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Reexamination of the Cobb and Ferguson Angles: Bigger Is Not Always Better

Ian A. F. Stokes, David D. Aronson, Peter J. Ronchetti, *Hubert Labelle, and *Jean Dansereau

*Department of Orthopaedics and Rehabilitation, University of Vermont, Burlington, Vermont, U.S.A., and *Sainte-Justine Hospital, Montréal, Québec, Canada*

Summary: In scoliosis, the Cobb measure of curve severity has been recommended over the Ferguson method because it had greater magnitude and appeared more sensitive to changes during progression and after treatment. This study made comparisons between the Cobb and Ferguson measures in radiographs of patients with idiopathic scoliosis to test whether the methods were really different, and to compare their precision. In 138 observations of 77 untreated patients there was a very high correlation ($R^2 = 0.98$) between Cobb and Ferguson angle, with Cobb angle averaging 1.35 times greater. For sequential measures (mean interval 10 months), the percent changes agreed closely ($R^2 = 0.5$). The relationship between Cobb and Ferguson angles remained the same in measurements of 24 patients wearing a brace compared with the unbraced condition and in 18 patients measured before and after Harrington rod surgery. Repeated measurements were made by three observers with the apex and end vertebrae premarked and held constant. For Cobb angle, the greatest range of measurements on any film was 8° (pooled SD = 1.3°). For Ferguson angle the greatest range was also 8° (pooled SD = 1.8°). Ferguson angle was slightly more sensitive to incorrect selection of end vertebrae. It was concluded that both methods can be useful for measuring curve magnitude. Ferguson angle should be measured and then adjusted by multiplying it by 1.35 in situations where Cobb angle measurement is technically difficult or invalid. Ferguson angle is better suited to automated measurement. **Key Words:** Scoliosis measurement—Cobb angle—Ferguson angle—Measurement error—Measurement reliability.

Cobb (2) and Ferguson (4) have described two different methods for measuring the curvature of a region of the spine. The Cobb method relies on the angulation of the end plates of vertebrae, whereas the Ferguson method relies on lines drawn through the midpoints of the end vertebrae and the apical vertebra (Fig. 1). The Scoliosis Research Society (SRS) (15) recommended the Cobb measure of curve severity over the Ferguson method because it had a greater magnitude (5,7,9,14) and appeared to be more sensitive to changes during progression and after treatment (5). The main practical difference between the two measurements is that the Cobb method depends on drawing lines across the end plates of two selected vertebrae, whereas the Ferguson method requires marking the centers of three vertebral bodies.

It is worth reexamining measurements of spinal asymmetry in the light of new measurement techniques and new thinking about the three-dimensional aspects of spinal deformity. Both the Cobb and Ferguson angles are made in a two-dimensional projection

Address correspondence and reprint requests to Ian A.F. Stokes, Department of Orthopaedics and Rehabilitation, Burlington, VT 05405, U.S.A.
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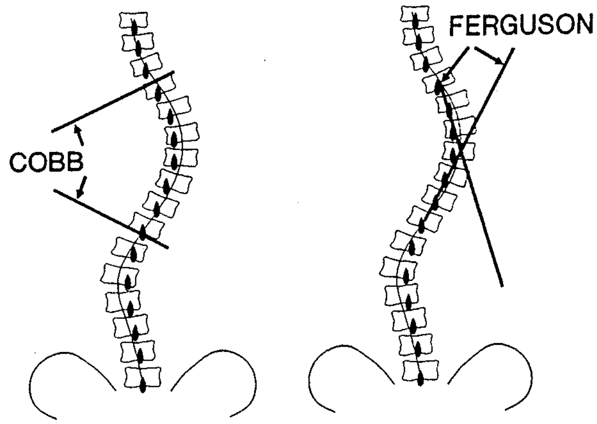

FIG. 1. Principle of measurement of Cobb angle (left) and Ferguson angle (right).

of the spine, and are regional measures relying on the selection of end points of a curved spinal region. Because the Cobb angle measures the tilting of the end vertebrae as well as the magnitude of the curvature, it is not a pure measure of curve severity (10). Also, it has relatively poor reproducibility (3,6,16,18), partly because of difficulty in selecting and measuring the two end vertebrae (1,11,12). Robinson and Wade (14) critically reviewed available data and concluded that "any further debate over the merits of the two methods should focus on their inter- and intra-observer reproducibility and their applicability after corrective treatment." This article compares Cobb and Ferguson measurements of radiographs made in a scoliosis clinic. Four groups of patient films were selected to address three aspects of this comparison:

1. The relationship (correlations and linearity) between the two measurements, and changes in these measurements over time in untreated patients.
2. Changes in the measurements of spinal asymmetry in response to treatment (before and after application of a brace and before and after Harrington distraction surgery).
3. Precision (reproducibility) of measurements within and between observers, and effects of intentionally altering the end vertebrae selected for measurement.

METHODS

Patients

The study involved four groups of patients with adolescent idiopathic scoliosis.

Group 1 was composed of 77 untreated patients who were followed with postero-anterior (PA) radiographs at the scoliosis clinic. The mean Cobb angle of the largest curve of these patients was 25° (range 6°–58°). The mean age was 14.3 years (range 9–20). There were 218 films of these patients, giving 138 sequential pairs of observations (two to nine PA radiographs, average 10 months between observations).

Group 2 was composed of 24 patients radiographed before fitting and subsequently wearing a Boston brace. There was an average of 1 month between radiographs. The mean Cobb angle before bracing was 39° (range 24°–50°). These patients were selected as typical of those with idiopathic scoliosis having brace treatment.

Group 3 was composed of 18 patients with idiopathic scoliosis who were treated with posterior spinal arthrodesis using Harrington instrumentation. The mean preoperative Cobb angle was 56° (range 39°–79°).

Group 4 was composed of 12 patients followed at the scoliosis clinic whose PA films were subjected to three repeated measurements by three observers. Sensitivity of measurements to selection of the end vertebrae was also studied. The mean Cobb angle of these patients was 35° (range 14°–50°). They were selected from patients in group 1 in order to provide a range of Cobb angle measurements.

Radiographic Measurements

Cobb angle (2) was measured using standard PA radiographs (film to tube distance of 2 m), the end vertebrae of the largest scoliosis curve were selected according to SRS (15) criteria as those with the greatest angle to the vertical axis. These end vertebrae were recorded by marking them with an indelible pen. A transparent square–drawing instrument was then positioned over each end vertebra in turn, with one of its edges overlying the end plate (upper end plate of upper end vertebra, lower endplate of lower end vertebra). A film-marking pencil was used to draw a line along the edge of the square, which was perpendicular to the endplate. A drafting-quality protractor (A.G. Thornton, Manchester, England) was used to measure the angle in degrees between the two resulting lines. After the angle had been recorded, all pencil marks were erased.

Ferguson angle (4) was originally described as the angle between two lines joining the center of the apical vertebra to the end vertebrae centers. The apical

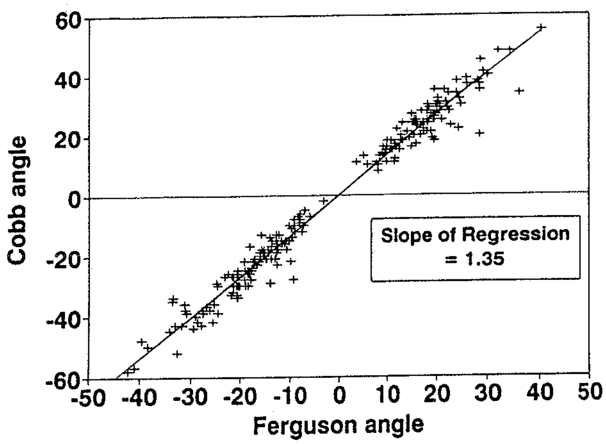

FIG. 2. Relationship between Cobb and Ferguson angles measurements of 318 radiographs of 77 patients with idiopathic scoliosis (cross-sectional study). Left convex curves are identified by negative values; right convex by positive values.

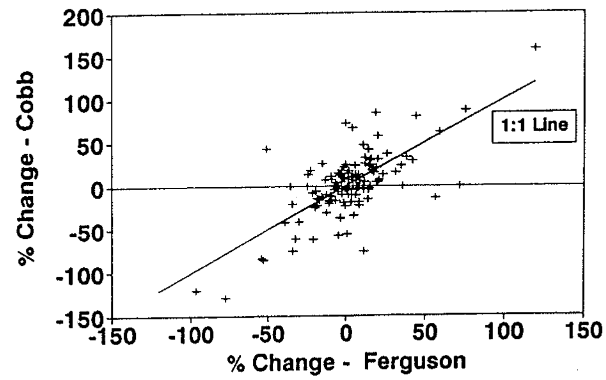

FIG. 3. Relationship between changes in Cobb and Ferguson angle measurements of 138 pairs of radiographs of 77 patients with idiopathic scoliosis (longitudinal study). Positive values indicate increasing curvature; negative values indicate decreasing curvature.

vertebra was defined as that having the greatest transverse plane rotation, and the end vertebrae were defined as those having the least transverse plane rotation. In this study we instead used the SRS definitions of apical and end vertebrae. End vertebrae were defined as the most tilted ones, and the apical vertebra was the most laterally deviated. The center of each selected vertebra was marked with a dot. Observers did this either visually or by finding the intersection of diagonal lines between lateral extremes of the endplate images, according to their individual choice. Then lines were drawn between the dots with the film-marking pencil and the protractor was used to measure the angle between the lines intersecting at the apical vertebra.

RESULTS

Cross-sectional Correlations

In the 77 untreated patients followed longitudinally there was a high correlation between the Cobb and Ferguson measures of each curve ($R^2 = 0.98$) with the slope of the regression relationship equal to 1.35 (Cobb angle averaged 1.35 times greater than Ferguson angle) (Fig. 2).

Longitudinal Correlations

For sequential pairs of measures of the largest curve in each patient (mean interval between films 10 months), the percent changes as measured by Ferguson and Cobb methods agreed closely in magnitude ($R^2 = 0.5$) (Fig. 3). After multiplying Ferguson measurements by 1.35 to convert them into estimates of Cobb angle, the standard deviation of differences between methods of measuring change in angle was 5.4° (greatest difference between methods was 20°).

Braced Patients

In the study of 24 patients managed with an orthosis there was no difference in the relationship between Cobb angle and Ferguson angle for radiographs made before and after fitting with the Boston brace. The gradient of the regression relationship for these measurements was 1.35. (Fig. 4).

Harrington Surgery

In the 18 patients measured before and after posterior spinal arthrodesis using Harrington instrumenta-

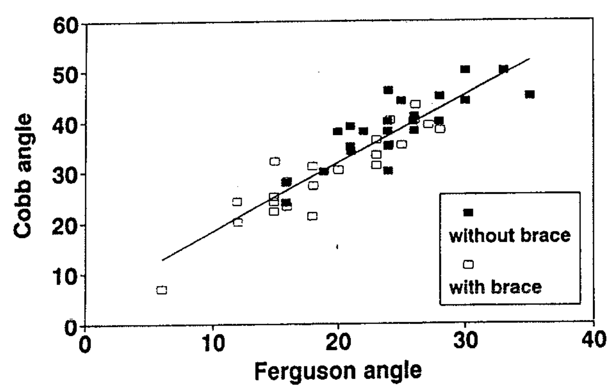

FIG. 4. Relationship between Cobb and Ferguson angle for 24 patients, with and without their Boston brace.

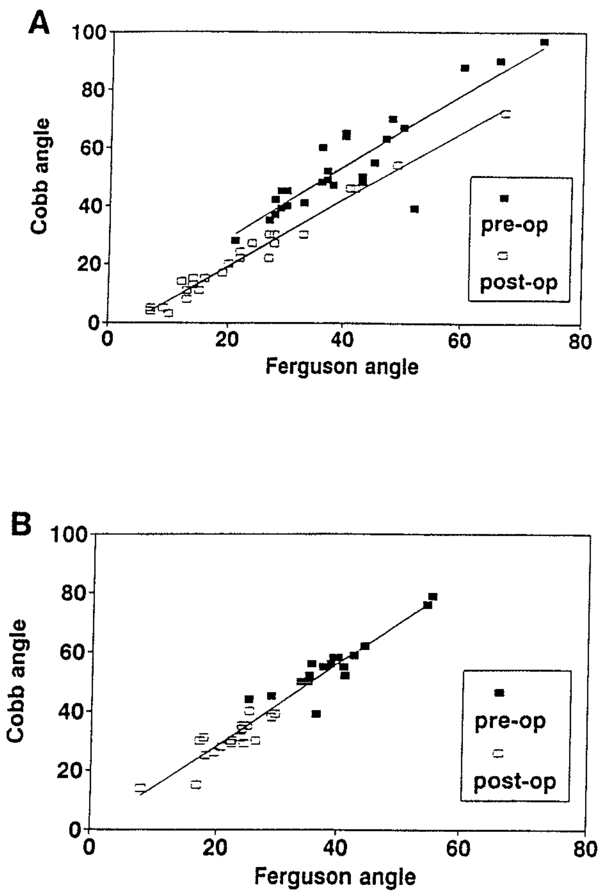

FIG. 5. Relationship between Cobb and Ferguson angle before and after surgery. **A:** Graph of data for 27 curves in 25 patients reported by George and Rippstein (5). **B:** Patients before and after Harrington distraction instrumentation. The trend of Cobb angle exaggerating the postoperative correction relative to the Ferguson measure, noted by George and Rippstein (5), is not apparent for the patients studied here.

tion, there was no difference between the pre- and postoperative relationship between Cobb and Ferguson measures. The gradient of the regression relationship for these measurements was 1.39. George and Rippstein (5) reported a differing relationship whereby Cobb angle exaggerated postoperative changes (Fig. 5).

Reproducibility of Measurement Study

PA films of 12 patients were subjected to three repeated measurements of both Cobb angle and Ferguson angle by three observers (nine measurements of each film). The observers were blinded to the identity of each patient's films, and for each measurement films were presented in a different order so that observers could not remember previous measurement values. The apex and end vertebrae were premarked and held constant. The errors appeared to be randomly distributed between observers and between trials. For the Cobb angle, the greatest range of measurements on any film was 8° (pooled SD = 1.3°, which equals 4% of the mean Cobb angle). For the Ferguson angle the greatest range was also 8° (pooled SD = 1.8°, which equals 7% of the mean Ferguson angle) (Table 1). The reliability of Cobb angle increased with the experience of the measurer, but all three were inexperienced in Ferguson measurement.

These findings showed that Cobb angle was somewhat more reproducible if the end vertebrae of the curve were predefined. In examining the sensitivity of measurements to intentional errors in selection of the end vertebrae, the percentage error introduced by selecting one vertebra incorrectly was 10% for Cobb angle and 12% for Ferguson angle. If both end vertebrae were misselected, the percentage error was 14% for Cobb angle and 17% for Ferguson angle (Table 1). Therefore, again, Cobb angle was slightly less subject to measurement errors.

DISCUSSION

We found that despite theoretical differences between these measurements, Cobb and Ferguson angles correlated closely. The precision of the Cobb angle was slightly better when the end vertebrae were held constant, and Cobb angle was also somewhat less sensitive to intentional changes in the selection of the end vertebra.

This study highlights the difficulty in detecting significant change in a spinal curvature because of precision of measurement. This applied to both measurement techniques. For detecting change, the difference between two measurements must be calculated. For example, an error of 5° in both measurements could

TABLE 1. *Standard deviations of errors of measurement*

	Cobb angle (mean = 35°)	Ferguson angle (mean = 27°)
Repeated measures (nine observations)	1.3° (4%)	1.8° (7%)
Intentional misplacing of one end vertebra	3.5° (10%)	3.2° (12%)
Intentional misplacing of two end vertebrae	5.0° (14%)	4.5° (17%)

give an error of 10° in the value of this difference. Measurement errors, although minimized in this controlled study, probably explain a large part of the variation between the two measurement techniques in the longitudinal study. Here the correlation between measures of change was $R^2 = 0.5$, and there was up to 20° difference in the estimates of change of curve magnitude by the Cobb angle and "corrected" Ferguson angle.

Although scoliosis is usually defined as a lateral deviation or curvature of the spine, it really involves a complex set of deformations in three dimensions. The Cobb angle has proved useful for measuring the magnitude of the frontal plane asymmetry. However, it is not really a measure either of lateral deviation or curvature, but rather it measures the relative tilt of the end vertebrae of the curve. In this respect, the Ferguson angle is geometrically purer because it is a measure of the curved alignment of the spine, independent of the angulation of the end vertebrae with respect to the horizontal. Errors in the Cobb angle result from variability in selecting the vertebrae for measurement, as well as in drawing and measuring the line indicating the angulation of the vertebral endplates. Errors in Ferguson measurement were probably due to difficulties in locating the center of the apex vertebra of larger curves with lesser radiography quality (9), as well as variability in selecting vertebrae for measurement.

This study shows that Ferguson angle presents clinicians with a viable alternative for measurement of spinal curvature in situations where the Cobb angle is difficult to measure. These situations include projections of the spine showing the endplates obliquely and therefore difficult to mark, congenital scoliosis where deformity of vertebrae is evident, postoperative conditions when bulky instrumentation obscures landmarks for Cobb measurement, and sagittal plane measurements in the thoracic spine where endplates are often unidentifiable. Ferguson angle can be converted to an "equivalent" Cobb angle value by multiplying it by 1.35.

In the future, the Ferguson angle may prove to be more suitable for automated measurement. It has been shown that when the vertebral images in a radiograph are digitized for computerized analysis of the line passing through the vertebral bodies, an analog of Cobb angle can be calculated with greater reliability than manual measurements (8,13,17). This approach first requires marking and digitizing of all vertebral centers. Then the computer program fits a smooth line through the digitized points, finds end points (inflectional points) and calculates angles without reliance on pencil lines and manual measurement instruments. Thus, computerized analysis may be more reliable in locating the inflectional points in the line. Even in a computerized analysis, the slope of the line with respect to the horizontal must be calculated, and this would be expected to be more error prone than calculating the angle between lines joining distinct landmarks (vertebral body centers) in the Ferguson method.

Although Ferguson angle is smaller in magnitude than Cobb angle, it was found that, when modified to use end and apical vertebrae as defined by the SRS, it gave measurements comparable with Cobb angle measurements for quantifying curve magnitude and longitudinal changes. It is a truer representation of curve magnitude unaltered by lateral tilting of end vertebrae or distortions of vertebral body shape. It is amenable to automated measurement from digitized radiographs.

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REFERENCES

1. Carman DL, Browne RH, Birch JG: Measurement of scoliosis and kyphosis radiographs. Intraobserver and interobserver variation. *J Bone Joint Surg [Am]* 72:328–333, 1990
2. Cobb JR: Outline for the study of scoliosis. *Am Acad Orthop Surg Instruct Lect* 5:261–275, 1948
3. Cowell HR: Editorial. Radiographic measurements and clinical decisions. *J Bone Joint Surg [Am]* 72:319, 1990
4. Ferguson AB: The study and treatment of scoliosis. *South Med J* 23:116–120, 1930
5. George K, Rippstein J: A comparative study of the two popular methods of measuring scoliotic deformity of the spine. *J Bone Joint Surg [Am]* 43:809–818, 1961
6. Goldberg MS, Poitras B, Mayo NE, Labelle H, Bourassa R, Cloutier R: Observer variation in assessing spinal curvature and skeletal development in adolescent idiopathic scoliosis. *Spine* 13: 1371–1377, 1988
7. Greenspan A, Pugh JW, Norman A, Norman R: Scoliotic index: a comparative evaluation of methods for the measurement of scoliosis. *Bull Hosp Joint Dis* 39:117–125, 1978
8. Jeffries BF, Tarlton M, DeSmet AA, Dwyer SJ, Brower AC. Computerized measurement and analysis of scoliosis. A more accurate representation of the shape of the curve. *Radiology* 134:381–385, 1980
9. Kittleson AC, Lim LW: Measurement of scoliosis. *AJR* 108: 775–777, 1970
10. McAlister WH, Shackelford GD: Measurement of spinal curvatures. *Radiol Clin North Am* 13:113–121, 1975
11. Morrissy RT, Goldsmith GS, Hall EC, Kehl D, Cowie GH: Measurement of the Cobb angle on radiographs of patients

who have scoliosis. Evaluation of intrinsic error. *J Bone Joint Surg [Am]* 72:320–327, 1990
12. Oda M, Rauh S, Gregory PB, Silverman FN, Bleck EE: The significance of roentgenographic measurement in scoliosis. *J Pediatr Orthop* 2: 378–382, 1982
13. Koreska J, Smith JM: Portable desktop computer-aided digitiser system for the analysis of spinal deformities. *Med Biol Eng Comput* 20: 715–726, 1982
14. Robinson EF, Wade WD: Statistical assessment of two methods of measuring scoliosis before treatment. *Can Med Assoc J* 129:839–841, 1983
15. Scoliosis Research Society (SRS), Terminology Committee: A glossary of scoliosis terms. *Spine* 1:57, 1976
16. Sevastikoglou JA, Bergquist E: Evaluation of the reliability of radiological methods for registration of scoliosis. *Acta Orthop Scand* 40:608, 1969
17. Stokes IAF, Shuma-Hartswick D, Moreland MS: Spine and back shape changes in scoliosis. *Acta Orthop Scand* 59:128–133, 1988
18. Ylikoski M, Tallroth K: Measurement variations in scoliotic angle, vertebral rotation, vertebral body height, and intervertebral disc space height. *J Spinal Disord* 3:387–391, 1990