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Idiopathic Scoliosis in Singapore Schoolchildren

A Prevalence Study 15 Years Into the Screening Program

Hee-Kit Wong, FRCS, James H. P. Hui, FRCS, Uma Rajan, FA, MS, and Hwee-Pin Chia, MMed

Study Design. A point prevalence survey of 72,699 schoolchildren in four age groups was performed.

Objectives. To determine the prevalence rates of idiopathic scoliosis and to compare with a previous prevalence study done 15 years earlier.

Summary of Background Data. Prevalence rates for idiopathic scoliosis of 5° or more in schoolchildren were established in a study performed in 1982. There have been no previous data on prevalence rate changes over time.

Methods. A total of 35,558 boys and 37,141 girls from randomly selected schools were screened for scoliosis. Those with scoliometer readings of more than 5° underwent radiographic evaluation. Prevalence rates were calculated for scoliosis at a predefined Cobb angle of 10° and 5°, the latter for comparison with the previous prevalence study. Curve type and distribution, pubertal status, and symptoms were correlated with the prevalence data.

Results. Prevalence rates were 0.05% for girls and 0.02% for boys at 6 to 7 years of age, 0.24% for girls and 0.15% for boys at 9 to 10 years of age, 1.37% for girls and 0.21% for boys at 11 to 12 years of age, and 2.22% and 0.66%, respectively, for girls and boys at 13 to 14 years of age. The ratio of girls to boys increased from 1.6 at 9 to 10 years of age to 6.4 at 11 to 12 years of age. Thoracolumbar curves were the most common (40.1%), followed by thoracic curves (33.3%), double/triple curves (18.7%), and lumbar curves (7.9%). Older children had greater proportions of larger curves. Compared with the previous prevalence study in 1982, there was a significant increase in the prevalence rate in girls 11 to 12 years of age. Screening of 11- to 12- and 13- to 14-year-old girls detected curves in the range suitable for bracing, with nearly 96% and 32% of the age groups, respectively, still amenarche or within a year of menarche, and 57% and 34% of the age groups, respectively, having low Risser grades of 0, 1, and 2.

Conclusions. The overall prevalence rate of idiopathic scoliosis in our school population in 1997 was 0.93% in girls and 0.25% in boys. The prevalence rates were low at 6 to 7 and 9 to 10 years of age but increased rapidly to 1.37% and 2.22% for girls at 11 to 12 and 13 to 14 years of age, respectively. The prevalence rate increased significantly in 11- to 12-year-old girls over a 15-year period from 1982 to 1997. Screening of 11- to 12- and 13- to 14-year-old girls identified a significant number who could benefit from brace treatment.

Key words: prevalence, scoliosis, screening, Cobb angle, epidemiology, spinal deformity. **Spine 2005;30:1188–1196**

Scoliosis in adolescents is a common problem. If left undetected and untreated, it can lead to increasing deformity and pain.[1] In the past few decades, the conservative and operative management of idiopathic scoliosis has greatly improved because of a better understanding of its natural history[2,3] and improvements in spinal instrumentation.

Early detection by comprehensive screening programs enables early institution of conservative treatment, with the aim of reducing the number of patients with curves reaching a magnitude that requires surgical treatment. Scoliosis detection through the screening of schoolchildren has been popularized over the past two decades and is currently carried out in 15 states in the United States, in the Middle East, Sweden, South Africa, and some parts of Japan.[4–8]

Prevalence rates of idiopathic scoliosis vary from 0.35% to 13%, depending on the defined Cobb angles, screening age, and sex.[4,9,10] In addition, there are regional and ethnic differences in the prevalence rate.[5–7,11,12]

Routine examination for spinal deformity as part of the national school health screening program was introduced in Singapore in 1981. This program, which also covers cardiac, eye and ear conditions, as well as obesity, screens more than 140,000 students for spinal deformity each year. Children suspected to have scoliosis on the forward bending test are referred for evaluation and treatment at the School Health Service, a central referral body. As resources are finite and limited in any screening program, it is important that screening be targeted at the optimal age group, in whom conservative management, such as bracing, can be instituted to control curve progression, and to reduce the need for surgery.

A prevalence study was carried out in 1982 where prevalence rates were established for three age groups, namely, 6 to 7 years, 11 to 12 years, and 15 to 16 years.[12] The predefined Cobb angle used in this study was 5°.

The objectives of our study were to determine the current prevalence of scoliosis and to compare this with the previous study in 1982 in the light of improvements in socioeconomic and healthcare standards in Singapore over the past 15 years. Curve distribution, magnitude,

From the Department of Orthopaedic Surgery, National University of Singapore, Singapore. Uma Rajan was formerly Director of School Health Service, Singapore, and Hwee-Pin Chia was formerly an Assistant Professor of the Department of Community, Occupational, and Family Medicine, National University of Singapore, Singapore.
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Address correspondence and reprint requests to Hee-Kit Wong, FRCS, Division of Spinal Surgery, Department of Orthopaedic Surgery, National University Hospital, 5 Lower Kent Ridge Road, Singapore 119074; E-mail: wonghk@nus.edu.sg

Table 1. Enrollment and No. of Students Screened

Age (yr)	Sex	Enrollment (approximate)	No. Screened	Minimum No. at Margin of Error
6–7	F	19,000	16,688	20,000@0.05%
	M	19,000	15,362	15,000@0.05%
9–10	F	20,000	8,080	NA
	M	20,000	8,675	NA
11–12	F	20,000	8,686	7000@0.3%
	M	20,000	9,415	2000@0.3%
13–14	F	17,000	3,687	3300@0.5%
	M	17,000	2,106	NA
Total		152,000	72,699	

NA = age groups not screened in 1982.
Note: The minimum no. to detect statistical significance, based on previous screening in 1982, and the margin of error are shown.

and pattern as well as sex ratio, symptoms, etiology, and family history were examined.

■ Materials and Methods

A 1-year prospective epidemiologic study was performed to determine the prevalence and distribution of various scoliotic parameters in schoolchildren in Singapore. In 1997, a total of 72,699 children aged 6 to 14 years, representing 50.7% of the total annual enrollment of 152,000 schoolchildren, were screened for scoliosis. The schools were randomly selected for each group out of a total pool of 191 primary and 142 secondary schools with no special consideration for geographic, economic, or ethnic representation. Once a school was selected, all students from that year were screened.

Four age groups were screened. Two age groups of 6 to 7 years (Primary One or First Grade) and 11 to 12 years (Primary Six or Sixth Grade) were chosen to compare with the previous prevalence data. Two additional groups of 9 to 10 years (Primary Four or Fourth Grade) and 13 to 14 years (Secondary Two or Eighth Grade) were added for new information. The 1982 study had included a group of 15- to 16-year-olds, but this group was excluded from the present study because the students in this grade were preparing for their GCE "O" level Examination. The sample size (Table 1) was calculated to achieve a precision of 5% on prevalence estimates based on those obtained in the previous prevalence study.[12] As such, the number of students screened varied with the age group. The largest proportion of those screened were 6- to 7 year-olds as the prevalence rate for this age group was expected to be very low.

A three-tier system similar to that used in the previous study was used. With permission from the Ministry of Health, schools and parents were informed of the objectives of this study and the details of the examination.

Initial screening was done in schools by State Registered Nurses with at least 10 years experience in school screening. Children who had been diagnosed previously or who were already being managed for scoliosis were not examined at the initial screening but were included in the data analysis. Their records were traced from hospitals and clinics, and questionnaires were administered to them as well. Spinal screening took place during the physical education class. Only female nurses participated in the screening; and at no time was a girl examined by a staff of the opposite sex. Boys and girls were examined separately. The boys wore shorts and the girls wore shorts and brassieres. The forward bending test was performed with the child bent forward while allowing the upper extremities to hang freely with the palms opposed in a relaxed manner, and the exposed back was viewed from the front as well as from the side. Children with scoliometer readings of 5° or more were referred to the School Health Service, a central national referral institute. Those who were missed during the screening visit were examined at a separate visit during the same year.

At the School Health Service, the forward bending test was rechecked by medical officers. Questionnaires were given to the children and their parents while they waited for their medical examination. The information requested were the age of menarche for girls and break of voice for boys; and "yes/no" answers to a previous history of chicken pox and varicella, family history of scoliosis among their parents, siblings, and grandparents, as well as whether they had back pain, perceived limited range of spinal motion, poor fit of clothes, and poor self-image (Appendix, available for viewing on Article Plus only). All those who attended the clinic completed the questionnaires. Physical examination, including the height and weight of the children, arm span, and abnormalities involving the trunk or spine such as humps in the ribs or lumbar regions, were performed at this stage and the results recorded. Those with scoliometer readings of more than 5° underwent radiographic evaluation. Tanner grading was not performed. Exclusion criteria include associated neuromuscular diseases such as cerebral palsy, muscular dystrophy and muscular atrophy, spinal bifida, and congenital myopathy.

A standing posterior-anterior radiograph was taken and read jointly by consensus by the authors (H.-K.W., J.H.P.H.). The intraobserver correlation coefficient in measuring the Cobb angle of a standing posterior-anterior radiograph was 0.991. Curve types, magnitude, rotation, and the Risser scores were recorded. The parameters were recorded in a computer with the use of a spreadsheet (Microsoft Excel). The statistical analysis was performed using t tests and χ^2 tests using a SPSS statistical package.

Prevalence rates were calculated at predefined Cobb angles of 5°, 10°, 20°, and 30°. A Cobb angle of 10° or more has been defined by the Scoliosis Research Society as positive for scoliosis; 20° and 30° Cobb angle cutoffs are treatment thresholds. In addition, a cutoff Cobb angle of 5° was also calculated to allow us to compare with the results from the previous prevalence study, which reported the prevalence rates at 5°.

■ Results

Of 759 children who were referred from school on the basis of positive scoliometer readings, 729 attended the referral clinic and were examined. Of those who at-

Table 2. Predictive Value of the Forward Bending Test by Age Group and Gender During the First and Second Steps of Screening

			No. Predicted Positive		Positive Predictive Value (%)		False Positive (%)	
Age (yr)	Sex	No. True Positive (Cobb angle ≥ 10°)	At School	At Referral Center	At School	At Referral Center	At School	At Referral Center
6–7	F	9	38	36	23.7	25.0	76.3	75.0
	M	3	17	17	17.6	17.6	82.4	82.4
9–10	F	19	79	73	24.1	26.0	75.9	74.0
	M	13	53	51	24.5	25.5	75.5	74.5
11–12	F	119	235	231	50.6	51.5	49.4	48.5
	M	20	84	80	23.8	25.0	76.2	75.0
13–14	F	82	172	164	47.7	50.0	52.3	50.0
	M	14	51	49	27.5	28.6	72.5	71.4
Total		279	729*	701	38.3	39.8	61.7	60.2

*30 out of 759 children referred from school did not attend the referral clinic.

tended, 28 were excluded because of repeat scoliometer reading of less than 5° or the presence of clinical features that suggest nonidiopathic scoliosis (Table 2). A total of 531 children had spinal curves of 5° or more on standing radiographs. Nine children were excluded because of congenital vertebral anomalies and leg length discrepancy, leaving 522 children with idiopathic scoliosis with curves of 5° or greater.

Prevalence

The prevalence rates by age group, gender, and Cobb angle are shown in Table 3. The overall prevalence rate of scoliosis in schoolchildren 6 to 14 years of aged with Cobb angles of 10° or more was 0.59% (0.93% in girls and 0.25% in boys). The prevalence rate in girls increased progressively from 0.05% at the age of 6 to 7 years, to 0.24%, 1.37%, and 2.22% at the ages of 9 to 10, 11 to 12, and 13 to 14 years, respectively. For boys, the prevalence rates were 0.02%, 0.15%, 0.21%, and 0.66% at the ages of 6 to 7, 9 to 10, 11 to 12, and 13 to 14 years, respectively. The ratio of girls to boys with scoliosis was 2.8:1 at the age of 6 to 7 years, 1.6:1 at the age of 9 to 10 years, 6.4:1 at the age of 11 to 12 years, and 3.3:1 at the age of 13 to 14 years. A comparison with unpublished data from Daruwalla[13] showed a significant difference in the prevalence rate in 11- to 12-year-old girls viz. 1.37% in present study against 0.83% in 1982 ($P < 0.05$). There was no difference between the prevalence rate in the present study and that in 1982 in 11- to 12-year-old boys and in 6- to 7-year-olds. The prevalence rates at a Cobb angle of 5° or more were compared with that from an earlier study from our institution that used a cutoff Cobb angle of 5°. There was a significant difference in the prevalence rate in 11- to 12-year-old girls with Cobb angles of 5° or more, being 2.15% in present study compared with 1.67% in 1982 ($P < 0.05$). There was no difference in prevalence rate in 11- to 12-year-old boys and in 6- to 7-year-olds in this comparison. The prevalence rates were lower with larger predefined curves. With the exception of girls 11 to 12 and 13 to 14 years of age, the prevalence rates of curves of 20° or more were 0.05% or less; and for curves of 30° or more, 0.01% or less. Defining a treatment threshold Cobb angle of 20°, we would have identified only 5 girls of 6 to 7 years of age, 10 girls and 2 boys of 9 to 10 years of age if we had screened the whole population of nearly 20,000 children at each age and gender group (Table 3). In contrast to the large number of girls of 11 to 12 and 13 to 14 years of age that would have been identified for potential brace treatment, there were only 4 boys 11 to 12 years of age and 40 boys 13 to 14 years of age with curves of 20° or more. Other than for girls 11 to 12 and 13 to 14 years of age, it would appear that none of the other age and

Table 3. Prevalence Rates of Idiopathic Scoliosis by Age Group, Gender, and Cobb Angle

		Cobb Angle ≥ 5°			Cobb Angle ≥ 10°			Cobb Angle ≥ 20°		Cobb Angle ≥ 30°	
Age (yr)	Sex	No.†	Prevalence (%)	Prevalence (1982)	No.†	Prevalence (%)	Prevalence (1982)*	No.†	Prevalence (%)	No.†	Prevalence (%)
6–7	F	21 (24)	0.13	0.15	9 (10)	0.05	0.07	4 (5)	0.02	0 (0)	0.00
	M	8 (10)	0.05	0.10	3 (4)	0.02	0.02	0 (0)	0.00	0 (0)	0.00
9–10	F	51 (126)	0.63	NA	19 (47)	0.24	NA	4 (10)	0.05	1 (2)	0.01
	M	30 (69)	0.35	NA	13 (30)	0.15	NA	1 (2)	0.01	0 (0)	0.00
11–12	F	187 (431)	2.15	1.67‡	119 (274)	1.37	0.83‡	50 (115)	0.58	18 (41)	0.21
	M	54 (115)	0.57	0.44	20 (42)	0.21	0.12	2 (4)	0.02	0 (0)	0.00
13–14	F	105 (484)	2.85	NA	82 (378)	2.22	NA	46 (212)	1.25	19 (88)	0.52
	M	21 (170)	1.00	NA	14 (113)	0.66	NA	5 (40)	0.24	0 (0)	0.00

NA = age groups not screened in 1982.
*Unpublished data from Daruwalla JS (1982).
†Numbers in parentheses indicate predicted no. if the entire enrollment were screened.
‡Statistically significant difference between present and 1982 data.

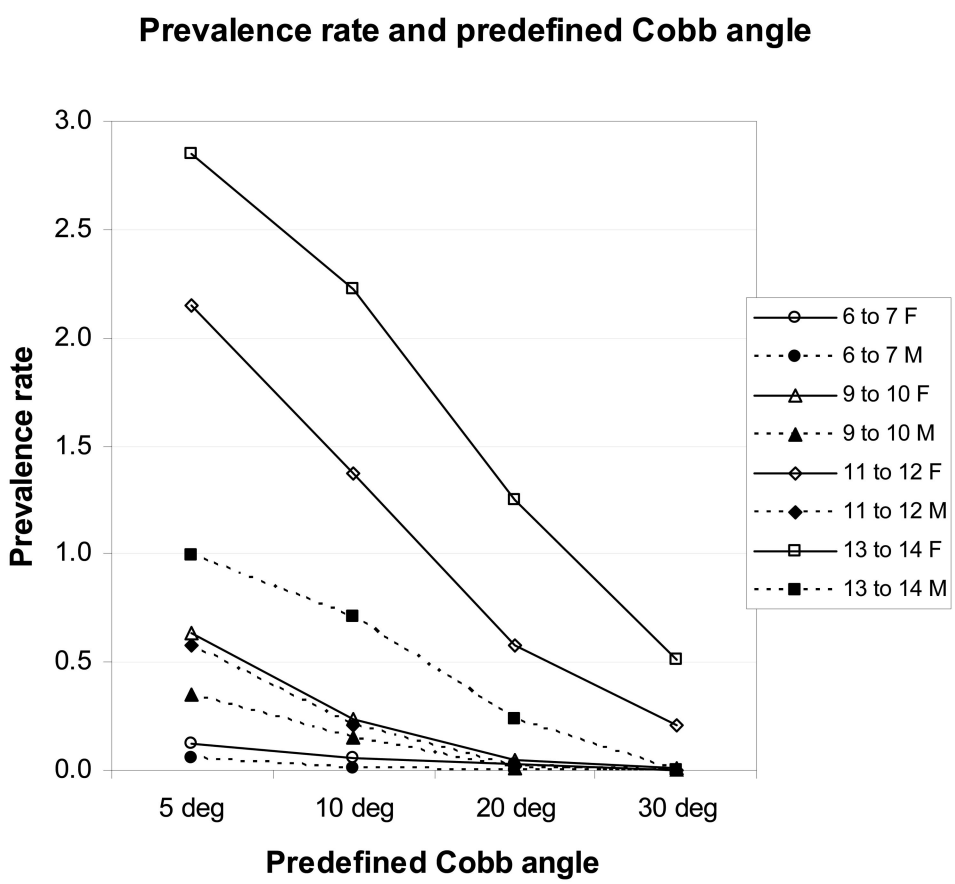

Figure 1. Change in prevalence rate with age, sex, and predefined Cobb angle.

gender groups would have curves above 30° even if we had screened the entire population since their prevalence rates were very low (Figure 1).

Predictive Value of the Forward Bending Test

The positive predictive values were lower for boys than for girls at all age groups (Table 2). There was a trend toward higher positive predictive values for girls with increasing age, increasing from 25% at 6- to 7- and 9- to 10-year age groups to just over 50% for the 11- to 12- and 13- to 14-year age groups. False-positive rates were correspondingly 75% and 50%, respectively. This trend was not present in boys, the positive predictive value ranged from 18% to 29% (false-positive rates 82% to 71%, respectively). Positive predictive values and false-positive rates did not differ significantly (<2.5%) between the screening at school and the reexamination at the referral center.

Curve Distribution

The proportion of smaller curves decreased, and that of larger curves increased with increasing age. For both boys and girls, the proportion of curves 10° to 19° decreased from 84% to 63% and 47% for the age groups 9- to 10-, 11- to 12-, and 13- to 14-year-old, respectively. Conversely, the proportion of curves of 30° or more increased from 3% to 13% and 20% for the same age groups.

The distribution of curve magnitudes for girls is shown in Figure 2. In 9- to 10-year-old girls, 15 (79%) had curves of 10° to 19°; 3 (16%) had curves of 20° to 29°; and 1 (5%) had a curve greater than 29°. In 11- to 12-year-old girls, 69 (58%) had curves of 10° to 19°; 32 (27%) had curves of 20° to 29°; and 18 (15%) had curves more than 29°. In 13- to 14-year-old girls, 36 (44%) had curves of 10° to 19°; 27 (33%), 20° to 29°, and 19 (23%) more than 29°. In the 1982 study, 149 (70.0%) of 11- to 12-year-old girls had curves of 10° to 19°; 48 (23%), 20° to 29°; and 16 (8%), more than 29°.[14] Compared with that of 1982, there was proportionately higher number of girls in the group with curves of more than 29° in the present study. This difference was statistically significant. Boys had fewer and smaller curves at all age groups screened. At 9 to 10 years of age, 12 (92.3%) boys had curves of 10° to 19°; 1 (7.8%), 20° to 29°; and none had curves more than 29°. At 11 to 12 years of age, 18 (90%) had curves of 10° to 19°, and 2 (10%) had curves of 20° to 29°. None had curves more than 29°. The findings were similar for boys 13 to 14 years of age. A total of 9 (64.3%) and 5 (35.7%) had curves of 10° to 19° and 20° to 29°, respectively, while none had curves more than 29°. There were only 12 children with idiopathic scoliosis in the 6- to 7-year-old group.

Of the 9 girls, 5 had curves of between 10° and 19°, while the remaining 4 had curves ranging from 22° to 26°. All three boys in the 6- to 7-year-old group had curves of less than 15°. In the study done in 1982, 14 girls and 4 boys in the 6- to 7-year-old age group were found

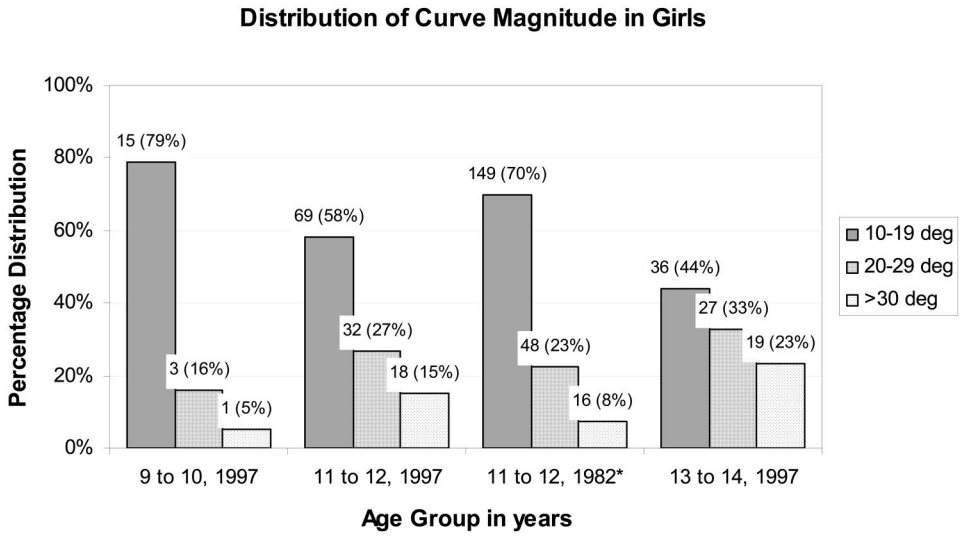

Figure 2. Distribution of curves 10° and above in different age groups in girls. *Daruwalla JS, unpublished data.

to have scoliosis. Ten girls had curves between 10° and 19°, while the remaining 4 girls had curves between 20° and 29°. All 4 boys had curves between 10° and 19°.

Curve Pattern

Thoracolumbar curves were the most common (40.1%), followed by thoracic curves (33.3%), double or triple curves (18.7%), and lumbar curves (7.9%). These findings were different from those in 1982, where thoracic curves were the most common type of curve (35.9%), followed by thoracolumbar curves (27.8%), double or triple curves (26.9%), and lumbar curves (9.4%). A possible reason for this difference could be the way double or triple curves and lumbar curves were assigned in the two studies. The current study follows the classification system of the Scoliosis Research Society, while the previous study in 1982 was done before the classification system was introduced. We were not able to obtain the radiographs from the previous study to check the classification. The distribution of the different curve patterns in the various age groups are shown in Table 4.

Pubertal Status

A total of 48% of 11- to 12-year-old girls with curves between 10° and 29° were premenarchal when their spinal curvature was detected, while another 48% were less than 1 year post menarche (Figure 3). In this age group and curve range, 57% of the girls were of Risser Grades 0, 1, and 2. Nearly a third of 13- to 14-year-olds with curves between 10° and 29° were either premenarche or less than 1 year from menarche on curve detection. In this age group, 34% of the girls were of Risser Grades 0, 1, and 2. There were too few boys in both age groups for analysis. There were no data available from 1982 on puberty status for comparison.

Backache, Fitting of Clothes, and Perception of Image

Four girls (3.4%) in the 11- to 12-year age group with curve magnitudes ranging from 11° to 15°, and 10 girls (12.2%) in the 13- to 14-year age group with curve magnitudes ranging from 15° to 38° experienced back pain. There was no correlation between back pain and the severity of the curvature. None of the girls complained of poor fitting of clothes. Only one girl (0.8%) in the 11- to 12-year age group and 4 girls (4.9%) in the 13- to 14-year age group expressed poor perception of self-image. All of them had curve magnitudes of more than 20°.

Etiology and Family History

A total of 41% of girls and 52% of the boys in the 11- to 12-year age groups had a history of chicken pox (vari-

Table 4. Distribution of Curve Types for Age Group and Gender

		Type of Curve							
		Thoracic		Thoracolumbar		Lumbar		Double/Triple	
Age (yr)	Sex	No.	%	No.	%	No.	%	No.	%
9–10	F	11	57.9	6	31.6	1	5.3	1	5.3
	M	4	30.8	7	53.8	1	7.7	1	7.7
11–12	F	37	31.1	50	42.0	8	6.7	24	20.2
	M	10	50.0	6	30.0	2	10.0	2	10.0
13–14	F	22	26.8	34	41.5	7	8.5	19	23.2
	M	5	35.7	4	28.6	2	14.3	3	21.4
Total		89	33.3	107	40.1	21	7.9	50	18.7

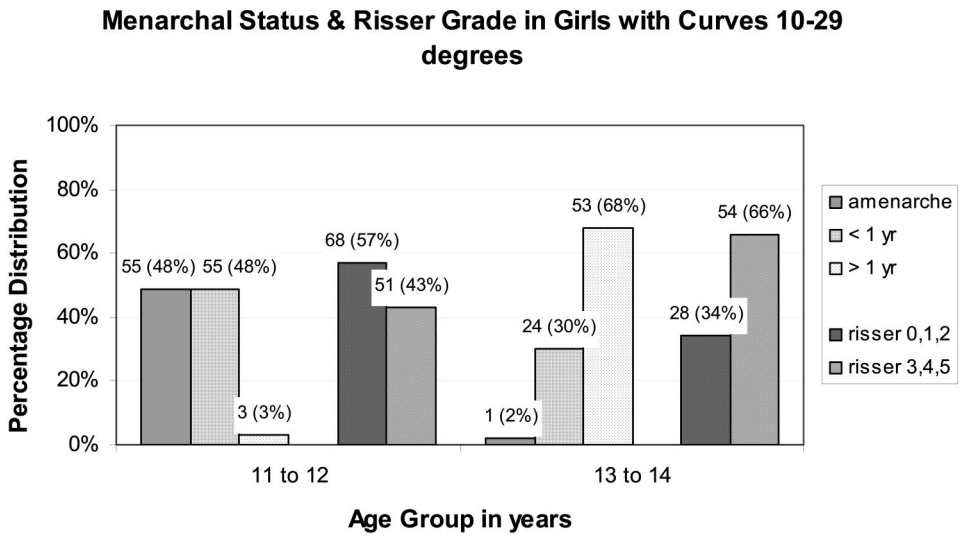

Figure 3. Distribution of menarche status and Risser grade of 11- to 12- and 13- to 14-year-old girls.

cella). The seroconversion rate for varicella in the general population was 50%.[14]

The family histories were gathered from the questionnaires completed by the children's parents. A total of 13% of girls who had scoliosis in the 11- to 12-year age group and 15% in the 13- to 14-year age group had a positive family history of scoliosis. Most of them had siblings with scoliosis. Overall, 83% of them had a history of siblings who had scoliosis. A total of 12% had a family history of scoliosis on their maternal side, and 5% had one of the grandparents involved.

■ Discussion

Screening, as defined by the American Commission on Chronic Illness, is the "presumptive identification of unrecognized disease or defect by application of tests, examination or other procedures which can be applied rapidly."[15] Scoliosis screening fulfills these criteria because it detects well people with the disease and refers those with positive findings for further evaluation. By targeting high-risk individuals, prescriptive screening for scoliosis facilitates early intervention, thus decreasing the need for surgery. Weiss *et al* reported that conservative treatment of scoliosis, which included high-correction-effect bracing based on plaster casting, showed an obvious reduction in the rate of surgery in patients with idiopathic scoliosis compared with those who were untreated.[16]

The forward bending test is a fast and simple method to detect the presence of minor curvatures in the spine although it may have false-positive rates of between 25% and 82%, depending on the screening method and criteria.[11,16–21] We found the false-positive rate in girls to decrease with age, most likely because of the concomitant increase in the prevalence rate of scoliosis. However, it was notable that the false-positive rate did not change as much in boys, remaining significantly high at over 70% for all age groups. The apparent lack of change in the false-positive rates, or conversely the positive predictive values in boys, may be due to the low rate of progression of prevalence rate with increasing age. However, the high false-positive rates for this group were harder to understand. We postulate that this effect could be the result of differences in muscular development between boys and girls that could lead to a higher incidence of trunk asymmetry in boys. We were also not able to observe any significant increase in the positive predictive values between the forward bending test at school and at the referral clinic for both boys and girls, presumably resulting from the use of the scoliometer in both settings.

We have no data on the false-negative rates as radiographs were not done on children with scoliometer readings of less than 5°. There were no returns to the School Health Service within the year for those who were below this screening threshold, and we did not have information on children who might have presented elsewhere for treatment.

Screening for scoliosis through schools reaches the persons who are at risk, *i.e.*, adolescents. However, epidemiologists have questioned whether the healthcare system can cope with the program. Lonstein has shown that the risk of curve progression is related to both the magnitude of the curve and the age of the patient.[2] Therefore, it is important in any screening program to know the prevalence so as to target treatment at the higher risk groups.

There are few reports on prevalence rates on idiopathic scoliosis from the Asian region. As far as we know, this is one of the only two Asian prevalence studies that were conducted in a nationwide school screening program, the other study being also from our institution 15 years ago. Zhang *et al* screened 20,418 Chinese schoolchildren in a selected suburb in Beijing from 7 to 15 years of age and found the prevalence to be 1.2% for girls and 0.8% for boys, using a predefined Cobb angle of 10°.[19] The prevalence rates in our study were slightly lower. Our overall predicted prevalence rate for children

6 to 14 years of age (comprising 6- to 7-, 9- to 10-, 11- to 12-, and 13- to 14-year-old groups) and using a predefined Cobb angle of 10° or more was 0.59%, 0.93% in girls, and 0.25% in boys. Ohtsuka *et al* screened a group of Japanese schoolchildren from five districts over an 8-year period.[5] Using a cutoff Cobb angle of 15° or more, they reported prevalence rates of 1.77% and 0.25% in 13- to 14-year-old girls and boys, respectively. They also found that children living in affluent urban areas have a higher prevalence when compared with those in remote ones. Our prevalence rates for 13- to 14-year-olds with curves of 10° or more were higher at 2.22% for girls and 0.66% in boys. The slightly higher prevalence rate in our study is likely to have resulted from the difference in the predefined Cobb angle between our study and that of Ohtsuka *et al*.[5]

Prevalence rates in this study were closer to those reported in other school screening programs.[10,11,20] Stirling *et al*, in a school screening study, reported prevalence rates of 0.4% and 2.2% in English girls 9 to 11 years of age and 12 to 14 years of age, respectively; the boys had prevalence rates of 0.1% and 0.3% in the two age groups.[20] Soucacos *et al* reported a prevalence of 1.7% in a screening of 82,900 Greek schoolchildren of 9 to 14 years old during a 1-year prospective study.[11] A total of 2.6% of the girls and 0.9% of the boys had radiographic evidence of structural scoliosis (Cobb angles of 10° or more). The prevalence varied according to age. A total of 0.07% of the children had scoliosis by the age of 9, 0.2% by age 10, and 0.4% at age 14. In our study, 0.04% of the children had scoliosis by the age of 7, 0.19% by age 10, and 1.44% by age 14, while the overall predicted prevalence rate for children 9 to 14 years of age (comprising 9- to 10-, 11- to 12-, 13- to 14-year-old groups) was 0.78% (1.23% in girls and 0.33% in boys). A Swedish study had a similar prevalence rate of between 1% and 2%.[8] All three studies used predefined Cobb angle of 10° or more. A summary of this discussion is presented in Table 5.

Comparisons were also made with prevalence rates in 1982 for 6- to 7- and 11- to 12-year-olds. The published prevalence data from the 1982 study was at predefined Cobb angles of 5°. The prevalence rates at 5° and above for girls or boys at 6 to 7 years of age and boys at 11 to 12 years of age were similar in both the present and the previous study. However, there was a significant increase in the prevalence rate from 1.67% to 2.15% in 11- to 12-year-old girls. Unpublished data from Daruwalla[13] for prevalence rates at predefined Cobb angles of 10° was also used for comparison with the present study. There was no significant difference in prevalence rates at 10° and above for girls or boys at 6 to 7 years of age and boys at 11 to 12 years of age. The prevalence rate at predefined Cobb angle of 10° or more for 11- to 12-year-old girls increased significantly from 0.83% in 1982 to 1.37% in 1997. We postulate that these changes in prevalence rates were due to more rapid growth and earlier maturation among the adolescent girls. There are no available data on the patterns of sexual or skeletal maturation in adolescents over the past 15 years in Singapore. There were, however, indirect indexes of significant improvements in general health and nutrition over this same period. School health data have shown that the average height of adolescent girls has increased by about 5 cm from 1983 to 1993[22,23]; and national health statistics have shown a reduction in the infant mortality rate from 11.7 per 1,000 live births in 1980 to 3.8 per 1,000 live births in 1996.[24]

Table 5. Prevalence Rates by Age Group and Sex in Different Studies

Author(s)	Cobb Angle	Age Group	Sex	Prevalence (%)
Present study, Wong *et al*, Singapore, 2004	10°	6–7	F	0.05
			M	0.02
		9–10	F	0.24
			M	0.15
		11–12	F	1.37
			M	0.21
		13–14	F	2.22
			M	0.66
Daruwalla JS, Singapore, 1982	10°	6–7	F	0.07
			M	0.02
		11–12	F	0.83
			M	0.12
Zhang *et al*, China, 1988	10°	7–15	F	1.20
			M	0.80
Ohtsuka *et al*, Japan, 1988	15°	13–14	F	1.77
			M	0.25
Stirling *et al*, England, 1996	10°	9–11	F	0.4
			M	0.1
		12–14	F	2.2
			M	0.3
Soucacos *et al*, Greece, 1997	10°	<9	All	0.07
		<10		0.20
		<14		0.40

There is some similarity in the distribution of the magnitude of curve between current study and that of 1982, in that majority of the curves falls in the range of 10° to 19°. However, there is an increase in the number of children with a higher magnitude (>30) of curves as compared with 1982. This, together with the increase in prevalence rate, suggests that the 11- to 12-year-old girls in the present study were developmentally more mature than the same chronologic age group screened in 1982.

The thoracolumbar curve was the most common curve type in this study. This pattern is comparable to the Californian study,[10] which showed the thoracolumbar curves to be predominant, but differs from the Scandinavian and English studies.[8,20] A report from Greece has also shown that both thoracolumbar and lumbar curves were more common.[11]

The overall predicted sex ratio for all age groups was 4.4:1. These figures were similar to that of Willner and Uden[8] who found that females outnumbered males by 6:1 but were much higher than the report from Soucacos *et al*,[11] which had an overall ratio of 2:1. In this latter study, the ratio of girls to boys with scoliosis increased steadily from 2:1 at age 10, to 2.8:1 at age 12, to 4.2:1 at

14 years of age. In contrast, the ratio of girls to boys in our study increased from 1.6:1 at 9 to 10 years of age to 6.4:1 at 11 to 12 years of age, and then decreased to 3.3:1 at 13 to 14 years of age. The higher prevalence in girls and rapid increase in the female-to-male sex ratio from the 9- to 10-year-old to 11- to 12-year-old age group reflects the earlier adolescent skeletal development and onset of idiopathic scoliosis in girls, while the reduction in female to male sex ratio at 13 to 14 years of age may be due to the relatively later onset of adolescent skeletal development and scoliosis in boys.

In girls 11 to 12 years of age who have curves 10° to 29°, 48% were amenarche, and another 48% were less than a year from menarche. Just over half of girls have Risser Grades 0 to 2. Even at 13 to 14 years, about 32% of girls with curves 10° to 29° were less than 1 year from menarche, 34% within the first three Risser grades. Thus, a large majority of those with scoliosis detected on school screening between 11 and 14 years would still be amenable to treatment by bracing. This is similar to the findings of Soucacos *et al*.[11]

Ramirez *et al* cited in a retrospective study that 23% of the patients experienced pain; 9% of the patients had underlying pathologic condition, namely, spondylolysis, Scheuerman kyphosis, syrinx, herniated disc, hydromyelia, tethered cord, or intraspinal tumor.[25] A prospective study by Pratt *et al* showed that 9.2% reported mild back pain in patients in the preoperative Visual Analogue Score for those with idiopathic scoliosis.[26] In both studies, pain was not correlated with gender, magnitude, or type of curve. Our findings were similar; 3.2% and 12.2% of children in the 11- to 12- and 13- to 14-year-old age groups, respectively, experienced pain. This further affirms that only a small proportion of children with idiopathic scoliosis detected during screening have symptoms. Very few (1.7%) reported perception of poor self-image, and none experienced ill-fitting of clothes, which agrees with the findings of Pratt *et al*.[26]

Varicella has been investigated as a possible etiology for scoliosis. There was, however, no increase in number of children in this study with varicella as compared with the general population. We found that less than 15% of the children had a positive family history of scoliosis, with most of these involved siblings.

It would be ideal if children at all age groups could be screened in a school screening program. However, as resources are finite, it is often the case that screening is targeted at those most at risk of developing scoliosis and at a time when brace treatment would be effective. This would include those age groups with high prevalence rates and where there are large proportions of those with low Risser grades and peri-menarchal girls. Girls 11 to 12 and 13 to 14 years of age would best fit the screening criteria among the four age groups surveyed in our study. At prevalence rates of 1.37% and 2.22%, respectively, 274 11- to 12-year-old girls would be detected by screening, of which 115 have spinal curvatures of 20° or more. Similarly, 378 girls 13 to 14 years of age would be detected by screening, of which 212 had curves of 20° or more. Overall, 85% of curves in 11- to 12-year-old girls fell within the range of 10° to 30°, which is the range suggested by Lonstein to be the most amenable to bracing.[2] Of this 85%, 96% of the girls were either amenarche or less than a year from menarche; 57% have low Risser grades, making this group excellent candidate for brace treatment. Even for the older group of 13- to 14-year-olds, 32% of those with curves 10° to 29° were either amenarche or less than 1 year from menarche, and 34% were in the lower Risser grades. Screening was not as efficient in the younger age groups and in boys in all age groups where the prevalence was very low and the curve magnitudes were generally small. False-positive rates at initial screening were also very high. We have since stopped screening for 6- to 7-year-olds. It might also not be worthwhile to screen boys of any age for the same reasons. In our opinion, the optimal age groups for school screening should be at the point where the prevalence rate shows a marked increase at puberty. The prevalence rate of 0.24% for 9- to 10-year-old girls is still quite low, and we believe the age group of 10 to 11 years, which was not screened in this study could well be the "turning point" from low to high prevalence at puberty. There was a significant increase in the prevalence rate from 0.83% in 1982 to 1.37% in the current study. We postulate that earlier skeletal development and sexual maturity could have hastened the onset of idiopathic scoliosis in our population by a year, and if such is the case, then the intermediate 10- to 11-year-old group could have prevalence characteristics similar or close to the 11- to 12-year-old group that was previously reported in 1982. Work is in progress to determine the prevalence of scoliosis in the 10- to 11-year-old age group.

■ Conclusion

The overall prevalence rate of idiopathic scoliosis in our school population in 1997 was 0.93% in girls and 0.25% in boys. The prevalence rates were low at 6 to 7 and 9 to 10 years of age but increased rapidly to 1.37% and 2.22% for girls at 11 to 12 and 13 to 14 years of age, respectively. The prevalence rate increased significantly in 11- to 12-year-old girls over a 15-year period from 1982 to 1997. The prevalence of curves larger than 20° was generally low, except for girls at 11 to 12 and 13 to 14 years of age where the prevalence was 0.58% and 1.25%, respectively. The female-to-male prevalence ratio was low at 6- to 7- and 9- to 10-year-olds but increased rapidly to 6.4:1 at 11- to 12-year-olds, to decrease to 3.3:1 at 13- to 14-year-olds, reflecting the earlier pubertal growth spurt in girls. Screening of 11- to 12- and 13- to 14-year-old girls identified a significant number of those who would benefit from brace treatment. Among the four age groups surveyed, screening appeared to be the most efficient resource for girls between 11 and 14 years of age because of the high prevalence and numbers of those who could benefit from treatment. Overall, thoracolumbar curves were most

common, followed by thoracic curves, double/triple curves, and lumbar curves. Less than 10% of those in 11- to 12- and 13- to 14-year-old groups experienced pain; there was no correlation between back pain and the severity or type of the curvature.

■ Key Points

- The prevalence rate of idiopathic scoliosis in our school population was comparable to those in other school screening studies.
- The prevalence rates were low at 6 to 7 and 9 to 10 years of age but increased rapidly to 1.37% and 2.22% for girls at 11 to 12 and 13 to 14 years of age, respectively.
- The prevalence rate increased significantly in 11- to 12-year-old girls over a 15-year period from 1982 to 1997.
- Screening of 11- to 12- and 13- to 14-year-old girls identified a significant number who could benefit from brace treatment.

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Note: Appendix available online through ArticlePlus.

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