese Children and Adolescents

As shown in Table 2, the overall prevalence of incorrect posture among Chinese children and adolescents was 65.3% (95% confidence interval [CI]: 65.0%–65.5%), and around 3.7% (95% CI: 3.6%–3.8%) children and adolescents were referred for radiography. The most serious sign of incorrect posture was high and low shoulders (left shoulder height: 30.2%, 95% CI: 30.0%–30.5%; right shoulder height: 24.5%, 95% CI: 24.2%–24.7%) and scapula tilt (tilt to the left: 25.2%, 95% CI: 25.0%–25.5%; tilt to the right: 17.0%, 95% CI: 16.8%–17.1%).

Prevalence of Incorrect Posture of Chinese Children and Adolescents Stratified by Gender

According to gender (as shown in Table 3), the prevalence of incorrect posture was significantly higher in girls than that in boys (76.0% versus 56.6%, $\chi^2 = 24,534.72$, $p < 0.001$), and girls had a 1.34 times higher prevalence of incorrect posture than boys. As for the prevalence of referral for radiography, girls accounted for a higher rate than boys (5.2% versus 2.4%, $\chi^2 = 3,270.10$, $p < 0.001$). Besides pelvic tilt and thoracic kyphosis, the rest of the abnormal signs were higher for girls than boys.

Prevalence of Incorrect Posture of Chinese Children and Adolescents Stratified by Age

According to age (as shown in Table 4), the prevalence of incorrect posture was significantly higher in students aged 10–15 years and >15 years than in students aged <10 years (64.8% and 71.1% versus 41.3%,

Variables	N (%)	95% CI
Total	5,95,057 (100.0)	–
High and low shoulder		
Normal	2,69,560 (45.3)	45.1%–45.6%
Left shoulder height	1,79,707 (30.2)	30.0%–30.5%
Right shoulder height	1,45,790 (24.5)	24.2%–24.7%
Scapula tilt		
Normal	3,43,942 (57.8)	57.6%–58.1%
Tilt to the left	1,49,954 (25.2)	25.0%–25.5%
Tilt to the right	1,01,161 (17.0)	16.8%–17.1%
Pelvic tilt		
Normal	5,48,642 (92.2)	92.0%–92.3%
Tilt to the left	22,612 (3.8)	3.7%–3.9%
Tilt to the right	23,803 (4.0)	3.9%–4.2%
Flat back		
Normal	5,90,891 (99.3)	99.2%–99.4%
Abnormal	4,166 (0.7)	0.6%–0.8%
Thoracic kyphosis		
Normal	5,78,990 (97.3)	97.2%–97.4%
Abnormal	16,067 (2.7)	2.6%–2.8%
Lumbar concave		
Normal	4,58,193 (77.0)	76.8%–77.2%
Left concave	55,340 (9.3)	9.2%–9.4%
Right concave	81,524 (13.7)	13.5%–13.8%
Lumbar lordosis		
Normal	5,92,081 (99.5)	99.4%–99.6%
Abnormal	2,976 (0.5)	0.4%–0.6%
Lumbar kyphosis		
Normal	5,93,866 (99.8)	99.7%–99.9%
Abnormal	1,191 (0.2)	0.1%–0.3%
Angle of thoracic rotation		
Normal (ATR: 0–5°)	5,86,131 (98.5)	98.4%–98.6%
Rotate to the left (ATR>5°)	2,380 (0.4)	0.3%–0.5%
Rotate to the right (ATR>5°)	6,546 (1.1)	1.0%–1.2%
Angle of lumbar rotation		
Normal (ATR: 0–5°)	5,82,560 (97.9)	97.8%–98.0%
Rotate to the left (ATR>5°)	9,520 (1.6)	1.5%–1.7%
Rotate to the right (ATR>5°)	2,977 (0.5)	0.4%–0.6%

Table 2. Prevalence of Incorrect Posture among Chinese Children and Adolescents (N = 595,057)

(Continued on next page)

Variables	N (%)	95% CI
Angle of thoracolumbar rotation		
Normal (ATR: 0–5°)	5,92,676 (99.6)	99.5%–99.7%
Rotate to the left (ATR>5°)	1,190 (0.2)	0.1%–0.3%
Rotate to the right (ATR>5°)	1,191 (0.2)	0.1%–0.3%
Incorrect posture ^a		
Normal	2,06,484 (34.7)	34.5%–35.0%
Abnormal	3,88,573 (65.3)	65.0%–65.5%
Referral for radiography ^b		
No	5,73,039 (96.3)	96.2%–96.4%
Yes	22,018 (3.7)	3.6%–3.8%

Table 2. Continued

N, number; CI, confidence interval; ATR, angle of trunk rotation.

^aIncorrect posture was defined as participant who was screened out one or more to the following abnormal physical signs: high and low shoulder, scapula tilt, pelvic tilt, flat back, thoracic kyphosis, lumbar concave, lumbar lordosis, lumbar kyphosis, angle of thoracic rotation>5°, angle of lumbar rotation>5°, angle of thoracolumbar rotation>5°.

^bReferral for radiography: an angle of trunk (thoracic, lumbar or thoracolumbar) rotation of 5° was the recommended threshold for referral to radiography.

$\chi^2 = 2,469.68$, $p < 0.001$); students aged 10–15 years and >15 years had a 1.57 and 1.72 times higher prevalence of incorrect posture than students aged <10 years, respectively. Students aged 10–15 years and >15 years had a higher prevalence of referral for radiography than students aged <10 years (3.3% and 6.7% versus 0.5%, $\chi^2 = 2,185.58$, $p < 0.001$). Besides lumbar lordosis and lumbar kyphosis, the rest of the abnormal signs were higher for students aged 10–15 years and >15 years than students aged <10 years.

DISCUSSION

Higher incidence of incorrect posture in children and adolescents may have negative impact on the whole metabolism, including the cardiopulmonary function and skeletal system (Yu et al., 2002; Macialczyk-paprocka et al., 2017). Our large-scale population-based study found that Chinese children and adolescents had serious body posture problems, and around 3.7% of the children and adolescents were referred for radiography; girls and senior students were especially at high risk. These findings help to describe the epidemiological characteristics of incorrect posture in Chinese children, and provide evidence for identifying high-risk groups and develop targeted interventions.

Our results illustrated that the overall prevalence of incorrect posture among children and adolescents in China was 65.3%, and around 3.7% children and adolescents were referred for radiography, which was similar to previous research findings (Luk et al., 2010; Lee et al., 2010). In Western countries, most of the primary and secondary school students have a certain degree of incorrect posture, and only 18%–50% children and adolescents have a correct body posture (Kratenová et al., 2007; Jakub, 2011). The findings of our study also showed similar epidemic characteristics with previous studies; the high and low shoulders and scapula tilt account for a high proportion, indicating that the physical posture of children and adolescents in China has become more serious, which needs to be seriously considered by education departments and related public health organizations.

Furthermore, our group comparison results showed that the prevalence of incorrect posture in girls was much higher than that in boys, and 5.2% girls were referred for radiography, which was 2.2 times higher than that in boys. Our findings were consistent with the studies of Alen (Alen Ćirić, 2015) and Penha (Penha et al., 2017), but a study conducted in northern China showed that boys had a higher prevalence of incorrect posture than girls (Li, 2018). This variation in results may derive from the different sampling areas and age structures. Owing to the earlier physiological development, girls are more likely to extend their neck and chest to reduce the change of appearance image (Cash and Pruzinsky, 1992; Feingold and Mazzella, 1998). Besides, girls may show less physical activity intensity than boys, which tends to lead to lack of muscle

Variables	Gender		χ^2	P
	Boy	Girl		
Total	3,24,932 (54.6)	2,70,125 (45.4)		
High and low shoulder			36,711.32	<0.001
Normal	1,80,987 (55.7)	87,521 (32.4)		
Left shoulder height	88,707 (27.3)	91,302 (33.8)		
Right shoulder height	55,238 (17.0)	91,302 (33.8)		
Scapula tilt			16,528.11	<0.001
Normal	2,09,256 (64.4)	1,34,252 (49.7)		
Tilt to the left	76,359 (23.5)	74,014 (27.4)		
Tilt to the right	39,317 (12.1)	61,859 (22.9)		
Pelvic tilt			8,221.85	<0.001
Normal	2,64,495 (81.4)	2,41,222 (89.3)		
Tilt to the left	22,745 (7.0)	14,317 (5.3)		
Tilt to the right	37,692 (11.6)	14,586 (5.4)		
Flat back			1,013.62	<0.001
Normal	3,23,632 (99.6)	2,67,154 (98.9)		
Abnormal	1,300 (0.4)	2,971 (1.1)		
Thoracic kyphosis			456.12	<0.001
Normal	3,14,859 (96.9)	2,64,182 (97.8)		
Abnormal	10,073 (3.1)	5,943 (2.2)		
Lumbar concave			8,201.27	<0.001
Normal	2,64,495 (81.4)	1,93,680 (71.7)		
Left concave	22,745 (7.0)	32,685 (12.1)		
Right concave	37,692 (11.6)	43,760 (16.2)		
Lumbar lordosis			120.80	<0.001
Normal	3,23,632 (99.6)	2,68,504 (99.4)		
Abnormal	1,300 (0.4)	1,621 (0.6)		
Lumbar kyphosis			60.05	<0.001
Normal	3,24,282 (99.8)	2,69,315 (99.7)		
Abnormal	650 (0.2)	810 (0.3)		
Angle of thoracic rotation			1,450.34	<0.001
Normal (ATR: 0–5°)	3,21,682 (99.0)	2,64,452 (97.9)		
Rotate to the left (ATR>5°)	1,300 (0.4)	1,351 (0.5)		
Rotate to the right (ATR>5°)	1,950 (0.6)	4,322 (1.6)		
Angle of lumbar rotation			1,656.85	<0.001

Table 3. Prevalence of Incorrect Posture Stratified by Gender (N = 595,057)

(Continued on next page)

Variables	Gender		χ^2	P
Normal (ATR: 0–5°)	3,20,383 (98.6)	2,62,291 (97.1)		
Rotate to the left (ATR>5°)	3,249 (1.0)	5,943 (2.2)		
Rotate to the right (ATR>5°)	1,300 (0.4)	1,891 (0.7)		
Angle of thoracolumbar rotation			514.32	<0.001
Normal (ATR: 0–5°)	3,23,957 (99.7)	2,68,234 (99.3)		
Rotate to the left (ATR>5°)	325 (0.1)	810 (0.3)		
Rotate to the right (ATR>5°)	650 (0.2)	1,081 (0.4)		
Incorrect posture^a			24,534.72	<0.001
Normal	1,41,020 (43.4)	64,830 (24.0)		
Abnormal	1,83,912 (56.6)	2,05,295 (76.0)		
Referral for radiography^b			3,270.10	<0.001
No	3,17,134 (97.6)	2,56,079 (94.8)		
Yes	7,798 (2.4)	14,046 (5.2)		

Table 3. Continued

ATR, angle of trunk rotation.

^aIncorrect posture was defined as participant who was screened out one or more to the following abnormal physical signs: high and low shoulder, scapula tilt, pelvic tilt, flat back, thoracic kyphosis, lumbar concave, lumbar lordosis, lumbar kyphosis, angle of thoracic rotation>5°, angle of lumbar rotation>5°, angle of thoracolumbar rotation>5°.

^bReferral for radiography: an angle of trunk (thoracic, lumbar or thoracolumbar) rotation of 5° was the recommended threshold for referral to radiography.

strength, making girls more difficult to control body posture than boys (Klassonheggebo and Anderssen, 2003). Therefore, based on these possible reasons, girls may be a high-risk group with incorrect posture.

Previous studies have shown that with age, body posture problems of children and adolescents would become more serious (Ludwig et al., 2016). Our results also found that students aged 10–15 years and aged >15 years had more serious body posture problems than students aged <10 years. The reason for the rising trend of incorrect posture rate with aging may be related to the increase of hormone secretion and the significant changes of physical development and mental status in adolescence (Richmond and Rogol, 2016; Hackney et al., 2016). In addition, with the rapid growth of adolescents in puberty, their biomechanical condition may change during this period (Stokes, 2007). Many adolescents are attending school and sitting for a long time, which may lead to muscular imbalance of their trunk muscles (Falk and Bradl, 2013). Therefore, adolescence may be a period of high incidence of incorrect posture.

In our large-scale school screening program conducted in south China, apart from the objective criteria (angle of trunk rotation of thoracic, lumbar, or thoracolumbar), a student would also be examined when there were significant signs of body appearances, including uneven shoulder height, scapular prominence, hip and pelvic obliquity, and so on (Hengwei et al., 2016; Lee et al., 2010). To our best knowledge, this is the first population-based study to report the prevalence of incorrect posture of children and adolescents. Our findings can provide essential information to better understand the epidemiology of incorrect posture, which can be an important reason for progression to adolescent idiopathic scoliosis, and to help policymakers develop appropriate program through rational planning. Our data showed that there is a high prevalence of incorrect posture among Chinese children and adolescents. As girls and senior students are found to account for a higher rate, it is of great importance to screen those students.

Limitations of the Study

The present study has several limitations that are worth noting. First, due to the cross-sectional nature of the data, it is difficult to make causal inferences. Second, our study sample included only school students and did not include children and adolescents who had dropped out of school or were not present in school

Variables	Age (year)			χ^2	P
	<10	10–15	>15		
Total	5,355 (0.9)	5,18,890 (87.2)	70,812 (11.9)		
High and low shoulder				2,906.49	<0.001
Normal	3,722 (69.5)	2,37,652 (45.8)	27,900 (39.4)		
Left shoulder height	562 (10.5)	1,53,591 (29.6)	25,634 (36.2)		
Right shoulder height	1,071 (20.0)	1,27,647 (24.6)	17,278 (24.4)		
Scapula tilt				732.69	<0.001
Normal	3,925 (73.3)	3,00,437 (57.9)	39,513 (55.8)		
Tilt to the left	702 (13.1)	1,30,241 (25.1)	19,261 (27.2)		
Tilt to the right	728 (13.6)	88,212 (17.0)	12,038 (17.0)		
Pelvic tilt				371.31	<0.001
Normal	5291 (98.8)	4,78,417 (92.2)	64,864 (91.6)		
Tilt to the left	27 (0.5)	19,718 (3.8)	2,762 (3.9)		
Tilt to the right	37 (0.7)	20,755 (4.0)	3,186 (4.5)		
Flat back				343.53	<0.001
Normal	5,339 (99.7)	5,15,777 (99.4)	69,962 (98.8)		
Abnormal	16 (0.3)	3,133 (0.6)	850 (1.2)		
Thoracic kyphosis				133.89	<0.001
Normal	5312 (99.2)	5,04,361 (97.2)	69,183 (97.7)		
Abnormal	43 (0.8)	14,529 (2.8)	1,629 (2.3)		
Lumbar concave				1,588.28	<0.001
Normal	4,840 (90.4)	4,02,140 (77.5)	51,197 (72.3)		
Left concave	220 (4.1)	46,700 (9.0)	8,497 (12.0)		
Right concave	295 (5.5)	70,050 (13.5)	11,118 (15.7)		
Lumbar lordosis				14.19	0.132
Normal	5,323 (99.4)	5,16,296 (99.5)	70,529 (99.6)		
Abnormal	32 (0.6)	2,594 (0.5)	283 (0.4)		
Lumbar kyphosis				3.04	0.218
Normal	5,350 (99.9)	5,17,852 (99.8)	70,670 (99.8)		
Abnormal	5 (0.1)	1,038 (0.2)	142 (0.2)		
Angle of thoracic rotation				825.29	<0.001
Normal (ATR: 0–5°)	5,350 (99.9)	5,12,144 (98.7)	68,971 (97.4)		
Rotate to the left (ATR>5°)	0 (0.0)	2,076 (0.4)	496 (0.7)		
Rotate to the right (ATR>5°)	5 (0.1)	4,670 (0.9)	1,345 (1.9)		
Angle of lumbar rotation				1,461.42	<0.001

Table 4. Prevalence of Incorrect Posture Stratified by Age (N = 595,057)

(Continued on next page)

Variables	Age (year)			χ^2	P
Normal (ATR: 0–5°)	5,339 (99.7)	5,09,550 (98.2)	68,050 (96.1)		
Rotate to the left (ATR>5°)	11 (0.2)	7,264 (1.4)	2,124 (3.0)		
Rotate to the right (ATR>5°)	5 (0.1)	2,076 (0.4)	638 (0.9)		
Angle of thoracolumbar rotation				240.36	<0.001
Normal (ATR: 0–5°)	5,350 (99.9)	5,16,814 (99.6)	70,246 (99.2)		
Rotate to the left (ATR>5°)	0 (0.0)	1,036 (0.2)	282 (0.4)		
Rotate to the right (ATR>5°)	5 (0.1)	1,040 (0.2)	284 (0.4)		
Incorrect posture^a				2,469.68	<0.001
Normal	3,143 (58.7)	1,82,649 (35.2)	20,465 (28.9)		
Abnormal	2,212 (41.3)	3,36,241 (64.8)	50,347 (71.1)		
Referral for radiography^b				2,185.58	<0.001
No	5,328 (99.5)	5,01,767 (96.7)	66,068 (93.3)		
Yes	27 (0.5)	17,123 (3.3)	4,744 (6.7)		

Table 4. Continued

Abbreviations: ATR, angle of trunk rotation.

The alpha level for paired comparison was set at $p = 0.0167$ after Bonferroni correction.

^aIncorrect posture was defined as participant who was screened out one or more to the following abnormal physical signs: high and low shoulder, scapula tilt, pelvic tilt, flat back, thoracic kyphosis, lumbar concave, lumbar lordosis, lumbar kyphosis, angle of thoracic rotation>5°, angle of lumbar rotation>5°, angle of thoracolumbar rotation>5°.

^bReferral for radiography: an angle of trunk (thoracic, lumbar or thoracolumbar) rotation of 5° was the recommended threshold for referral to radiography.

on the day the screening was conducted. Third, although gender and age have been reported to be important factors in incorrect posture (Ludwig et al., 2016), other relevant influencing factors (e.g., genetics, hormone, and nutritional status) (Weinstein et al., 2008; Yang et al., 2009; Sousa et al., 2016) have not been investigated in this study. In addition, our study did not measure students' height, weight, and body fat, so we could not explore the association of these anthropometric data with incorrect posture.

Conclusion

Our population-based epidemiology evidence showed that Chinese children and adolescents have a significantly high prevalence of incorrect posture, and girls and older students may be an especially high-risk group. Appropriate prevention and intervention programs targeted for school students should be established to improve their physical health.

METHODS

All methods can be found in the accompanying [Transparent Methods supplemental file](#).

DATA AND CODE AVAILABILITY

The datasets used and analyzed during this study are available from the corresponding authors upon reasonable request.

SUPPLEMENTAL INFORMATION

Supplemental Information can be found online at <https://doi.org/10.1016/j.isci.2020.101043>.

ACKNOWLEDGMENTS

The authors would like to express sincere respect to the local health professionals and department of education and would like to thank Director Ling Zhang for their valuable contribution in setting up the

Shenzhen school screening program. In addition, the authors also thank Mr. Qihua Que, Ms. Qian Zhang, and other rehabilitation therapists for screening tests of school students and data collection. Finally, we would like to thank Ms. Qiaohong Chen for providing professional language help. This study was financially supported by the Scoliosis Screening Program for primary and secondary school students in Shenzhen (Project number: SFG [2019] No.780) and Study on the training effects of adolescent idiopathic scoliosis in Shenzhen (Project number: No.20193357005).

AUTHOR CONTRIBUTIONS

Y.H. designed and supervised the research; B.Y. and X.L. collected the screening data; B.Y. carried out the statistical analysis; B.Y. and Y.H. wrote the original draft; Y.H. reviewed and corrected the revised manuscript.

DECLARATION OF INTERESTS

The authors declare no conflict of interest.

Received: December 9, 2019

Revised: February 27, 2020

Accepted: April 2, 2020

Published: May 22, 2020

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iScience, Volume 23

Supplemental Information

Prevalence of Incorrect Posture among Children and Adolescents: Finding from a Large Population-Based Study in China

Lei Yang, Xinhai Lu, Bin Yan, and Yeen Huang

TRANSPARENT METHODS:

Study design and participants

This is a school-based cross-sectional study in children and adolescent students from the Shenzhen city in south China. All students were selected by a 3-stage, stratified-cluster, random-sampling method. In stage 1, we divided Shenzhen city into three economic stratifications (high-level, middle-level, and low-level) by per capita GDP (gross domestic product), and then selected two districts from each stratification by simple randomization using random number generator. In stage 2, schools in each district were divided into three categories: primary schools (i.e., grades 1-6), junior high schools (i.e., grades 7-9), and senior high schools (i.e., grades 10-12). Based on the proportions of these three types of schools, six primary schools, six junior high schools, and three senior high schools were randomly selected from each representative district. In stage 3, all classes from each grade within the selected schools were included in our study, and all available students in the selected classes were invited to voluntarily participate in the present study. In total, 595,057 students were completed and qualified for our study.

Ethical statement

This study was conducted in accordance with the Declaration of Helsinki, and was approved by the Shenzhen Second People's Hospital Institutional Review Board. Written or oral informed consent was obtained from the parent or legal guardian of each participating student under 18 years old or from each participating student who was at least 18 years old.

Data collection

To protect the privacy of the students, all students in the selected classes were screened for scoliosis in a closed room or tent, and administered by research assistants without the presence of teachers or other school personnel (to avoid potential information bias). All screening data were collected from September 2019 to January 2020.

School screening program

The school screening program for AIS in Shenzhen was started in 2013 as part of the national public health project, and conducted and administered by the Shenzhen Youth Spine Health Center (SYSHC) of the Shenzhen Second People's Hospital using a national scoliosis screening standardized protocol (GB/T 16133-2014) ([National Standardization Administration Commission of China, 2019](#)).

The day before we started school screening, we informed parents to require their children to wear tight clothing and underwear for screening on the next day. On the day of screening, all students participating in the screening were divided into two groups according to their gender, and each group of students entered one by one in a sealed tent to ensure personal privacy. In order to ensure the accuracy of body posture measurement, boys and girls could only wear underwear during screening. If some students refused to wear only underwear for certain reason (such as not wanting the therapists to see their body), we respected their choice and let them wear tight clothing for screening. Students in primary schools, junior high schools, and high schools were invited to participate in the screening program voluntarily. School screening was performed by an experienced team of trained rehabilitation therapists from SYSHC using the Adams forward bending test (FBT), visual inspection, and measurement of the angle of trunk rotation (ATR) using the scoliometer ([Grossman et al., 2018](#)). Each student participating in the screening was judged by two independent therapists separately. If the results were inconsistent, a third therapist made a final judgment to minimize subjective bias.

Incorrect posture

Incorrect posture was assessed by visual inspection, FBT, and ATR ([Hengwei et al., 2016](#); [Fong et al., 2010](#)). The standard visual inspection was performed in the upright position. The examiner checked for spine alignment, shoulder asymmetry (high and low shoulder), scapula prominence (scapula tilt), hip and pelvic obliquity (pelvic tilt), back symmetry (flat back, thoracic kyphosis), lumbar curvature (lumbar concave, lumbar

lordosis, and lumbar kyphosis), distance of the hands from the flanks, and length of the lower limbs (Luk et al., 2010). The FBT was performed with the student's feet placed together, knees straight, while bending at the hips to nearly 90 degrees with the arms freely hanging forward, palms together. Any significant clinical sign was recorded. The ATR was used to decide the angle of trunk rotation and when the students should be referred for radiography directly by measuring with a scoliometer, including angle of thoracic rotation, angle of lumbar rotation, and angle of thoracolumbar rotation (Grossman et al., 1995). Students with an ATR>5° or with 1 or more significant clinical signs were identified as having incorrect posture.

Demographic variables

Demographic variables included gender (boy, girl), age, ethnic group, school category, and grade. Ethnic group was assessed based on the student's self-report about their ethnic group (Han or minorities) (Yang et al., 1998). School category included primary school (grade 1-6), junior middle school (grade 7-9), and high school (grade 10-12).

Statistical analysis

First, descriptive analyses were conducted to describe the demographic characteristics (e.g. gender and age) of children and adolescents in south China. Second, prevalence of incorrect posture among total population was reported, and sample was further divided into different groups to calculate gender-, age, school-specific prevalence rates. Chi-square test (χ^2) was used to compare the differences between groups. Bias-corrected 95% confidence intervals (CI) were estimated using 1000 bootstrap samples. All data were analyzed using SPSS 22.0 (IBM Corp, Armonk, NY, USA), *P*-value less than 0.05 was considered statistically significant (tested two-sided).

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