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# Variation in Cobb angle measurements in scoliosis

J.E.H. Pruijs, M.D.[1], M.A.P.E. Hageman, M.D.[1], W. Keessen, Ph.D., M.D.[1]*, R. van der Meer, M.D.[2], J.C. van Wieringen, Ph.D., M.D.[2,3]

[1] Department of Orthopaedics, State University, Utrecht, The Netherlands
[2] Department of School Health, Municipal Health Service, Utrecht, The Netherlands
[3] Department of Social Paediatrics, State University, Utrecht, The Netherlands

**Abstract.** In order to determine the reliability of the Cobb angle measurement as it is used in the clinical management of scoliosis, a methodological survey was carried out. In the measurement of a Cobb angle two phases can be distinguished: (a) the production of a spinal radiograph and (b) the measurement of the angle itself. In respect of the first phase, the variation in production of the radiographs was calculated on Cobb angle measurements made by one investigator on serial radiographs of patients who underwent spinal fusion for scoliosis and therefore had a fixed spinal curvature. For the second phase, the accuracy of Cobb angle measurement was investigated by comparing measurements on the same radiographs of 46 scoliosis patients obtained by three investigators, namely two orthopaedic surgeons and an orthopaedic fellow who was assigned to a school screening project. Results were expressed as a Spearman correlation coefficient and a standard deviation of the differences. The Spearman correlation coefficient was 0.98 for the repeated radiographs (production variation) and also 0.98 for the repeated measurements on one radiograph (interobserver measurement variation). The standard deviation of the differences in Cobb angle for the repeated radiographs amounted to 3.2° and for the repeated measurements on one radiograph it was 2.0°. Although there is a good reproducibility of the Cobb angle measurement between different investigators, the variation in production of a spinal radiograph is an important source of error. This should be taken into account when making decisions in scoliosis management.

**Key words:** Scoliosis – Interobserver variation – Cobb angle

The Cobb angle as measured on spinal radiographs of scoliosis patients is the most important feature in assessing the severity of a scoliosis. It is of importance in the clinical follow-up and in particular in the detection of progression. Therefore the estimation of the angle should be as reliable as possible.

Two phases can be distinguished in the measurement of a Cobb angle. Phase I consists of the production of a spinal radiograph; phase II is the measurement of the Cobb angle on the radiograph. A number of studies have been published concerning the variation in phase II, that is, in the determination of the Cobb angle by different observers measuring the same radiograph [1–4]. The production of the spinal radiograph itself, that is phase I, is probably of greater importance in the variation of the measurements [5, 6]. This study was undertaken with the purpose of establishing the magnitude of the measurement error in each phase.

## Materials and methods

Measurements were performed on radiographs of the spine which were obtained in a standing position in posteroanterior projeciton, with a distance between the X-ray tube and the film of 150 cm. Measurement was performed as described by Cobb [7]. After identifying the vertebra at each end of the curve, the angle of inclination of the endplates of these vertebrae was measured and the Cobb angle was determined.

In respect of phase I – the production of a spinal radiograph – data were acquired from ten patients who had undergone spinal fusion for idiopathic scoliosis. For each patient three different radiographs were available. The Cobb angle (R1, R2, R3) on these radiographs ranged from 12° to 66° (mean 37.1°). Since in the 1st year after spinal fusion some change in curvature is usual, only radiographs taken at least 1 year after the operation were used. These radiographs were measured by an orthopaedic fellow (author M.A.P.E.H.). All patients were checked beforehand to ensure that the spinal fusion was consolidated soundly and that the Risser sign exceeded the fourth phase.

In respect of phase II – the measurement on a spinal radiograph – three investigators, (I1, I2, and I3, authors J.E.H.P., W.K. and M.A.P.E.H., respectively), determined the Cobb angle on 46 spinal radiographs obtained in patients who visited the or-

* We regret to inform the reader of the sudden and unexpected death on 4 December 1993 of our colleague, Dr. W. Keessen, initiator of this study.

*Correspondence to:* J.E.H. Pruijs, University Hospital for Children and Youth "Het Wilhelmina Kinderziekenhuis", P.O. Box 18009, NL-3501 CA Utrecht, The Netherlands

**Table 1.** Phase I: variation in radiograph production Cobb angle measurement by one investigator on three different radiographs (R1–R3) of the same ten patients who underwent spinal fusion

| | R1 | R2 | R3 | R1, R2, R3 |
|---|---|---|---|---|
| Number | 10 | 10 | 10 | 10 |
| Mean Cobb angle (°) | 37.7 | 36.4 | 37.3 | 37.1 |
| Cobb angle range (°) | 14–61 | 13–65 | 12–66 | 12–66 |
| | paired Student's *t*-test | | | MANOVA |
| Compared pairs | R1–R2 | R2–R3 | R3–R1 | R1, R2, R3 |
| Difference range (°) | –4 +4 | –6 +4 | –5 +5 | – |
| Mean difference (°) | –0.6 | 0.0 | 0.6 | – |
| Standard deviation (°) | 2.6 | 3.5 | 3.2 | – |
| Standard error (°) | 1.9 | 1.2 | 1.1 | 2.2 |
| Correlation | 0.99 | 0.98 | 0.98 | – |
| *p* | 0.001 | 0.001 | 0.001 | – |

**Table 2.** Phase II: variation in the measurement of a radiograph. Cobb angle measurement by three investigators (I1–I3) on the same radiographs of 46 subjects visiting the scoliosis clinic

| | I1 | I2 | I3 | I1, I2, I3 |
|---|---|---|---|---|
| Number | 46 | 46 | 46 | 46 |
| Mean Cobb angle (°) | 12.7 | 12.5 | 12.6 | 12.7 |
| Cobb angle range (°) | 3–36 | 2–34 | 4–39 | 2–39 |
| | paired Student's *t*-test | | | MANOVA |
| Compared pairs | I1–I2 | I2–I3 | I3–I1 | I1, I2, I3 |
| Difference range (°) | –4 +4 | –5 +7 | –6 +4 | – |
| Mean difference (°) | 0.2 | –0.1 | –0.04 | – |
| Standard deviation | 1.9 | 2.2 | 2.0 | – |
| Standard error (°) | 0.3 | 0.3 | 0.3 | 1.4 |
| Correlation (°) | 0.98 | 0.97 | 0.98 | – |
| *p* | 0.001 | 0.001 | 0.001 | – |

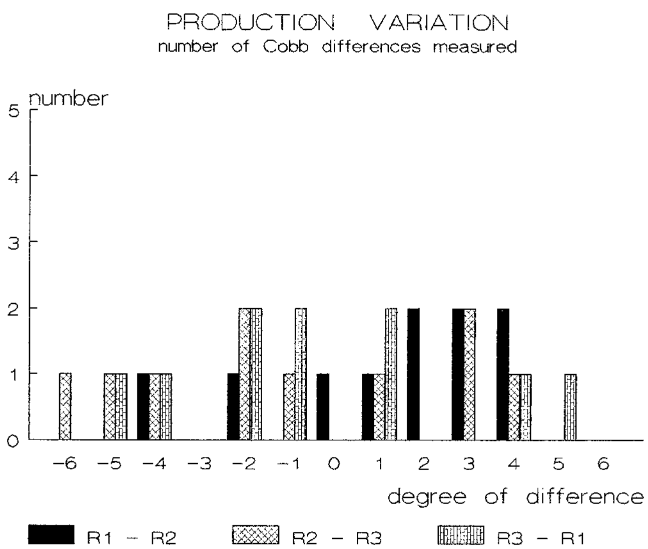


**Fig. 1.** Differences in Cobb angle determination by one investigator on three radiographs

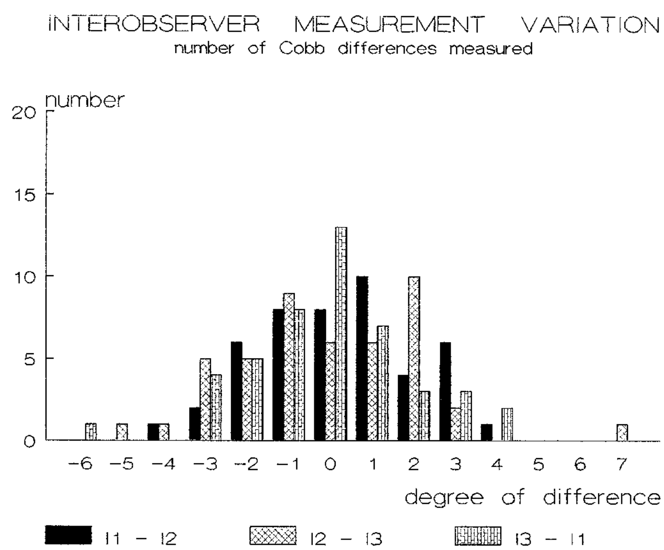


**Fig. 2.** Differences in Cobb angle determination by three investigators

thopaedic outpatient department. The mean Cobb angle on these radiographs was 12.6° (range 2–39°).

All radiographs were numbered, data concerning the patient were covered and signs of earlier measurements were removed. The investigators measured independently at different times and were allowed to choose their own end vertebrae.

Whereas in phase I the radiographs were examined by one investigator, it should be noted that in phase II the examination was performed by three. Hence, the measurements in phase I include the intraobserver variation of the Cobb angle measurement and the variation as mentioned in phase II should be regarded as the interobserver variation of the Cobb angle measurement. Statistical

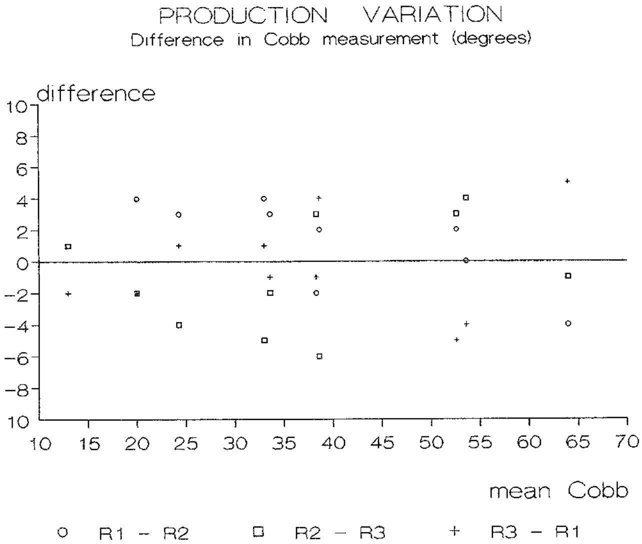


**Fig. 3.** Differences in phase I of Cobb angle determination, grouped by mean values

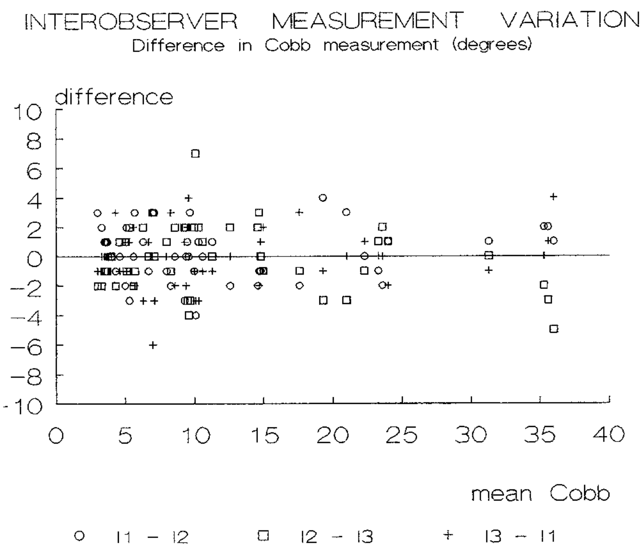


**Fig. 4.** Differences in phase II of Cobb angle determination, grouped by mean values

analysis was done by calculating the standard deviations of the differences (paired Student's *t*-test and MANOVA with repeated measurements) of subsequent radiographs in phase I (R1, R2, R3) or between the paired measurements in phase II (I1, I2, I3). The Pearson correlation coefficient of all pairs of measurements was computed.

## Results

Results of phase I variation assessments are summarized in Table 1 and those of phase II variation assessments in Table 2. The determination of the end vertebrae by the three investigators was always within a range of one vertebral level.

Figures 1 and 2 show the differences in measurement variation as compared to each other, that is, measurement 1 minus measurement 2, 2 minus 3, and 3 minus 1, for phase I and phase II respectively. No systematic error was found in the measurements of any of the investigators.

In Figs. 3 and 4 the measurement variations are plotted against the mean Cobb angle magnitude for phase I variation and subsequently for phase II variation. These figures demonstrate that there is no increase or decrease in any of these variations with the change in Cobb angle, and hence the magnitude of the Cobb angle does not influence the variations in measurement.

## Discussion

*Phase I: Variaton in the production of a radiograph*

Phase I- variation as related to differences in the position of the subject in front of the X-ray cassette, was considered by Schumpe et al. [6]. Using a mathematical model, they calculated a considerable variation in Cobb angle by turning the subject around the longitudinal axis over a few degrees. A vertical shift in the position of the X-ray tube of 22 cm together with an axial rotation of the subject of 10° could bring about a difference in Cobb angle of 30°. Desmet et al. [4] reported a mean difference in Cobb angle of 2.4° when radiographs were taken in reverse directions, that is, anteroposteriorly or posteroanteriorly. This difference was not related to the magnitude of the Cobb angle.

In our series of measurements on serial radiographs of the same patients the maximum difference was 7°. We found no association between the difference measured and the magnitude of the Cobb angle. Therefore, the theoretical idea of Schumpe et al., that a slight rotation of the patient can cause a major difference in Cobb angle on subsequent radiographs, was not confirmed to be of great clinical importance. Apparently, subjects with established spinal deformity assume a more or less similar position each time they are subjected to X-ray examination.

*Phase II: Interobserver variation*

Beekman and Hall reported on the difference between measurements taken by two physicians reading ten radiographs of scoliotic patients with a maximum Cobb angle of 25° [1]. Their 95% confidence interval for the true mean difference was 2.1° – 6.3° (range in differences 1 – 10°).

Morrissy et al. [3] reported on the measurements of four orthopaedic surgeons on 38 radiographs of scoliotic patients with a Cobb angle between 20° and 40°. The standard deviation of the differences in this study ranged from 1.4° to 3.3° for the intraobserver measurements of the four investigators and was 2.4° for the interobserver variation between four examiners (difference range 1° – 10°). They showed that the selection of the end vertebral and the protractor used were the main aetiological factors behind these differences. Variations in the baseline placement of these devices were also found. In the study of Carman et al. [8] four orthopaedic surgeons and one physical therapist measured the Cobb angle on eight radiographs of scoliotic patients. They reported a standard deviation of the differences of 2.97° with a range of differences of 0° – 10°.

Goldberg et al. [2] studied the measurements taken by two orthopaedic surgeons and two technicians on 30 spinal radiographs with Cobb angles of 10°–90°. They found a standard deviation of 2.5° (difference range 0°–10°) and reported an increase in standard deviation in measuring Cobb angles of smaller magnitude. The increase in standard deviation occurred in particular in the measurement of the secondary curves and was explained by the fact that these curves were overlooked by some investigators.

The standard deviations in our study are of the same magnitude as reported in the studies mentioned.

It should be noted that the correlation coefficients in our study were not influenced by the use of different protractors. Two of the investigators used a rotation measuring device of their own design to assess the angle of inclination of the upper and lower end vertebrae, while the third measured the Cobb angle in the original way by drawing lines on the radiographs [9]. No systematic error in their outcomes could be found.

We could not confirm the finding of Goldberg et al. [2] of an increase in measurement variation with decrease in the Cobb angle. However, the most important decisions in the treatment of scoliosis are made with Cobb angles between 20° and 50°. In this range Cobb angle increments of 5° or more are believed to be true changes and thus constitute valid arguments concerning bracing and operation. Therefore not only the orthopaedic surgeon but also the radiologist must be aware of these erroneous variations in Cobb angle measurements.

We are now investigating the real variation of the Cobb angle in the follow-up of untreated scoliotic patients with clinically stable scoliosis.

## Conclusion

The measurements obtained from spinal radiographs and used in the clinical management of scoliosis can obviously be influenced by variations in radiographic technique and interobserver measurement. The standard error of radiographic production variation calculated from measurements of three serial radiographs of the same post-operative patient is 2.2°. The standard error of interobserver measurement variation is 1.4°. Differences of less than ± 4.3° (that is, ± 1.96 × SE = 1.96 × 2.2) as compared to measurement on the previous radiograph do not carry a real clinical significance since they are within the 95% probability limits of Cobb angle determination if the measurements are taken by the same investigator. This fact should be remembered when making decisions in the clinical management of scoliosis. The error is not influenced by the actual magnitude of the Cobb angle.

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