Measuring Angles on Digitalized Radiographic Images Using Microsoft PowerPoint

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ABSTRACT

Objective: *To introduce the "virtual goniometer", a method of measuring angles on digital images using Microsoft PowerPoint, a readily available and inexpensive software programme.*
Methods: *Twenty-six X-rays of scoliosis curves were photographed with a digital camera. Six examiners measured the angles of curvature on their computers using the goniometer (Set 1). Under a blinded protocol, repeated measurements on these digitalized X-rays were done three weeks later (Set 2). Intra-observer differences were analyzed. To assess validity, four examiners also measured the angles using the Cobb method. Measurements achieved by both methods were analyzed by the paired samples* t*-test. To assess inter-observer differences, the Pearson correlation coefficient was calculated.*
Results: *Pearson correlation coefficients were significant, r (24) $ 0.975,* p *< 0.001. For intra-observer variability, the average 95% CI range was 2.23 degrees between Set 1 and Set 2. The average 95% CI range was 2.38 degrees for the difference between the digital and Cobb methods.*
Conclusions: *Clinicians using this technique can reliably assume that repeated measurements of scoliosis curvatures will vary in the range of less than 3 degrees. The 95% CI range for intra-observer variability, an index of the technique's repeatability, was $ 2.4 degrees. A high correlation of measurements can also be expected between different observers with the goniometer. This new technique allows practitioners to utilize an easily accessible computer programme to evaluate angular deformities on digitalized radiographic images accurately and hence reliably make clinical decisions based on these measurements.*

La Medición de Ángulos en las Imágenes Radiográficas Digitalizadas, Mediante el uso de Microsoft PowerPoint

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RESUMEN

Objetivo: *Introducir el "goniómetro virtual", un método de medición de ángulos sobre imágenes digitales usando Microsoft Power Point, un programa de software no costoso y fácilmente disponible.*
Métodos: *Veintiséis rayos X de curvas de escoliosis fueron fotografiados con una cámara digital. Seis examinadores midieron los ángulos de curvatura en sus computadoras usando el goniómetro (Set 1). Bajo un protocolo ciego, se realizaron mediciones repetidas de estos rayos X digitalizados, tres semanas más tarde (Set 2). Se analizaron las diferencias intra-observador. Para evaluar la validez, cuatro examinadores también midieron los ángulos usando el método de Cobb. Las mediciones logradas por ambos métodos fueron analizadas mediante la prueba de t de muestras pareadas. Para evaluar las diferencias inter-observador, se calculó el coeficiente de correlación de Pearson.*
Resultados: *Los coeficientes de correlación de Pearson fueron significativos, r (24) $ 0.975,* p *< 0.001. Para la variabilidad intra-observador, el 95% promedio del rango del CI fue de 2.23 grados entre el Set 1 y el Set 2. El 95% promedio del rango del CI fue de 2.38 grados para la diferencia entre el método digital y el método de Cobb.*
Conclusiones: *Los clínicos que usen esta técnica, pueden con toda confiabilidad asumir que las mediciones repetidas de las curvaturas de escoliosis variarán en un rango menor de 3 grados. El 95% del rango del CI para la variabilidad intra-observador – un índice de la repetibilidad de la técnica –*

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West Indian Med J 2008; 57 (1): 14

fue $ 2.4 grados. También puede esperarse una alta correlación de las mediciones, entre diferentes observadores con el goniómetro. Esta nueva técnica permite a los practicantes utilizar un programa de computación fácilmente accesible a fin de evaluar con precisión las deformidades angulares en imágenes radiográficas digitalizadas, y tomar por lo tanto decisiones clínicas de modo confiable a partir de estas mediciones.

West Indian Med J 2008; 57 (1): 15

INTRODUCTION

In orthopaedics, measuring angles on radiographs is an integral component of the evaluation of a patient's clinical status. Determining if angular deformities fall outside of acceptable parameters is often used to guide the clinician towards consideration of surgical intervention (*eg* Blount's disease or fracture alignment). In the management of scoliosis, measurement of the Cobb angle is commonly used to assess progression of the spinal curvature (1).

As digital image technology becomes more commonplace, the ability to perform accurate measurements of angles on digital radiographs will become increasingly important to physicians. There are commercial software programmes that can be used to make these measurements but these are usually expensive and may not be easily available or accessible to individual physicians. The purpose of this paper is to introduce a simple technique for measuring angles on digital radiographic images using the ubiquitous Microsoft PowerPoint programme.

Measurements of Cobb angles using traditional method were compared with those done on corresponding digital radiographic images using this new technique: the virtual goniometer. Use of Cobb measurements for scoliosis was chosen as the index for comparison because the reliability of this traditional method has been well explored in the literature and the statistical methods to assess the intra-observer and inter-observer variability have been described (2–4). These statistical parameters were also analyzed in this study.

METHODS

Twenty-six posterior-anterior scoliosis radiographs (Manual Set) were chosen and identifying marks on the X-rays were masked. Superior and inferior vertebrae were selected and marked with radiographic pencil. Each radiograph was given a code number. Digital photographs of the X-rays were taken using a Sony Mavica, MVC-FD71 camera. Each digital image was given an alphabetic code (Set 1). Set 1 was then duplicated, the order of the images randomly scrambled and new code letters given (Set 2). The images (Set 1) and written instructions regarding the measurement technique were given to each of six examiners on a 3½ inch floppy disc. Their measurements of the Cobb angles using the PowerPoint programme were recorded. Two weeks later, a second disc with images (Set 2) was given to the examiners and the measuring process repeated. Four of the examiners also measured Cobb angles on the Manual Set using the traditional Cobb method. In order to limit any potential bias of examiners, one researcher took the responsibility for maintaining blinding and anonymity of the X-rays, their coding and also the data.

Technique of measurement

The PowerPoint software is opened in the *"Normal"* mode. The digital radiograph image is inserted into the slide by selecting the *"Insert"* command on the top menu bar and choosing *"Picture….From file"*. The measuring tool is created by first drawing a line using the line drawing tool from toolbar at the bottom of the screen. This line (X) becomes the virtual goniometer (Fig. 1a). Once the line "X"

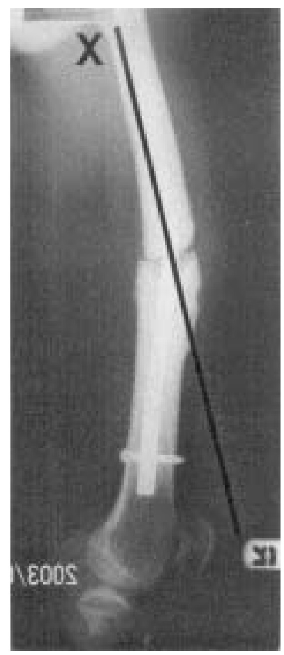

Fig. 1a: To measure the angulation of the fracture, the initial line "X" is drawn along the longitudinal axis of the proximal fragment.

has been selected, the command *"Format"* in the top menu bar is selected. In this dialogue box, the command *"AutoShape"* is selected to open the *"Format AutoShape"* dialogue box and the *"Size"* tab is selected. The rotation of the line "X" is listed as zero degrees. The dialogue box is then closed.

With line "X" selected, the *"Draw"* command in the toolbar at the bottom of the screen is then selected. From the menu options, the command *"Rotate or Flip> Free Rotate"* is chosen. Green dots will appear at the ends of line "X"; these are handles that can be used to rotate the line. The midpoint of the line is the axis of rotation. The line is rotated clockwise to position X^1 (Fig. 1b) to allow measurement of the degree of angulation of the fracture.

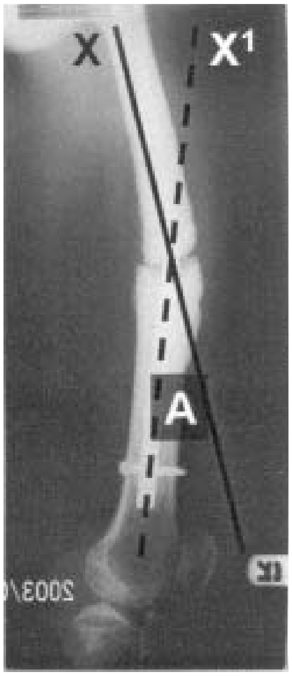

Fig. 1b: Line "X" has been rotated clockwise to position "X^1", superimposed on the longitudinal axis of the distal fragment. Angle "A" represents the degrees of rotation of the line "X" and corresponds to the angulation of the fracture.

The mid-point of the line is then placed at the apex of angulation. With line "X" now rotated to the new position "X^1", the *"Format Auto Shape"* dialogue box is selected as before and the *"Size"* tab again chosen. The command *"Rotation"* now gives a value equal to the magnitude of rotation of line "X". This value equates with the measurement of the angle being evaluated (the fracture angulation). Rotation of the line "X" should always be done in a clockwise direction since the computer calculation starts at zero degrees and increases to 360 degrees as the line is rotated clockwise.

It should be noted that after the initial line (X) has been drawn, releasing the mouse-click button fixes the rotation of the line at zero degrees. The initial placement of the line cannot be adjusted after the mouse button has been released. If this is done, the starting point for measuring the angle would not be zero degrees. To avoid this source of error the examiner must delete and draw a new line if an adjustment to the initial placement was done after the mouse-button is released.

To measure the Cobb angle on a curve that is convex to the right, line "X" is first drawn at the superior endplate of the upper vertebra as in the traditional method. With the help of the computer mouse, the line has to be dragged to the inferior endplate of the inferior vertebra. The mid-point of the line "X" is placed at the midpoint of the inferior endplate. This allows line "X" to be in the correct position when it is rotated. The line "X" is rotated clockwise to position "X^1" to align with the inferior endplate as in the traditional method of measuring the Cobb angle (Fig. 2a). For left curves, the

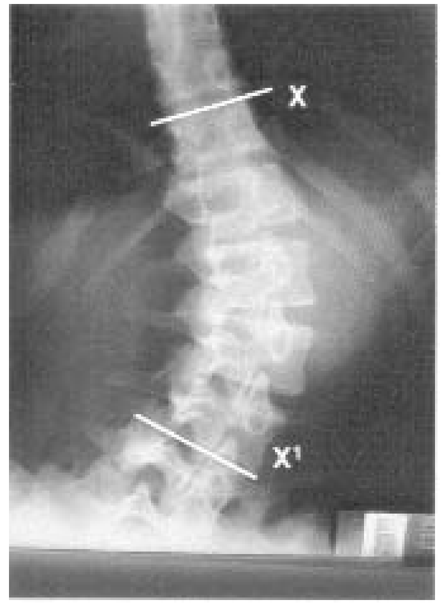

Fig. 2a: Measurement of a right scoliosis curvature. The initial line "X" is placed at the superior endplate of the upper vertebra. Line "X" is then dragged and rotated clockwise to position "X^1" at the inferior endplate of the lower vertebra.

above procedure may be reversed; the initial line "X" is placed at the inferior endplate of the inferior vertebra (Fig. 2b).

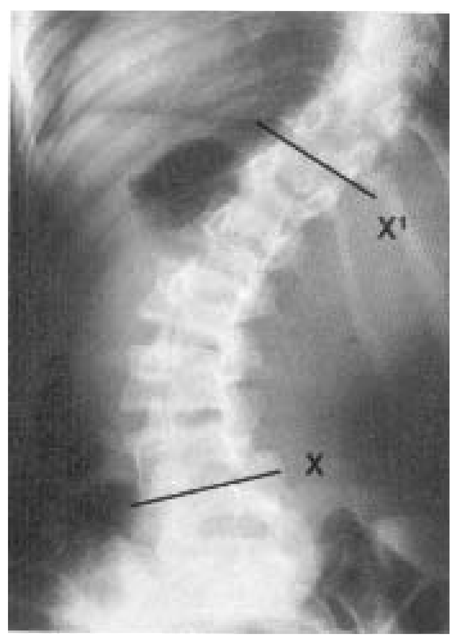

Fig. 2b: Measurement of a left scoliosis curvature. The initial line "X" is placed at the inferior endplate of the lower vertebra. Line "X" is then dragged and rotated clockwise to position "X^1" at the superior endplate of the upper vertebra.

Statistical methods

Statistical analysis of the data was performed using Statistical Package for Social Sciences (SPSS) – version 11 software. Intra-observer differences were calculated for the successive digital measurements of the six examiners (Set 1 and Set 2) and for the four examiners who measured the manual Set and the digital Set 1. The paired samples *t*-test was used to provide 95% confidence intervals for errors in measurements. In addition, frequency and cumulative per cent distribution for the intra-observer differences were analyzed for both groups of comparisons. Inter-observer differences for the digital measurements of six examiners (Set 1) were analyzed by calculating the Pearson Correlation Coefficient.

RESULTS

The distribution of the difference between pairs of angles measured in Set 1 and Set 2 is depicted for each of the six examiners in Table 1. For example, examiner Ex1 measured four of twenty-six curves with perfect agreement between the first and second measurements, ten with a one degree difference, *etc.* Similar data for angles measured in the pairs from the digital Set 1 and the manual set are given in Table 2.

The paired samples *t*-test was used to analyze the differences between pairs of angles measured. The results of the analyses are expressed as mean, standard deviation, standard error of the mean and the 95% confidence interval range. These data were tabulated for measurements between the pairs of digital readings (Table 3). For example, when examiner Ex2 measured pairs of angles in Set 1 and Set 2 using the virtual goniometer technique, the mean of the difference between pairs was 0.54 degrees (Table 3). For this examiner, the 95% CI value predicts that for successive measurements on the same radiograph, 95% of the time, the value obtained in the second reading would not differ from the first reading outside the range of -0.46 and +1.54 degrees.

Table 1: Frequency and cumulative per cent distribution for differences between angles measured twice by each examiner (Set 1 and Set 2).

Difference between angles measured twice	**No of curves (JJ)**	**Cum % of curves (JJ)**	**No of curves (DB)**	**Cum % of curves (DB)**	**No of curves (SP)**	**Cum % of curves (SP)**	**No of curves (LW)**	**Cum % of curves (LW)**	**No of curves (LG)**	**Cum % of curves (LG)**	**No of curves (WS)**	**Cum % of curves (WS)**
0	4	15.4	1	3.8	4	15.4	2	7.7	3	11.5	4	15.4
1	10	53.8	9	38.5	2	23.1	6	30.8	8	42.3	6	38.5
2	6	76.9	6	61.5	5	42.3	5	50.0	1	46.2	7	65.4
3	4	92.3	6	84.6	9	76.9	5	69.2	10	84.6	2	73.1
4	1	96.2	3	96.2	4	92.3	3	80.8	3	96.2	2	80.8
5	1	100	1	100	1	96.2	2	88.5	1	100.0	4	96.2
6					1	100	2	96.2				
7							1	100				
8												
9											1	100
	26		**26**		**26**		**26**		**26**		**26**	

Cum % = cumulative %

Table 2: Frequency and cumulative per cent distribution differences between angles measured on manual set and digital Set 1 by each examiner.

Difference between angles measured twice	**No of curves (JJ)**	**Cum % of curves (JJ)**	**No of curves (PC)**	**Cum % of curves (PC)**	**No of curves (SP)**	**Cum % of curves (SP)**	**No of curves (WS)**	**Cum % of curves (WS)**	**Total No of curves**	**Total Cum % of curves**
0	2	7.7	3	11.5	2	7.7	2	7.7	9	8.7
1	8	38.5	5	30.8	7	34.6	3	19.2	23	30.8
2	3	50.0	6	53.8	5	53.8	6	42.3	20	50.0
3	5	69.2	4	69.2	3	65.4	6	65.4	18	67.3
4	7	96.2	6	92.3	4	80.8	6	88.5	23	89.4
5	1	100.0	2	100.0	3	92.3	2	96.2	8	97.1
6					1	96.2	1	100.0	2	99.1
7					1	100.0			1	100.0
8										
9										
10										
12					1	100			1	100.0
	26		**26**		**26**		**26**		**104**	

Table 3: Statistical data from paired t-tests for differences between the angles measured by the first digital reading and the second digital reading for each examiner

Characteristics estimated	**JJ**	**DB**	**SP**	**LW**	**LG**	**WS**
Mean of differences	0.73	0.54	-0.38	0.62	0.73	0.58
Standard deviation	1.97	2.47	2.99	3.35	2.54	3.20
Standard error of mean	0.39	0.48	0.59	0.66	0.50	0.63
95% confidence interval range	-.07 to 1.53	-.46 to 1.54	-1.59 to .82	-.74 to 1.97	-.29 to 1.76	-.72 to 1.87

For example, if the first reading was 35 degrees, the second would be between 34.54 and 36.54 degrees, a range of 2 degrees. The average 95% CI range was noted to be 2.23 degrees.

Similar data were displayed for measurements between Set 1 and the manual set (Table 4). For the four examiners, the average 95% CI range was 2.38. This implies that 95% of the time the range of difference between the Cobb and digital measurements would be 2.38 degrees.

Table 4: Statistical data from Paired t tests for differences between angles measured on manual set and digital Set 1 by each examiner.

Characteristics estimated	**JJ**	**PC**	**WS**	**SP**
Mean of differences	.31	.73	.15	1.69
Standard deviation	2.83	2.81	3.32	2.85
Standard error of mean	.55	.55	.65	.56
95% confidence interval range	-.83 to 1.45	-.40 to 1.86	-1.19 to 1.49	.54 to 2.84

To assess inter-observer variability, Pearson correlation coefficients were computed among these measurements of the first digital readings (Set 1) for the six examiners. To confirm the assumption that there was a linear relationship between these measurements for the six examiners, scatter plots were created. All correlations were statistically significant, r (24) $ 0.975, *p* < .001.

DISCUSSION

As early as 1980, computer assisted measurement of scoliosis angles has been reported (5). In 1989, Dutton (6) reported high correlation between traditional and computer assisted measurement of Cobb angles. However, during that era, personal computers were not commonplace. In 1998, Shea *et al* (2) compared manual *versus* computer assisted radiographic measurements using Orthographic software. In the method reported by Cheung (7) in 2002, digital reconstruction of radiographic images was used to measure curves for scoliosis and kyphosis.

X-ray systems supporting digital radiography (DR) or computer radiography (CR) are expensive; hardware and software for acquiring, distributing and viewing the image are required (8). With these systems, image manipulation including measurement of angles can be performed using the PACS software (Picture Archiving and Communications Systems). The method introduced in this paper utilizes a common software programme, PowerPoint. It is ideally suited for the physician who does not have access to other more expensive software programmes that may be in use at large institutions. The user should find that the level of difficulty to master this technique is similar to that of the traditional methods. Familiarity with manipulating images and using basic features of PowerPoint are required.

Variations and errors associated with various methods of measurement of scoliosis angles have been reported by many authors (7, 9–12). In the present study, the well established and widely accepted Cobb method was used as a benchmark for evaluating the technique. Cobb's method of measurement has been reported to have high variability with regards to intra-observer and inter-observer differences (7, 12). The Cobb method has often been used as the index for comparison of other techniques for measuring angular spine deformities such as Perdriolle torsionmeter (13), the Quantec measurement (14) and three-dimensional imaging and reconstruction of the spinal column (15).

High validity in addition to low inter-observer and intra-observer variability must be demonstrated for any new technique. Low inter-observer variability was demonstrated by the computation of Pearson correlation coefficients when the digital measurements of six examiners for Set 1 were compared. The observed correlation coefficient of 0.975 demonstrates that there will be low variability in the results when a given angle is measured by different examiners.

Intra-observer variability, an indication of the repeatability, was assessed by evaluating the difference between two sequential measurements of a series of twenty-six angles by each examiner. Ninety-five per cent confidence interval for intra-observer variability using the traditional Cobb method has been reported to range from 2.8 to 10 degrees (3, 4). Using a method to measure Cobb angles on digital images, Shea *et al* reported a value of 2.6 degrees (2). Results of the present study demonstrate that the new technique has a 95% confidence interval comparable to the results of Shea *et al* and lower than the traditional Cobb's method. With the new technique presented, the greatest 95% CI range for intra-observer variability noted was -0.74 to 1.97 degrees, a range of 2.71 degrees (Table 3; examiner Ex4).

The validity of a measuring technique indicates the accuracy of the technique in assessing the true angle. Since the true value on the angle measured on a radiograph is an unknown quantity, the assumption is that the true value is approached when the measuring technique has low inter-observer and intra-observer variability, and acceptable agreement with a widely accepted method. Analysis of the results of the manual set compared to the digital (Set 1) demonstrated that the average range for the 95% CI for the difference in measurements was 2.38 degrees (Table 4). Acceptable agreement with the traditional Cobb method has therefore been demonstrated.

The user should be cognizant of the limitation when measuring angles whose trus value approach the absolute error of measurement of this technique (three degrees). For example, if the true value of the angle to be measured is 4 degrees, then an error of 3 degrees is relatively large and the exercise would be useless. In clinical situations where the value of the angle may influence treatment options, the value of the angle is always much greater than three degrees and so the relative error will be small. For example, bracing for scoliosis would not usually be considered for Cobb angles less than 20 degrees; surgical intervention is usually for curves over 45 degrees (3). Using the traditional method of measuring, this limitation related to the relative error also exists.

The virtual goniometer removes sources of intrinsic error that have been identified in the traditional technique: variability introduced by using different protractors for repeated measurements, inaccuracy of standard protractors, and the use of wide diameter radiographic markers (3, 4). The technique does not remove the error which may result from inaccurate placement of the line on the digital image, for example, at the inferior or superior endplate of the vertebral body. It does improve the accuracy of measuring angles on radiographs and would allow physicians to generate data that can be more reliably used to guide in the clinical decision-making process. This technique can be used to calculate any of the myriad angles measured on radiographs by orthopaedic surgeons.

ACKNOWLEDGEMENTS

The authors express their appreciation to the examiners who performed the measurements on the radiographs: Dr Winston Seale, Dr Shyam Prasad, Dr Prasad Chode, Dr Laura Gill, and Damien Best (medical student). Special thanks to Mrs Claire Williams and Dr Michelle Asafu-Adjaye for their encouragement in the early stages of developing the technique.

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