

A Comparison of Cobb Angle Measurement on Digitized Radiographs Using A Computer Pointing Device (Mouse): Without Endplate Extrapolation Versus With Endplate Extrapolation

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ABSTRACT

AIM: Advancements in technology have improved the reliability of Cobb angle measurements. Precision of new measurement techniques have to be quantified and established for their valid clinical application. In this study, we investigated the reliability and precision of commonly utilised semi-automatic techniques of Cobb angle measurement, with and without endplate extrapolation using PACS Synapse V4.

METHODS: 53 spinal curves on digitised radiographs, were mea-

sured without and with endplate extrapolation, by three assessors independently on two separate occasions. Reliability testing using Cronbach's Alpha test was conducted for intra-observer reliability. ANOVA assessed the inter-observer correlate. All datasets were assessed for normality using D'Agostino and Pearson. Cobb angle techniques without and with extrapolation were compared using a two-way unpaired Students' T-test. $p < 0.05$ was accepted as significant.

RESULTS: All datasets passed normality testing. All intra-observer reliability was excellent (>0.9). The mean Cobb for all assessors, across both datasets, without extrapolation was 48.2° (95%CI 46.5-50.0) and with extrapolation was 48.1° (95%CI 46.4-49.8).

CONCLUSION: No significance ($p = 0.968$) was observed in Cobb values measured between these semi-automatic techniques. Both Cobb angle measurement techniques produces results that are not significantly different, highly reliable, precise and thus could be utilised interchangeably in clinical practice.

Key words: Cobb angle; Computer-assisted measurement; Scoliosis

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INTRODUCTION

Scoliosis is a spinal disorder that affects 2-4% adolescents^[1-4]. The management of life-long and debilitating scoliosis involves serial full-length PA radiographs over time to quantify the curve magnitude and progression via the Cobb method^[5]; change in Cobb readings is reported to be a risk factor for scoliotic progression^[6]. Although Cobb angles are an objective 2-dimensional measure of a 3D spinal deformity^[5-7], and despite its high intra and inter-observer errors^[4, 8-11], it is still considered the "gold standard" radiographic parameter to quantify scoliotic curves due to its inherent simplicity. Given the

multidisciplinary management of scoliosis, many different observers will be interpreting these radiographs. Decisions regarding surgical interventions and physiotherapeutic or orthotic options will be made based on scoliotic curve progression denoted by the Cobb angle^[5]. Hence an accurate, precise and reliable method is of paramount clinical importance, especially considering even a 5° degree curve progression is potentially clinically important^[12,13]. Several new cost-effective technological advancements have made the measurement of Cobb angles more efficient and reliable. However a paucity of evidence exists with regards to some of the technical intricacies that have yet to be fully investigated^[14].

Many factors increase the error in Cobb angle measurement and pose limitations to its assessment: diameter of radiographic markers, varying observer experience and technical competence, subjects under investigation (biological variance), selection of varying end-vertebrae and errors in construction technique^[11,15-17]. Recent technical advancements have given rise to several new digital methods that have been developed to measure the Cobb angle including smart phone app assisted, semiautomatic and automatic computer assisted techniques. Several studies have attempted to quantify the intra- and inter-observer reliability of several techniques used to quantify scoliosis progression and assessment. Most techniques have a high reliability, albeit a hierarchy of reproducibility exists between techniques. Multiple studies have established that digital methods of measuring Cobb angles are more reliable and accurate when compared to manual techniques^[11,18].

Currently, 2 semi-automatic methods of Cobb angle measurement are predominantly utilised; without (Figure 1) and with (Figure 2) end-plate extrapolation. Reliability (reproducibility) and precision (consistency) of Cobb angle measurements between these differing semi-automatic techniques has yet to be established. The aim of this study was to assess both the reliability of Cobb angle measurements for each semi-automatic digital technique and the precision of measurements obtained between these semi-automatic techniques on digitized radiographs.

MATERIAL AND METHODS

Methodology:

Using the search term ‘whole spine scoliosis’ on our Patient Archiving and Communication System (PACS), we identified a cohort of patients with spinal radiographs retrospectively. The technical quality of each whole spine radiograph was assessed ensuring compliance with the minimum standards as detailed by the Scoliosis Research Society (SRS)^[19]. 43 scoliosis patient radiographs, above the SRS radiographic quality threshold, were identified and anonymised into a separate file on the archive. 10 of the posterior-anterior (PA) radiographs had two apparent structural curves, giving a total of 53 curves for assessment. Curves included were that of the thoracic, thoracolumbar and lumbar spine from the original preoperative digitized PA radiographs. Given that the aim was to assess the reliability and precision of measurement techniques in isolation, we considered gender and upper limit of curve magnitude not to be significant baseline patient factors. Patients with curves above 20 degrees (°) were included as these are the potentially clinically significant (6). Exclusion criteria included; curves of magnitude of less than 20°, patients with spinal instrumentation or evidence of previous surgery, radiographs failing to meet SRS radiographic quality standards and patients older than 30 years to avoid the presence of significant degenerative changes which may confound the measurement techniques.

Three assessors included a medical student (NNK), spinal surgical fellow (DT) and a senior consultant spinal surgeon (IJH). All assessors

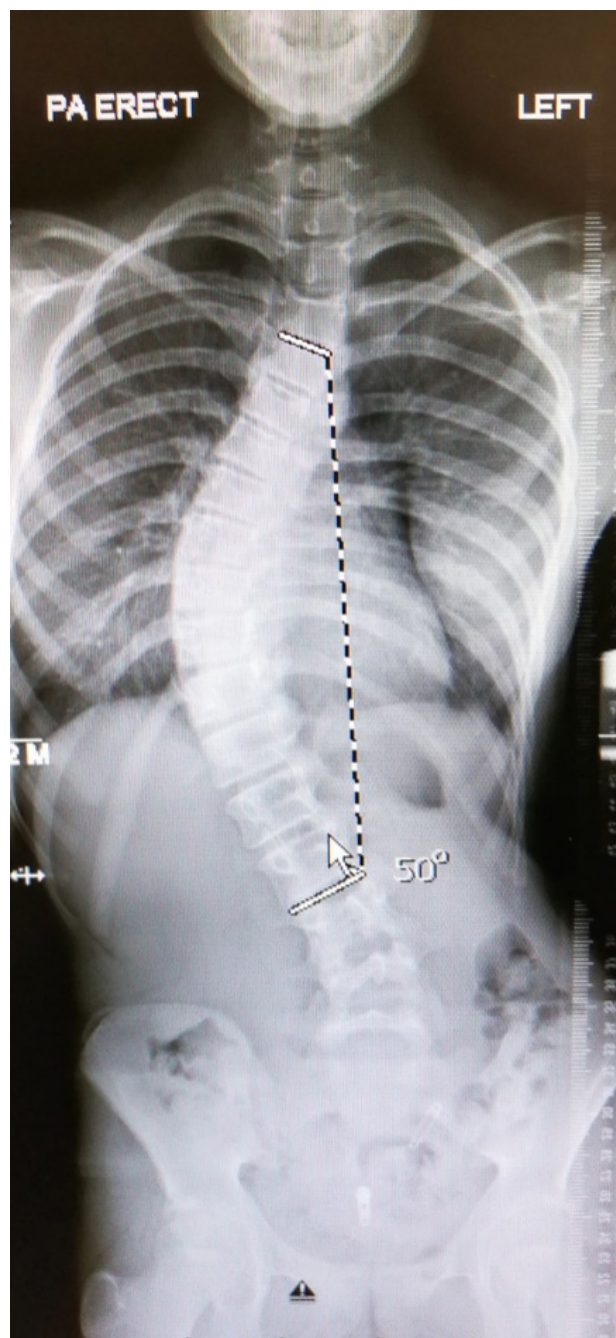


Figure 1 Technique of measuring Cobb angle without endplate extrapolation.

underwent training in the precise methodology, using both semi-automatic techniques, for Cobb angle measurement as originally described^[5]. Most cranially and caudally tilted endplate vertebrae were identified and recorded by the senior assessor (IJH) to eliminate this as a potential source of measurement error^[12]. Each assessor independently measured the Cobb angles on the same set of 53 curves in a random order generated by the random function of Microsoft Excel version 16.33 (2010). On each occasion all assessors were blinded to patient details, previous measurements and the measurements of other assessors. Assessors completed Cobb angle measurements using the digitized technique without extrapolation first, then repeated them using the technique with extrapolation. After a measurement was made, the software reset the radiograph to its original form without saving the previous measurement or technical alteration i.e. magnification and contrast. Readings were repeated by each assessor

at a 4-week interval to allow assessment of intra-observer reliability. The primary measurement of Cobb angle was labelled 'dataset 1' and the secondary as 'dataset 2'.

Radiographic measurement technique

All the assessors used the same angle measuring software on PACS Synapse V4 (Synapse, London) to measure Cobb angles on each radiograph using both techniques. Both techniques involved measuring the Cobb angle in a 2D plane by drawing a superimposed cursor line along the upper and lower vertebral endplates, of the most cranially and caudally tilted vertebrae respectively, as described by Cobb JR^[5]. For the non-extrapolated technique, the cursor lines solely spanned the width of the vertebral body (Figure 1) and for the extrapolated technique the cursor lines were drawn up until their point of intersection (Figure 2). The digital angle displayed on screen by Synapse, for both techniques, was then recorded.

Statistical Methods

Graphed Prism Version 7 was used to analyse the data. Normality testing of all datasets using D'Agostino and Pearson was initially performed. Cronbach's Alpha test was used to measure intra-observer reliability between datasets 1 and 2 for each of the assessors (Table 1). A 2-tailed paired Students' T-test was used to compare measurements between datasets 1 and 2, for each assessor, both without and with extrapolation (Table 1). Analysis Of Variance (ANOVA) was then used to assess the inter-observer correlate within each of the datasets, of all three assessors (Table 2). Finally a 2-tailed unpaired Students' T-test was then used to compare techniques without and with extrapolation, to test for variability in measured Cobb values between the techniques. $P < 0.05$ was accepted as significant.

RESULTS

Study population included 30 females and 13 males with a mean age of 15.9 years (10-30) at the time the radiograph was taken. All the datasets passed normality testing. Intra-observer reliability between datasets 1 and 2, for all assessors both without and with extrapolation, was excellent or better (> 0.9) (Table 1).

The mean Cobb angle in dataset 1 (all assessors) without extrapolation was 48.4° (95%CI 46.0-50.9) and with extrapolation was 48.1° (95%CI 45.7-50.5). The mean Cobb angle in dataset 2 (all assessors) without extrapolation was 48.0° (95%CI 45.6-50.5) and with extrapolation 48.1° (95%CI 45.7-50.5). No significance was observed in the Cobb values measured for any assessor (intra-observer reliability), either with or without extrapolation, between all datasets (Table 1).

Analysis of Variance (ANOVA) identified a significant high interobserver correlate in both datasets, with and without extrapolation. All R^2 values were > 0.880 confirming precision of Cobb measurements between assessors (Table 2). The overall mean Cobb measurement (all assessors, both datasets) without extrapolation was 48.2° (95%CI 46.5-50.0) and with extrapolation was 48.1° (95%CI 46.4-49.8). Overall comparison of Cobb angle measurements obtained between these semi-automatic techniques, with and without extrapolation, was not significant ($p = 0.913$).

DISCUSSION

Since its conception in 1948^[5], Cobb measurement techniques have changed with technology however its principles have remained the same. Multiple studies have investigated the most reliable technique for Cobb measurement with *S.Langensiepen et al*^[14] reporting in

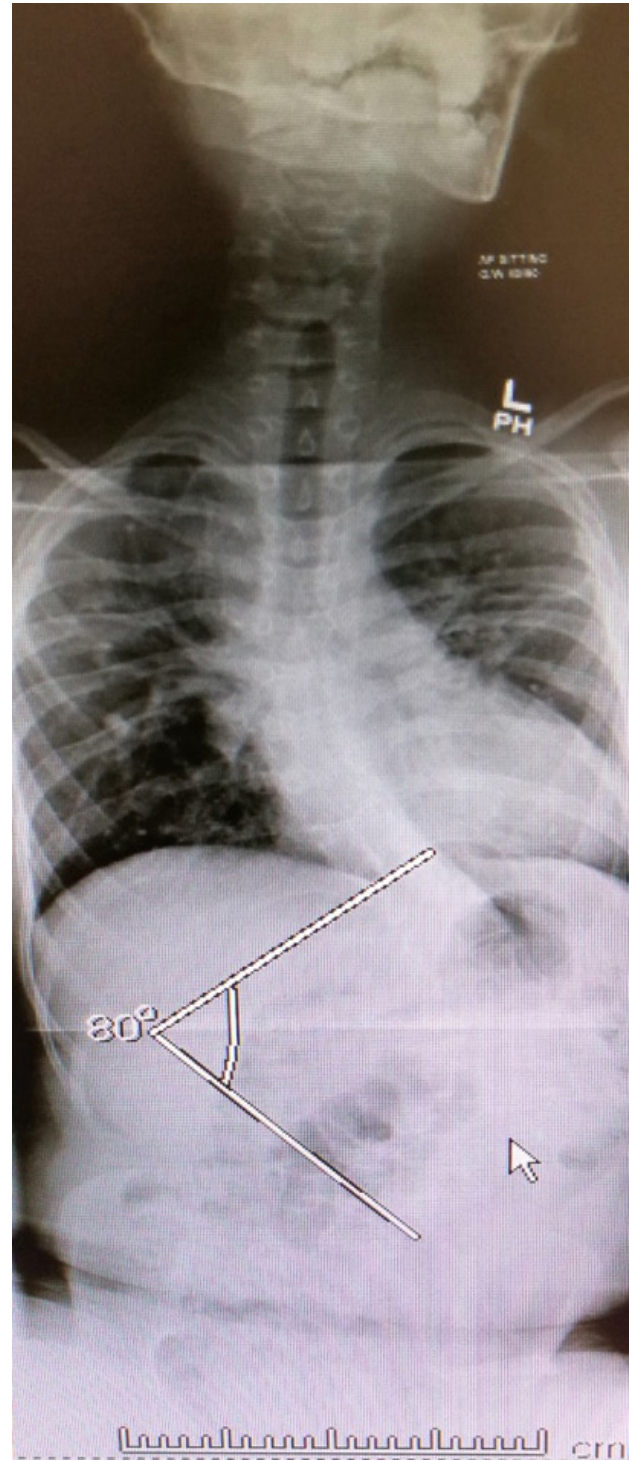


Figure 2 Technique of measuring Cobb angle with endplate extrapolation.

a systematic review that digital techniques were more reliable than manual methods, albeit reporting significant variability in the reliability between automatic methods. Therefore establishing the difference in Cobb measurement reliability, in particular the unreported precision between commonly utilised semi-automatic techniques, helps guide clinicians to accurately and safely determine the optimal management decision for every patient with spinal deformity. Furthermore potential exists to reduce additional unnecessary follow-up radiographs with the well documented harmful effects particularly observed in younger patient subgroups^[20].

Conflicting findings of the importance of the seniority of the surgeon taking the Cobb measurement have been reported, with the

Table 1 Intra-observer reliability between datasets 1 and 2, both without and with endplate extrapolation, for all assessors.

Cobb angle measurement without extrapolation				
Assessor	Mean Cobb (95%CI) [Dataset 1]	Mean Cobb (95%CI) [Dataset 2]	Cronbach Alpha	P Value
1	49.0° (45.1-52.8)	48.6° (44.2-53.0)	0.968	0.588
2	45.6° (41.5-49.7)	45.3° (41.3-49.2)	0.975	0.59
3	50.7° (45.6-55.5)	50.3° (45.7-54.9)	0.997	0.206
Cobb angle measurement with extrapolation				
Assessor	Mean Cobb (95% CI) [Dataset 1]	Mean Cobb (95% CI) [Dataset 2]	Cronbach Alpha	P Value
1	47.5° (43.8-51.2)	47.4° (43.3-51.6)	0.973	0.954
2	45.3° (41.1-49.6)	45.4° (41.6-49.3)	0.975	0.882
3	51.5° (46.8-56.1)	51.5° (47.0-56.0)	0.996	1

Table 2 Interobserver correlate in datasets 1 and 2 both without and with endplate extrapolation.

Cobb angle measurement without extrapolation			
	Mean Cobb (95% CI)	R2	P
Dataset 1 all assessors	48.4° (46.0-50.9)	0.899	<0.0001
Dataset 2 all assessors	48.0° (45.6-50.5)	0.912	<0.0001
Cobb angle measurement with extrapolation			
	Mean Cobb (95% CI)	R2	P
Dataset 1 all assessors	48.1° (45.7-50.5)	0.88	<0.0001
Dataset 2 all assessors	48.1° (45.7-50.5)	0.899	<0.0001

level of experience of the surgeon being both identified as a potential source of error^[11,21], and also not relevant^[12] when measuring the Cobb. In this study, the assessors intra-observer reliability both without and with extrapolation between datasets 1 and 2, showed a tendency towards improved levels of reliability (increasing Cronbach Alpha scores) with the seniority of the reporting surgeon (Table 1), albeit these were not significant. Our study supports the importance of observer training to improve the reliability of Cobb measurement with both semi-automatic techniques, and shows excellent reliability of Cobb measurement regardless of the seniority of the reporting surgeon.

Advancements in technology and the use of standard digital archives in most institutions enable both these semi-automatic techniques to continue to be widely used at a low cost. Both techniques are rapid, user-friendly and cost effective, as all it involves is the cursor or a computer screen pointing device (mouse) and a monitor with access to the digital radiograph archive. Overall our study has established no significant difference between the Cobb measurements obtained using either of the described semi-automatic techniques, and thus both techniques can be used interchangeably to measure Cobb angles on digitized radiographs.

Strengths and limitations

There are several strengths to our study: (1) We used radiographs of patients from a young cohort (< 30 years) largely excluding the presence of degenerative changes (i.e. wedging, osteophyte, distortion and collapse) affecting vertebral endplates. (2) We used curves of a potential clinical significant magnitude (>20°). (3) Standardised equipment was used throughout the study to reduce measurement error and maintain digital consistency (i.e. computer screen size, computer screen pointing device(mouse), monitor screen display and resolution). The same software, Synapse V4, was used to reduce variability in terms of number of landmarks and/or positioning of the digitized radiograph (e.g. horizontal rotation). (4) Synapse V4 includes enhanced software options that enable the contrast, brightness and

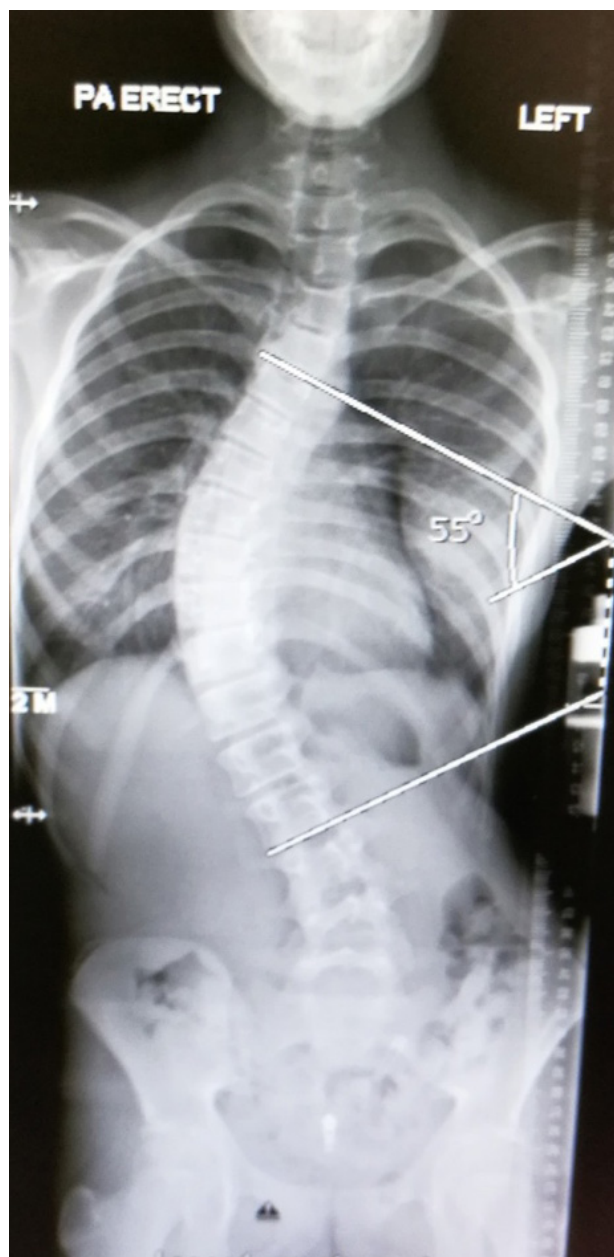


Figure 3 Limitation faced with endplate extrapolation technique.

magnification to be altered. This improved the precision for assessors identifying and marking the superimposed lines on the vertebral endplates. (5) Preselection of endplates for measurement, by the senior author (IJH), reduced further measurement variability between assessors (6) All assessors underwent Cobb measurement training to comply with the international SRS standards. Study limitations included; (i) While using the extrapolated endplate technique in the angle measurement assessors faced a limitation, whereby the screen was not large enough for the lower and upper endplates to intersect. In such cases, endplate lines were just drawn till the limits of the screen as illustrated (Figure 3).

CONCLUSION

Both semi-automatic techniques (without and with endplate extrapolation) described and assessed in this study remain convenient, cost effective and widely utilised methods for quantifying the severity and progression of scoliosis. This study demonstrates that both

techniques utilising PACS Synapse V4 software are highly reliable and precise. Furthermore results between these semi-automatic techniques are not significantly different and are expected to produce similar results, thus could be used interchangeably.

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