SPINE Volume 22, Number 17, pp 1985–1989

Cut-off Point of the Scoliometer in School Scoliosis Screening

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Study Design. A large-scale study on school screening for scoliosis was conducted to assess the referral rate, prevalence rate, and positive predictive value using different angles of trunk rotation as criteria for referral.

Objective. To determine an ideal angle of trunk rotation cut-off point to be used for referral in school screening for scoliosis.

Summary of Background Data. When using the Scoliometer (Orthopedic Systems, Inc., Hayward, CA) in school scoliosis screening, 5° and 7° angles of trunk rotation have been recommended as criteria for referral. Low positive predictive values and over-referral at these levels have been reported.

Methods. The Adams forward bend test and Scoliometer measurement were combined for school scoliosis screening in 33,596 girls from the fifth, sixth and seventh grades. Nurses were the primary screeners. Girls with trunk rotation angles of 5° or more were referred for radiography.

Results. The referral rate was 5.2%. By selecting 6°, 7°, 8°, 9° or 10° angles of trunk rotation as criteria for referral, the referral rate became 2.4%, 1.4%, 0.7%, 0.5%, or 0.3%, respectively. The prevalence rate for scoliosis equal to or larger than 10°, 20°, 30°, or 40° of the Cobb angle was 1.47%, 0.21%, 0.04% and 0.02%, respectively, by using a 5° angle of trunk rotation as the criterion for radiography. The positive predictive value was 28.3% for scoliosis of 10° or more, 4% for scoliosis of 20° or more, 0.8% for scoliosis of 30° or more, and 0.4% for scoliosis of 40° or more with a 5° angle of trunk rotation as the criterion for referral. By selecting angles of trunk rotation larger than 5° as criteria for referral for radiography, the positive predictive value increased, but positive cases with larger Cobb angles also decreased markedly.

Conclusion. The optimal cut-off point for referral when using the Scoliometer in school screening of scoliosis is still difficult to determine. [Key words: school screening, Scoliometer, scoliosis, scoliosis prevalence]
Spine 1997;22:1985–1989

School screening of scoliosis has been conducted for 30 years in many countries using various methods for primary and secondary screening.[5,9,10] The effects of these screening programs have been early detection of minor curves and a decrease in the necessity for surgery and in the number of severe curves requiring surgery.[17] Because of a lack of specificity of various screening methods, over-referral and many other unsolved problems exist in school screening. The routine school screening of adolescents for idiopathic scoliosis is still controversial.[6,11,19–21]

Measurement of the angle of trunk rotation (ATR) using the Scoliometer first was advocated by Bunnell.[3] He suggested a 5° ATR as a criterion for referral for secondary screening. He stated that the method is simple, reliable, and inexpensive, with a high degree of sensitivity and specificity. Even after the Scoliometer was used in school screening programs, over-referral still was found to be a problem.[8] Bunnell[4] later suggested a 7° ATR as a criterion for referral in an attempt to decrease the referral rate to 3%, but it is still not clear whether this is the optimal cut-off point of ATR for referral in routine school screening.

In this study, the Adams forward bend test and Scoliometer measurement were combined in a large-scale school scoliosis screening program to determine the referral rate, prevalence rate, and positive predictive value (PPV), using different ATR values as criteria for referral. The author of this study hoped to determine an ideal cut-off point of ATR to be used as a criterion for referral in school screening for scoliosis.

Materials and Methods

In 1994, school screening for scoliosis was conducted in 202 schools throughout Changhua county, Taiwan. Only female students in the fifth and sixth grades in elementary school and in the first grade in junior high school were included. There was a total of 34,234 students studied. After completing training with lectures, demonstrations, and practice, nurses were responsible for the primary screening using the Adams forward bend test and Scoliometer measurement for all students, under the supervision of orthopedists. The ATR was measured at the thoracic, thoracolumbar, and lumbar areas with the student in the standing forward bend position. Students with an ATR of 5° or more in any of the thoracic, thoracolumbar, or lumbar areas were referred for secondary screening by radiographic examination. Radiography was performed with the student in the standing position. Individuals with a Cobb angle of 10° or more were considered as having scoliosis.

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Acknowledgment date: April 25, 1996.
First revision date: July 16, 1996.
Acceptance date: July 31, 1996.
Device status category: 2.

Table 1. Positive Predictive Value of the Scoliometer by Selecting Different Angle of Trunk Rotation for Roentgenogram

	Cobb Angle			
ATR (°)	≥10°	≥20°	≥30°	≥40°
≥5	28.3	4.0	0.8	0.4
≥6	34.8	6.1	1.6	1.0
≥7	40.0	9.5	2.8	1.8
≥8	47.9	15.5	3.4	2.0
≥9	54.1	20.4	5.1	3.1
≥10	57.8	23.4	4.7	3.1

ATR = angle of trunk rotation.
Values for positive predictive values are percentages.

■ Results

Of the 34,234 eligible students, 33,596 attended the primary screening. The rate of attendance was 98.1%. Among these students, nine had congenital anomalies, seven had sequel of poliomyelitis, six had cerebral palsy, and 20 had other disorders. A 5° ATR was selected as a criterion for referral for radiography. In all, 1,743 students were advised to undergo radiographic examination. The referral rate was 5.2% for students with an ATR of 5° or more and would have been 2.4% for students with an ATR of 6° or more, 1.4% for those with an ATR of 7° or more, 0.7% for those with an ATR of 8° or more, 0.5% for those with an ATR of 9° or more, and 0.3% for those with an ATR of 10° or more. The referral rate decreased as higher degrees of ATR were selected.

Of the 1,743 students with an ATR equal to or larger than 5°, 1,188 (68.2%) agreed to undergo radiographic examination. By selecting a Cobb angle of 10° or more as a criterion for scoliosis, 336 of the 1,188 students were diagnosed with scoliosis. The PPV or proportion of those who tested positive and were diagnosed with scoliosis was 28.3% (Table 1). The PPV was 4% for scoliosis of 20° or more, 0.8% for scoliosis of 30° or more, and 0.4% for scoliosis of 40° or more. The PPV for the various severities of scoliosis, measured by radiography, also increased with increasing ATR cut-off values.

In the 336 patients with scoliosis of 10° or more, two had congenital scoliosis, one had a sequel of poliomyelitis, one had cerebral palsy, and four had other spinal disorders. Most (97.6%) of the cases of scoliosis were idiopathic. The location of scoliosis in these 336 patients was thoracic in 105 patients (31.3%), thoracolumbar in 121 (36.0%), and lumbar in 110 (32.7%).

There was a positive correlation between Cobb angle and ATR (correlation coefficient = 0.29, $P = 0.001$). The distribution of Cobb angle with ATR is shown in Figure 1. The Cobb angle was less than 10° in 71.7% of curves, from 10° to 19° in 24.2%, from 20° to 29° in 3.2%, from 30° to 39° in 0.4%, and more than 40° in 0.4%. By taking into account the attendance rate for radiographic examination, the calibrated prevalence of scoliosis for different degrees of curves was determined and is shown in Table 2.

■ Discussion

Scoliosis is a three-dimensional deformity of the spine, manifested by trunk asymmetry and uneven back surface as a result of lateral deviation and rotation of the spinal column. The rib or back hump is caused mainly by a prominence of the attaching rib cage and muscles. The uneven surface of the back may be caused by many factors and is not directly related to the lateral curvature of scoliosis.[9,16] Because it is not easy to detect lateral deviation of the spine, various methods of measurement of asymmetry of the back surface have been used for indirect detection and follow-up evaluation of scoliotic patients. Among these methods, the Adams forward bend test is the most frequently used and inexpensive method.[10,14] Because of its qualitative nature, the presence of scoliosis is quite subjective. The sensitivity and specificity depend on the skill of the examiner and the degree of spinal curvature being sought. The quantitative measurement of difference of height of the back surface by ruler can be affected greatly by the size of the patient. Moire topography, which requires special equipment and trained individuals to interpret the results, has not been widely used in school scoliosis screening programs.[9,18] The inclinometer (Scoliometer) designed by Bunnell[3] can quantitate the asymmetry of back shape by measuring the ATR. It has gained widespread use because of its low cost and its convenience.

Pearsall et al[13] compared three noninvasive methods, *i.e.*, the Scoliometer, the back-contour device, and Moire topographic imaging, for measuring scoliosis. Pearsall et al[13] and Stokes et al[15] found that factors other than trunk deformity, such as the posture assumed by the subject during measurement and limb length discrepancy, may have influence on ATR. Among the three

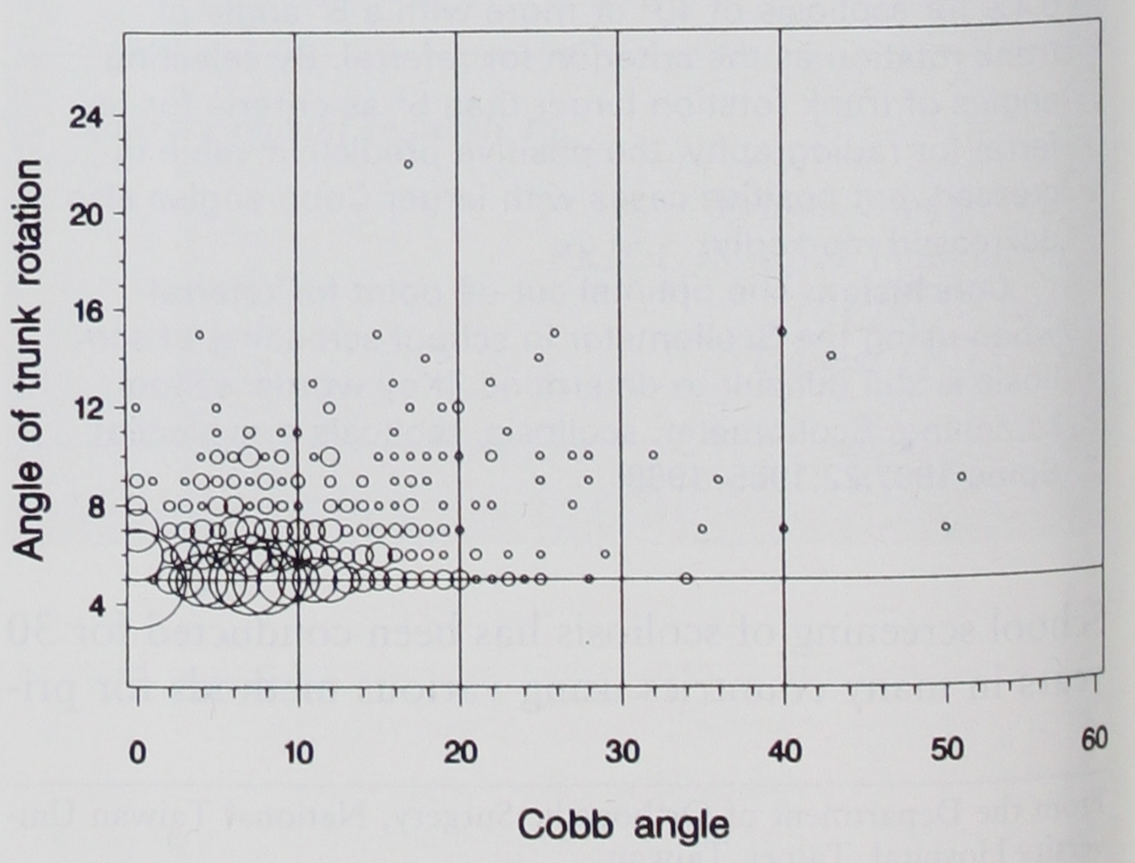

Figure 1. Distribution of angle of trunk rotation and Cobb angle. The number of subjects are represented by the size of the circles. The smallest circle represents one subject.

Table 2. Referral Rate, Number of Patients, and Prevalence Rate of Scoliosis by Selecting Different Angle of Trunk Rotation as Criterion for Roentgenogram

		Cobb Angle							
		≥10°		≥20°		≥30°		≥40°	
ATR (°)	RR	No.	PR	No.	PR	No.	PR	No.	PR
≥5	5.2	336	1.47	48	0.21	10	0.04	5	0.02
≥6	2.4	178	0.83	31	0.14	8	0.04	5	0.02
≥7	1.4	114	0.55	27	0.13	8	0.04	5	0.02
≥8	0.7	71	0.34	23	0.11	5	0.02	3	0.01
≥9	0.5	53	0.27	20	0.10	5	0.03	3	0.02
≥10	0.3	37	0.29	15	0.12	3	0.02	2	0.02

ATR = angle of trunk rotation; RR = referral rate; No. = no. of patients; PR = prevalence rate of scoliosis.

methods, Moire topography had the best correlation between trunk rotation and Cobb angle, especially in the thoracic region. Those authors concluded that these techniques appear to provide valid estimates of lateral curvature of the spine in the thoracic region of the trunk, but not in the lumbar region.

From his study of 1,065 scoliotic patients, Bunnell[3] suggested that a 5° ATR be used as a criterion for referral in school screening. He predicted that the number of referred patients with a Cobb angle of less than 20° would be reduced by 50%. Any patient with an ATR of less than 5° would have a 96% chance of having a curve of less than 20°. The predicted false-negative rate was 0.1%. Ashworth[2] pointed out that an ATR of 5° supplies 100% sensitivity with only 47% of specificity; whereas an ATR of 7° has a sensitivity of 83%, but a specificity of 86%, thereby minimizing false-positive referrals. The validity and reliability of the Scoliometer was tested by Amendt et al[1] in 65 patients with idiopathic scoliosis. Their results indicated good measurement reproducibility. They suggested that the validity of Scoliometer measurement is not sufficient to use this method alone for determining patient diagnosis and management. They stated that the use of this tool as a screening device would be appropriate based on the positive frequency analysis. The reliability of the Scoliometer also was assessed by Murrell et al[12] in 25 patients with idiopathic scoliosis. Their results indicated that the Scoliometer can be a reliable, noninvasive tool for assessing spinal axial rotation repeatedly when used by a single trained observer. In the above studies, the Scoliometer was not used for screening school children.

Although Bunnell[3] claimed that the Scoliometer had high sensitivity and specificity, this has not been validated in school screening programs. To avoid unnecessary x-ray exposure, only students with an ATR of 5° or more were referred for radiographic examination in this study, as recommended by Bunnell. Therefore, the true sensitivity and specificity of this method in school screening of idiopathic scoliosis cannot be known. In the present author's previous study using the Adams forward bend test and the Scoliometer in a school screening of 12,641 female students, the PPV was only 41.2% for scoliosis of 10° or more and 8.4% for scoliosis of 20° or more.[8] In current study, the PPV was 28.3% for scoliosis of 10° or more, 4% for scoliosis of 20° or more, 0.8% for scoliosis of 30° or more, and 0.4% for scoliosis of 40° or more. By increasing the cut-off value of ATR, the PPV for each degree of scoliosis increased. However, it was still low even at 10° ATR, with a PPV of only 4.7% for scoliosis of 30° and 3.1% for scoliosis of of 40°. Goldberg et al[6] used a three-tier screening method and follow-up examination, which included repeated Adams tests followed by Scoliometer measurement. Radiography was recommended on the basis of the Scoliometer reading, adapted from Bunnell, and maturity as follows:

Table 3. Comparison of Referral Rate, Positive Predictive Value, and Prevalence Rate of Scoliosis in Different Screening Programs

				Positive Predictive Value (%)			Prevalence Rate (%)		
Reference	Screening Method	No. of Cases	Referral Rate (%)	≥10°	≥20°	≥30°	≥10°	≥20°	≥30°
Lonstein et al	Adams	2,000,000*	3.4	35.3			1.2		
Morais et al	Adams	29,195		17.9	3.5		1.76	0.34	
Laulund et al	Adams + Moire	1034	8.4	29			4.1		
Tu et al	Moire	6387	10.6	33.8	3.3		3.20	0.38	
Huang et al	Adams + Scoliometer	12,641	8.4	41.2	8.4		3.46	0.70	
Current study	Adams + Scoliometer	33,596	5.2	28.3	4.0	0.8	1.47	0.21	0.04

* Estimated number.

for premenarchial girls radiography was recommended if there was a thoracic hump of 8° or a loin hump of 10°, and for postmenarchial girls radiography was recommended if there was a thoracic hump of 10° or a loin hump of 15°. They found that the sensitivity of this method for scoliosis of 40° or more was 83% by radiographic examination. The specificity, or the proportion of correctly identified cases of no scoliosis, was 99%. The PPV for scoliosis greater than 39° at diagnosis or during the follow-up period was 8%.[6] The PPV of any screening method actually varies with the degree of curvature by which a true positive is defined, the prevalence of scoliosis in the screening population, the screening methods, and the skill of examiners.[8,10,11,18] From the low PPV of the Scoliometer, especially for large curves, its effectiveness in student screening should be questioned.

In a previous study by the author of the present study, the referral rate was 8.4% when a 5° ATR was used as a criterion for referral.[8] By raising the value of the ATR to more than 5°, the number of referrals can be decreased, but many cases of significant curves would be missed. In 1993, Bunnell[4] suggested that a 7° ATR was an appropriate referral criterion for spinal screening at any level of the spine, based on study of 1,000 high school students with consideration of the referral rate. The referral rate was 3% when a 7° ATR was used as the criterion and 12% when a 5° ATR was used.[4] The present study is as yet the largest field study of the effectiveness of the Scoliometer that has been performed. The results indicate that if a 3% referral rate is chosen, a 6° ATR should be selected as a cut-off value for referral. If this cut-off point had been chosen, 17 of 31 cases with scoliosis of more than 20° and two of 10 cases of scoliosis of more than 30° would have been missed. All five cases of scoliosis of more than 40° would have been detectable. If we do not want to miss any cases of more than 30° scoliosis, then a 5° ATR should be selected as the criterion for referral. If we aim only to detect all cases of scoliosis of more than 40°, a 7° ATR can be selected as a criterion for referral. In this case, two of five cases of scoliosis between 30° and 40° would have been missed. If an ATR of 8° had been selected, the referral rate would have been 0.7%. Two of five cases of scoliosis between 30° and 40°, and two of five cases of scoliosis of more than 40° would have been missed. The author of this study is not sure of the ideal referral rate for use in school scoliosis screening. There is still no clear ATR cut-off point that reduces unnecessary referral without missing cases with significant curves.

In Taiwan, there have been only two previous school scoliosis screening programs. Tu et al[18] used Moire topography to screen 6,389 students in fifth and sixth grades of elementary school and the first grade of junior high school in Taipei city. The present author's previous study used Adams forward bend test and the Scoliometer to screen 12,641 students in grades 1–3 of junior high school in Taipei city.[8] Orthopedic residents were responsible for this primary screening. The current study was similar to the author's previous study, except that the screening was conducted in female students in the fifth and sixth grades of elementary school and in the first grade of junior high school in a suburban county, and screening was conducted by trained nurses. When the results of the current study were compared with those of Lonstein et al,[10] Morais et al,[11] Laulund et al,[9] Tu et al,[18] and with those of the author's previous study,[8] the referral rate was higher than that Lonstein et al, but lower than that of the other studies (Table 3.) The low referral rate might be related to a lower prevalence rate of scoliosis, inexperienced screening teams, and insensitive screening method. The PPV of this study was higher than that in the study by Morais, but lower than that of other studies. Because the author of the present study used a similar method in this study and his previous study, this low PPV may be a result of a low prevalence of scoliosis, less experienced screening teams, and low specificity.

Grossman et al[7] evaluated the ability of the Adams forward bend test and the Scoliometer to detect truncal rotation or asymmetry in a school screening setting. Of 954 sixth-grade students examined with each test independently, 123 and 13 (using an ATR of $> 5°$ and 7°, respectively) were found to be abnormal on Scoliometer examination but normal on the Adams test. They concluded that usefulness of selecting children for Scoliometer examination on the basis of the Adams test was not supported by their data. Ashworth[2] found that adding the Scoliometer results to those of the Adams test increased the specificity of that test from 56% to 86%. In the current study, the screening teams examined students with the Adams forward bend test and Scoliometer measurement, so patients with significant asymmetry of the back surface should not have missed.

In this study, a high referral rate, a low prevalence rate for large curves, and low PPV of scoliosis were found by selecting a 5° ATR as a referral criterion. The optimal ATR for use in scoliosis screening that would also detect large curves could not be determined.

Acknowledgments

The author thanks Min-Huo Hwang, Superintendent of Show Chwan Memorial Hospital, Changhua, Taiwan, for supporting this study, and Charng-Er Shyu, PhD, for her help in statistical analysis.

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Point of View

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School screening for scoliosis is still an accepted and widely used method for early detection of spinal curvature. A commonly used detection device is the scoliometer, which uses a 5°- or 7°-angle of trunk rotation (ATR) as the cut-off point for referral. The authors of this article point out the difficulty in using different cut-off points for the ATR as criteria for referral or radiography.

If the cut-off point for the ATR were changed from 5° to 7°, 21 of the 48 curves over 20° (44%) and two of the 10 curves over 30° (20%) would not be detected. All the curves over 40 degrees would be detected, but increasing the ATR to 8° would result in even curves over 40 degrees not being detected.

This study shows that increasing the cut-off point of the scoliometer reading for curves in school screening is fraught with problems. Each person must make his or her own decision and recommendations, but anyone increasing the cut-off point by more than 5° must be aware of the rate of false-negative findings, *i.e.*, children with curves whose curves are not detected.