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DEFORMITY

Prevalence of Adolescent Idiopathic Scoliosis in the State of São Paulo, Brazil

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Study Design. A cross-sectional study.

Objective. To estimate the prevalence of adolescent idiopathic scoliosis (AIS) in cities in the state of São Paulo, Brazil, as well as to identify demographic, clinical, and lifestyle factors associated with AIS.

Summary of Background Data. AIS is a common three-dimensional spinal deformity. Epidemiological data about the condition in the southern hemisphere are scarce, and Brazil has no public health policies to implement school-based scoliosis screening programs.

Methods. We assessed 2562 adolescents between 10 and 14 years of age. The screening procedure included measurement of the angle of trunk rotation using a scoliometer in the Adams forward bend test and the radiographic examination.

Results. The overall prevalence of AIS was 1.5% (95% confidence interval [CI]: 1%–1.9%). The AIS prevalence was higher among the females than among the males—2.2% (95% CI: 1.4%–2.9%) and 0.5% (95% CI: 0.1%–0.9%), respectively. The following factors were associated with the development of AIS: being female (OR = 4.7, 95% CI: 1.8–12.2; $P = 0.001$) and being in the 13- to 14-year age group (OR = 2.2; 95% CI: 1.0–4.8; $P = 0.035$). Double curves and right laterality were more common (59.4% and 56.8%, respectively), although the curves were of low magnitude (75% of the curves having a Cobb angle $\leq 22°$), as was the progression factor (≤ 1.2 in 75% of the cases).

Conclusion. The prevalence of AIS in cities within the state of São Paulo was similar to that reported in the literature, was higher among females, and was higher during puberty (13–14 years of age). Because puberty occurs later for males than for females, the recommendation to screen both sexes at 10 to 14 years of age should be reconsidered.

Key words: adolescent, mass screening, prevalence, school health services, scoliosis.

Level of Evidence: 3

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Adolescent idiopathic scoliosis (AIS) is defined as a three-dimensional spinal deviation greater than 10°, occurring after the age of 10 years and before the musculoskeletal system has fully matured.[1] Although the etiology of AIS remains unknown, there are numerous hypotheses, involving hormonal, neuromuscular, biomechanical, or genetic factors.[2–4]

The reported prevalence of AIS varies widely (0.13%–13.00%) and is lower in countries that are closer to the equator.[5,6] In addition, studies involving screening for AIS differ in terms of the age range of the subjects, the instrument employed in identifying or quantifying the deviation (scoliometer, Moiré topography, or three-dimensional surface topography), the rates of referral for radiography, and the Cobb angles defined.[7–9]

Recent literature reviews and meta-analyses have shown clinical evidence that school-based AIS screening programs are effective.[10–12] According to Plaszewski and Bettany-Saltikov,[12] recommendations against conducting school-based AIS screening programs are based on poor-quality evidence.

In Brazil, there are no public policies related to school-based screening for AIS. Studies of the prevalence of AIS in Brazil have used quite divergent methodologies, not only in the evaluation but also in the sampling techniques and age ranges evaluated,[13–17] as well as not following the standards described in the consensus statement issued by the International Society on Scoliosis Orthopaedic and Rehabilitation

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Treatment.[18] None of the studies conducted in Brazil have used a scoliometer as the means of quantifying the curvature of the spine. In addition, there is a paucity of epidemiological data on the prevalence of AIS in the southern hemisphere, which results in a lack of information on the etiology and natural history of this type of scoliosis.[18,19] The aims of this study were to determine the AIS prevalence rates in cities within the state of São Paulo, Brazil; and to identify demographic, clinical, and lifestyle factors associated with AIS.

MATERIALS AND METHODS

Population and Sample

The data used in this study were collected at public schools in three cities within the state of São Paulo: Amparo, Pedreira, and Mogi Mirim. The state of São Paulo is in the southeastern region of Brazil, where socioeconomic conditions are better, the Human Development Index for all three cities being approximately 0.785, compared with 0.754 for the country as a whole.[20] During the study period, there were a total of 14,205 adolescents (10–14 years of age) in the three cities. Of those, 5302 were enrolled in public schools and were considered eligible to participate in the study.

This was a cross-sectional study in which we evaluated 2562 adolescents between 10 and 14 years of age. We excluded subjects with a difference in limb length of 1.5 cm or more,[16] as well as those with any condition that would prevent the forward flexion of the trunk.[21]

The sample size calculation took into account the fact that, on average, the prevalence of AIS reported in the literature is 2%.[8] Therefore, for a maximum error of 3% in 95% of the possible samples, it would have been necessary to include 2096 adolescents in the study. Allowing for losses, we estimated the necessary sample size to be 2516.

This study was authorized by the Regional Board of Education of Mogi Mirim. The study design was approved by the Research Ethics Committee of the University of São Paulo School of Medicine (Protocol no. 254/12).

Procedures

Initially, the teachers and adolescents were educated about AIS and informed of the research procedures. For each student, we collected data related to the following: sex; age (in years); body mass (in kg); height (in m); body mass index (in kg/m^2); race (skin color); handedness; age at and time since menarche (in years); secondary male characteristics; physical activity, at school or elsewhere (min/week); and any apparent discrepancy in length between the lower limbs.[22]

For the evaluation of the spinal curvature, we used a Bunnell scoliometer.[18,21] The subjects were instructed to flex their torso forward, looking down, with their feet approximately 6 inches (15 cm) apart, knees extended, shoulders relaxed, elbows extended, and palms together in front of the knees.[5,18] Each subject first performed a 45° trunk flexion, in accordance with the methodology described by Palmer and Epler,[22] to allow the determination of the greatest angle of trunk rotation (ATR) of the thoracic spine. The subject then continued to flex the trunk to 60° and 90° (or as much as possible) to allow the determination of the greatest ATR in the thoracolumbar and lumbar regions, respectively. During an Adams forward bend test (Figure 1), the zero mark of the scoliometer was positioned over the spinous process of each vertebra of the thoracic, thoracolumbar, and lumbar spine, and the greatest ATR value was recorded.[23] To facilitate the localization of spinal regions, the spinous processes of the fourth, eighth, and twelfth thoracic vertebrae were marked with self-adhesive labels, as were those of the first, third, and fifth lumbar vertebrae. To take a scoliometer reading, the examiner was positioned behind the subject, in such a way that the instrument was at eye level.[5] Three measurements were taken, the subject returning to the upright position between each measurement.[21] The mean of the two closest values was registered. All measurements were made with the same scoliometer.[21] Two physiotherapists trained previously performed the physical examination described.

When the ATR was 7° or more for any of the regions (thoracic, thoracolumbar, or lumbar), the adolescent was referred for standing anteroposterior radiographic assessment of the spine. On the basis of that criterion, 129 (5%) the 2562 adolescents evaluated were referred for radiographic examination. The radiographs were used to measure the Cobb angle and evaluate the Risser sign.[24] The curve

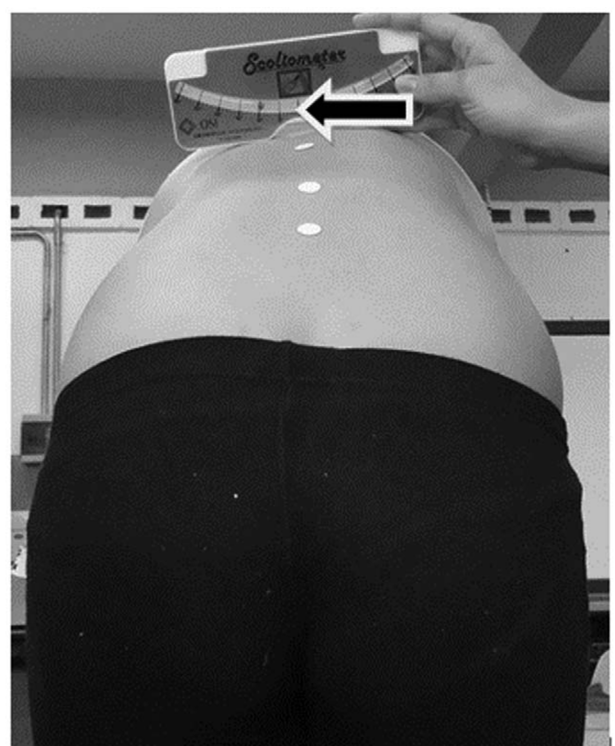

Figure 1. Illustrative photograph of the use of the scoliometer for measurement of the angle of trunk rotation.

with the greatest magnitude was designated the primary curve. To calculate the Cobb angle, we followed the steps described by Panchmatia *et al*[24] (1) to draw a vertical line passing through the center of the sacrum; (2) to identify the apical vertebra which is most laterally deviated from the vertical line; (3) to identify the upper end vertebra which is the first vertebra in a superior direction from the curve apex whose superior surface is tilted maximally toward the concavity of the curve; (4) to identify the lower end vertebra which is the first vertebra in a inferior direction from the curve apex whose inferior surface is tilted maximally toward the concavity of the curve; (5) to draw perpendicular lines at the middle point of upper and lower end vertebrae; (6) the Cobb angle is the angle formed by these perpendicular lines (Figure 2). The Risser sign was used to calculate the "progression factor", which indicates the progression of the curvature, as described by Lonstein and Carlson.[25] The regions of the spinal curves were classified according to the location of the apical vertebra, as follows: thoracic (T2-T11), thoracolumbar (T12-L1), and lumbar (L2-L4).[24] One of the investigators scheduled the radiographic examinations at each municipal hospital. The same technic at each municipal hospital performed and the same physiotherapist interpreted the radiographic examinations.

Reliability

We evaluated the inter-rater reliability for the use of the scoliometer. Two physiotherapists evaluated 10 adolescents on two different occasions, with a 15-day interval between each evaluation. For the calculation of the intraclass correlation coefficient, we used the program R, version 2.15.1, with the irr package, version 0.84 (R Development Core Team—www.r-project.org). The reliability was satisfactory (0.78) for the ATR at 60° of trunk flexion, very good (0.88) for the ATR at 90° of trunk flexion, and unacceptable (0.49) for the ATR at 45° of trunk flexion.

Statistical Analysis

To identify associations between variables, we used the χ^2 test. We used Student *t* tests to quantify differences between the sample as a whole and the scoliosis group in terms of the mean values for sex, age, body mass index, race (skin color), menarche, male sexual characteristics, family history, physical activity, and handedness, as well as to identify associations between those variables and the laterality and type of curvature.

Point prevalence values, with 95% confidence intervals (CIs), were estimated for scoliosis, stratifying the subjects by sex, age, and Cobb angle ($\geq$20°). We also determined the frequency of the type and laterality of scoliosis, by sex and by age.

Bivariate analyses were performed to identify associations between scoliosis and the independent variables (sex, age, height, time since menarche, male sexual characteristics, and posture). Three multiple logistic regression models were constructed to estimate the influence of each independent variable (after adjustment for the other variables in the model and potential confounding factors): for all adolescents; for the adolescents with suspected scoliosis (ATR $\geq$7° and Cobb angle $<$10°); and for the female adolescents (including the time since menarche). It was not possible to construct a model for the male adolescents, because all of the male subjects with scoliosis had sexual characteristics, precluding the calculation of the odds ratio.

For all hypothesis tests, the level of statistical significance was set at 5%. The statistical analysis was performed with the Stata statistical software package, version 13.0 (StataCorp LP, College Station, TX) and with Microsoft Excel 2010.

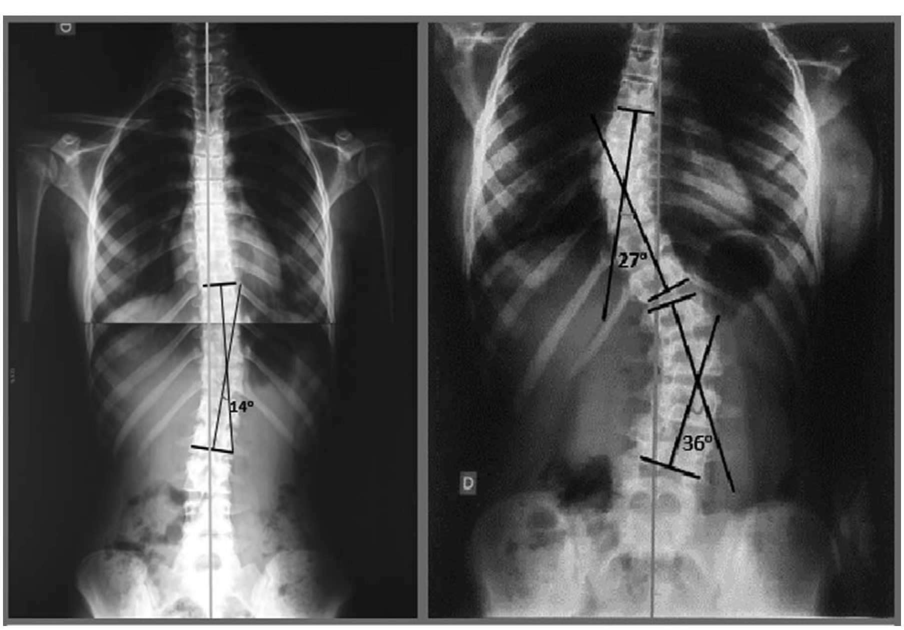

Figure 2. Illustrative photograph of single and double scoliotic curves in x-rays defining Cobb angles for both.

RESULTS

Tables 1 and 2 show the demographic, anthropometric, and clinical characteristics of the adolescents in the sample as a whole and of those in the subgroup with AIS. In our study sample, the overall prevalence of AIS was 1.5% (95% CI: 1.0%–1.9%). On average, the prevalence of AIS was statistically higher for females than for males (Figure 3).

Among the female adolescents, AIS occurred after 11 years of age and its prevalence was higher at 14 years of age. Among the males, it occurred after 12 years of age and its prevalence also increased thereafter.

In the present study, double curves were more common than were single curves (seen in 59.5% and 40.5%, respectively). Among the females, 62.5% of the curves were double, compared with only 40% of those occurring in the males. There was no statistical sex-based difference between single and double curves ($P = 0.341$). There was, however, a statistically significant difference between the males and females in terms of the location of the double curves ($P = 0.005$) (Figure 4).

The distribution of the curves by Cobb angle is shown in Figure 5. The Cobb angle was 22° or lesser in 28 (75.7%) of the 37 cases. The prevalence of curves with a Cobb angle of 20° or more was 0.6% (95% CI: 0.3%–0.9%), being higher among the females (0.9%, 95% CI: 0.4%–1.4%) than among the males (0.1%, 95% CI: −0.1%–0.3%). The

TABLE 1. Demographic and Clinical Characteristics of Adolescents Evaluated in a School-Based Scoliosis Screening Program

Characteristic	Sample as a Whole (n = 2562) n (%)	Scoliosis Group (n = 37) n (%)	*P*
Sex			
Female	1490 (51.2)	32 (86.5)	<0.000*
Male	1072 (41.8)	5 (13.5)	
Age (yr)			
10	159 (6.2)	0 (0)	0.036*
11	593 (23.2)	5 (13.5)	
12	712 (27.8)	7 (18.9)	
13	633 (24.7)	14 (37.8)	
14	465 (18.1)	11 (29.7)	
Skin color			
White	1502 (58.6)	28 (75.7)	0.211
Black	265 (10.3)	2 (5.4)	
Yellow	4 (0.2)	0 (0)	
Other	791 (30.9)	7 (18.9)	
Menarche			
Yes	937 (62.9)	25 (78.1)	0.073
No	553 (37.1)	7 (21.9)	
Male sexual characteristics			
Yes	429 (40)	5 (100)	0.006*
No	643 (60)	0 (0)	
Family history			
Yes	170 (6.6)	3 (8.1)	0.594
No	1881 (73.4)	29 (78.4)	
Unknown	510 (19.9)	5 (13.5)	
Physical activity at school			
Yes	2434 (95)	34 (91.9)	0.380
No	128 (5)	3 (8.1)	
Physical activity elsewhere			
Yes	889 (34.7)	13 (35.1)	0.949
No	1673 (65.3)	24 (64.9)	
Handedness			
Right	2344 (91.5)	32 (86.5)	0.539
Left	217 (8.5)	5 (13.5)	
Ambidextrous	1 (0.04)	0 (0)	

*Statistically significant (χ^2 test for proportions).

TABLE 2. Anthropometric and Clinical Characteristics of Adolescents Evaluated in a School-Based Scoliosis Screening Program

Variable	Sample as a Whole (n = 2562) Mean (SD)	Scoliosis Group (n = 37) Mean (SD)	*P*
Age (yr)	12.2 (1.2)	12.8 (1)	0.002*
Weight (kg)	50.1 (13.2)	50.4 (9.1)	0.876
Height (m)	1.6 (0.1)	1.6 (0.1)	0.024*
Body Mass Index (kg/m^2)	20.2 (4.1)	19.7 (3.6)	0.441
Age at menarche (yr)	11.6 (1.1)	11.6 (1.4)	0.947
Time since menarche (yr)	0.9 (1)	1.3 (1.4)	0.011*
Physical activity at school (min/wk)	95.4 (22.8)	91.9 (27.7)	0.339
Physical activity elsewhere (min/wk)	90.3 (180.7)	60.8 (105.0)	0.320

*Statistically significant (Student t test for means).

SD indicates standard deviation.

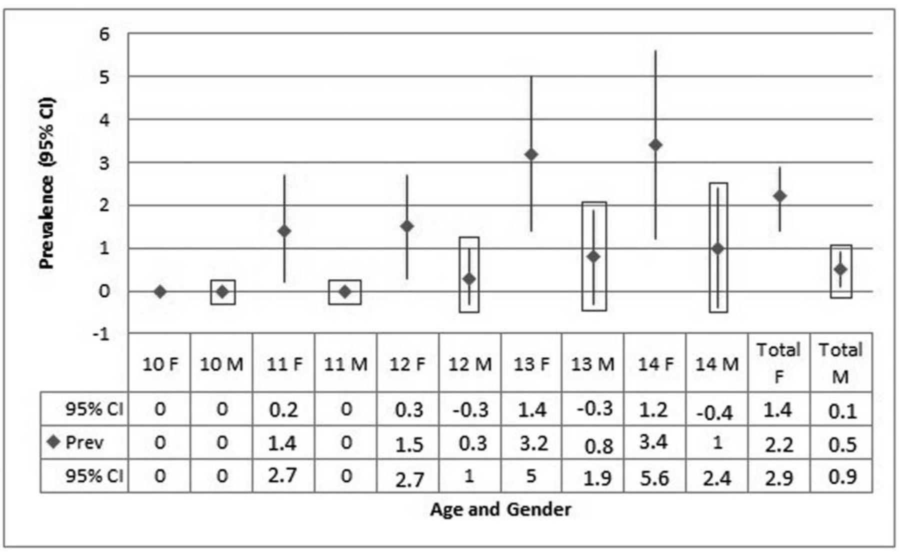

Figure 3. Prevalence (Prev) of adolescent idiopathic scoliosis, by age and sex. CI indicates confidence interval.

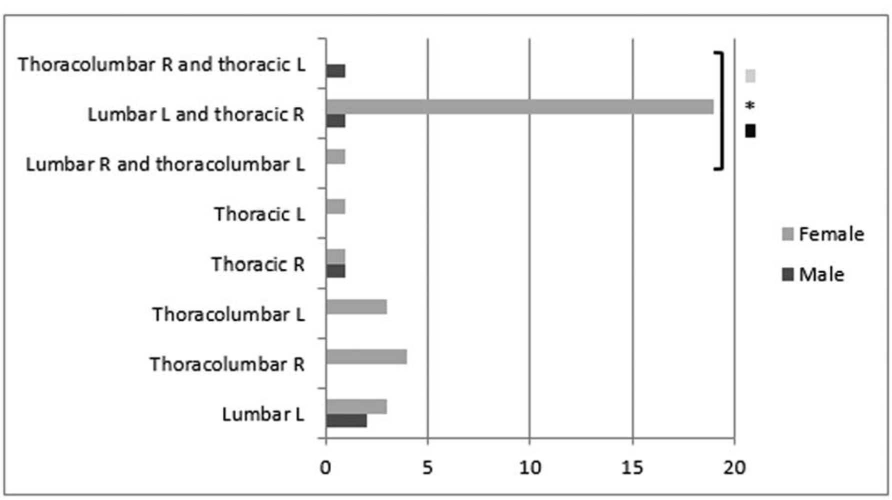

Figure 4. Characteristics of adolescent idiopathic scoliosis, by sex, number, region, type, and laterality. *Statistically significant difference ($P = 0.005$). χ^2 to proportions. R: right, L: left.

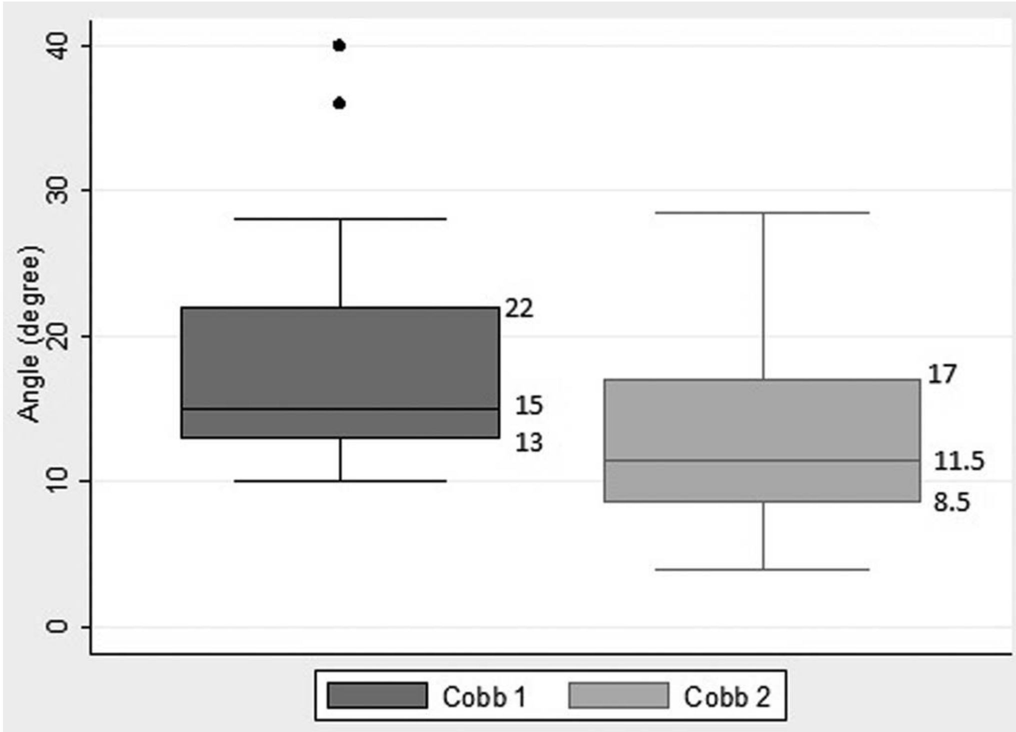

Figure 5. Box plot for Cobb angle of the primary curve (Cobb 1) and secondary curve (Cobb 2). The boxes represent the Cobb angle quartiles, and the whiskers represent the outliers.

mean Cobb angle was greater for the right-sided curvatures than for the left-sided curvatures ($20.8^\circ \pm 7.3^\circ$ *vs.* $13.8^\circ \pm 4.1^\circ$), and the difference was statistically significant ($P = 0.003$).

Of the adolescents with scoliosis in our sample, 75% had a progression factor of 1.2 or lesser (Figure 6), indicating a risk of progression of up to 40%. As can be seen in Table 3, female sex and being between 13 and 14 years of age were

Figure 6. Distribution of progression factor values among adolescents with adolescent idiopathic scoliosis. *Analysis based on the Risser sign in 31 adolescents.

TABLE 3. Logistic Regression Models of Factors Associated With Adolescent Idiopathic Scoliosis

	Model 1 All Adolescents (n = 2546)		Model 2 Suspected Scoliosis (n = 113)		Model 3 Females (n = 32)	
Factor	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Female sex	4.7 (1.8–12.2)	0.001*	3.6 (1.2–10.6)	0.019*		
13–14 Years of age	2.2 (1–4.8)	0.035*	2.6 (1–6.5)	0.038*	1.7 (0.7–4.2)	0.219
Height >1.56 m	1.7 (0.8–3.7)	0.171	1 (0.4–2.7)	0.964	1.6 (0.7–3.6)	0.278
Time since menarche					1.2 (0.9–1.7)	0.295

*Statistically significant difference ($P < 0.05$).
CI indicates confidence interval; OR, odds ratio.

the strongest predictors of scoliosis. No association was found between the time since menarche and the development of scoliosis. There were no statistical differences between the adolescents with single-curve scoliosis and double-curve scoliosis in terms of menarche ($P = 0.151$), age ($P = 0.421$), or time since menarche ($P = 0.918$).

DISCUSSION

The reported prevalence of AIS varies widely. That is mostly due to methodological differences across studies regarding the age group evaluated, as well as the criteria employed to refer a patient for radiographic examination and to make the diagnosis of scoliosis. However, most studies have reported an AIS prevalence of approximately 2%.[6,26] Screening programs for AIS in Brazil have not employed scoliometers (using radiographic examination only for diagnostic confirmation), and the AIS prevalence rates derived from those programs have ranged from 1.03% to 6.70%.[13–17]

In the present study, as in previous studies,[7–9,27] AIS was more prevalent in females than in males. In our study, being female increased the chance of developing scoliosis 4.7 times. The higher prevalence of AIS in females can be explained by the so-called "Carter effect."[4]

The female/male ratio for the prevalence of scoliosis varies considerably in the literature. In a study evaluating 82,901 adolescents between 9 and 14 years of age, Soucacos *et al*[7] found a female/male ratio of 2.1:1 among those with scoliosis, compared with 11:1 among those with scoliosis within a sample of 255,875 adolescents between 11 and 14 years of age evaluated by Ueno *et al*.[9] Wong *et al*[8] found that the female/male ratio for the prevalence of scoliosis varied according to the age group studied. The authors evaluated 72,699 adolescents and found that, among those with scoliosis, the female/male ratio was 6.4:1 in the 11- to 12-year age group and 3.3:1 in the 13- to 14-year age group. In a meta-analysis of 38 articles involving a collective total of 697,043 primary and middle school students in China, Zhang *et al*[27] found the female/male ratio among those with scoliosis to be 1.54:1. The scoliosis screening is not mandatory in Brazil, but our sample size is statistical significant and allows to calculate CIs for prevalence.

In the present study, as in those conducted by Wong *et al*[8] and Zhang *et al*,[27] the prevalence of scoliosis was found to increase with age in both sexes and the chance of developing scoliosis was found to be 2.2 times greater among individuals in the 13- to 14-year age group than in other age groups. In our sample, only one (0.3%) of the cases of scoliosis occurred in a 12-year-old male, whereas five cases (1.4%) occurred in 11-year-old females. That can be explained by the AIS develops and progresses during the growth spurt phase, which occurs later in males than in females (at 13–15 and 11–13 years of age, respectively).[28] In the present study, all of the male adolescents with scoliosis presented male sexual characteristics; that is, they had already entered puberty. Our findings lead us to question the Scoliosis Research Society recommendation that males and females should be screened at the same age (10–14 years).[18] It has been suggested that screening programs for AIS should target females 11 years or older and males 13 years or older.

Among the cases of scoliosis identified in the present study, double curves were considerably more common than were single curves. In the literature, most scoliosis curves occur in the thoracic region of the spine.[13,16,27,29] There is evidence that delayed menarche increases the likelihood of a double curve.[30] However, in our sample, we found that the type of curve was not associated with the occurrence of menarche, age at menarche, or time since menarche.

In the majority of the cases of AIS identified in the present study, the Cobb angle was 22° or lesser. Curves with a Cobb angle of more than 20° were considerably more common among the females than among the males. In a study of 12-year-olds in Norway, Adobor *et al*[6] identified no curves with a Cobb angle of more than 20° among the males, although they identified such curves in 0.13% of the females, a prevalence lower than that observed in our sample. Other authors have also reported that curves with smaller Cobb angles (10°–19°) are more common.[7,9]

We found that right-sided curves presented larger Cobb angles than did left-sided curves, which is in agreement with the findings of Goldberg *et al*.[29]

Most of the curves identified in this school-based screening study showed a low progression factor ($\leq$1.2), indicating a relatively low ($\leq$40%) risk of progression. According to the literature,[31] such individuals should be only monitored. However, a recent cohort study conducted in England found that presenting small curves (10°–15°) at 15 years of age was significantly associated with low back pain and school/work absenteeism at 18 years of age.[32] Grauers *et al*[33] showed that spinal problems and limited physical activity were both more common in individuals with scoliosis than in those without. In a study conducted by Mayo *et al*,[34] most of the individuals with AIS reported intense, continuous generalized pain, throughout the spine and radiating to the extremities, whereas those without scoliosis did not. It should be borne in mind that the calculation of the progression factor takes into account the magnitude of the Cobb angle, the Risser signal, and the chronological age of the adolescent. However, according to Zhang *et al*,[27] factors such as apical vertebral rotation and growth velocity of the spine (mm/year) are also important to improve accuracy in predicting the progression of the curvature and should be evaluated in conjunction with the magnitude of the Cobb angle and the Risser sign stage.

In conclusion, the prevalence of AIS in cities within the state of São Paulo was similar to that reported in the literature, was higher among females, and was higher during puberty (13–14 years of age). Because puberty occurs later for males than for females, the recommendation to screen both sexes at 10 to 14 years of age should be reconsidered.

➢ Key Points

- The AIS prevalence rate was 1.5% overall, 2.2% among females, and 0.5% among males (0.5%), similar to the values reported in the literature.
- Female gender and being 13 to 14 years of age increased the chance of developing AIS by 4.7 times and 2.2 times, respectively.
- Because puberty occurs later for males, we suggest screening females starting at 11 years of age and males starting at 13 years of age.

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