Intra-and Inter-Observer Accuracy of Cobb's Angle in Scoliosis; Six Weeks Apart

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ABSTRACT

Objective: Cobb's angle is important for assessing the severity and progression of the curvature, as well as for monitoring and managing spine deformities. The reliability in the determination of Cobb's angle depends on the technical expertise of the observer, as well as on the correct angle measurement and determination of the end vertebra. This study was aimed to find inter and intra observer variations while measuring cobb's angle on same radiographs 6 weeks apart.

Methods: A Prospective cohort study of total of 39 radiographs were studied and each observer with a different level of experience measured the same radiographs. Measurements were taken by trained observers at two time points, six weeks apart by five different readers with different years of experience, to check the accuracy in terms of years of experience at 6 weeks' interval at Dr. Ziauddin Hospital Karachi.

Results: The mean differences in Inter-observer Cobb's angle recorded among raters ranged from 2.1° to 13.2° whereas the mean Intra-Observer Cobbs angle ranged from 2.31° to 10.15° when measuring on the same PA radiographs.

Conclusion: The reliability in the determination of Cobb's angle depends on the technical expertise of the observer, as well as on the correct angle measurement and determination of the end vertebra. However, even with the same end vertebra used as a reference, Cobb's measurement may vary.

Keywords: Scoliosis, Cobbs Angle, Apex, End Vertebra, Risser sign.

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INTRODUCTION

Scoliosis is not just a sideways curvature of the spine but in fact is a complex deformity of the spine which is a three-dimensional, it can be etiologically classified under idiopathic (infantile/ juvenile/ adolescent), congenital (osteogenic/neuropathic), developmental (skeletal dysplasia/ skeletal dysostosis), neuromuscular (neuropathic/ myopathic) or tumor-associated (osseous/ extraosseous)[1]. Scoliosis is considered to be the most common spinal deformity in children[2]. Infantile scoliosis occurs from 0 till the age of 3, juvenile between the age 4 to 10 and Adolescent idiopathic scoliosis (AIS) occurs between the age of 10 to 18 years, with a reported frequency between 0.47 and 5.2%[3]. Cobbs angle measurement is frequently used to measure the deviation angle of lateral curvature of the scoliosis in the coronal plane and an angle of more than 10° from midline is considered to be a scoliotic curve and it's a widely acceptable method internally. On a Coronal plain radiograph the angle between most tilted vertebras at both end of the curves is taken and calculated and is known as the Cobb's angle[4]. The End vertebra is the vertebra which is most tilted at both cranial and caudal ends of the curve and after which the curve starts to straighten. Apex of the curve is the vertebra or the disc space furthest from the central sacral line (SCL) and has the highest point of curvature[5]. The stable vertebra, is the vertebra which is bisected or nearly bisected by the SCL at the distal end of the curve. Lastly, Neutral vertebra is the one with no axial rotation at the lower end of the curve with the two pedicles look equidistant from the lateral walls[6].

For manual method of calculation a pencil and protractor are used and the angle is measured using a goniometer[7]. Whereas the digital method of measuring cobbs while using picture archiving and communication system (PACS), is debated to be more reliable in literature[8], The use of PACS benefits by helping the reader in adjusting the brightness, contrast of the radiograph along with benefiting in even adjusting the magnification to visualize the exact ends of the vertebras[9]. Phone-assisted and ultrasound-guided methods have also been used[4].

Cobb's angle is important for assessing the severity and progression of the curvature, as well as for monitoring and managing spine deformities. The reliability in the determination of Cobb's angle depends on the technical expertise of the observer[7], as well as on the correct angle measurement and determination of the end vertebra[8]. However, even with the same end vertebra used as reference, Cobb's measurement may vary by 3-5°[3]. Cobb's angle of >5 in two successive X-Ray examinations is a criterion for progression of scoliosis[3]. Treatment options depend on the skeletal maturity, i.e., Risser sign and increased curvature degree.

Measurement errors such as intra-observer and inter-observer variability, range from 2.4°-8.8°, when measuring on the same PA radiographs[10]. Therefore, it is imperative to determine intraobserver and inter-observer errors while measuring Cobb's angle. The goal of this paper is to address the intra-observer and inter-observer variability in the manual calculation of cobb's angle. We hypothesize that results may vary based on the experience of the observer and having repeated readings with the same observer over a 2-3 weeks' time period.

MATERIAL AND METHODS

Study Design: This is a prospective observational study aimed at assessing the intra- and inter-observer accuracy of Cobb's angle measurements in scoliosis cases. Measurements were taken by trained observers at two-time points; six weeks apart, for intra-observer accuracy and inter-observer variability of 5 different readers with different years of experience, to check the accuracy in terms of years of experience.

Data Collection: A total of 39 radiographs of AIS patients were used from the records of patients who had visited the clinic of Dr. Ziauddin Hospital Clifton campus in 2023. Prints of the plain radiographs were taken of all 39 patients and then all observers were made to draw Cobb's angle on each separately on the same day and then at an interval of 6 weeks.

Inclusion Criteria: Patients diagnosed with Adolescent Idiopathic Scoliosis with pre-operative plain radiographs of whole spine standing (True AP & Lateral Views), All age groups

Exclusion Criteria: Patients with previous spinal surgeries, Degenerative Scoliosis, Congenital Scoliosis, Neuromuscular Scoliosis.

The sample size was determined based on power analysis to ensure statistical robustness.

Observer Training: All observers underwent a standardized training program of 3 classes to enhance consistency in Cobb's angle measurements. The training included a review of scoliosis anatomy and Cobb's angle measurement techniques. Practical sessions for landmark identification and measurement techniques. Calibration exercises to ensure uniform understanding and application of measurement protocols.

Measurement Protocol: Patients were positioned according to established guidelines for Cobb's angle measurements. Landmarks, including the endplates of the most tilted vertebrae, were identified on standing anteroposterior radiographs. Cobb's angle was measured as the angle between the lines drawn along the superior endplate of the vertebra above the curve and the inferior endplate of the vertebra below the curve.

Timing of Measurements: Each observer took baseline measurements and the observers were blinded to their initial measurements. Follow-up measurements were performed by the same observer six weeks later.

Inter-Observer Analysis: Inter-observer accuracy was assessed by comparing measurements taken by different observers at both time points. Statistical analysis included intraclass correlation coefficient (ICC) and Bland-Altman analysis to evaluate agreement and potential bias.

Intra-Observer Analysis: Intra-observer accuracy was assessed by comparing measurements taken by the same observer at both time points. ICC and Bland-Altman analysis were used to evaluate the agreement and consistency of measurements.

Statistical Analysis: For the measurements of Cobb's angle, descriptive statistics (mean and

standard deviation) were computed. The reliability benchmarks that have been established were used to interpret the ICC results. To visualize agreement and detect any systematic bias, Bland-Altman plots were employed.

Ethical Considerations: Informed and written consent was taken from all patients or consented by their guardians. ERC (ethical review committee) approval was obtained from the Ziauddin University review committee.

Data Analysis Software: The statistical analysis of the data was performed using IBM SPSS v.24, and potential disadvantages, such as variations in patient placement or radiography techniques, were found.

Future Directions: It is recommended that future research focus on improving the weaknesses and delving deeper into the accuracy of Cobb's angle measurements across a variety of demographic groups. This methodology provided a comprehensive framework for evaluating the intra- and inter-observer accuracy of Cobb's angle measurements in scoliosis cases, with a six-week interval between measurements.

RESULTS

All 39 radiographs were examined simultaneously by all 5 readers, with R1 = Spine surgeon/ professor (25 years' experience), R2 = Spine Surgery Fellow (7 years' experience), R3 = Senior Resident (5 years' experience), R4 = Junior Resident (2 years' experience), R5 = Intern (6 months experience) and then again at 6 weeks interval. The previous readings of all readers were kept secret and anonymous at the time of data collection until the results were calculated by the statistician. Readers with greater experience had better 95% confidence interval along with mean Cobbs angle measurements.

Table – 1 (a): Inter-Rater Reliability at Presentation

Raters	Intra-class Correlation Coefficient (ICC)	95% Confidence Interval	Reliability
Professor (R1) – Fellow (R2)	0.980	0.963 – 0.990	Excellent
Professor (R1) – Senior Resident (R3)	0.925	0.861 – 0.960	Excellent
Professor (R1) – Junior Resident (R4)	0.893	0.806 – 0.943	Good
Professor (R1) – Intern (R5)	0.748	0.689 – 0.909	Fair
Fellow (R2) – Senior Resident (R3)	0.937	0.884 – 0.967	Excellent
Fellow (R2) – Junior Resident (R4)	0.884	0.789 – 0.937	Good
Fellow (R2) – Intern (R5)	0.710	0.650 – 0.946	Fair
Senior Resident (R3) – Junior Resident (R4)	0.820	0.683 – 0.902	Good
Senior Resident (R3) – Intern (R5)	0.849	0.729 – 0.918	Good
Junior Resident (R4) – Intern (R5)	0.812	0.669 – 0.897	Good

Table 1 (b): Reliability of Inter-rater at 6 weeks interval.

Raters	Intra-class Correlation Coefficient (ICC)	95% Confidence Interval	Reliability
Professor (R1) – Fellow (R2)	0.970	0.943 – 0.984	Excellent
Professor (R1) – Senior Resident (R3)	0.907	0.830 – 0.950	Excellent
Professor (R1) – Junior Resident (R4)	0.860	0.750 – 0.924	Good
Professor (R1) – Intern (R5)	0.729	0.634 – 0.958	Fair
Fellow (R2) – Senior Resident (R3)	0.911	0.838 – 0.952	Excellent
Fellow (R2) – Junior Resident (R4)	0.858	0.732 – 0.925	Good
Fellow (R2) – Intern (R5)	0.706	0.649 – 0.952	Fair
Senior Resident (R3) – Junior Resident (R4)	0.854	0.740 – 0.921	Good
Senior Resident (R3) – Intern (R5)	0.866	0.756 – 0.928	Good
Junior Resident (R4) – Intern (R5)	0.851	0.659 – 0.929	Good

Table 2: Intra-rater reliability at presentation and after 6 weeks.

Raters	Intraclass Correlation Coefficient (ICC)	95% Confidence Interval	Reliability
Professor (R1)	0.985	0.972 – 0.992	Excellent
Fellow (R2)	0.983	0.967 – 0.991	Excellent
Senior Resident (R3)	0.961	0.927 – 0.979	Excellent
Junior Resident (R4)	0.889	0.799 – 0.940	Good
Intern (R5)	0.798	0.726 – 0.918	Good

Intraclass Correlation Coefficient of 0.9 or higher was revealed to be excellent, within 95% confidence interval when assessing Inter-rater reliability between the pairs of; Professor (R1) – Fellow (R2), Professor (R1) – Senior Resident (R3) and Fellow (R2) – Senior Resident (R3) which showed excellent reliability. The reliability was considered to be fair when the ICC values ranged below 0.8, as seen in the pairs; Fellow (R2) – Inter (R5) and Professor (R1) – Intern (R5). The results of this table show that reliability is directly related to the years of experience despite all readers going through the same training regimen

Intraclass Correlation Coefficient of 0.9 or higher was revealed to be excellent, within 95% confidence interval when assessing Inter-rater reliability between the pairs of; Professor (R1) – Fellow (R2), Professor (R1) – Senior Resident (R3) and Fellow (R2) – Senior Resident (R3). The reliability was considered to be fair when the ICC values ranged below 0.8, as seen in the pairs; Fellow (R2) – Inter (R5) and Professor (R1) – Intern (R5). Measurements taken at 6 weeks interval reveal similar results to that of initial values.

The table demonstrates intra-observer reliability with a ICC scores to be excellent for more experienced readers at 6 weeks. The intra-rater reliability, assessed using the intra-class correlation coefficient, exceeded 0.85 at both presentations and after a 6-week interval for most raters, except Intern (R5). Reliability was consistently rated as excellent or good for all other raters.

The one way ANOVA analysis and its corresponding statistics for comparison of mean cobb angle with standard deviation at presentation $p>0.999$, was greater than the significance level $=0.05$, across all raters. The mean Cobbs angle between the five raters at presentation were all >60. (Table 3)

The recorded mean differences in Cobb's angle among raters ranged from 2.1 degrees to 13.2 degrees. The mean was higher, more noticeable, among pairs with the greatest difference in years of experience, with mean difference in Cobbs angle of only 2.1 ° between R1 and R2 and highest difference was noted between R2 and R5 with a mean difference in Cobbs angle documented to be 13.2 °.

Table 3: Comparison of mean Cobb's angle across raters at presentation

Raters	Mean	Standard Deviation	P-value
R5	66.08	19.111	>0.999
R4	67.49	18.443	
R3	68	18.830	
R2	68.28	18.157	
R1	69.16	14.638	

Table 4: Mean differences in Cobb's angle among different raters at presentation

Raters	Mean Difference
Professor (R1) – Fellow (R2)	2.1°
Professor (R1) – Senior Resident (R3)	5.3°
Professor (R1) – Junior Resident (R4)	8°
Professor (R1) – Intern (R5)	17°
Fellow (R2) – Senior Resident (R3)	5.1°
Fellow (R2) – Junior Resident (R4)	7.95°
Fellow (R2) – Intern (R5)	13.2°
Senior Resident (R3) – Junior Resident (R4)	8.1°
Senior Resident (R3) – Intern (R5)	7.6°
Junior Resident (R4) – Intern (R5)	5.2°

The one-way ANOVA analysis, comparing the mean Cobb angle with standard deviation after 6 weeks, yielded a p-value 0.835, surpassing the significance level of = 0.05 for all raters. At 6 weeks, the mean Cobb angles measured by the five raters were similarly all greater than 60.

Table 5: Comparison of mean Cobb's angle across rates after 6 weeks

Raters	Mean	Standard Deviation	P-value
R5	67.85	19.210	0.835
R4	66.69	17.987	
R3	68	18.689	
R2	70.08	17.164	
R1	65.38	16.937	

The recorded mean differences in Cobb's angle among raters after 6 weeks now ranged from 3.2 degrees to 19.3 degrees, which was higher than at presentation. The mean was again higher, more noticeable, among pairs with the greatest difference in years of experience. At 6 weeks the mean difference had increased showing a similar difference in angle like initial, but an increase in mean difference was noted in most inter-observer readings. (Table 6)

A paired sample t-test, conducted on a sample size of n=39, was utilized to compute the mean difference of Cobb's angle between presentation and after 6 weeks for each individual rater, with a significance level set at 0.05. The mean differences ranged from 2.31 degrees to 10.15 degrees depending on the level of experience, with an average mean Intra-observer was 6.41°. The observed trend in mean differences among raters remained consistent, taking into consideration the experience level of each rater. It's noteworthy that none of the calculated values reached statistical significance.

Table 6: Mean difference in Cobb's angle among different raters after 6 weeks

Raters	Mean Difference
Professor (R1) – Fellow (R2)	3.2°
Professor (R1) – Senior Resident (R3)	6.3°
Professor (R1) – Junior Resident (R4)	6°
Professor (R1) – Intern (R5)	15°
Fellow (R2) – Senior Resident (R3)	5.1°
Fellow (R2) – Junior Resident (R4)	11.5°
Fellow (R2) – Intern (R5)	19.3°
Senior Resident (R3) – Junior Resident (R4)	5.3°
Senior Resident (R3) – Intern (R5)	10.1°
Junior Resident (R4) – Intern (R5)	7.9°

Table 7: Comparison of Cobb's angle at presentation and after 6 weeks for five different raters

Raters	N	Cobb's Angle Mean Difference	P-value
R1 (at presentation)	39	2.31 °	0.670
R1 (after 6 weeks)	39		
R2 (at presentation)	39	2.29 °	0.641
R2 (after 6 weeks)	39		
R3 (at presentation)	39	7.6 °	0.099
R3 (after 6 weeks)	39		
R4 (at presentation)	39	9.7 °	0.082
R4 (after 6 weeks)	39		
R5 (at presentation)	39	10.15 °	0.061
R5 (after 6 weeks)	39		

DISCUSSION

Evaluating Cobb's angle is crucial for assessing the progression of spinal scoliotic curves in patients. It provides guidance for treatment decisions such as bracing, surgical correction, and fusion. A shift of ≥ 5 degrees in consecutive radiographs typically indicates progression. There is a recognized range of error during manual calculation of between 3-8 degrees[11]. Despite this margin, manual techniques persistently find application due to their simplicity and cost-effectiveness. This served as an underlying rationale for our study. Our study demonstrates similar reliability of clinical application of Cobb's angle by incorporating both novices, residents and fellow physicians, and a professor-level observer as supported by literature[12,13]. The role of the experience level of the observers can be highlighted in the results.

Prior investigations focused on scoliotic curves within the 20-40-degree range in their sampled patient population[14,15]. In contrast, our study observed a higher mean Cobb's angle[16]. Literature

suggests that a broader range of scoliotic curves analyzed can result in reduced relative error[17,18].

Consistently, our raters recorded mean Cobb angles exceeding 40 degrees at presentation and after 6 weeks, indicating a predominance of patients with severe scoliosis in our data[19]. The range of mean Cobb angles among raters at presentation varied from 66.08 to 69.16 (Table 3), with no statistical significance observed. Even with a sample paired t-test used, comparing mean Cobb's angles at presentation and after 6 weeks, no statistical difference emerged (Table 7), indicating the angles did not vary significantly.

Notably, less experienced observers (R3, R4, and R5) exhibited larger mean differences in Cobb's angle, surpassing the acceptable range of <=5 degrees. These substantial differences may stem from challenges related to image quality during Cobb angle calculation, making it more challenging for an inexperienced observer to identify appropriate end plates on radiograph images. For example, observer R5, less experienced, showed a broader range of consistent Cobb's angles, with more variability; with a mean standard deviation of 19.111 (table 3), compared to the other observers. This variability likely contributed to the lower intra-rater reliability of R5, as suggested by an ICC of 0.798 (table 2)[3].

Similarly, the greatest range of variability was observed in the inter-rater Intraclass Correlation Coefficient (ICC) between professors (R1) - intern (R5), both at the initial presentation (0.748) (table 1), and after a 6-week period (0.729) (Table 1b). This pattern of variability was similarly evident in the inter-rater ICC between fellow (R2) - intern (R5), with scores of 0.710 (table1) at presentation and 0.706 after 6 weeks (table 1b). Looking into literature, Gstoettner et al. determined a mean Intraclass Correlation Coefficient (ICC) of 0.97 through a manual approach for Cobb's angle[20]. Qiao et al. documented an intraobserver ICC of 0.955 and an interobserver ICC of 0.936 using the manual method[20]. Whereas Qiao J et al documented the intraobserver ICC variability as 0.965 and interobserver variability as 0.964 for scoliogauge set[21]. The Intraclass Correlation Coefficient was 0.985 for the reader(Professor) with the most experience compared to the least experienced reader (Intern) with an Intraclass Correlation Coefficient of 0.798 compared to the literature where smartphones were used which showed an Intraclass Correlation Coefficient ranging from 0.997 to 0.991 with similar experience level but using different smartphones instead of manual method[22]. Pepe et al. recommend using smartphone while measuring Cobb's angle, demonstrated by his results with decreased errors while measuring smartphone-assisted Cobb's angle hence, improving the accuracy of end vertebrae selection[23].

Numerous studies in the literature conducted interobserver and intraobserver analyses with a pre-selected end vertebra, potentially influencing the reliability of their findings[16,24]. Our observers relied less on a pre-selected end vertebra, causing room for error. Other sources of error can include inaccuracies in measuring angles or drawing lines[17]. The strength of this study is evident with observers being blinded to the subject's information, and not given a pre-selected end vertebra.

Limitations: The use of individual protractors and pencils, rather than standardized tools, resulted in significant mean differences in Intraclass Correlation Coefficients (ICC). Although, this created a similar situation to a clinical environment. However, clinically acceptable reliabilities were only found in experienced observers. Factors such as the use of wide-diameter pencils and inaccurate protractors were identified as contributors to adverse impacts on measurements. Lack of digital imaging is another limitation of this study. Furthermore, when employing Cobb's method, underestimation of 10-20 degrees can arise, as well as inconsistencies in the angle interval[25].

CONCLUSION

This study sought to analyze the intra- and inter-observer accuracy of Cobb's angle measurements in scoliosis cases, with evaluations done six weeks apart. Our results showed that the observer's expertise level affects Cobb's angle measurements' reliability. For the majority of raters, intra-observer reliability continually maintained excellent or good, indicating that the same observer can repeat consistent measurements over an extended period. Less experienced observers showed a wider range of variability, which highlights the difficulties new raters encounter when determining the proper end plates on radiographs. Inter-observer dependability, however, varied; pairings with comparable levels of experience showed outstanding reliability, while pairs with notable disparities in experience showed fair reliability.

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