Original Article

Validation of the concavity–convexity quotient as a new method to measure the magnitude of scoliosis

ABSTRACT

Objectives: We propose a novel and simple method to determine the magnitude of the curve in scoliosis and its correlation with the Cobb angle.

Methods: Using multiple rounds of nominal group technique and an established consensus-building methodology, a multidisciplinary research group identified a simple method to value the curve deformity based on the vertebral pedicles.

Measurements: A mathematical study was performed to determine the relationship between the Cobb angle and the concavity–convexity quotient (CCQ). To evaluate the clinical correlation between the Cobb angle and CCQ, spine surgeons measured 48 curves (before and after follow-up) of congenital scoliosis.

Results: This quotient reflects the ratio between the distance from the upper end of the most inclined upper vertebra to the lower end of the most inclined lower vertebra on the concave side (A-distance) and the corresponding distance on the convex side of the curve (B-distance). The existing mathematical relationship is based on changing the explicit coordinates to polar coordinates. Finally, the clinical correlation between the Cobb angle and CCQ was statistically significant ($r = 0.688$; $P < 0.001$ in first measure and $r = 0.789$; $P < 0.001$ in the second measure).

Conclusions: Our study provides Level III evidence that CCQ represents a promising alternative or a complementary method to the traditional Cobb angle due to its simple and reliable ability to measure the magnitude of the curve.

Keywords: Cobb angle, congenital scoliosis, spine

Gonzalo Mariscal, Jorge H. Nuñez[1,2], Paulo Figueira[3], Ana Malo[4], Verónica Montiel[1], Miguel A. López[5], Miguel Castro[6], Carlos Barrios, Pedro Domenech Fernández[7]

Institute for Research on Musculoskeletal Disorders, Valencia Catholic University, [7]Department of Orthopedic Surgery, University and Polytechnic La Fe Hospital, Valencia, [1]Department of Traumatology and Orthopedic Surgery, University Hospital Sant Joan de Deu, L'Hospitalet de Llobregat, [2]Spine Unit, Department of Traumatology and Orthopedic Surgery, Spine Unit, University Hospital of Mutua Terrassa, Terrassa, [4]Department of Traumatology and Orthopedic Surgery, University of Navarra Clinic, Pamplona, [5]Department of Mathematics, Polytechnic University School, Castilla-La Mancha University, Ciudad Real, [6]Departmet of Orthopedic Surgery, A Coruña University Hospital, Coruña, Spain, [3]Department of Orthopedic Surgery, Curry Cabral Hospital, Lisbon, Portugal

Address for correspondence: Dr. Gonzalo Mariscal, Institute for Research on Musculoskeletal Disorders, Valencia Catholic University, Carrer De Quevedo, 2, 46001, Valencia, Spain. E-mail: gonzalo.mariscal@mail.ucv.es

Submitted: 21-Feb-20 **Accepted:** 25-Feb-20
Published: 04-Apr-20

INTRODUCTION

The clinical measurement of Cobb's angle is important for the assessment of the severity of scoliosis and for predicting the progression of the curvature.[1] Classically, the most accurate and extended way to measure the magnitude of a curve in scoliosis is the Cobb angle.[2] The Cobb angle consists of selecting the upper plate of the most inclined vertebra above the curve and the lower plate of the more inclined vertebra located below the curve.[3] Regardless of its theoretical simplicity, some difficulties are found in clinical practice.[1,2,4]

One of the most important drawbacks of the Cobb angle measurement is the presence of great interobserver and intraobserver variability. These measurement errors range from 2.4° to 8.8°, with 5° an acceptable value for the manual method.[5-7] Although most of these studies have been associated with idiopathic scoliosis,[7] to our knowledge, only

Access this article online	
Website: www.jcvjs.com	**Quick Response Code**
DOI: 10.4103/jcvjs.JCVJS_22_20	

How to cite this article: Mariscal G, Nuñez JH, Figueira P, Malo A, Montiel V, López MA, *et al*. Validation of the concavity–convexity quotient as a new method to measure the magnitude of scoliosis. J Craniovert Jun Spine 2020;11:31-5.

three studies have evaluated the Cobb angle measurement for congenital scoliosis.[1,8,9] They showed that the Cobb angle was difficult to measurement due to the severity of the spine deformity turning the appropriate endplates of the vertebra difficult to find.[8] Moreover, there has been reported an interobserver variance of 11.8° and intraobserver variance of 9.6° when using the Cobb method in congenital scoliosis.[8] This variance is important because obtaining an inaccurate measurement does not reflect the true magnitude of the curve.

The aim of this study was to validate a new approach for measuring the magnitude of the curve in congenital scoliosis and to correlate it with the Cobb angle. We think that the concavity–convexity quotient (CCQ) is a method that will address some of the problems generated by the Cobb angle methodology.

METHODS

Design

This study was approved by the Institutional Review Board at our institute. Patients were included if they were diagnosed with congenital scoliosis. The magnitude of the scoliotic curves was measured on conventional X-rays of the whole spine in standing position according to the Cobb procedure.[2] The measurements were performed preoperatively and in the first radiological check-up after surgery. All measurements were performed by two expert's spine surgeons.

Concavity–convexity quotient measurement explication

Once the mathematical correlation was established, the new method was put into practice. CCQ is a new way to calculate the magnitude of the curve. This quotient reflects the ratio between the distance from the upper end of the most inclined upper vertebra to the lower end of the most inclined lower vertebra on the concave side (A-distance) and the corresponding distance on the convex side of the curve (B-distance) [Figure 1].

Mathematical correlation between the Cobb angle and the concavity–convexity quotient

The existing relationship is based on changing the explicit coordinates to polar coordinates. The polar coordinates depend on two variables: a radius and an angle. A and B are straight lines that if joined together, their ends are cut at one point. From that point, on it is related to the radius (*r* and *R*) and the angle. This angle is the same for A as for B, and therefore, A and B are related to the sin of the angle [Figure 2].

Statistical analysis

Statistical analysis was performed using the IBM SPSS software version. 24.0 (IBM Corp., Armonk, NY, USA). The categorical variables were described with their absolute values and percentages. The quantitative variables were presented by their measures of central tendency (mean and standard deviation [SD]). Pearson correlation was used to assess the relationship between CCQ and Cobb angle. We also assessed the interobserver and intraobserver reliability by the intraclass correlation coefficient with the respective 95% confidence intervals.

RESULTS

Practical correlation

Twenty-four patients were included in the study, resulting in a total of 48 curves. The mean age of the patients at the diagnosis was 4.9 (SD 3.6) years. The most common scoliosis curve was the thoracic curve (32%). The general characteristics of the patients are summarized in Table 1. All the mean values of the two measurements are shown in Table 2. Pearson correlation between CCQ and Cobb angle

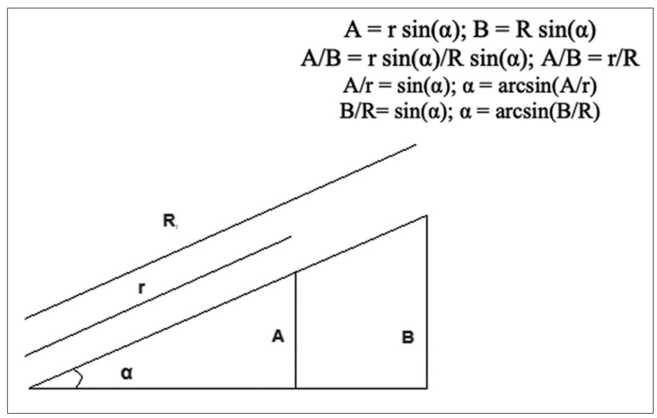

Figure 1: Concavity–convexity quotient. The distance from the upper end of the upper vertebra to the lower end of the lower vertebra on the concave side of the curve is named A-distance. The B-distance is the distance from the upper end of the upper vertebra to the lower end of the lower vertebra on the convex side of the curve. Finally, the quotient between A and B would be calculated

Table 1: Baseline characteristics of 24 patients included in the study

Characteristics	Values
n	20
Age (years)	11.5±5.3
Diagnosis age (years)	4.9±3.6
Follow-up (years)	7.4±2.9
Male (%)	42
Female (%)	58
Cervical (%)	8
High thoracic (%)	16
Thoracic (%)	32
Thoracolumbar (%)	24
Lumbar (%)	20

SD: Standard deviation

was 0.99 [Figure 3]. In CCQ, we founded an intraobserver and interobserver variance of 0.03 [Figure 4].

DISCUSSION

The Cobb angle measurement presents a great interobserver and intraobserver variability.[7] For that reason, the CCQ is present as a new method for measuring the magnitude of the curve in congenital scoliosis. The aim of this study was to validate a new approach for measuring the magnitude of the curve in congenital scoliosis and to correlate it with the Cobb angle.

Several previously described radiographic studies have showed that the Cobb angle is a difficult measurement due to the severity of the spine deformity.[5-7] In congenital scoliosis, to our knowledge, there are three studies that have evaluated the Cobb angle.[1,8,9] Loder *et al.*, in their study, analyzed 67 scoliotic curves from children. They found intraobserver variability as 9.6° and interobserver variability as 11.8°. Hence, they concluded that if the Cobb method is used to determine the progression of a curve in congenital scoliosis between two measurements, and based on two different observers at different times, then at least 23° of change is necessary to ensure with 95% confidence that the increase in the curve is not due to chance or error

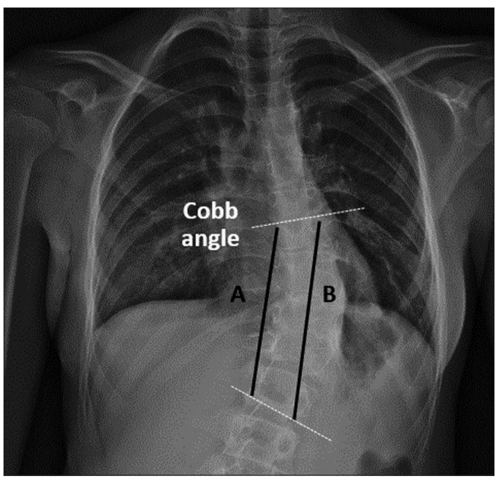

Figure 2: Mathematical correlation. The existing relationship is based on changing the explicit coordinates to polar coordinates. The polar coordinates depend on two variables: A radius and an angle. A and B are straight lines that if joined together, their ends are cut at one point

Table 2: Values of the concavity-convexity quotients and the Cobb angles

Cobb angle pre	CCQ pre	Cobb angle post	CCQ post
24	,65	35	,64
19	,80	41	,77
35	,83	44	,76
11	,89	40	,79
35	,80	41	,78
34	,63	10	,91
29	,65	24	,73
24	,76	17	,86
39	,60	29	,73
28	,68	33	,75
33	,63	35	,66
35	,62	37	,64
28	,71	25	,74
25	,72	34	,73
3	1,00	2	1,00
39	,75	44	,66
27	,76	43	,76
24	,77	27	,79
31	,88	32	,85
43	,55	48	,62
15	,90	7	,94
24	,79	28	,82
34	,69	23	,79
32	,88	24	,88

CCQ: Concavity–convexity quotient

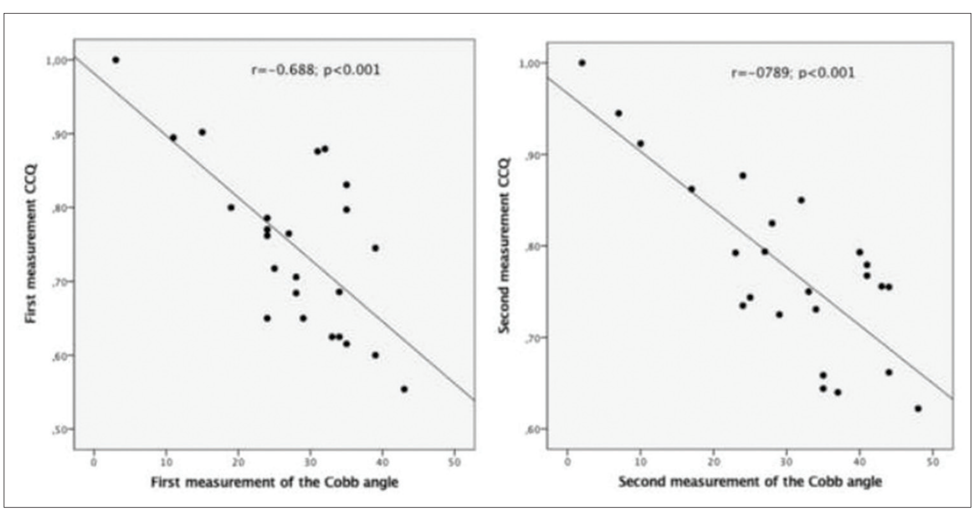

Figure 3: Pearson correlation between concavity–convexity quotient and Cobb angles

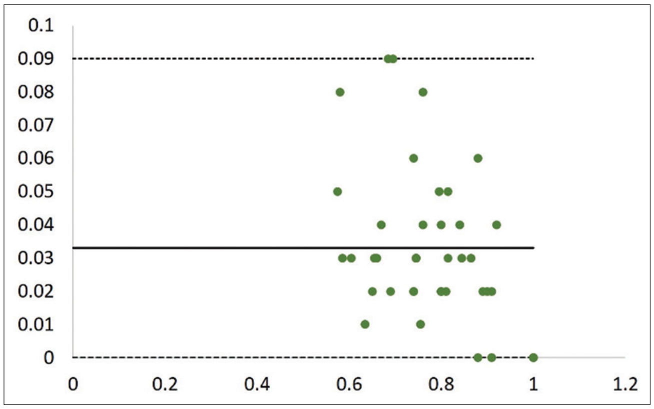

Figure 4: Bland–Altman plot shows interobserver variability for concavity–convexity quotient

of measurement but to an increase in the curve itself.[8] Even this high variability presented in this study, the other two have found a lower intraobserver and interobserver variance. Facanha-Filho *et al*. reported an intraobserver variance ranged from 1.9 to 5.0°, with an average of 2.8° (95% confidence limit, ± 3°) and lower interobserver variance of 3.35° (95% confidence limit, 7.86°).[9]

Accuracy and consistency are crucial in the radiographic assessment of scoliosis.[6] Cobb angle >10° means that scoliosis exists, 10°–25° means regular recheck shall be performed, and 25°–45° means orthosis shall be needed. Cobb angle >45° means surgical interference is needed. Cobb angle >5° in two X-ray examinations indicates the scoliosis deformity progress.[3] Therefore, the measuring error for the Cobb angle >5° will possibly interfere with the diagnosis and treatment results. In our study, the CCQ presented an interobserver variability of 0.03.

Other point is that the CCQ could be the measurement in simple X-rays. As for the bigger bending deformity of the coronal spine plane, the Cobb angle is the included angle of the upper-end vertebra end plate line directly intersected with the lower end vertebra end plate line. For the smaller deformity of the spine, the intersected point of two end plate lines is outside of the X-ray film, and hence, the vertical line of the upper-end vertebra end plate line and that of the lower end vertebra end plate line shall be drawn to perform the measurement.[10] In modern medical health-care systems with digital radiographs and analyses, the idea of reducing drawing artifacts on an X-ray film or make mathematics is somewhat redundant.[3] We believe that in developing countries, that still analyze the radiographs on conventional X-ray films, the measuring distances could be easier and more evident, even nonexpert personnel could measure it, as opposed to the Cobb angle.

Our study has several limitations; first, the CCQ was tested only in conventional radiography. Although the most common measurement of the Cobb angle is on anteroposterior spine X-ray, we believe that this was a correct method of beginning test this new measurement.[1] We believe the CCQ could be extended to other types of imaging tests such as magnetic resonance imaging, computed tomography (CT), or three-dimensional CT, increasing the accuracy of this strategy. Second, this study was only performed in patients with congenital scoliosis, so nowadays, these results cannot be extrapolated to other types of scoliosis. Although it has been described that congenital scoliosis curves are more difficult to measure due to skeletal immaturity.[8] One of the strengths of our study is the development of a conversion equation that could be applied in the clinic to allow a semiquantitative estimate of CCQ-based Cobb Angle. COB Angle = arcsin (A/r) or COB Angle = arcsin (B/R). Even this strength, we believe that more studies will be necessary to assess the interobserver and intraobserver validity and reproducibility of this innovative method.

CONCLUSIONS

In summary, our study provides evidence, that CCQ represents promising alternative or a complementary method to the traditional Cobb angle due to its easy and reliable ability to measure the magnitude of the scoliosis curve.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Tauchi R, Tsuji T, Cahill PJ, Flynn JM, Flynn JM, Glotzbecker M, *et al*. Reliability analysis of Cobb angle measurements of congenital scoliosis using X-ray and 3D-CT images. Eur J Orthop Surg Traumatol 2016;26:53-7.
2. Tanure MC, Pinheiro AP, Oliveira AS. Reliability assessment of Cobb angle measurements using manual and digital methods. Spine J 2010;10:769-74.
3. Wang J, Zhang J, Xu R, Chen TG, Zhou KS, Zhang HH. Measurement of scoliosis Cobb angle by end vertebra tilt angle method. J Orthop Surg Res 2018;13:223.
4. Shea KG, Stevens PM, Nelson M, Smith JT, Masters KS, Yandow S. A comparison of manual versus computer assisted radiographic measurement. Intraobserver measurement variability for Cobb angles. Spine (Phila Pa 1976) 1998;23:551-5.
5. Adam CJ, Izatt MT, Harvey JR, Askin GN. Variability in Cobb angle measurements using reformatted computerized tomography scans. Spine (Phila Pa 1976) 2005;30:1664-9.
6. Lechner R, Putzer D, Dammerer D, Liebensteiner M, Bach C, Thaler M. Comparison of two- and three-dimensional measurement of the Cobb angle in scoliosis. Int Orthop 2017;41:957-62.

7. Langensiepen S, Semler O, Sobottke R, Fricke O, Franklin J, Schönau E, *et al*. Measuring procedures to determine the Cobb angle in idiopathic scoliosis: A systematic review. Eur Spine J 2013;22:2360-71.
8. Loder RT, Urquhart A, Steen H, Graziano G, Hensinger RN, Schlesinger A, *et al*. Variability in Cobb angle measurements in children with congenital scoliosis. J Bone Joint Surg Br 1995;77:768-70.
9. Facanha-Filho FA, Winter RB, Lonstein JE, Koop S, Novacheck T, L'Heureux EA Jr., *et al*. Measurement accuracy in congenital scoliosis. J Bone Joint Surg Am 2001;83:42-5.
10. Morrison DG, Chan A, Hill D, Parent EC, Lou EH. Correlation between Cobb angle, Spinous Process Angle (SPA) and apical vertebrae rotation (AVR) on posteroanterior radiographs in adolescent idiopathic scoliosis (AIS). Eur Spine J 2015;24:306-12.