Trunk rotation in scoliosis

The influence of curve type and direction in 150 children

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We compared the angle of trunk rotation (ATR) from scoliometer readings with Cobb angle measurements of the lateral deviation of the spine in 150 children referred to hospital for evaluation of scoliosis. The mean Cobb angle in thoracic curves was 16°, in thoracolumbar curves 17° and in lumbar curves 20°. In thoracic curves and in right convex curves no patient with a Cobb angle of 25° or more had an ATR below 9°. In thoracolumbar and lumbar and in left convex curves, 7° ATR was occasionally associated with scoliosis of 25° or more. The correlation coefficient between the ATR and Cobb angle in right convex curves was 0.65 compared to 0.57 in left convex curves. We conclude that a criterion of > 7° ATR for thoracic or right convex curves and one of > 6° ATR for thoracolumbar and lumbar or left convex curves seem adequate for identification of patients with Cobb angles of 25° or more, which reduces the need for spinal radiography and follow-up outside the school screening programs.

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A valid, reliable and simple method is needed for spinal screening programs for scoliosis to minimize over-referral of children for orthopedic evaluation. Available methods are based on different ways to evaluate the associated trunk asymmetry which is highly suggestive of scoliosis. The simplest method is Adams' forward-bending test (FBT) (1865) which lately has been quantified by the angle of trunk rotation (ATR) or inclination of Bunnell (1984). Techniques like ultrasonic digitization (Letts et al. 1988), tracing the contour of the shape of the back (Burwell et al. 1983), Moiré photography (Willner 1984), computerized video raster stereophotography (Stokes et al. 1987) and ISIS scanning (Weizs et al. 1988) are too complicated to use in a school spinal screening program.

The optimum ATR for referral for orthopedic evaluation needs further investigation (Huang et al. 1988). To establish spinal screening referral criteria with special regard to curve type and direction, we evaluated our 3-year experience of inclinometer measurements of the ATR and the corresponding Cobb angles.

Subjects and methods

The study group consisted of 150 children who, after a primary spinal school screening, were referred for evaluation to the Scoliosis Unit at Örebro Medical Centre Hospital between January 1993 and December 1995. There were 28 boys and 122 girls with a mean age of 13 (6–19) years. All children were examined by an orthopedic surgeon (LS) for scoliosis using an inclinometer for measurement of the ATR (Bunnell 1984), and a posteroanterior standing radiograph of the spine was taken.

The lateral deviation of the spine was measured by a radiologist without knowledge of the ATR readings (LN). We used the method of Cobb (1948) and the curves were classified according to direction and type into right or left convex thoracic, thoracolumbar, lumbar and double primary ones. We also used the Finnish modification of the Bunnell inclinometer (Scoliometer, Pedihealth ky, Oulu, Finland), which is an inverted U-shaped fluid-filled tube, with an air bubble enclosed, which seeks the highest point of the tube where the ATR can be read.

The angle of trunk rotation (ATR) was measured in a standardized way, with the child in a standing forward-bending position and the feet together, the knees straight, the shoulders loose and both arms dangling, without hands clasped or placed between the knees (Stokes et al.1987). The child was instructed to continue to bend forward stepwise 4 times, making possible tangential measurements from behind at the upper thoracic, midthoracic, lower thoracic and lumbar regions. The measurements were repeated at least once, with the patient standing erect between each set of 4 readings, until 2 consecutive ATR readings were the same. The level and the highest degree of the ATR

Clinical and radiographic data in 150 children screened for scoliosis

Curve type	Number of children	Mean age	Cobb angle mean	ATR degree	Curve direction right	Curve direction left	r
Thoracic	102	12.6	16	8.3	90	12	0.61
Thoracolumbar	25	13.4	17	7.6	8	17	0.51
Lumbar	16	13.6	20	9.6	2	14	0.61
Double primary	7	14.4	26	11	7	7	0.88

r Correlation of ATR and Cobb angle.

readings and the side of the corresponding rib hump or lumbar prominence was recorded. Leg length inequality was not compensated. Inclinometer readings in the sitting forward-bending position were not made.

Statistics

Continuous variables were tested with the Student's t-test—e.g., scoliometer readings. Fisher's exact test and z-transformation of correlation coefficients were used to study the relationship between curve direction and type. Multiple regression was used to study the correlation between Cobb angles and scoliometer readings and curve type. The measurement error of the Cobb angles was estimated by one of the authors (LN) who calculated the standard deviation of repeated measurements in 50 cases. The interobserver measurement error of the ATR angles was determined in 23 patients, comparing available ATR readings from the school screening procedure with our own measurements. Data on the lower curve in cases with double primary scoliosis were not included. The 5% level of significance was accepted.

Results

The curve type was thoracic in 102 cases, thoracolumbar in 25, lumbar in 16 and double primary in 7 cases. The convexity of the curve was to the right in 107 cases and to the left in 43 cases. The trunk was asymmetric or rotated to the opposite side of the convexity of the curve in 4 thoracic, 1 thoracolumbar and 2 lumbar curves (Table).

In thoracic, lumbar or double primary curves with an ATR < 10°, 3/63 patients had a Cobb angle of 25° or higher. At the same levels and with an ATR < 9°, none of the 46 patients had a Cobb angle of 25° or more.

At the thoracolumbar level and with an ATR < 9°, 4/16 patients had a Cobb angle of at least 25°. With an ATR < 8°, 3 of 7 girls had Cobb angles of 25°, 30° and 35°. Their ages were 16, 14.5 and 12.5 years. None of the 6 patients had a Cobb angle greater than 22° with an ATR < 7°.

In right convex curves, regardless of type, the mean ATR was 9 (2–17)° and mean Cobb angle was 17 (3–52)°. With an ATR < 9°, the highest Cobb angle was 23° (Figure 1). The left convex curves had a mean ATR of 8 (3–15)° and mean Cobb angle of 19 (4–39)°. With an ATR < 8°, the same patients with thoracolumbar scoliosis of 25° or more were identified (Figure 2).

The standard deviation of repeated Cobb angle measurements was 1.2°, i.e., differences between repeated measurements are less than 3.4° in 95% of cases. The standard deviation of the differences between ATR readings obtained at school screening and readings at the Scoliosis Unit was 0.6° which means that the interobserver variation is below 1.7° in 95% of cases.

The correlation coefficient between the ATR and Cobb angle was 0.65 in right convex curves which was the same as in thoracic curves, double thoracic curves included. In thoracolumbar and lumbar curves, the correlation coefficient between the ATR and the Cobb angles was 0.56, compared to 0.57 in left convex curves, regardless of level.

Discussion

Bunnell (1984) stated that an ATR of 5° justified referral for a spine radiograph. He showed that measurements of the ATR with a scoliometer were useful for reducing the referral to hospital of patients with mild scoliosis and he reported a high correlation coefficient of 0.89 for the relationship between the Cobb angle and the ATR. The increasing awareness that most curves need no treatment if Cobb angle is below 25°–30° has made Bunnell (1993) recommend a change from 5° ATR to 7° at any level of the spine as an appropriate referral criterion for Cobb angles of at least 30° to be identified with a low false-negative

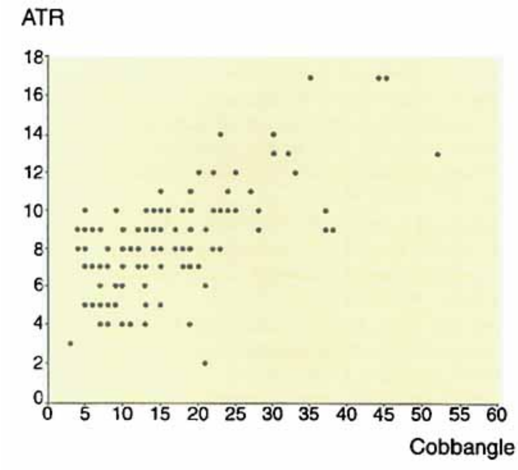

Figure 1. The angle of trunk rotation (ATR) versus Cobb angle in 107 right convex curves regardless of level. Each point may represent more than one child.

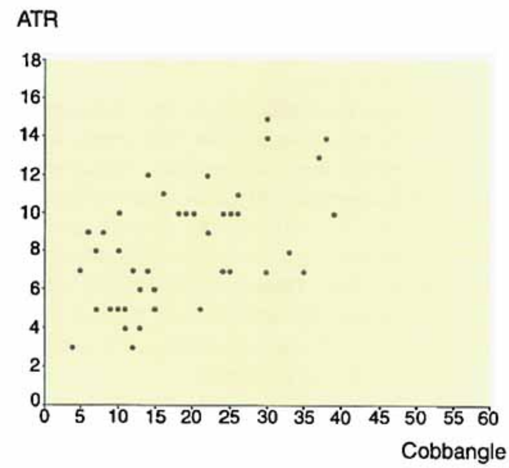

Figure 2. The angle of trunk rotation (ATR) versus Cobb angle in 43 left convex curves regardless of level. Each point may represent more than one child.

rate. By selecting higher degrees of ATR as a criterion for referral, we can reduce the number of referrals, but quite a few cases with substantial curves will be missed.

Our findings suggest that, in the routine screening for scoliosis, different ATR criteria can be proposed for thoracic curves, on the one hand, and thoracolumbar and lumbar curves, on the other. The strength of the correlation between the ATR and the Cobb angle was higher in right convex curves than in left convex ones and it was equal in thoracic curves, but the difference was not significant ($p > 0.3$). The discrepancy between right and left convex curves suggests that different ATR referral criteria can also be based on the side of the lumbar prominence and the rib hump, as, with few exceptions, it is situated on the convex side of a scoliosis (Figures 1 and 2). The strength of the correlation between the ATR and the Cobb angle equalled the high correlation coefficient of 0.89 reported by Bunnell (1984) only in the 7 double primary curves. On the other hand, it was higher than the correlations of 0.46–0.54 reported by Amendt et al. (1990) and by Mubarak et al. (1985) who found no correlation at all at the thoracic or lumbar level. A difference in patient inclusion criteria, classification of the curves, number of patients or measurement techniques may contribute to their weaker relationship between the ATR and the Cobb angles, compared to our results.

The reliability of the ATR readings by single trained observers screening for scoliosis is high for intrarater and interrater comparisons (Amendt et al. 1990, Murrell et al. 1993). Similarly, the intrarater and interrater agreement in assessing primary Cobb angles is reported to be excellent (Goldberg et al. 1988) and the precision of an inclinometer is within 1°–2° in the range of 0°–25° (Mubarak et al. 1985, Amendt et al. 1990, Murrell et al. 1993). Our measurement errors in Cobb and ATR angles were similarly low.

Unequal leg length affects the magnitude of trunk asymmetry in the standing forward-bending test and shortening of a leg is related to a contralateral prominence or hump on the back especially at the lumbar level (Burwell et al. 1983, Stokes et al. 1987). Upadhyay et al. (1988) also reported that the degree of rotation of the surface of the back increased in the lumbar region during forward bending, but was minimally changed in the thoracic region. Furthermore, forward flexion reduced the thoracic rib hump but magnified the lumbar prominence. An equalization of leg length by a block under the foot before measuring the ATR or performing it in a sitting position was recommended. Our aim was to study the ATR in a well defined but simple and reproducible screening situation. Clinical methods for the determination of leg length are rather inaccurate (Friberg et al. 1988). Because of this and because the use of radiologic methods is limited owing to both access and radiation and is unethical in screening studies, we did not correct for unequal leg length.

The finding that an ATR of 8° at the thoracic level or in right convex curves was not associated with curves exceeding 25° contrary to lower or left convex curves made us choose the thoracic curvature in double primary scoliosis (Figure 1). The correlation between the ATR and the Cobb angle is probably less disturbed by the postural effect of a LLI or a sacral tilt at the thoracic level and the lack of spinal flexibility also makes tangential ATR readings more difficult to perform at lower levels.

In conclusion, our findings show that inclinometer measurements reduce the need for radiography in patients with minor trunk asymmetries identified in school spinal screening programs. Serial ATR measurements might also diminish the need for repeated spinal radiographs as well as follow-up examinations at the scoliosis clinic. There is still a need for further research to establish the optimum ATR referral criteria for different Cobb angles in relation to curve type and the patient's physical maturity.

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