Validity and Reliability Testing of the Scoliometer®

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This study was designed to evaluate the Scoliometer®, an instrument that measures axial trunk rotation in individuals with scoliosis. The objectives included determining 1) the Scoliometer's® screening capability and validity and 2) the intrarater and interrater reliability of Scoliometer® measurements. Scoliometer® measurements made by two raters on 65 persons with idiopathic scoliosis were correlated with radiographic assessment of vertebral (pedicle) rotation and lateral curvature (Cobb method). Correlations ranged from .32 to .46 with pedicle rotation and from .46 to .54 with the Cobb angle. Frequency analysis revealed relatively good specificity, sensitivity, and predictive capability of the Scoliometer®. Intrarater and interrater reliability coefficients were high (r = .86–.97). These results indicate good measurement reproducibility. The less-than-optimal between-method correlation coefficients suggest that the validity of Scoliometer® measurements is not sufficient to use this method alone for determining patient diagnosis and management. Based on the positive-frequency analysis, however, the use of this tool as a screening device would be appropriate. [Amendt LE, Ause-Ellias KL, Eybers JL, et al: Validity and reliability testing of the Scoliometer®. Phys Ther 70:108–117, 1990]

Key Words: *Neck and trunk, scoliosis; Scoliosis; Spinal curvatures; Tests and measurements, functional.*

The recent widespread use of school screening programs for the early detection of scoliosis has led to the development of various clinical methods to quantify scoliotic deformities. The forward-bend test (FBT) is the most popular clinical assessment tool.[1] It involves having the child bend forward with feet together, knees straight, arms dangling, and hands together as the examiner looks for trunk asymmetries. The FBT, however, does not allow a quantitative documentation of the deformity, and the efficacy of the test depends on the training and skill of the examiner. Many other techniques are currently used for the early detection of spinal deformities including rotation assessment via moiré topography,[2–8] rib hump measurement using a jig,[9,10] photogrammetry involving photography through a mesh screen,[11] and trunk rotation assessment via the Scoliometer®.*[11–14]

The value of widespread school scoliosis screening, however, has come into question in recent years. Opponents of school scoliosis screening state that the costs of school screening

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*Model 5280, Orthopedic Systems Inc, Hayward, CA 94545.

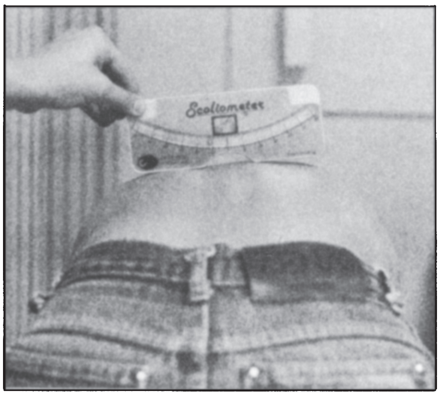

Fig. 1. *Scoliometer® used to measure axial trunk rotation (ie, trunk asymmetry).*

outweigh its benefits and that conventional screening methods are too sensitive and result in an unacceptable number of false positive findings.[15]

Proponents of mandatory school screening claim that early screening and diagnosis of spinal deformity allows for effective nonoperative measures to be used instead of surgical intervention. These claims are supported by numerous studies citing cost and time effectiveness of an efficient screening program.[1,7,11,16–19] Torell et al reported that efforts to detect scoliosis early have resulted in a threefold increase in the number of patients who could be conservatively treated for scoliosis, thus decreasing the percentage of patients who required surgery.[19]

Possession of a valid, reliable tool for screening purposes would greatly enhance the ability of experts to decide whether to recommend school screening programs. This need led to the present investigation of the Scoliometer®.

The Scoliometer® is an inclinometer designed to measure trunk asymmetry, or axial trunk rotation (ATR), also commonly referred to as "rib hump deformity" (Fig. 1). Bunnell, developer of the Scoliometer®, proposed that it provides objective measurements that can effectively determine whether further orthopedic evaluation is needed.[11] From an eight-year prospective study of 1,065 patients referred for orthopedic evaluation of scoliosis, Bunnell concluded that an ATR of 5 degrees (as measured by the Scoliometer®) was a good criterion for identifying lateral curvatures of the spine with Cobb angles of 20 degrees or more. Bunnell stated that the Scoliometer® is simple, reliable, and inexpensive to use and that this method of measurement is easily taught to lay personnel for school screening. He also suggested that this method could be used to provide clinical measurements on sequential visits and that these data, rather than additional radiographic studies, could serve to document curve progressions.[11]

Review of the Literature

A multicenter study in the United Kingdom used Scoliometer® measurements for early detection of scoliosis and referral for management in school children.[12] Investigators used 7.5 and 10 degrees of ATR in both a standard forward-bend position and in a standard sitting forward-bend position as the threshold for referral to a hospital. The investigators concluded that thresholds of 7.5 and 10 degrees of ATR, as determined by the Scoliometer® in these positions, had low predictive values for lateral spinal curves of 20 degrees or more (Tab. 1). Table 1 also contrasts these results with those of three other studies investigating scoliosis screening methods, including forward-bend tests, photogrammetry, and moiré topography.

Huang assessed the effectiveness of the Scoliometer® by screening 12,642 junior high-school students.[13] A total of 1,004 students (8.40%) had an ATR of 5 degrees on the Scoliometer®, but only 8.38% of these students had a lateral curve of 20 degrees (91.62% false positive rate).

Mubarak et al found high intrarater and interrater variation of ATR measurements with the Scoliometer®, but they conceded that the device does provide a simple and inexpensive means of quantifying the clinical deformity of trunk rotation in patients with scoliosis.[14]

The purpose of this study was to investigate the validity and reliability of scoliometry for patients referred with an initial diagnosis of idiopathic scoliosis. The specific objectives were

1. To determine intrarater and interrater reliability for two investigators with similar training in using the Scoliometer®.
2. To compare Scoliometer® measurements of ATR to the conventional radiographic technique for measuring vertebral rotation via pedicle alignment.
3. To investigate the validity of the assumption that there is a relationship between trunk rotation and lateral spinal curvature as determined by Cobb-angle measurements.
4. To assess the specificity, sensitivity, and predictive capability of the Scoliometer® as a screening device.

Prior to the study, we postulated the following hypotheses:

1. There would be a stronger relationship between Scoliometer®-derived ATR and the conventional radiographic technique for measuring vertebral (pedicle) rotation than between ATR and the Cobb angle (lateral spinal curvature).
2. The sensitivity and predictive value of a positive test would be higher than the specificity and predictive value of a negative test.
3. Intrarater reliability would be higher than interrater reliability.

Method

Subjects

We studied 65 patients (57 female, 8 male) referred to the University of Iowa Hospitals' Scoliosis Clinic. The patients' ages ranged from 5 to 37

Table 1. *Literature Review of Scoliosis Screenings*

Authors	N	Screening Method	Minimum Cobb Angle (°)	Minimum Scoliosis Angle (°)	Sensitivity %	Sensitivity Ratio	Specificity %	Specificity Ratio	PV+[a] %	PV+[a] Ratio	PV−[b] (%)
Burwell[12] (1986)	102	FBT[c] and Scoliometer®	20	7.5					20	(8/40)	
			20	10.0	46	(6/13)	84	(75/89)	30	(6/20)	
		Sitting forward-bend position and Scoliometer®	20	7.5					20	(8/40)	
			20	10.0					18	(3/17)	
		Standing thoracic ATR[d] minus standing lumbar ATR	20	10.0	38	(5/13)	96	(85/89)	56	(5/9)	
		Standing thoracic ATR minus sitting lumbar ATR	20	10.0	69	(9/13)	92	(82/89)	56	(9/16)	
Howell, et al[28] (1978)	54	Photogrammetry	10		29		81		62		
	54	FBT by physical therapists	10		87		42		65		
	28	FBT by nurses	10		74		49		60		
Lauland, et al[4] (1982)	195	Moiré topography	10						29		99.7
		FBT by school physicians	10						18		97.0
Sahlstrand[6] (1986)	129	Moiré topography	5		99		57				
		FBT[e]	5		97		64				

[a]Predictive value of a positive test.

[b]Predictive value of a negative test.

[c]Forward-bend test.

[d]Axial trunk rotation.

[e]Clinical evaluation of rotation if FBT was quantified with two rulers. A value of at least 0.5 cm was considered positive.

years ($\bar{X}$ = 14.8). Thirty-four patients had single spinal curves ($\bar{X}$ Cobb angle = 21°), and 31 had double spinal curves ($\bar{X}$ Cobb angle = 29°). In comparison, the literature reports a 0.4% to 0.7% prevalence of >5 degrees of scoliosis in the general population.[1] Patients excluded from this study were those with nonidiopathic forms of scoliosis, fusion or other spinal surgeries, or any associated problems interfering with the ability to properly perform an FBT. In compliance with the Human Subjects Research Review Committee at The University of Iowa, informed written consent of patients, parents, or guardians was obtained prior to the patients' participation in the study.

Design and Data Collection

A treatment-×-subjects design was used in which repeated measures (three trials) were taken by each of two examiners (KLA and JLE). Following the protocol for the use of the instrument, both examiners were self-trained using the Scoliometer®.[11] The order in which the testers evaluated a patient was randomized. The investigators took the measurements independently without communicating their results to each other. All ATR measurements were taken using the same Scoliometer®. The Scoliometer® was calibrated with a protractor and a level over a functional range from 0 to 25 degrees and was found to be accurate to within ± 1 degree. The patients were instructed to bend forward, exposing visible trunk asymmetries. During each forward bend, the investigator took an upper measurement over the apex of the curve in the thoracic region. The patient was then instructed to continue to bend forward, exposing the apex of the curve in the lumbar region, and the investigator took a lower measurement. These measurements were repeated two more times with the patient coming to an erect standing position between trials.

Standard anterior-posterior (AP) or posterior-anterior radiographs were obtained for each patient and read by the orthopedist serving as director of the Scoliosis Clinic. The radiological appraisal included Cobb angle,[20] vertebral rotation,[21] and type of curve. The Cobb angle was determined by drawing a horizontal line at the superior border of the superior-end vertebra and another horizontal line at the inferior border of the inferior-end vertebra. Perpendicular lines were then drawn from each of the horizontal lines, and the intersecting angle was determined as the Cobb angle (Fig. 2).[20] Pedicle rotation, as a criterion of vertebral rotation, is considered a more stable indicator than spinous process rotation because the pedicles are closer to the axis of vertebral rotation.[21] Pedicle rotation was ranked on a scale of 0 to 4 by estimating the amount that the pedicles of the vertebrae had rotated as seen in the radiograph (Fig. 2).[20] In this ranking system, 0 indicates no rotation, 1 indicates that the pedicle on the con-

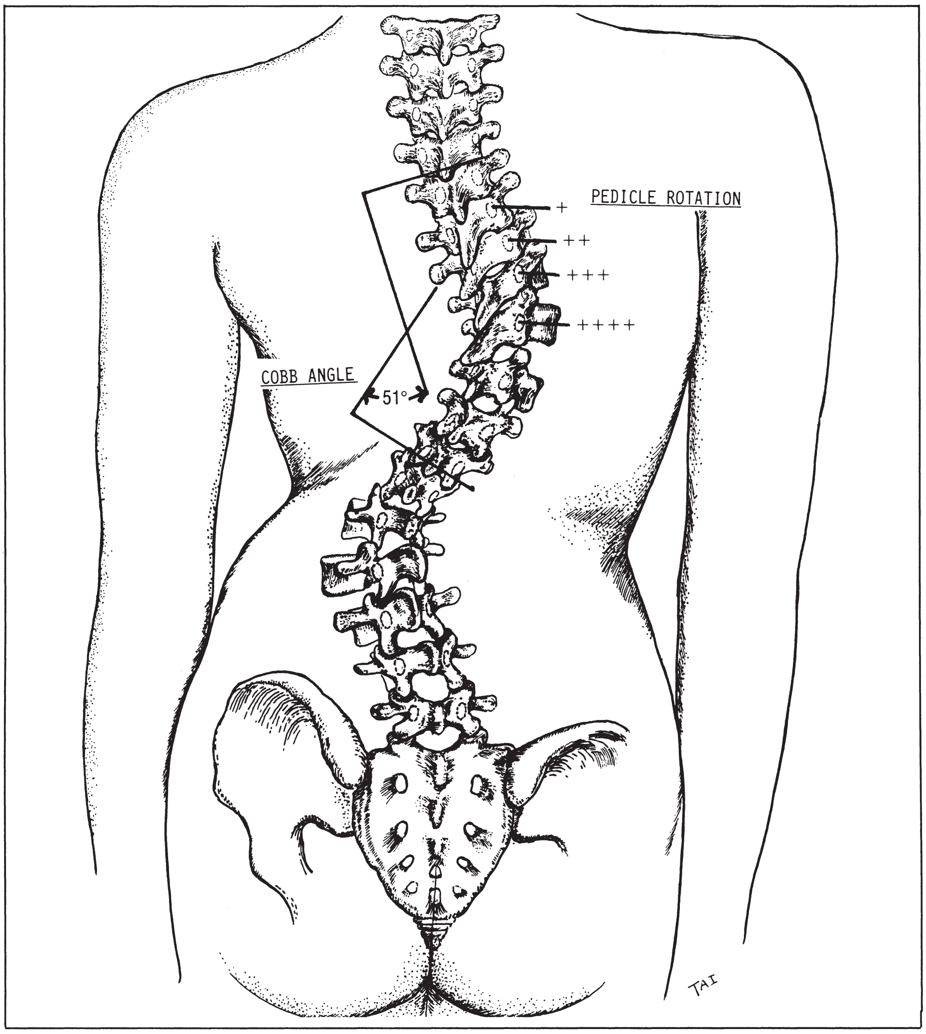

Fig. 2. *Lateral curvature measured by Cobb method is intersection angle of lines perpendicular to superior and inferior surfaces of end vertebrae. Vertebral rotation indicated by pedicle alignment is defined as follows: + = pedicle on convex side of curve is slightly nearer to the vertebral body bisection; ++ = pedicle is two thirds of the way toward the vertebral body bisection; +++ = pedicle is on the vertebral body bisection; ++++ = pedicle is beyond the vertebral body bisection.*

vex side of the curve is slightly nearer to the vertebral body bisection, 3 indicates the pedicle is two thirds of the way toward the vertebral body bisection, and 4 indicates the pedicle is beyond the vertebral body. Type of curve—single versus double—was determined from the radiograph. Age and sex were recorded from the patients' charts.

Data Analysis

Descriptive statistics were calculated for all variables. Correlation coefficients were computed between the ATR measurements obtained with the Scoliometer® and the Cobb angle and pedicle rotation measurements. Correlation coefficients were also calculated for Cobb angle versus pedicle rotation. The Spearman rank-order technique was used for computations involving the ranked pedicle rotation data. The Pearson product-moment correlation method was used on the ratio-type data. Intraclass correlation coefficients (type 1) were calculated following a one-way analysis of variance of the three repetitive measurement trials to determine intrarater reliability.[22] Interrater reliability was assessed with Pearson product-moment correlation coefficients (r) computed between the means of the three trials for each of the two raters. The accuracy of the measurements obtained by evaluating systematic differences was assessed by means of Bonferroni adjusted t tests.[23] The .05 level of probability was adopted as the criterion for statistical significance.

To assess the screening capability of the Scoliometer®, a frequency analysis was used to determine the sensitivity, the specificity, and the predictive values of positive and negative tests.[24] We chose criterion levels of 5, 7.5, and 10 degrees of ATR based on Bunnell's use of 5 degrees of ATR as a criterion for identifying Cobb angles of 20 degrees or more[11] and Burwell's use of 7.5 and 10 degrees of ATR for predicting curves of 20 degrees or more.[12] A description of the method is presented in Table 2.

Results

As shown in Figures 3 through 5, the descriptive data indicate that the patients in this study had mild to moderate scoliosis, because their Cobb angle means were between 20 and 30 degrees and their pedicle rotation means were between 1.25 and 1.40 degrees. A lateral curve with a Cobb angle of <20 degrees is generally not braced. A curve of 20 to 30 degrees is watched closely for signs of rapid progression and braced accordingly. The range for ATR measurements was 0 to 19 degrees, the range for Cobb angle measurements was 2 to 71 degrees, and the range of pedicle rotation was 0 to 3 degrees.

The reliability analysis indicated slightly better intrarater reliability as compared with interrater reliability, except for single lower curves. The correlation coefficients, however, were high for both, and all were statistically significant (Tab. 3). Two of the between-trial differences were statistically significant but of neglible magnitude (Tab. 4). None of the between-rater mean contrasts were statistically significant (Tab. 5). These results verify the consistency of the Scoliometer® measurements and

Table 2. *Definitions and Calculations of Terms Used in Scoliosis Screening Test*

Scoliometer® Test Procedure[a]	Diagnosis[b]: Scoliotic	Diagnosis[b]: Not Scoliotic
ATR > criterion measure	a = number of true positive tests	b = number of false positive tests
ATR < criterion measure	c = number of false negative tests	d = number of true negative tests

$$\text{Sensitivity} = \frac{a}{a+c} \times 100 \qquad \text{Predictive value of a positive test} = \frac{a}{a+b} \times 100$$

$$\text{Specificity} = \frac{d}{b+d} \times 100 \qquad \text{Predictive value of a negative test} = \frac{d}{c+d} \times 100$$

[a]Measured axial trunk rotation (ATR) > or < three criterion measures: 5°, 7.5°, and 10°

[b]Lateral curve of >20° indicates presence of scoliosis; lateral curve of <20° indicates absence of scoliosis.

good intrarater as well as interrater measurement reproducibility.

Correlation coefficients between the different measurement techniques are presented in Table 6. The coefficients between ATR and pedicle rotation ranged from .32 to .46. Only the double-curve values were statistically significant. Correlation coefficients for ATR and Cobb angle ranged from .46 to .54, and all were significant. Pedicle rotation versus Cobb angle produced coefficients ranging from .48 to .70, which were also significant for all curves (Tab. 7). In patients with double curves, the Pearson product-moment correlation values were higher for the upper curves than for the lower curves. These results suggest that the Scoliometer® predicts pedicle rotation less accurately than Cobb angle.

The screening capabilities of the Scoliometer® varied with the designated criterion measure (Tab. 8). As the criterion measure increased (5° to 7.5° to 10°), the sensitivity and predictive value of a negative test decreased and the specificity and predictive capability of a positive test increased.

Discussion

Reliability

Fundamental to using any type of measuring device, intrarater and interrater reliability must be considered. We found the Scoliometer® to be highly reliable for intrarater and interrater measurement comparisons (r = .86–.97). The significant mean contrasts found in intrarater reliability were of little clinical importance because the difference in the means was less than 1 degree, which is the measurement precision of the Scoliometer® (Tab. 3). This finding had no effect on interrater reliability because there were no significant differences in the means between raters. In another study, Mubarak et al reported standard deviations of ± 3 degrees for intrarater reliability and ± 4 degrees for interrater reliability for thoracic and lumbar measurements.[14]

Correlational Relationships

Pedicle rotation and rib hump deformity often occur in scoliosis; however,

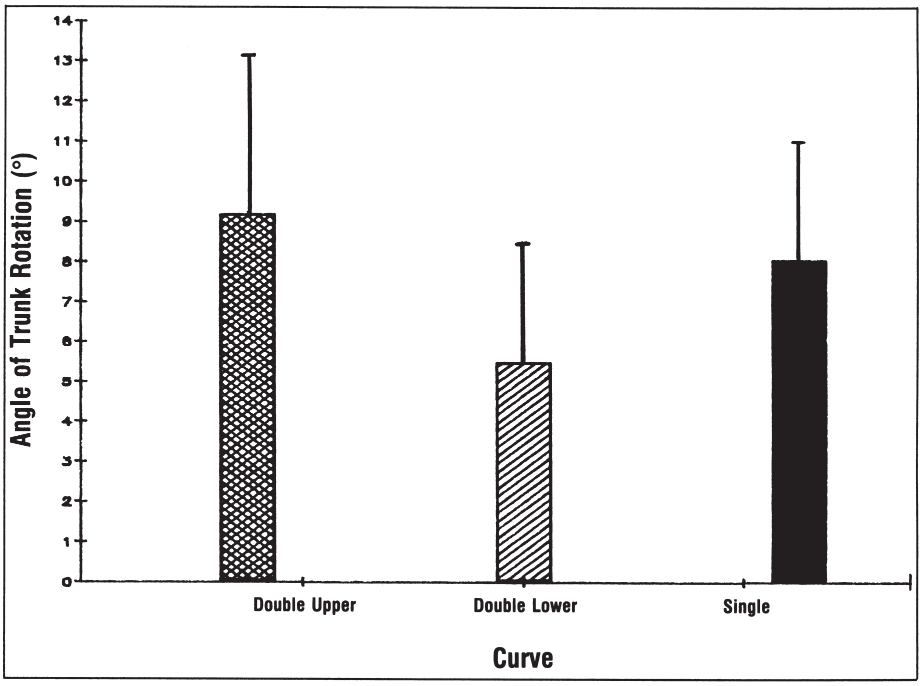

Fig. 3. *Range of Scoliometer® measurements. Scoliometer® measurement means with standard deviations for double spinal curves (upper and lower curves subdivided) and single spinal curves.*

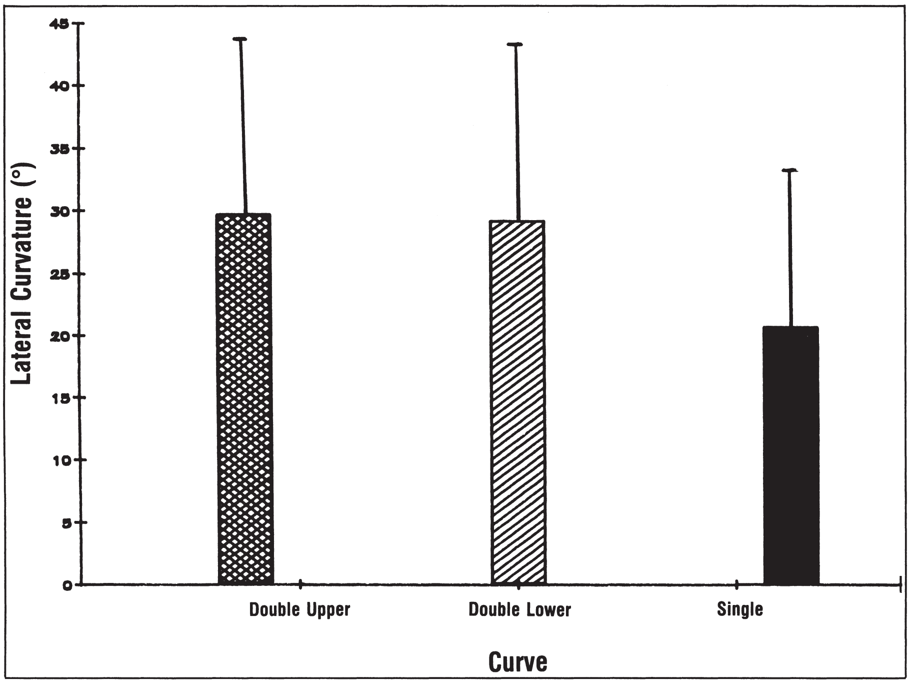

Fig. 4. *Range of Cobb angle measurements. Cobb angle means with standard deviations for double spinal curves (upper and lower curves subdivided) and single spinal curves.*

there appears to be an inconsistent relationship between vertebral rotation and severity of the rib hump deformity.[9] Results from our study show a poor relationship between pedicle rotation and ATR measurements (r = .32–.46) (Tab. 6). These results are similar to the findings by Burwell et al who used a "formulator body-contour tracer" to measure trunk asymmetry on 34 children with clinical evidence of lateral spinal curvature.[10] They found a poor, but statistically significant, correlation between radiographic assessment of vertebral rotation and trunk asymmetry values (r = .35; $.02 < p < .05$). Their study also revealed that in children with clinically straight spines, approximately one fourth had objectively detectable rib and lumbar humps, demonstrating that a rib or lumbar hump can be present in the absence of lateral curvature. In another study, Steinway et al quantified vertebral rotation and rib hump deformities from AP spine radiographs and contour tracings, respectively.[9] No positive statistical correlation was found between any aspect of vertebral rotation and the severity of the rib hump deformity. Lawhon and Bunnell, however, found a stronger relationship between vertebral rotation and ATR (r = .67, no probability value given) in their study using a template overlay on standing AP radiographs of the spine.[25] These studies, along with our findings, demonstrate that pedicle rotation is weakly related to the presence or absence of a rib hump deformity in patients with idiopathic scoliosis.

Although scoliosis is defined as lateral curvature of the spine accompanied by trunk rotation, scoliotic spines can have lateral curvature without rotation and vice versa. The results of our study suggest a weak, but statistically significant, relationship between lateral curvature, as indicated by Cobb angles, and ATR, as indicated by Scoliometer® measurements (r = .46–.54) (Tab. 6). These results are similar to those of Burwell et al, who found a correlation coefficient of .42 (p = .02) between Cobb angles and trunk asymmetry scores (based on rib hump measurements).[10] Mubarak et al concluded that there was not a significant

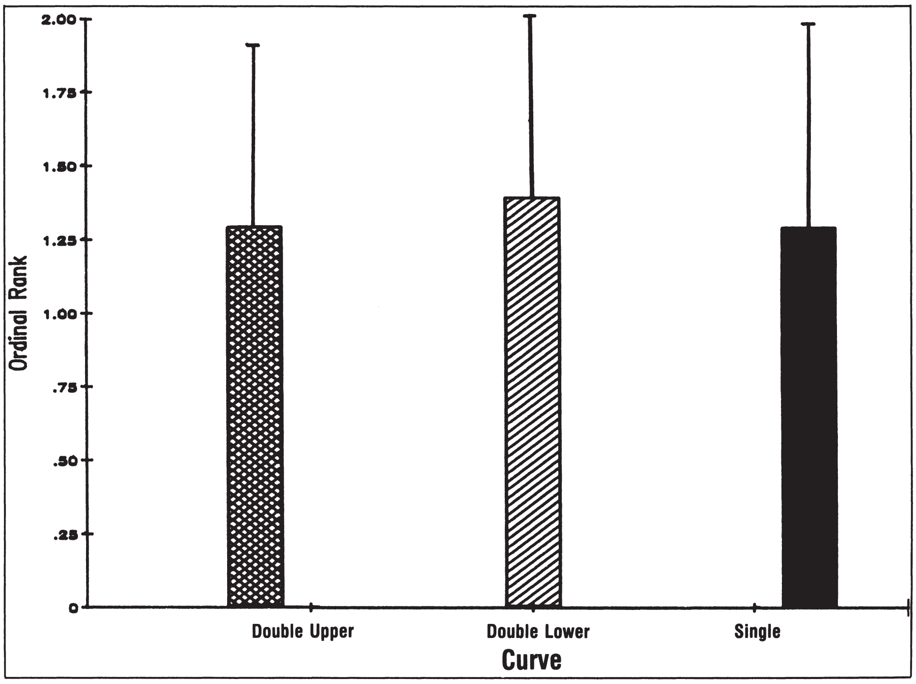

Fig. 5. *Range of pedicle rotation measurements. Pedicle rotation means with standard deviations for double spinal curves (upper and lower curves subdivided) and single spinal curves.*

Table 3. *Intrarater and Interrater Reliability Coefficients[a] and Standard Deviations for Patients with Single (n = 34) and Double (n = 31) Spinal Curves*

Type of Curve	Intrarater[b] Rater 1	Intrarater[b] Rater 2	Interrater[c]
Double			
Upper	.97 ± .77	.92 ± 1.09	.90 ± 1.19
Lower	.91 ± .98	.92 ± .89	.88 ± .97
Single			
Upper	.95 ± 1.08	.94 ± 1.13	.92 ± 1.17
Lower	.90 ± 1.07	.86 ± .98	.96 ± 1.35

[a]All coefficients were statistically significant (Ho = 0, $p < .05$).

[b]Intraclass correlation analysis. Standard deviations were calculated from the square root of the common variance derived from the variance pooled within patients among trials.

[c]Pearson product-moment correlation analysis. Standard deviations were calculated from the square root of the common variance derived from the common variance pooled within patients among raters.

correlation between Cobb angle and ATR (r = .42).[14] In contrast to these studies, Bunnell found a correlation coefficient of .89 (no probability value given) for the relationship between Cobb angle and the ATR as measured by the Scoliometer®.[11] Bunnell states that the "angle of trunk rotation is almost always higher than expected for any degree of Cobb angle... which lends very strong support to the use of the scoliometer as a screening process."[11(p1385)]

We also identified the relationship between Cobb angle and pedicle rotation. Single curves (r = .48) showed a lower correlation than double curves (r = .70 and .60 for upper and lower measurements, respectively) (Tab. 7). In comparison, Burwell et al found a stronger relationship between Cobb angle and vertebral rotation using Perdriolle's torsiometer (r = .89, p = .001).[10] Although the noticeable differences in correlation coefficients between these two studies are difficult to explain, the differences in techniques and levels of measurement may be factors.

We did not expect to find that the correlation coefficient for ATR versus Cobb angle would be higher than those for ATR versus pedicle rotation. However, the statistical power of the Pearson product-moment correlation test used to calculate correlation coefficients for ATR versus Cobb angle is higher than that of the Spearman rank-order test used to calculate correlation coefficients for ATR versus pedicle rotation, which may have been a factor in our results.

Screening Capabilities

The clinical usefulness of a screening test is determined not only by the sensitivity and specificity of the test but also by the predictive capabilities of the test.[26] As indicated in Table 2, sensitivity is calculated from the ratio of the number of patients with true positive ATR responses over the number of those who have scoliosis. Specificity is the ratio formed by dividing the number of patients with true negative ATR test results by the number of patients who do not have scoliosis. More simply stated, sensitivity can be described as the percentage of patients with the scoliosis who exhibit positive test results, whereas specificity is the percentage of persons without scoliosis who exhibit negative

Table 4. *Scoliometer® Intrarater Mean Contrasts[a] for Patients with Single (n = 34) and Double (n = 31) Spinal Curves*

Type of Curve	Rater 1						Rater 2					
	Trial 1		Trial 2		Trial 3		Trial 1		Trial 2		Trial 3	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Double												
Upper	9.0	.14	9.1	.14	9.1	.14	8.9[b]	.18	9.6	.18	9.6[b]	.18
Lower	5.6	.18	5.7	.18	5.7	.18	5.4	.16	5.2	.16	5.2	.16
Single												
Upper	6.0	.18	6.5	.18	6.2	.18	6.0[b]	.18	6.5	.18	6.8[b]	.18
Lower	4.8	.18	4.9	.18	5.1	.18	5.1	.17	4.8	.17	4.9	.17

[a]Follow-up analysis to analysis of variance of trial means for individual raters and curves.

[b]Statistically significant ($p < .05$).

Table 5. *Scoliometer® Interrater Mean Contrasts[a] for Patients with Single (n = 34) and Double (n = 31) Spinal Curves*

Type of Curve	Rater 1		Rater 2	
	$\bar{X}$	SE	$\bar{X}$	SE
Double				
Upper	9.1	.23	9.4	.23
Lower	5.7	.20	5.2	.20
Single				
Upper	6.3	.23	6.5	.23
Lower	4.9	.29	4.9	.29

[a]Based on Bonferroni adjusted t tests, all contrasts were statistically nonsignificant ($p > .05$). Means computed on three trials for each rater.

Table 6. *Correlation of Scoliometer® (Axial Trunk Rotation) Measurements with Lateral Curvature (Cobb Angle) and Vertebral (Pedicle) Rotation for Patients with Single (n = 34) and Double (n = 31) Spinal Curves*

Type of Curve	Lateral Curvature (r)	Vertebral Rotation (r)
Single	.54[a]	.32
Double		
Upper	.52[a]	.46[a]
Lower	.46[a]	.43[a]

[a]Statistically significant ($p < .05$).

Table 7. *Correlation of Lateral Curvature (Cobb Angle) and Vertebral (Pedicle) Rotation for Patients with Single (n = 34) and Double (n = 31) Spinal Curves*

Type of Curve	r[a]
Single	.48
Double	
Upper	.70
Lower	.60

[a]Statistically significant ($p < .05$).

ATR test results. Although sensitivity and specificity are important, a screening test must also provide clinical evaluative and diagnostic information. The clinician needs to know the probability that a positive or negative test has in documenting the presence or absence of disease. In this context, the test's predictive value is of primary clinical importance. As indicated in Table 2, the predictive value of a positive test is computed from the ratio of the number of patients with positive test results who have scoliosis (true positive results) over the total number of persons with positive results (both true and false positive results). Conversely, the predictive value of a negative test is calculated from the ratio of the number of persons without scoliosis who have negative ATR test results (true negative results) over the total number of persons with negative results (both true and false negative results).

Applying this criterion to our data, we found that the predictive value of a positive test was consistently higher in patients with double curves than in those with single curves. At the 5-degree ATR criterion level, the sensitivity and predictive value of a negative test for double curves attained 100%, whereas at the 10-degree ATR criterion level, the specificity and predictive value of a positive test for double curves attained 100%. None of the single curve measurements reached the 100% level. As a result of the high sensitivity at 5 degrees of ATR, this level appears to be the best criterion

Table 8. *Scoliometer® Screening Capabilities at 5-, 7.5-, and 10-Degree Criterion Levels*

Criterion Level	Type of Curve	Sensitivity		Specificity		PV+[a]		PV−[b]	
		%	Ratio	%	Ratio	%	Ratio	%	Ratio
5°	Double	100	(25/25)	33	(2/6)	85	(25/29)	100	(2/2)
	Single	94	(15/16)	28	(5/18)	54	(15/28)	83	(5/6)
	Combined	98	(40/41)	29	(7/24)	70	(40/57)	86	(7/8)
7.5°	Double	76	(19/25)	67	(4/6)	90	(19/21)	40	(4/10)
	Single	81	(13/16)	78	(14/18)	76	(13/17)	82	(14/17)
	Combined	78	(32/41)	75	(18/24)	84	(32/38)	67	(18/27)
10°	Double	52	(13/25)	100	(6/6)	100	(13/13)	33	(6/18)
	Single	50	(8/16)	94	(17/18)	89	(8/9)	68	(17/25)
	Combined	51	(21/41)	96	(23/24)	95	(21/22)	53	(23/43)

[a]Predictive value of a positive test.

[b]Predictive value of a negative test.

for referral from a scoliosis screening program. The advantage of this criterion level would be a decreased chance of not identifying individuals with scoliosis, while still maintaining a relatively high predictive value of a positive test. The screening capability of the Scoliometer® in our study, especially at the 5-degree ATR level, compared quite favorably with the findings of other screening tests (Tab. 1). Differences among the screening capabilities of the Scoliometer® at various criterion levels allows the clinician to choose the appropriate level desired for specific screening purposes.

Limitations

The fact that the subjects in our study were patients from a scoliosis clinic with Cobb angles ranging from 2 to 71 degrees somewhat limits the screening prediction implications for a general population of subjects. Another confounding variable is that the Scoliometer® measurements were taken in the forward-bend position to maximize the rib hump deformity,[27] whereas spinal radiographs were taken with the patient standing, which may minimize vertebral rotation. Also, a lack of flexibility (both spinal and hamstring muscle) was observed in some patients, making Scoliometer® measurements more difficult to obtain.

Clinical Implications and Suggestions for Further Research

The objective of scoliosis screening is to identify high-risk, previously unsuspected cases for referral and possible intervention before deformity progresses.[28] The Scoliometer's® high interrater reliability and validity values suggest that this instrument would provide useful data in scoliosis screening programs. Traditionally, such programs have relied heavily on the FBT, but the FBT is inadequate as a single screening procedure.[4] The Scoliometer® offers a quantitative documentation of deformity not afforded by the subjective clinical examination alone. These objective data also may assist in monitoring increases or decreases of scoliometric curves and aid in documentation.

Scoliometer® measurements, however, do not correlate highly with radiographic assessment of the Cobb angle and pedicle rotation; therefore, clinicians should not use the Scoliometer® exclusively as a diagnostic tool. We recommend it as an adjunct to other tests that are available.

We suggest expanding this study to include subjects not previously screened for scoliosis. The issue of whether to advocate use of the Scoliometer® as a screening device is best addressed when applied in the setting in which it is to be used.

Conclusions

The relatively high values for validity based on the predictive value of a positive test using the Scoliometer® at the 5-degree ATR criterion level and the high intrarater and interrater reliability indicate that the Scoliometer® may contribute to scoliosis screening examinations. These values indicate that the Scoliometer® is useful for providing objective measurements. Correspondingly, the high interrater reliability values suggest that, if necessary, monitoring may be carried out reliably by different therapists.

Based on the low correlation coefficients found for ATR versus Cobb angle and for ATR versus pedicle rotation, however, we believe that Scoliometer® measurements alone are not sufficient to use as a basis for treatment decisions such as bracing or surgical intervention. In addition to the more subjective postural evaluation and the FBT, the Scoliometer® measurements would provide objective data for a more thorough assessment. Based on the results of these tests, physical therapists and physicians may elect to manage a patient conservatively or request additional radiographic studies.

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