Original Article

Prevalence of Adolescent Idiopathic Scoliosis among Female School Children in Singapore

Flordeliza Yong,[1] *MD, MMed (Public Health)*, Hee-Kit Wong,[2] *MMed (Surg), FRCS (Glas), MchOrth (Liv)*, Khuan-Yew Chow,[3] *MB.BCh (NUI), MMed (Public Health)*

Abstract

Introduction: Screening for scoliosis started in Singapore schools in 1982 and is currently being done for both boys and girls, as part of the annual school-based health screening programme in all primary and secondary schools. The screening levels in the current protocol were based on the 1997 prevalence study by Wong et al. In the study, it appeared that there was a significant increase in prevalence rates between 9- and 11-year-old girls (i.e. between Primary 4 and Primary 6) but there was no data on the prevalence rates of scoliosis in 10-year-old girls (Primary 5) and in 12-year-old girls (Secondary 1). In order to decide on whether to make changes to the screening levels, a review was conducted to determine the prevalence of scoliosis among the 10-year-old girls (in Primary 5) and 12-year-old girls (in Secondary 1). Materials and Methods: A total of 93,626 female students, aged between 9 and 13 years old were screened. The study covered all of the 183 primary schools and only 83 of the 165 secondary schools due to a disruption of health screening in schools during the outbreak of SARS (severe acute respiratory syndrome). In mid-2003, schools in Singapore were closed because Singapore was one of the countries affected by SARS. Scoliosis screening was done for all female students in the Primary 4, 5 and 6 levels as well as in the Secondary 1 and 2 levels. Male students were routinely screened for scoliosis in the Primary 6 and Secondary 2 levels. Scoliosis screening was done by measuring the angle of trunk rotation (ATR) using a scoliometer. All students with ATR ≥5° were referred to the Student Health Centre (SHC) where second-tier screening was done. At SHC, if ATR ≥5°, postero-anterior radiograph of the spine was done. Of the 3186 female students in the primary level, aged between 9 and 13 years old who were referred to SHC for the second-tier screening, 2438 attended, and for secondary students aged between 12 and 13 years old, 1587 out of 1720 students attended. Results: The prevalence rates of idiopathic adolescent scoliosis for the 9- to 13-year-old female students were 0.27%, 0.64%, 1.58%, 2.22% and 2.49%, respectively, which showed an increasing trend in the prevalence rates with increasing age. There was a significant increase in the prevalence rates of adolescent idiopathic scoliosis (AIS) in the 10- to 11-year-old females compared to the 9-year-old females (OR, 1.7; 95% CI, 1.1-2.4; *P* = 0.010). There was also a significant increase in the prevalence rates in the 12- to 13-year-old females (OR, 2.2; 95% CI, 1.4-3.3; *P* = 0.001). Conclusions: The study showed a significant increase in the prevalence rates of scoliosis in the 10- to 11-year-old female students and again a significant increase in the prevalence rates in the 12- to 13-year-old female students. Since the prevalence rate for the 9-year-old females was quite low (0.27%), and there was a significant increase in the prevalence rates in the 10- to 11-year-old and 12- to 13-year-old females, it was recommended that screening for females be performed every year commencing at 10 years old (Primary 5) until 13 years old (Secondary 2).

Ann Acad Med Singapore 2009;38:1056-63

Key words: Angle of trunk rotation, Cobb angle, Forward bending test, Prevalence rates, Scoliometer, Screening

Introduction

Scoliosis screening in schools is still widely practised worldwide despite some countries abandoning the practise in recent years. Screening usually consists of visual inspection of the back, Forward Bending Test (FBT) and measurement of the angle of trunk rotation (ATR) using a scoliometer.

Scoliosis screening in Singapore schools started in 1982 using the FBT. The use of the scoliometer for measuring the ATR was introduced in 1990 and together with the Adam's FBT, was used as a screening test for scoliosis. The cut-

[1] Student Health Centre, Youth Health Division, Health Promotion Board, Singapore
[2] Department of Orthopaedic Surgery, Yong Loo Lin School of Medicine, National University of Singapore, Singapore
[3] National Registry of Diseases Office, Research & Strategic Planning Division, Health Promotion Board, Singapore
Address for Correspondence: Dr Flordeliza Yong, Student Health Centre Level 3, Health Promotion Board, 3 Second Hospital Avenue, Singapore 168937.
Email: flordeliza_yong@hpb.gov.sg

off point for referral from the school to the Student Health Centre (SHC) is an ATR reading of ≥5° on the scoliometer.

In 1994, computerised skeletal analysis was introduced to minimise the number of students referred for spinal X-ray. Computerised skeletal analysis was performed on students with positive FBT and an ATR of 5° to 7°. Only students with ATR of ≥8° had spinal X-ray.

In 1997, there was a change in the level of screening from Primary 6 and Secondary 4 to Primary 4 and Primary 6 levels. This was done to identify early those with curves likely to progress faster due to early onset of pubertal development and menarche in females.

In 1998, changes were made on the levels of screening for scoliosis resulting from the findings of the 1997 study on school screening. Screening for scoliosis ceased for Primary 4 students due to the very low prevalence rates of scoliosis (0.15% for boys and 0.24% for girls) among the Primary 4 students. Primary 6 students (males and females) and Secondary 2 students (males and females) continued to be screened for scoliosis.

At the Primary 6 level, screening was done as part of the school-based medical examination and at the Secondary 2 level, as part of routine health screening. Following screening in school, the student was referred to the SHC for further assessment and management if the ATR is ≥5°.

The screening levels in the current protocol were based on the 1997 prevalence study by Wong et al.[1] The results of this study showed that prevalence rates in girls increased progressively from 0.05% at the age between 6-7 years, to 0.24%, 1.37% and 2.22% at the age of 9-10, 11-12, and 13-14 years, respectively (Table 1). There was also a significant increase in prevalence rates between 9- and 11-year-old girls (that is between Primary 4 and Primary 6); but there was no data on the prevalence rates of scoliosis in 10-year-old girls (Primary 5) and in 12-year-old girls (Secondary 1). Moreover, in 2001, about 45% (10,721) of the 23,786 Primary 6 girls screened, reported that they already had their menarche. Twenty-nine per cent (6931) and 6% (1364) of the 23,786 girls screened at Primary 6 reported their age of menarche as 11 and 10 years old, respectively. In order to decide on whether to make changes to screening levels, a review was conducted to determine the prevalence of scoliosis among the 10-year-old girls (in Primary 5) and 12-year-old girls (in Secondary 1).

Materials and Methods

Health screening was done in all of the 183 primary schools in Singapore in 2003. However for secondary schools in that year, only 83 out of the 165 secondary schools were covered due to the occurrence of severe acute respiratory syndrome (SARS) in the middle of the study. In mid-2003, schools in Singapore were closed because Singapore was one of the countries affected by SARS. Although screening covered only 83 secondary schools, a significantly large population of students was screened and the demographics of students in schools not covered by health screening did not differ from students in schools covered by the health screening. A total of 93,626 out of 119,611 (78.28% coverage) female students in the primary and secondary levels, aged 9 to 13 years old, were screened (Table 2).

For the study, screening of idiopathic adolescent scoliosis was done for all female students in the Primary 4 (9-10 years old), Primary 5 (10-11 years old), Primary 6 (11-12 years old), Secondary 1 (12-13 years old) and Secondary 2 (13 years old) levels.

A letter regarding the study was sent to the principals of all the primary and secondary schools involved, as well as to the parents of the children to be screened. Parents were informed of the study protocol and that their child may be referred to the SHC for further assessment and management. They were also informed that a spinal x-ray may be done where necessary.

Scoliosis screening in schools were carried out by doctors and trained nurses from the SHC of the Health Promotion Board. Screening for scoliosis in school was performed by visual inspection of the back and by measuring the ATR during the Adam's FBT using the scoliometer, which is an inclinometer designed to measure trunk asymmetry or ATR.[2]

Students with ATR ≥5° were referred to the SHC for

Table 1. Comparison of Prevalence in Girls by Age for Prevalence Studies done in 1982, 1997 and 2003

Age	Prevalence (%)		
(y)	1982	1997	2003
6	0.07	0.05	–
9	–	0.24	0.27
10	–	–	0.64
11	0.83	1.37	1.58
12	–	–	2.22
13	–	2.22	2.49

Table 2. Screening Coverage for Female Students by Age Based on MOE 2003 Enrolment

Age (y)	Enrolment (MOE)	No. screened	Coverage (%)
9	23,718	23,371	98.54
10	23,823	23,516	98.71
11	23,931	23,991	100.25
12	24,920	11,825	47.45
13	23,219	10,923	47.04
Total	119,611	93,626	78.28

MOE: Ministry of Education

further management. Out of the 3186 female primary school students between the ages of 9 and 11 years referred to the SHC for the second-tier screening, 2438 attended. For the 1720 female students in the secondary level, between the ages of 12 and 13 years who were referred for the second-tier screening, 1587 attended.

At the SHC, students were examined by a doctor, and the findings were recorded using the Scoliosis Prevalence Study Medical Examination Form. The ATR measurement during the FBT was checked again using the scoliometer. A standing postero-anterior (PA) radiograph of the spine was performed for students with ATR measuring ≥5°. The spinal X-rays were read and the Cobb angle was measured by medical officers at the SHC. These medical officers have previously undergone training in Cobb angle measurement. Students with Cobb angle ≥10° were referred to the Spinal Specialist Clinic (SPC) for further management by a spine specialist.

For the calculation of prevalence, scoliosis was deemed to be present when there is a lateral curvature of the spine of 10° or more as measured using the Cobb method on a standing PA radiograph, and as defined by the Scoliosis Research Society (SRS).

Statistical Analyses

Data from the Scoliosis Prevalence Study Medical Examination Forms were entered into MS Access Databases and analysed using SPSS version 15.

Chi-square test was used to test the difference between proportions. Factors associated with adolescent idiopathic scoliosis (AIS) were analysed using logistic regression. $P \leq 0.05$ were taken as significant.

Results

Prevalence

The results showed that the prevalence rates of idiopathic adolescent scoliosis for the 9-year-old, 10-year-old and 11-year-old female students were 0.27%, 0.64% and 1.58%, respectively (Table 3). The rates showed a 2-fold increase from a prevalence rate of 0.27% for the 9-year-old female students to 0.64% for the 10-year-old female students. The prevalence rate for the 11-year-old female students was 1.58%, which is more than twice the prevalence rate for the 10-year-old female students. The prevalence rates for the 12- and 13-year-old female students were 2.22% and 2.49%, respectively. The increase in the prevalence rate for the 10- to 11-year-old was statistically significant (OR, 1.7; 95% CI, 1.1-2.3; $P = 0.010$). Likewise, the increase in the prevalence rates for the 12- to 13-year-old females were also statistically significant (OR, 2.2; 95% CI, 1.4-3.3; $P = 0.001$). The results showed that there was an increasing trend in the prevalence rates of idiopathic adolescent scoliosis among female students between the ages of 9 and 13 years.

The proportions of female students who received active intervention (use of brace or surgery for those with severe curves) were as follows: 9/63 (14%) 9-year-old students, 31/150 (21%) 10-year-old students, 55/373 (15%) 11-year-old students, 44/262 (17%) 12-year-old students and 42 /271 (15%) 13-year-old students. There was a 50% increase (from 14% to 21%) in the number of female students who received active intervention from the 9 and 10 years old age group.

Types of Curve

Of the 1118 female students found to have scoliosis (Cobb ≥10°), 56.08% (627) have single curves, 39.62% (443) have double curves, and 4.30% (48) have triple curves. The most common type was the double curve (39.6%), followed by the left thoraco-lumbar curve (21.4%), right thoraco-lumbar curve (14.9%), right thoracic curve (13.9%), triple curve (4.3%), left thoracic (3.5%), left lumbar (2.1%) and right lumbar (0.4%), in decreasing order (Table 4).

Menarchal Status

Of the 3235 female students seen at the SHC, the average age of menarche was 11.5 years (standard deviation, 0.964) with 55.9% (1806) who reported having menarche by 12 years old. Of the female students who attained menarche, 42.2% (762) had AIS.

Table 3. Prevalence Rates (Prev) of Idiopathic Scoliosis Among Female Students by Age and Cobb Angle

	Cobb angle													
	0-9°		10°-19°		20°-29°		30°-39°		40°-49°		≥50°		≥10°	
Age (y)	No.	Prev (%)	No.	Prev (%)	No.	Prev (%)	No.	Prev (%)	No.	Prev (%)	No.	Prev (%)	No.	Prev (%)
9	83	0.36	43	0.18	14	0.06	3	0.01	1	0.004	2	0.01	63	0.27
10	98	0.42	105	0.45	25	0.11	12	0.05	4	0.02	4	0.02	150	0.64
11	270	1.14	251	1.06	72	0.30	38	0.16	9	0.04	3	0.01	373	1.58
12	118	1.00	182	1.54	58	0.49	15	0.13	3	0.03	4	0.03	262	2.22
13	147	1.35	173	1.59	68	0.63	18	0.17	10	0.09	2	0.02	271	2.49

Factors Associated with AIS

Analysis of factors associated with AIS among females in this study using logistic regression, showed age, age at menarche, upper segment (trunk) to lower segment ratio and body mass index (BMI) to be statistically significant in the univariate as well as multivariate analysis model (Table 5). The risk of scoliosis was higher for the 10- to 11-year-old as compared to the 9-year-old (OR, 1.7; 95% CI, 1.1- 2.4; $P = 0.010$). The risk for scoliosis for the 12- to 13-year-old females was even higher (OR, 2.2; 95% CI, 1.4-3.3; $P = 0.001$). The result showed an increased risk with increasing age between 9 and 13 years old. Underweight female students (BMI <18.5) had higher risk of AIS (OR, 1.5; 95% CI, 1.2-1.8; $P = 0.001$) as compared to females whose weight were in the healthy range (BMI = 18.5 to >25) and overweight range (BMI ≥25).

As for menarchal status, the risk for females who had menarche before 13 years old was 1.5 ($P = 0.003$; 95% CI, 1.1-1.9). Increasing height and sitting height were statistically significant only in the univariate model. However, the upper segment (trunk) to lower segment ratio was statistically significant both in the univariate model and after adjustments in the multivariate model. Females whose upper segment (trunk) to lower segment ratio was >1.2 had a higher risk of AIS (OR, 1.6; 95% CI, 1.1-2.3; $P = 0.013$) as compared to females whose upper segment (trunk) to lower segment ratio was ≥1.2. Ethnicity showed a weak significance in the univariate model ($P = 0.049$), which showed that Malays had a lower risk of AIS compared to Chinese.

Discussion

AIS is a lateral curvature of the spine measuring 10° or more on an X-ray as determined by the Cobb method.[3] It can be classified according to its etiology, age of onset, direction, location and magnitude.[4] It is a structural curve of the spine, most of which occurs in children during adolescence and is detected during routine physical examination in school screening programmes.[5]

Screening as defined by the Commission on Chronic Illness is the presumptive identification of unrecognised disease or defect by the application of tests, examinations, or other procedures that can be applied rapidly. According to Lonstein, scoliosis screening fulfills these criteria because it detects people with the disease, is not diagnostic and refers the positive findings for further evaluation.[6] The Adam's FBT is a simple and effective test, according to Pearsall[7] and the use of the scoliometer is a quick, simple, inexpensive and acceptable test used for mass screening.[3] Though it is not a diagnostic tool currently, it is the only widely used screening method. Screening can be carried out on a large scale, either in a community or a location such as a school where the children are together and easily screened.[6] Although the prevalence of scoliosis is very low, many researchers still advocate screening school populations in certain age groups, grades or levels. According to Richards and Vitale,[8] the school environment provides the opportunity to diagnose the condition and make referral for appropriate medical care. A school screening programme conducted for children between 10 and 16 years old who are at high risk for progressive AIS may achieve this.[4]

There have been a number of reports that had either discouraged or supported routine scoliosis screening. According to Reamy and Slakey,[9] mass screening can lead to unnecessary referrals of adolescents with minimal scoliosis who are at low risk for progression and can cause marked anxiety and lost time from school and work, but on the other spectrum, delayed referrals with high-risk curves can lead to increased morbidity; and in either situation, the psychological and social effects of the disease can be profound. There is also the issue regarding the cost-effectiveness of conducting a scoliosis screening programme. The prevalence of clinically significant scoliosis that warrants active intervention is low. Most patients with scoliosis (Cobb >10°) are treated expectantly without any active intervention. Bracing is started at higher angles depending on the age of the patient and likelihood of progression of the curve. Thus, only a small proportion

Table 4. Distribution of Curve Types In Females by Age

Age (y)	Right thoracic		Right thoracolumbar		Right lumbar		Left thoracic		Left thoracolumbar		Left lumbar		Double curve		Triple curve	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
9	9	14.3	16	25.4	1	1.6	2	3.2	15	23.8	1	1.6	18	28.6	1	1.6
10	21	14.0	18	12.0	0	0	7	4.7	36	24.0	5	3.3	56	37.3	7	4.7
11	42	11.2	55	14.7	3	0.8	14	3.7	78	20.9	5	1.3	158	42.2	19	5.1
12	47	17.9	43	16.3	0	0	9	3.4	50	19.0	5	1.9	97	36.9	12	4.6
13	36	13.4	35	13.1	0	0	7	2.6	60	22.4	7	2.6	114	42.5	9	3.4
Total	155	13.9	167	14.9	4	0.4	39	3.5	239	21.4	23	2.1	443	39.6	48	4.3

Table 5. Univariate and Multivariate Analysis of Factors in Females Associated with AIS

	% Scoliosis	Univariate analysis			Multivariate analysis*		
		OR	95% CI	*P*	OR	95% CI	*P*
Age (y)							
9	43.4	1.0			1.0		
10-11	58.9	1.9	1.3-2.7	0.001	1.7	1.1-2.4	0.010
12-13	66.7	2.6	1.8-3.7	<0.001	2.2	1.4-3.3	0.001
Menarche							
No menarche yet (9-12 y)	54.2	1.0			1.0		
Early menarche (<13 y)	64.7	1.5	1.3-1.9	<0.001	1.5	1.1-1.9	0.003
Late menarche (≥13 y)	69.6	1.9	1.3-3.0	0.002	1.5	0.9-2.4	0.110
Standing height (cm)							
150	55.3	1.0			1.0		
>150	63.7	1.5	1.2-1.7	0.001	1.0	0.8-1.3	0.93 (ns)
Sitting height (cm)							
≤75	52.0	1.0			1.0		
>75	62.5	1.5	1.2-2.0	0.002	1.1	0.8-1.5	0.71 (ns)
Ratio of upper to lower segments							
≥1.2	51.9	1.0			1.0		
<1.2	61.8	1.5	1.1-2.1	0.024	1.6	1.1-2.3	0.011
BMI							
Healthy and overweight (>18.5)	57.4	1.0			1.0		
Underweight (≤18.5)	63.0	1.3	1.0-1.5	0.021	1.5	1.2-1.8	0.001
Race							
Chinese	62.0	1.0			1.0		
Malay	54.5	0.7	0.5-1.00	0.049	0.7	0.5-1.0	0.058
Indian	62.8	1.0	0.7-1.6	0.88	1.1	0.7-1.7	0.79 (ns)
Others	47.6	0.6	0.2-1.3	0.18	0.5	0.2-1.2	0.13 (ns)

95% CI: 95% confidence interval; BMI: body mass index; ns: not significant; OR: odds ratio

* Significant variables in the univariate analysis are forced into the multivariate model

of school children screened to have scoliosis actually get any form of active intervention. Asher and Burton[10] noted in their article that only about 1 in 10 curves progresses to the point that treatment with bracing is warranted, and only 1 in 25, or 0.1%, to the point that surgery is warranted.[10]

According to Bunnell,[3] epidemiologists and policymakers who view the problem at a macro level consider the total healthcare burden of scoliosis to be low, the prevalence low and the cost of screening excessive, consider screening for scoliosis not indicated. Whereas from an orthopaedic standpoint, scoliosis screening is beneficial as it provides an individual the opportunity for early diagnosis and non-surgical treatment which is often missed in the absence of screening.

The SRS has recommended annual screening of all children aged between 10 and 14 years old and the American Academy of Orthopaedic Surgeons has recommended screening girls at 11 and 13 years old and boys once at 13 or 14 years old. The American Academy of Pediatrics (AAP) has recommended scoliosis screening at routine health supervision visits at age 10, 12, 14 and 16 years.[9] In Singapore, scoliosis screening is being done as part of its annual routine health screening programme among school children. Screening is conducted in all primary and secondary schools by doctors and nurses who were trained in scoliosis screening. Scoliosis screening in Singapore is carried out using visual inspection of the back and measuring the ATR using a scoliometer, during the FBT.

AIS is the most common spinal deformity affecting children with the reported prevalence from mass screening programmes of 1% to 3% depending on the age, curve magnitude and the population screened.[6,4,11] According to

Reamy and Slakey,[9] AIS is present in 2% to 4% of children between 10 and 16 years of age and it accounts for 65% of adolescent patients with structural scoliosis. School screening studies showed prevalence rates between 0.3% and 15.3%, the range reflecting different techniques or detection methods, population screened and definitions of scoliosis. Where scoliosis is defined as a curve over 10°, the prevalence is 1.5% to 3%, for curves over 20°, it is 0.3% to 0.5% and for curves over 30°, it is 0.2% to 0.3%.[12] In Greece, Grivas et al[13] did a study on the incidence of scoliosis of both genders aged between 8 and 14 years old and found to have an incidence of 2.9%. In northwestern and central Greece, the prevalence rate for those aged 9 to 14 years old, of both genders for Cobb ≥10°, was 1.7%.[14] In Quebec, a study by Morais et al,[15] showed a prevalence of 42 per 1000 among school children aged between 8 and 15 years old. They reported the prevalence to be higher among girls (51.9/1000) than boys (32.0/1000), and the prevalence rates increase with age between 8 and 15 years old and more markedly so for girls.[15] In Israel, Nussinovitch et al[16] did a study, over a 5-year period, of students between 12 to 18 years old attending the local public high school and found that 1.6% had scoliosis (Cobb ≥11°) with a three-fold predominance of girls over boys. The prevalence of AIS among school children in Singapore is similar to that reported in other countries. Daruwalla et al[17] in their study on the prevalence of scoliosis in Singapore in 1982, showed the prevalence in those aged 11 to 12 years old was 1.7% for girls and 0.4% for boys, a ratio of 3.2 to 1. In girls aged 16 to 17 years old, the prevalence was 3.1%. In this study, the overall prevalence rates in school screening for the 9- to 13-year-old girls with Cobb ≥10° was 1.4%. The prevalence rates for 9, 10, 11, 12 and 13 years old were 0.24%, 0.67%, 1.58%, 2.22% and 2.49%, respectively (Table 3).

In this study, although the prevalence was low, there was a substantial number of female students diagnosed with scoliosis who received active intervention, which ranged from 14% to 21% out of the total number of female students (9 to 13 years). There was also a 50% increase (from 14% to 21%) in the number of female students who received active intervention from 9 to 10 years old.

Gender, age, magnitude of the curve, apex and direction of the curve are factors associated with scoliosis.[18] AIS has been shown to occur more commonly in girls than in boys.[7,19] Females compared to males were also at an increased risk of developing the more severe grades of scoliosis.[14] In this study, comparing the prevalence rates between females in the study with the prevalence rates of males in routine health screening, the prevalence rate for the 11-year-old female was 1.58% while that of the 11-year-old male (routine screening) was 0.19%, which was much lower. The prevalence rate for the 13-year-old female students was 2.49% while that of the 13-year-old male students was only 0.64%. The results of this study are consistent with the 1997 prevalence study by Wong et al[1] which showed that the prevalence rates were much higher in girls than in boys. In their study, the prevalence rates for the 11- to 12-year-old and 13- to 14-year-old boys were 0.21% and 0.66%, respectively, whereas the prevalence rates for the 11- to 12-year-old and 13- to 14-year-old girls were 1.37% and 2.22%, respectively. The ratio of girls to boys with scoliosis was 6.4:1 between the ages of 11 to 12 years and 3.3:1 between the ages of 13 to 14 years.

With regard to age, this study showed an increasing prevalence rates with increasing age from 9 to 13 years old (Table 3). The prevalence rates for the 9-, 11- and 13-year-old females were 0.27%, 1.58% and 2.49%, respectively. These results are consistent with the 1997 prevalence study by Wong et al.[1] In their study, the prevalence rate in girls increased progressively from 0.24% between the ages of 9 to 10 years, to 1.37% and 2.22% between the ages of 11 to 12 years and 13 to 14 years, respectively.

As for the magnitude of the curve, the findings were similar to those reported in the literature. Most of the curves were small curves (Table 3). The prevalence of smaller curves was higher than the prevalence of larger curves. The prevalence rates of scoliosis with curves 10° to 19° were 0.18%, 0.45%, 1.06%, 1.54% and 1.59% for females aged 9, 10, 11, 12 and 13 years old, respectively, which were higher than the prevalence rates of scoliosis with curves ≥20°. Again, results are consistent with the 1997 study by Wong et al.[1] In their study, the prevalence rates were lower with larger predefined curves. The prevalence rates for the 11- to 12-year-old girls were 1.37%, 0.58% and 0.21% for Cobb angle ≥10°, Cobb angle ≥20° and Cobb angle ≥30°, respectively. For 13- to 14-year-old girls, the prevalence rates were 2.22%, 1.25% and 0.52% for Cobb angle ≥10°, Cobb angle ≥20° and Cobb angle ≥30°, respectively.

In another study, 40% of the scoliotic deformities involved the thoracic region, whereas 30% and 22% of curves were confined to the thoracolumbar and lumbar area, respectively.[20] In Finland, a study by Nissinen et al[19] showed that the most common curves were at the thoracic area. Morais et al[15] in Quebec had the following findings: 31% were located at the thoracic, 37% were located at the thoraco-lumbar, 22.2% were located at the lumbar, and 9.5% had double major curves. In northwestern and central Greece, Soucacos et al[14] noted in their study that the most common type of curve identified was the thoraco-lumbar followed by lumbar curves. In this study, the most common curve pattern was the double curve (39.6%), followed by the single thoraco-lumbar curve (36.3%), thoracic curves (17.4%), triple curves (4.3%) and lumbar curves (2.5%) in decreasing occurrence (Table 4). In contrast to the 1997 prevalence study by Wong et al,[1] the thoracolumbar curves were the most common (40.1%), followed by the thoracic curves (33.3%), double or triple curves (18.7%) and the lumbar curves (7.5%). Wong et al reported in their study in 1997 among school children in Singapore, that 48% of the 11- to 12-year-old girls with curves between 10° and 29° were pre-menarchal when their spinal curvature was detected and another 48% were less than 1 year post-menarche.[1] In our study, 42% of the 11-year-old girls and 19.6% of the 12-year-old girls with curves between 10° and 29° were pre-menarchal when their spinal curvature was detected.

Daruwalla et al[17] did a study on the prevalence and ethnic distribution of idiopathic scoliosis among school children in Singapore 26 years ago in 1982. In their study, in the 11- to 12-year-old group, there was no significant difference between the ethnic groups amongst the boys but there was a highly significant difference amongst the girls. The greatest difference was between the Chinese and the non-Chinese groups (P <0.001). Their study showed that Chinese girls in Singapore have a significantly higher prevalence of idiopathic scoliosis than Malay and Indian girls. In this study, ethnicity showed a weak significance where Malays had a lower prevalence of AIS as compared to the Chinese (P = 0.049).

In a cross-sectional investigation of eating pathology in adolescent females with scoliosis and diabetes by Smith et al,[21] the authors noted that patients with scoliosis weighed less and had lower BMI scores (P <0.001) than control participants. In our study, logistic regression analysis showed that underweight female students (BMI <18.5) were 1.5 times (P = 0.001; 95% CI, 1.2-1.8) at risk of having scoliosis compared to females whose weight were in the healthy range (BMI = 18.5 to >25) and overweight range (BMI ≥25).

In a study by Nissinen where 896 children were followed-up for development of scoliosis, several anthropometric measurements including standing and sitting height were studied for their prediction of scoliosis. In the children of both sexes who eventually had scoliosis, body height, sitting height, and growth of sitting height were greater than in other children, but these factors had no statistical significance in the logistic analyses.[19] In our study, both standing height and sitting height were significant in the univariate model but both were not significant factors in the multivariate model. The upper body segment to lower segment ratio which was less than 1.2 was statistically significant (OR, 1.6; 95% CI, 1.1-2.3; P = 0.011).

Conclusions

The prevalence studies by Daruwalla in 1982 and Wong et al in 1997 showed an increase in the prevalence rates of scoliosis for females aged 11 and 13 years old from 1982 to 1997 (Table 1). In 1982, the prevalence rate for the 11- to 12-year-old females was 0.83%. In 1997, the prevalence rates for females were 0.24%, 1.37% and 2.22% at the ages of 9 to 10, 11 to 12 and 13 to 14 years old, respectively. However, both studies did not include the 10- and 12-year-old females. In this study, a significant increase in the prevalence rates for the 10- to 11-year-old female students in the primary level as well as for the 12- to 13-year-old female students in the secondary level was noted.

This study also showed a 50% increase in the number of female students who received active intervention from the ages of 9 to 10 years (from 14% to 21%).

We conclude that screening of 10- and 12-year-old females identified a significant number who had AIS who would otherwise be missed if this group had not been screened.

Moreover, Bunnell[3] noted in his study that it has been observed that all scoliosis eventually requiring treatment can be identified by rib deformity at age 10. He noted that nearly all significant curvatures can be found on physical examination by the age of 10. In addition, screening the 10 year olds is in line with the recommendation of the SRS and the AAP on the age by which screening should commence. However, to be able to conclude that screening the 10 year olds is cost-effective, a follow-up study with more data is needed to further analyse the proportion of patients at each level that actually were managed at the SHC.

Recommendation

As there was a statistically significant increase in the prevalence of AIS among 10- to 11-year-old female students as well as among the 12- to 13-year-old female students, it was recommended that screening for females be performed every year commencing at 10 years old (Primary 5) until 13 years old (Secondary 2).

The scoliosis screening programme is being reviewed regularly and this study was done as part of the review process. Changes to the screening levels were recommended based on the results of this study. However, a study on the cost effectiveness of the scoliosis screening programme is ideal and will be considered.

Acknowledgement

The authors would like to thank the Director of Youth Health Division, Health Promotion Board, the Deputy Director of Student Health Centre, Health Promotion Board and the Deputy Director of the School Health Service, Health Promotion Board for their support, without whom, the study would not be possible. The authors would like to acknowledge the doctors, nurses and staff of the School Health Service and Student Health Centre for the assistance rendered in the conduct of the study.

REFERENCES

1. Wong HK, Hui JH, Rajan U, Chia HP. Idiopathic scoliosis in Singapore schoolchildren: a prevalence study 15 years into the screening. Spine 2005;30:1188-96.
2. Amendt LE, Ause-Ellias KL, Eybers JL, Wadsworth CT, Nielsen DH, Weinstein SL. Validity and reliability testing of the scoliometer. Phys Ther 1990;70:108-17.
3. Bunnell WP. Selective screening for scoliosis. J Clin Orthop Relat Res 2005;434:40-5.
4. Dickman D, Caspi O. Diagnosis and monitoring of idiopathic scoliosis, overview and technological advances. OrthoScan, Cinical Application Notes 2001.
5. Casella MC, Hall JE. Current treatment approaches in the nonoperative and operative management of adolescent idiopathic scoliosis. Phys Ther 1991;71:897-909.
6. Lonstein JE. Natural history and schools screening for scoliosis. Orthop Clin North Am 1988;19:227-37.
7. Pearsall DJ, Reld JG, Hedden DM. Comparison of three noninvasive methods for measuring scoliosis. Phys Ther 1992;72:648-57.
8. Richards BS, Vitale MG. Screening for idiopathic scoliosis in adolescent. The Orthopaedic Forum. J Bone Joint Surg Am 2008;90:195-8.
9. Reamy BV, Slakey JB. Adolescent idiopathic scoliosis: review and current concepts. Am Fam Physician 2001;64:111-6.
10. Asher MA, Burton DC. Adolescent idiopathic scoliosis: natural history and long term treatment effects. Scoliosis 2006;1:2.
11. Goldberg CJ, Dowling FE, Fogarty EE, Moore DP. Adolescent idiopathic scoliosis developmental instability. Genetica 1995;96:247-55.
12. Lonstein JE. Adolescent idiopathic scoliosis. Lancet 1994;344:1407-12.
13. Grivas TB, Koukos K, Koukou UI, Maziotou C, Polyzois BD. The incidence of idiopathic scoliosis in Greece – analysis of domestic school screening programs. Stud Health Technol Inform 2002;91:71-5.
14. Soucacus PN, Saucacos PK, Zacharis KC, Beris AE. School-screening for scoliosis, a prospective epidemiological study in northwestern and central Greece. J Bone Joint Surg Am 1997;79:1498-503.
15. Morais T, Bernier M, Turcotte F. Age- and sex-specific prevalence of scoliosis and the value of school screening programs. Am J Public Health 1985;75:1377-80.
16. Nussinovitch M, Finkelstein Y, Amir J, Greebaum E, Volovitz B. Adolescent screening for orthopedic problems in high school. Public Health 2002;116:30-2.
17. Daruwalla JS, Balasubramaniam P, Chay SO, Rajan U, Lee HP. Idipathic scoliosis: prevalence and ethnic distribution in Singapore school children. J Bone Joint Surg Br 1985;67:182-4.
18. Soucacus PN, Zacharis K, Soultanis K, Gelalis J, Xenakis T, Beris AE. Risk factors for idiopathic scoliosis: review of a 6-year prospective study. Orthopedics 2000;23:833-8.
19. Nissinen M, Heliovaara M, Seitsamo J, Poussa M. Trunk assymmetry, posture, growth and risk of scoliosis. Spine 1993;18:8-13.
20. Koukourakis I, Giaourakis G, Kouvidis G, Kivernitakis E, Blazos J, Koukourakis M. Screening school children for scoliosis on the island of Crete, Greece. J Spinal Disord 1997;10:527-31.
21. Smith FM, Latchford GJ, Hall RM, Dickson RA. Do chronic medical conditions increase the risk of eating disorder? a cross-sectional investigation of eating pathology in adolescent females with scoliosis and diabetes. J Adolesc Health 2008;42:58-63.