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Accuracy and applicability of measurement of the scoliotic angle at the frontal plane by Cobb's method, by Ferguson's method and by a new method

K. M. Diab, J. A. Sevastik, R. Hedlund, and I. A. Suliman

Department of Orthopaedic Surgery, Huddinge University Hospital, Karolinska Institute, Stockholm, Sweden

Summary. A new method for the measurement of scoliotic curves in antero-posterior (AP) radiographs is presented, in which the centre of the surface image of the vertebral bodies of the apical and two end vertebrae of the curvature are defined on the basis of geometric principles. Measurements using the Cobb, the Ferguson, and the new method were performed on ten AP radiographs from each of three groups of young patients with right convex thoracic idiopathic scoliosis with Cobb angles of between 7 and 15°, 16 and 45° and 46 and 80°, respectively. Measurements using the Cobb method yielded significantly higher values than measurements using either the Ferguson method or the new method. In curves with Cobb angles of between 7 and 15°, the values using Ferguson's method were significantly lower than those using the new method; the difference increased significantly in curves with a Cobb angle of 16° or more. The level of significance of the intra- and interobserver differences between the new, the Cobb and the Ferguson methods was significantly higher in curves with a Cobb angle of 16° or more. It is argued that measures of the scoliotic angle obtained by the new method are of greater clinical relevance than those obtained by the two other methods. Unlike the Cobb method, the new method takes into consideration the translation of the apical vertebra in relation to the end vertebrae and not only the tilt of the end vertebrae of the curve. As compared to the Ferguson method, the new method is based on standardised geometric principles, and is not influenced by changes in the shape of the vertebral body. Moreover, the repeatability of the new method is greater than that of both the Cobb method and the Ferguson method. Therefore, it is believed that the new method provides a more accurate measure of the scoliotic curve than do the two other methods, and it is to be preferred over the other two methods in longitudinal evaluation of the development of the curve.

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Correspondence to: J. A. Sevastik, Department of Orthopaedic Surgery, Huddinge University Hospital, S-141 86 Huddinge, Sweden

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There are two radiographic methods for measuring the degree of scoliotic curvature at the coronal plane: one described by Ferguson in 1945 [8] and the other by Cobb 3 years later [5]. Since then, to the best of our knowledge, only one more method has been proposed for measurement of the scoliotic angle on antero-posterior (AP) radiographs [4].

Several reports have shown that the Ferguson method evaluates the scoliotic curve more accurately in that it takes into consideration not only the tilt of the end vertebrae of the curve, as does the Cobb method, but also the position of the apical vertebra. Despite this, the Cobb method has become more used than the Ferguson method in clinical practice as well as for scientific purposes. In 1966 the Cobb method was adopted by the Scoliosis Research Society as the standard method for quantification of scoliotic deformity at the coronal plane. The method is also used for measurement of the curve at the sagittal plane. However, since then, the accuracy of the Cobb method has been questioned in several studies.

The question of which method is most suitable for measuring the scoliotic curve is pertinent not only when it comes to decision making before treatment but also for evaluation of results of scientific longitudinal studies. Therefore, a reappraisal of the accuracy of the Cobb and Ferguson methods is appropriate when presenting a new method by which the degree of the scoliotic angle on A-P radiographs can be read.

The aim of this study was (a) to present a new method for measurement on A-P radiographs of scoliotic angles of different degrees and to study its accuracy in relation to the Cobb and the Ferguson methods; (b) to compare the repeatability of the three methods; and (c) to study the applicability of the three methods for evaluation of spine instrumentation results.

Materials and methods

The study included 30 A-P radiographs from patients with adolescent idiopathic scoliosis (28 female and 2 male) with a mean age of 13.3 years (range 11.3–14.9 years). All were right convex thoracic curves. The material was divided according to the Cobb angle into three groups of ten radiographs each. Group I comprised-Cobb angles of between 7 and 15°, group II those between 16 and 45° and group III those between 46 and 80°. The mean Cobb angle of all radiographs was 32° (range 7–80°), and the apical vertebra was between T7 and T10.

In addition, pre- and postopertive A-P radiographs of ten patients having undergone Harrington or Cotrel-Dubousset spinal instrumentation were evaluated by all three methods.

Measurements of the scoliotic angle at the coronal plane were carried out using the standard Cobb and Ferguson methods. In addition, measurements were done using the new method, as follows: the end vertebrae and the apical vertebra of the curvature and the four corners of each were defined, and lines were drawn delineating both the upper and lower endplates of the three vertebrae. The midpoint of each line was determined with a ruler. Perpendiculars were drawn through the midpoint of these lines. The intersection of the lines represents the geometric centre of the projected image of the vertebral body. Lines were then drawn through the centre of the three vertebrae, and the angle thus formed (Fig. 1 B) was measured with a goniometer. The same vertebrae, in all measurements, were used for all three methods (Fig. 2 A–C). The same goniometer and the same type of pencil were used for all measurements.

In order to study the repeatability of the three methods, measurements on the 30 radiographs were carried out six times by the same observer for estimation of the intraobserver degree of variation expressed as a standard deviation (SD) of the six measurements. The same radiographs were independently measured twice by another observer to evaluate the interobserver difference of the measurements, also expressed as SD of the two measurements.

The interval between measurements was between 3 and 7 days and the skeletal landmarks were not preselected.

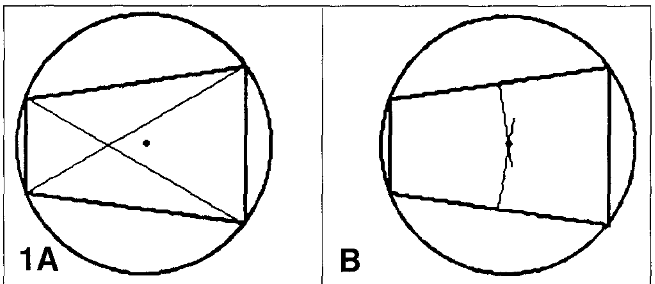
To study the applicability of the three methods in instrumented spines, pre- and postoperative A-P radiographs from ten patients were measured by the three methods.

Statistical analysis of the intraobserver and interobserver values between measurements in the three groups was performed by analysis of variance at 99.9%, 99% and 95% confidence levels.

Results

The mean intraobserver Cobb angle in group I was 11.4°, in group II 29.9° and in group III 55.2°; the mean Ferguson angles were 6.0°, 17.9° and 33.3°, respectively; and the mean angles obtained by the new method were 7.2°, 21.8° and 40.4°, respectively (Table 1). The mean value of the interobserver measurements of the Cobb angle in group I was 10.9°, in group II 28° and in group III 53.2°; the mean Ferguson angles were 6.1°, 16.1° and 36.2°, respectively; and the mean angles obtained by the new method were 7.1°, 20.0° and 41.9°, respectively (Table 2).

Analysis of the differences between the intraobserver and interobserver measures showed that the difference



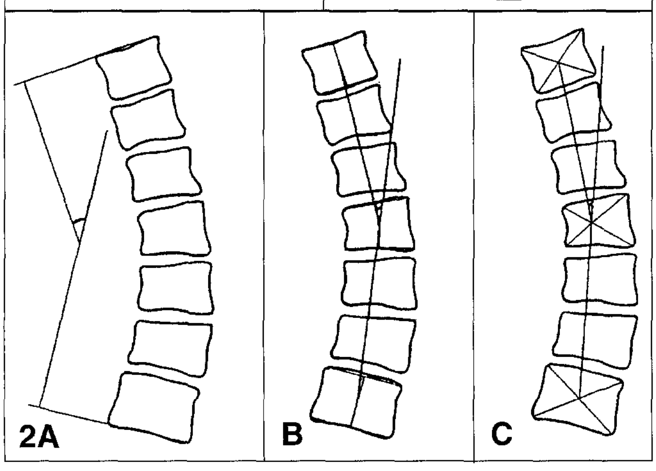


Fig. 1 A. The point of intersection of the diagonals of the vertebral body within a circle does not coincide with the centre of the circle. **B** The point of intersection of the perpendiculars from the midpoint of the upper and lower end plates of the vertebral body is the true geometric centre of the circle

Fig. 2 A–C. Measurements of the same curve with **A** the Cobb method, **B** the new method and **C** the Ferguson method yield angles of 33°, 22° and 16°, respectively

Table 1. Intraobserver measures (mean ± SD) by group for the three methods (degrees)

	Cobb method	New method	Ferguson method
Group I	11.4 ± 2.76	7.2 ± 2.04	6.0 ± 2.05
Group II	29.9 ± 10.27	21.8 ± 7.21	17.9 ± 6.82
Group III	55.2 ± 10.1	40.4 ± 7.56	33.3 ± 6.57

Table 2. Interobserver measures (mean ± SD) by group for the three methods (degrees)

	Cobb method	New method	Ferguson method
Group I	10.9 ± 2.73	7.1 ± 2.64	6.1 ± 2.33
Group II	28.0 ± 10.14	20.0 ± 8.62	16.1 ± 8.74
Group III	53.2 ± 11.08	41.9 ± 6.74	36.2 ± 6.86

Table 3. Mean differences between intraobserver and interobserver measures for each method by group (degrees)

	Difference for Cobb	Difference for new method	Difference for Ferguson
Group I	0.5	0.1	–0.1
Group II	1.9*	1.8	1.8
Group III	2.0*	–1.5	–2.9*

* Significant at 95%

Table 4. Comparison of intraobserver mean differences between the methods for the three groups (degrees)

	Cobb vs new method	Cobb vs Ferguson	New method vs Ferguson
Group I	4.2***	5.4***	1.2*
Group II	8.1***	12.0***	3.9**
Group III	14.8***	21.9***	7.1***

* Significant at 95%; ** significant at 99%; *** significant at 99.9%

Table 5. Comparison of interobserver mean differences between the methods for the three groups (degrees)

	Cobb vs new method	Cobb vs Ferguson	New method vs Ferguson
Group I	3.8***	4.8***	1.0
Group II	8.0***	11.9***	3.9**
Goup III	11.3***	17.0***	5.7**

** Significant at 99%; *** significant at 99.9%

Table 6. Mean intraobserver differences between the groups by the three methods (degrees)

	Cobb method	New method	Ferguson method
Gr. I vs Gr. II	18.0***	14.6***	11.9***
Gr. I vs Gr. III	43.8***	33.2***	27.3***
Gr. II vs Gr. III	25.3***	18.6***	15.4***

*** Significant at 99.9%

Table 7. Mean interobserver differencese between the groups by the three methods (degrees)

	Cobb method	New method	Ferguson method
Gr. I vs Gr. II	17.1***	12.9***	10.0**
Gr. I vs Gr. III	42.3***	34.8***	30.1***
Gr. II vs Gr. III	25.2***	21.9***	20.1***

** Significant at 99%; *** significant at 99.9%

was not significant in group I for any of the three methods. In group II, the difference was significant for the Cobb method only, and in group III the difference was not significant for the new method but was significant for the other two methods. Thus the results show that there were no significant differences between intraobserver and interobserver measures for the new method in any of the three groups (Table 3).

Comparison of registered measures between the methods showed that there were significant differences between the methods in all groups for the intraobserver values (Table 4).

Comparison of the interobserver values showed that the differences between the Ferguson method and the new method were not significant for group I but were indeed significant for groups II and III.

The differences between the Cobb method and the new method, and between the Cobb and the Ferguson method were significant in all three groups (Table 5).

The intra- and interobserver measures for each method showed highly significant differences between the groups (Tables 6, 7).

The study of the applicability of the three methods showed that postoperative measurement of the curve using either the Ferguson or the new method was hampered by the metallic rods and hooks, which often concealed at least one, and often two or more, of the needed bony landmarks of the end vertebrae of the curve. However, a simple regression between the values obtained by the Cobb and the new method yields the equation: new method value = (Cobb value $\times$ 0.74) – 0.62. This allows a conversion of Cobb to equivalent new method values if the new method is difficult to apply.

Discussion

In measuring a scoliotic angle, factors influencing the accuracy, i.e. freedom from errors of the obtained values arising from the method of measurement itself and from the object of the examination, should be taken into account as well as factors affecting the reliability of the measurements, i.e. the degree of confidence that can be put in the obtained values. Some of these factors, for instance the position of the patient in relation to the X-ray tube, are common for all methods of measuring a scoliotic angle on radiographs, and they are difficult to neutralise. Others can easily be detected and corrected.

By definition, measurement of an angle requires three fixed points, Changes of the degree of the angle are connected with positional changes of any of these points. The three reference points for evaluation of a scoliotic angle are related to the apical and two end vertebrae of the curvature.

The Cobb method of measuring the scoliotic angle takes into account the declination of the end vertebrae of the curve, but not the translation of the apical vertebra. Therefore, the Cobb angle cannot be considered as a pure measure of curve severity [12].

Ferguson's method uses as reference points for measurement of the scoliotic curve the intersection of the diagonals of the vertebral body of the apex and the two end vertebrae of the curve. However, the defined centre of the projected surface of the vertebral body does not always coincide with the geometric centre of the image of the vertebra [10].

The method described by Capasso [4] is based on elaborate geometric principles evaluating the whole scoliotic curve as an arc of a circumference. In practice, the method uses as landmarks for determination of the scoliotic angle the upper and the lower corner of the vertebral body of the upper and the lower end vertebra of the curve respectively, and the midpoint of the body of the apical vertebra at the side of the concavity.

The new method for measurement of the scoliotic curve, devised by one of the authors (K.M.D.), uses as reference points the true geometric centre of the surface area of the apical and the two end vertebrae of the curve. It is therefore more accurate and clinically more relevant than other methods in evaluating the degree of curvature at the frontal plane projected on A-P radiographs.

Variations in the outcome of measurements of scoliotic angles depend on the position of the patient in relation to the X-ray tube and the degree of the position changes of the vertebrae at the three cardinal planes. Significant differences in measurements using the Cobb method have been reported between radiographs taken while the patient was standing freely and those taken in a standardised position [6], between A-P and P-A radiographs [7], between radiographs taken at different times of day [18] and between radiographs taken with the patient lying and those taken in the standing position [17]. These variations are common to all methods and therefore have not been evaluated in the present study.

The reliability of the results of the measurements, expressed as intraobserver and interobserver SD, is related to the selection of the three reference vertebrae, the definition of landmarks on the radiographs and the experience and skill of the reader.

In a model study on two scoliotic skeletons [15], minor rotation of the spine or movements of the X-ray tube or a combination of both gave a mean difference of reading by two authors of up to 8° for the Cobb angle. The mean error using the Cobb method was $3.12 \pm 0.48°$ compared to $1.82 \pm 0.21°$ for the Ferguson method.

It has been reported that in measuring the progression of a scoliotic curve using the Cobb method, a difference of at least 10° can be considered to represent a true change with 95% confidence [3], whereas, a difference of less than 4° has been considered to result from measurement variability [2]. The interobserver variability in three sets of measurements made by four observers, using the Cobb method with or without preselected levels of the curve, has been found to be between 6.3 and 7.2°, and the intraobserver variability between 2.8 and 4.9° [13].

As in the present study, previous comparative studies of the results of measurements using different methods have shown that the Cobb method gives consistently higher values than the Ferguson [4, 15, 16]. The exaggeration of the curve in measurements using the Cobb method has been explained on the basis of geometric principles [11].

It has been reported that, Fergusion angle value can be converted to an equivalent Cobb value by multiplying it by 1.35, and that the Ferguson method is better suited to automated measurements [16]. Conversion of Cobb to new method values can be achieved using the equation: new method angle = (Cobb angle $\times$ 0.74) – 0.62.

It has also been stated that the Ferguson method is best suited for curves of less than 50° and the Cobb for curves of more than 50° [10] and that measurement of the scoliotic curve after surgery by the Cobb method gives a greater degree of correction than using the Ferguson method [9].

The results of the present study show that measurement of a scoliotic curve by the Cobb method yields significantly higher values than measurements made using either the Ferguson or the new method, in all three groups of radiographs, i.e. in curves with a Cobb angle between 7 and 80°.

The Capasso method is based on landmarks at the periphery of the vertebral bodies on the concavity and, therefore, the results may be influenced by the degree of ossification of the vertebral body in children, by vertebral modelling in severe cases of scoliosis or by osteophytic formation in elderly patients. The method gives significantly higher values than the Ferguson and Cobb methods; the Ferguson value equals 40% and the Cobb 62.4% of the values obtained by this method [4].

In curves with Cobb angles between 7 and 15° there was a significant difference in the intraobserver but not the interobserver measures between the Ferguson and the new method. The level of significance was still higher for the intraobserver and the interobserver measures in curves of 16° or more. Since both the Ferguson and the new method use the same vertebrae as reference points, this observation implies that in early scoliosis a minor deformity of the apical vertebral body results in only slight displacement of the point of intersection of the diagonals from the geometric centre of the apical vertebra. With increasing curvature and corresponding wedging of the apical vertebral body, the point of intersection of the diagonals moves to the side of the concavity, away from the geometric centre, leading to a significantly increasing difference between the new method and the Ferguson values.

However, it has to be kept in mind that the image of a scoliotic curve on plain A-P radiographs represents merely the surface projection of the displaced vertebral bodies and gives no indication of the degree of the true three-dimensional spinal deformity.

Although it has been reported recently that the curve measured using the Cobb method is sometimes underestimated after instrumentation because the standard landmarks of the end vertebrae are obscured by metal [1], only the Cobb method is considered to provide reliable and comparable measurements of the scoliotic curve before and after surgery.

The Cobb method is easier to apply than the Ferguson method, and the new method is somewhat more elaborate than the Ferguson. The new method, using three vertebrae for estimation of the scoliotic curve, is considered more accurate than the Cobb method; the use of the geometric centre instead of the changing position of the intersection of the diagonals of the vertebrae increases the accuracy of the new method as compared to the Ferguson method. Moreover, the new method consistently yields lower values than the Cobb method and higher values than the Fergusion method at least for curves with a Cobb angle of up to 80°.

Finally, the repeatability of measurements is more reliable for the new method than for the other two methods. Therefore, the new method is to be preferred over other methods both in scientific work to evaluate longitudinal changes in the scoliotic curve and in decision making before treatment.

The principles of the proposed new method can also be used without qualification for measurement of the kyphotic angle of the spine at the sagittal plane.

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Announcement

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This has been accomplished by holding annual meetings throughout the world. Unfortunately, there are many countries, especially in underdeveloped areas, that are not represented. The members of the Society feel that a great deal of information could be exchanged if these countries actively participated.

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