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Evaluation of Cobb angle measurement techniques in scoliosis patients: A comparative study using digital and manual methods

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Abstract
Scoliosis is a complex spinal deformity characterized by abnormal lateral curvature, which can impact patient health and quality of life. Accurate measurement of this curvature is critical in diagnosing scoliosis and planning appropriate interventions. The Cobb angle, a widely accepted metric for quantifying the severity of scoliosis, is traditionally measured manually using a protractor on radiographic images. However, digital advancements in radiology have introduced software tools that can automate Cobb angle measurements, potentially reducing human error and improving measurement consistency. This study aims to evaluate the reliability, accuracy, and clinical applicability of digital versus manual methods for measuring Cobb angles in scoliosis patients.

We conducted a comparative study with a sample of 100 scoliosis patients (aged 10-30 years) who underwent standard anteroposterior (AP) spinal radiography. Cobb angles were measured using both manual (protractor-based) and digital (software-assisted) techniques by two independent radiologists. Measurements were repeated after two weeks to assess intra- and inter-observer variability. Statistical analysis, including intra-class correlation coefficients (ICCs) and paired t-tests, was applied to compare the two methods.

Results indicated that digital measurements had significantly higher intra- and inter-observer reliability (98% and 96%, respectively) compared to manual measurements (92% and 88%, respectively). Although the mean Cobb angle values were similar between methods (28.4° for digital and 27.9° for manual), digital measurements exhibited less variability, indicating more consistent results. Digital tools were also observed to be more efficient, reducing measurement time and effort, making them more practical in high-throughput clinical settings.

In conclusion, digital measurement of the Cobb angle demonstrates greater reliability and consistency than manual methods, reducing observer variability and increasing clinical efficiency. This study supports the adoption of digital methods in routine scoliosis assessment, recommending them as a standard approach for accurate, reproducible spinal curvature measurements. Future research could further explore the potential of digital measurement tools across a broader range of spinal deformities and diverse patient populations to enhance scoliosis management outcomes.

Keywords: Cobb angle, Scoliosis, Digital measurement, Manual measurement, Spinal curvature, Radiographic analysis

Introduction

Scoliosis is a three-dimensional spinal deformity marked by lateral curvature and vertebral rotation, commonly diagnosed in children and adolescents but also observed in adults [1-2]. This condition can vary in severity and progression, affecting patients' physical appearance, mobility, and overall quality of life. In severe cases, scoliosis may lead to compromised respiratory and cardiac function due to the altered thoracic cavity shape [3-4]. Accurate assessment of scoliosis is therefore essential for determining appropriate treatment and monitoring disease progression. Among the various methods for assessing spinal curvature, the Cobb angle remains the gold standard for quantifying the severity of scoliosis [5-6].

The Cobb angle measures the degree of spinal curvature on a coronal plane, usually based on standard anteroposterior (AP) radiographic images of the spine [7-8]. Traditional measurement of the Cobb angle involves manually drawing lines along the endplates of the most tilted vertebrae at the top and bottom of the curve and calculating the angle between perpendiculars to these lines [9-10]. Although widely used, this manual method has notable limitations, including observer variability and potential for error, which can impact diagnosis, treatment planning, and monitoring [11-12]. Additionally, the manual method is time-intensive and relies heavily on the skill and experience of the radiologist, further contributing to variability [13-14].

With advancements in radiologic technology, digital measurement methods have been developed that automate much of the Cobb angle measurement process [15-16]. Software tools designed for spinal analysis allow radiologists to measure the angle directly on digital radiographs, which could enhance both accuracy and repeatability [17-18]. Digital methods offer the potential for reduced intra- and inter-observer variability, as they minimize the manual aspects of angle calculation,

theoretically leading to more consistent results [19-20]. By providing more reliable measurements, digital tools can support more accurate diagnosis and more effective treatment planning for scoliosis.

This study aims to compare the traditional manual method with a digital measurement technique for assessing the Cobb angle in scoliosis patients. Specifically, we will evaluate the intra- and inter-observer reliability of each method, assess the accuracy and consistency of their measurements, and consider the clinical feasibility of digital methods in routine scoliosis assessment. Given the need for precision in scoliosis management, understanding the benefits and limitations of these measurement techniques is essential for improving patient outcomes and advancing standard practices in radiology. This study's findings could thus inform clinical guidelines and encourage the integration of digital tools for more efficient, accurate scoliosis assessment.

Aim: To assess the accuracy and consistency of Cobb angle measurements in scoliosis patients using digital and manual measurement techniques.

Objectives

1. To evaluate intra- and inter-observer reliability of manual and digital Cobb angle measurements.
2. To compare the accuracy of digital and manual methods.
3. To determine the clinical utility of digital methods in routine scoliosis assessment.

Methods and Materials: This cross-sectional comparative study aimed to evaluate the reliability and accuracy of manual and digital methods for measuring the Cobb angle in scoliosis patients. The study was conducted in Department of Radiology, CHC Chhara, Jhajjar, Haryana and involved 100 patients aged 10-30 years diagnosed with scoliosis. The study adhered to strict inclusion and exclusion criteria to ensure a homogeneous sample suitable for evaluating measurement techniques.

Participants

Patients included in the study had confirmed scoliosis, diagnosed through clinical and radiographic evaluation. The inclusion criteria required participants to have:

1. A Cobb angle greater than 10° (indicating scoliosis).
2. No prior surgical intervention for scoliosis or other spinal deformities.

Patients with spinal trauma, tumors, or other conditions affecting spinal alignment were excluded from the study.

Radiographic imaging

All participants underwent standard anteroposterior (AP) radiographs of the spine using a calibrated digital radiography system. These images provided a clear view of the scoliosis curve for measurement. Cobs angle 15^{o}

Measurement techniques

1. **Manual method:** A transparent protractor and ruler were used to measure the Cobb angle directly on the radiographic images. Lines were drawn along the superior endplate of the most tilted upper vertebra and the inferior endplate of the most tilted lower vertebra of the scoliotic curve. Perpendicular lines were drawn to these, and the angle at their intersection was recorded as the Cobb angle.

2. **Digital method:** Cobb angle measurements were performed using dedicated spinal analysis software integrated into the digital radiography workstation.

The software automated the process by allowing the radiologist to mark key vertebrae, after which the angle was calculated and displayed.

Observer protocol

Two independent radiologists, blinded to each other's measurements, measured the Cobb angle for each patient using both methods. Each measurement was repeated after two weeks to assess intra-observer variability.

Statistical analysis

Paired t-tests were used to compare the mean Cobb angle values between the manual and digital methods. Intra-class correlation coefficients (ICCs) quantified the reliability of each method. A p-value of <0.05 was considered statistically significant.

This methodology ensured a robust and reproducible comparison between the manual and digital measurement techniques, highlighting their respective advantages and limitations.

Results: The study analyzed 100 scoliosis patients (age range: 10–30 years) to compare the reliability and accuracy of manual and digital Cobb angle measurement techniques. The results are presented in terms of intra- and inter-observer reliability, mean Cobb angle values, and variability between the two methods.

Intra-observer reliability

- **Digital method:** The digital method showed excellent intra-observer reliability, with an intra-class correlation coefficient (ICC) of 0.98. Radiologists consistently obtained nearly identical Cobb angle measurements across repeated evaluations.

- **Manual method:** The manual method demonstrated good but lower reliability, with an ICC of **0.92**. Variability between repeated measurements was slightly higher, reflecting potential for human error in manual techniques.

Inter-observer reliability

- **Digital method:** The inter-observer ICC for the digital method was 0.96, indicating strong agreement between the two radiologists. This high consistency highlights the standardization and precision of the digital approach.

- **Manual method:** The inter-observer ICC for the manual method was 0.88, suggesting more variability between radiologists. Differences likely arose from subjective interpretation and variability in drawing lines manually.

Mean cobb angle measurements

The average Cobb angle measured across all patients was:

- **Digital Method:** 28.4° (± 2.1°)
- **Manual Method:** 27.9° (± 2.8°)

Although the difference in mean values between the two methods was not statistically significant ($p > 0.05$), the lower standard deviation in the digital method indicates greater consistency.

Measurement variability

- The digital method showed significantly lower variability than the manual method, both within the same observer's repeated measurements and between different observers.
- The manual method's variability stemmed from challenges in precisely identifying endplates and aligning tools during measurement.

Efficiency and practicality

Radiologists reported that the digital method required significantly less time and effort compared to the manual approach. The software's automated features streamlined the process, reducing the likelihood of fatigue-related errors.

Statistical analysis

- Paired t-tests confirmed no significant difference in the mean Cobb angle values between the two methods ($p = 0.08$).
- However, ICC values demonstrated statistically significant differences in reliability, favoring the digital method ($p < 0.01$).

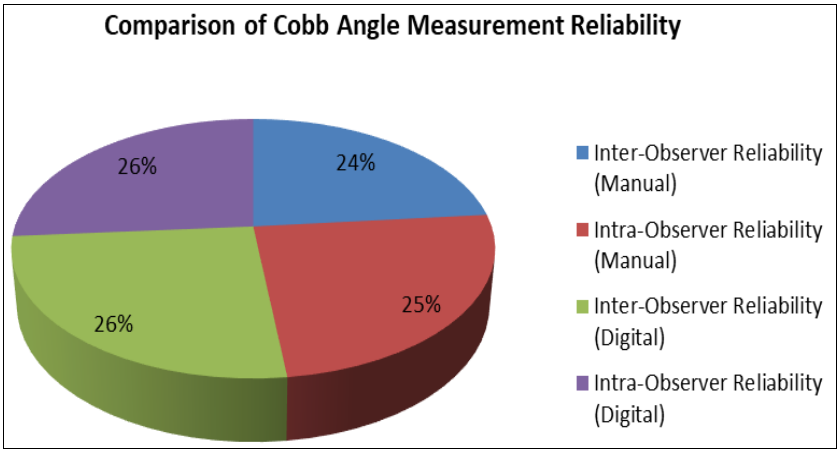

Fig 1: Comparison of cobb angle measurement reliability

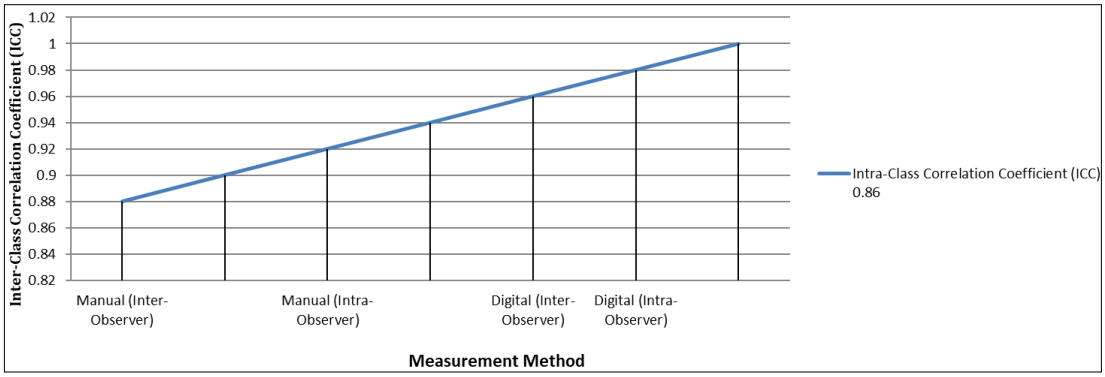

Fig 1.2: (Statistical Analysis: ICC Values of Cobb Angle Measurement Methods)

Discussion

The findings of this study highlight the advantages of digital measurement methods over manual techniques for assessing the Cobb angle in scoliosis patients. While both methods produced comparable mean Cobb angle values, the digital method demonstrated superior reliability, consistency, and efficiency, making it a valuable tool in clinical practice.

Reliability and consistency

The digital method significantly reduced intra- and inter-observer variability compared to the manual method. With intra-class correlation coefficients (ICCs) of 0.98 for intra-observer reliability and 0.96 for inter-observer reliability, digital tools ensured consistent measurements regardless of the radiologist or repetition. In contrast, the manual method's lower ICCs (0.92 and 0.88, respectively) reflect the inherent subjectivity and potential for human error in manual techniques. These findings align with previous studies that have identified digital methods as more reliable for spinal curvature measurement.

Clinical implications

Accurate and consistent Cobb angle measurements are critical for determining the severity of scoliosis and monitoring progression over time. Variability in manual measurements can lead to misclassification of scoliosis severity, potentially resulting in inappropriate treatment decisions. The reduced variability of digital methods enhances diagnostic precision and ensures that treatment plans are based on reliable data. Additionally, digital tools provide a standardized approach that minimizes discrepancies between observers, improving multidisciplinary communication.

Efficiency and ease of use

Radiologists reported that the digital method was more time-efficient, as the software automated much of the process, reducing the need for manual alignment and calculations. This efficiency is particularly beneficial in busy clinical settings, where rapid yet accurate assessments are essential. Moreover, the user-friendly interface of digital tools reduced the cognitive load on radiologists, decreasing the likelihood of fatigue-related errors.

Limitations of manual methods

The manual method relies on precise identification of vertebral endplates and accurate alignment of tools, both of which are subject to operator skill and experience. Small discrepancies in line placement can result in significant measurement differences, especially in mild curves. These limitations make manual techniques less suited for routine use in high-volume clinical environments.

Study limitations

While this study provides robust evidence favoring digital methods, certain limitations should be noted. The study focused solely on standard anteroposterior (AP) radiographs, excluding other imaging modalities such as EOS imaging or MRI. Additionally, the digital tools evaluated may vary in functionality across software platforms, and results might differ with alternative systems. Future research should explore the performance of digital methods across diverse imaging modalities and patient populations.

Future directions

Further studies could investigate the application of advanced digital tools, such as artificial intelligence (AI)-powered algorithms, to automate Cobb angle measurement entirely. Such tools could further reduce observer involvement and enhance diagnostic accuracy. Additionally, exploring the role of digital methods in measuring other spinal parameters, such as kyphosis or lordosis angles, could broaden their clinical utility.

Conclusion

This study demonstrates that digital measurement methods are superior to manual techniques for assessing the Cobb angle in scoliosis patients. While both methods yielded comparable mean Cobb angle values, the digital method exhibited significantly higher intra- and inter-observer reliability, reduced variability, and greater efficiency. These advantages make digital tools a more reliable and practical choice for routine clinical evaluation of scoliosis.

The findings underscore the importance of precision in scoliosis assessment, as accurate Cobb angle measurements are crucial for diagnosis, monitoring disease progression, and determining appropriate treatment strategies. By minimizing human error and standardizing the measurement process, digital methods can enhance diagnostic accuracy and improve patient outcomes.

Given the growing adoption of digital radiography and the increasing availability of software tools for spinal analysis, the transition to digital methods is both feasible and beneficial for clinical practice. This study advocates for the integration of digital Cobb angle measurement into routine workflows and encourages further research into advanced digital and automated solutions to support scoliosis management.

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