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Scoliometer measurements of patients with idiopathic scoliosis

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ABSTRACT | Background: Patients with idiopathic scoliosis are exposed to approximately 25 radiographic examinations of their spine throughout the clinical follow-up using the Cobb angle. Several non-invasive and radiation-free methods have been proposed to measure scoliotic deformities, including the scoliometer. **Objectives:** To measure the intra- and interrater reliability of the scoliometer measurements, to assess the correlation of the values obtained by the scoliometer measurements with the Cobb angles obtained by radiography, and to assess the sensitivity and specificity of the scoliometer measurements for the different diagnostic criteria for the referral of idiopathic scoliosis. **Method:** Sixty-four patients were selected for the study: half with idiopathic scoliosis and half without. The 17 levels of the spine of each volunteer were measured with a scoliometer in the forward bending position. The measurements were performed three times on 42 volunteers by two different raters to obtain data for calculating the reliability values. Anteroposterior radiographs were taken to determine the Cobb angles, which were then compared with the highest trunk rotation value. Sensitivity and specificity were evaluated using radiograph criteria for referral: a Cobb angle of 10° and axial trunk rotation values between 5° and 10°. **Results:** Excellent intrarater reliability values and very good interrater reliability values were obtained. The correlation between the scoliometer measurements and radiograph analyses was considered good ($r=0.7$, $p<0.05$). The highest sensitivity value was for a trunk rotation of 5° at 87%. **Conclusions:** The scoliometer measurements showed a good correlation with the radiographic measurements.

Keywords: physical therapy; scoliometer; scoliosis; spine; evaluation.

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Introduction

Patients with idiopathic scoliosis are exposed to approximately 25 radiographic examinations of their spine throughout the clinical follow-up using the Cobb angle to measure the magnitude of scoliotic curvature[1-3]. These patients' excessive exposure to radiation has been associated with an increased risk of developing breast cancer up to 5.4%[4].

Several non-invasive and radiation-free methods have been proposed to measure scoliotic deformities[5-8], including the scoliometer[9-11]. The scoliometer is an inclinometer that measures the asymmetries between the sides of the trunk in axial rotation degrees. The first attempt to correlate the values of the scoliometer measurements with Cobb angles was performed when developing the device[12]. Since then, there has been no consensus regarding the correlation of these values. Mubarak et al.[13], Amendt et al.[9] and Pearsall et al.[14] stated that the values obtained with the scoliometer had poor or insignificant correlations with the Cobb angles. However, Bunnell[12], Korovessis and Stamatakis[15], Sapkas et al.[11] and Griffet et al.[16] found a high correlation between the axial trunk rotation (ATR) values and the Cobb angles.

The consistency of the values obtained by the scoliometer has been evaluated using intra and interrater reliabilities[9,15]. Amendt et al.[9] evaluated 65 patients with scoliosis and found correlation values between 0.86 and 0.97 for the intra and interrater values. Korovessis and Stamatakis[15] evaluated the interrater reliability of the scoliosis measurement values, referring to the vertebral level with the greatest trunk asymmetry, and found reliability values ranging between 0.64 and 0.92. The study by Côté et al.[17] showed that the reliability in determining the level of greatest trunk asymmetry was only 0.25. These authors suggested that methodological and statistical analysis flaws had compromised the conclusions of the earlier studies reporting low correlations.

The precision of the scoliometer test has also been the subject of previous studies[9,12,15,17-19]. Measurements

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using the scoliometer require a value that identifies a minimal deformity to determine whether the patient needs clinical treatment[12]. The criteria for referral found in the literature ranged between 5°ATR, with a 23% sensitivity[12], and 7.5°ATR, with an 87% sensitivity[18], for Cobb angles greater than 20°. However, there is still no consensus about the diagnostic criteria for referral using scoliometer measurements, with repercussions for the values of the instrument`s sensitivity and specificity.

Hence, the purpose of this study was to 1) assess the intra- and interrater reliability of the scoliometer measurements, 2) assess the correlation of the values obtained by the scoliometer measurements with the Cobb angles obtained from radiographs, and 3) measure the sensitivity and specificity of the scoliometer measurements for the different diagnostic criteria for the referral of idiopathic scoliosis using the scoliometer.

Method

The participants were enrolled by convenience in a sample of 32 patients with idiopathic scoliosis for the scoliosis group (SG), which was seen at the Clinic of Orthopedics and Spine of the Clinics Hospital of the Medicine School of Ribeirão Preto, Universidade de São Paulo (HCFMRP-USP), Ribeirão Preto, SP, Brazil. The patients were diagnosed as having scoliosis by a spine specialist orthopedic physician after a physical evaluation and radiographic diagnosis. Another 32 volunteers with Cobb angles smaller than 10° were enrolled at the USP as the control group (CG). The weight and height variables were paired based on the scoliosis group. The volunteers' ages were not paired because, considering the study's objective, it was more important to control the structural ratio of the body segments that were studied. All subjects signed the consent form. This study was approved by the Ethics Committee for Research involving Human Beings at the Committee of Ethics in Human Research of the HCFMRP-USP under process number 9164/2006 in 08/28/2006.

The participants in the SG were on average 18.2 years old (±3.9 years), with an average weight of 54.9 kg (±8.7 kg) and height of 1.61 m (±0.78 m). The average age in the CG was 21.1 years (±2.2years), with an average weight of 55.3 kg (±7.6 kg) and average height of 1.60 m (±0.72 m) (Table 1). The SG, comprising 32 volunteers (31 females and 1 male), presented a total of 47 curves in the frontal plane, considering primary and secondary curves. The curves' magnitudes ranged between Cobb angles of 10° and 101° (average of 25.5°±18.4°). Overall, 16 volunteers had curves between 10° and 20°, eight had curves between 21° and 30°, five had curves between 31° and 40°, and three had curves greater than 40°. The CG also comprised 31 females and 1 male.

The inclusion criteria for the study were the following: volunteers between 10 and 25 years of age, no history of surgery on the back or lower limbs, and a lower limb length discrepancy smaller than 2.5 cm. Only patients with a diagnosis of idiopathic scoliosis were included in the SG.

The female volunteers had their hair tied up and wore a customized backless t-shirt to provide a full view of their back. The male volunteers performed the tests bare-chested. Through palpation, the spinous processes T1 to L5 and the posterior iliac superior spine were located and marked using a marker pen. The same rater performed the process of locating and marking the areas. The rater had four years of experience in manual therapy, which involves the palpation of anatomic structures of the spine.

On top of each anatomic reference mark, 5-mm metal markers were attached using double-sided tape. These markers did not interfere with the scoliosis measurement because they were 3 mm high and did not touch the scoliometer during the measurement process. These markers remained taped over the spinous processes until the experiment was completed to ensure that every measurement was made with the same markings.

During the scoliometer measurement, the patients bent their trunk forward until it was parallel to the ground, keeping the palms of their hands together

Table 1. Anthropometric data, mean and standard deviation of the volunteers in the Scoliosis Group and Control Group showing the differences between the groups and the p values for Student's t-test.

	Scoliosis Group	Control Group	Difference	p
Age (years)	18.2 (±3.9)	21.1 (±2.2)	2.9	<0.01
Weight (kg)	54.9 (±8.7)	55.3 (±7.6)	0.4	0.44
Height (m)	1.61 (±0.78)	1.60 (±0.72)	0.1	0.69

with their arms hanging down and perpendicular to their trunk. In this position, rater 1 (R1) measured the ATR value of the 17 previously marked levels of the 64 volunteers. The ATR values were obtained by positioning the center of the scoliometer over the spinous process and perpendicular to the spine.

Two months before beginning the data collection, the raters were trained to use the scoliometer (Orthopaedic Systems Inc, Hayward, CA) on volunteers with and without scoliosis to become familiar with handling the device and taking measurements.

Forty-two of the sixty-four volunteers submitted to this measurement three times to obtain the data for calculating the interrater reliability values. This group consisted of 25 volunteers from the SG and 17 from the CG. The first and third measurements were performed by a second rater (R2), and the second measurement was performed by R1. Each rater made their measurements, which took approximately three minutes, with no breaks. Between the measurements, the volunteers were instructed to return to the upright position. The measurement made by R1 was performed shortly after a rest interval, the duration of which was determined by the volunteer, after the first measurement was performed by R2. Between the first and last measurements by R2, there was a 15-20 minutes interval for procedures that were not analyzed in this study. At the end of each measurement, 17 ATR values were obtained, one for each vertebral level.

After completing the scoliometer measurements, an anteroposterior (AP) radiograph was obtained of each volunteer, comprising the entire spine in an orthostatic position. The same radiology technician performed all of the radiographic examinations. The Cobb angle was determined by R1 after the completion of the measurements, always using the same negatoscope and goniometer.

The reliability data analysis for the 714 ATR values was performed using SPSS11 software. The intrarater reliability analysis assessed the values from the first measurement by R2 with the values from the second measurement by R2. The test used for this analysis was the Intraclass Correlation Coefficient (ICC) one-way random model with measures of absolute agreement. The interrater reliability was determined by comparing the values of the first measurement by R2 with the values of the measurement by R1. The test used for this analysis was the Intraclass Correlation Coefficient two-way random model with measures of absolute agreement. ICC values smaller than 0.7 were considered unacceptable; the ICC values were considered acceptable between 0.71 and 0.79, very good between 0.8 and 0.89, and excellent above 0.9[20].

The data from the scoliometric and radiographic analyses were correlated using Pearson correlation coefficients with a level of significance of 5%, using Statistica 6.0 software. The Cobb angles were compared with the highest ATR value obtained in the R1 scoliometer measurements of all 64 volunteers. Correlation values smaller than 0.25 were considered poor, between 0.25 and 0.49 were low, between 0.50 and 0.69 were moderate, between 0.70 and 0.89 were good, and between 0.90 and 1.0 were excellent[21].

The 64 volunteers were analyzed for sensitivity, specificity, positive predictive value, and negative predictive value using a Cobb angle of 10° as the radiographic criteria for referral. Referral criteria of 5, 6, 7, 8, 9, and 10 ATR degrees were also investigated.

The same analysis was performed for 17 SG volunteers and 17 CG patients paired according to height and weight for a Cobb angle of 20° as the criteria for radiographic referral.

Results

Forty-two subjects were assessed to obtain the intra- and interrater reliability values. They showed a mean angle of 3.9° (±4.0°) for the 714 ATR values obtained in the measurements by R1. In the second measurement by R2, the mean value for the 714 ATR values was 3.7° (±4.0°), and 3.8° (±4.0°) was the mean for the 714 values obtained in the third measurement by R2. The intrarater reliability was 0.92, and the interrater reliability was 0.89.

The highest mean ATR values obtained in the scoliometer measurements of the 64 volunteers was 7.3° (±4.3°), and the mean Cobb angle was 13.2° (±18°). The correlation between the scoliometer measurement and the radiographic analysis was $r=0.7$ with $p<0.05$. The linear regression equation determining the Cobb angle from the ATR value was $Cobb=-6.3 + 2.7 * ATR$.

Table 2 presents the sensitivity, specificity, positive predictive value and negative predictive value for the referral criteria of 5, 6, 7, 8, 9, and 10 ATR degrees of the scoliometer measurement for a scoliotic curvature greater than 10° Cobb. The greatest sensitivity and negative predictive value were found at 5° trunk rotation, which were 87% and 73%, respectively.

Table 3 presents the sensitivity, specificity, positive predictive value and negative predictive value for the

Table 2. Sensitivity, specificity, and positive and negative predictive values of the scoliometer measurements at different values of axial trunk rotation (ATR) used for referral and of scoliotic curvatures greater than 10° Cobb.

ATR	5°	6°	7°	8°	9°	10°
Sensitivity	0.87	0.68	0.62	0.56	0.46	0.37
Specificity	0.34	0.68	0.75	0.81	0.87	0.90
Positive Predictive Value	0.57	0.68	0.71	0.75	0.78	0.80
Negative Predictive Value	0.73	0.68	0.66	0.65	0.62	0.59

Table 3. Sensitivity, specificity, positive and negative predictive values of the scoliometer measurements at different values of axial trunk rotation (ATR) used for referral and of scoliotic curvatures greater than 20° Cobb (n=34).

ATR	5°	6°	7°	8°	9°	10°
Sensitivity	1	0.76	0.66	0.70	0.64	0.53
Specificity	0.35	0.70	0.66	0.76	0.76	0.82
Positive Predictive Value	0.60	0.72	0.66	0.75	0.73	0.75
Negative Predictive Value	1	0.75	0.66	0.72	0.68	0.63

referral criteria of 5, 6, 7, 8, 9, and 10 ATR degrees of the scoliometer measurement of scoliotic curvature greater than 20° Cobb. The sensitivity and negative predictive value were both 100% at the 5° trunk rotation.

Discussion

The present study found excellent intrarater reliability values and very good interrater reliability values for ATR. The results previously reported in the literature are contradictory in terms of the intra- and interrater reliability values of the scoliometer measurements[9,10,15,17]. In the studies cited, only the vertebral level presenting the greatest asymmetry between the trunk sides was considered. The method proposed in the present study measured the reliability of all vertebral levels of the thoracic and lumbar spine, which makes it possible to state that regardless of the vertebral level and magnitude of the patient's ATR, the scoliometer measurement is reliable.

Predicting the radiographic Cobb angle using noninvasive methods has great potential as it would permit professionals to clinically follow up the scoliotic curvature without recourse to measurements using ionizing radiation. The present study found good correlation between the scoliometer measurements and the Cobb angles. Reports in the literature are contradictory, with some authors proposing a strong correlation between the methods[11,12,15] and others stating there is a poor correlation[9,13,14]. These studies correlated the ATR of the level with the greatest asymmetry with the Cobb angle value. However, the level of greatest asymmetry was determined in a subjective manner by the examiner. The low reliability in determining the level with the greatest asymmetry used to measure the trunk rotation can lead to measurement errors[14]. In the present study, the level of greatest asymmetry was determined after evaluating every vertebral level, and the one with the greatest ATR value was used for the correlation with the Cobb angle. The correlation function presented in the present study permitted the estimation of the Cobb angle using the scoliometer measurement. Hence, a clinician can screen idiopathic scoliosis patients with a scoliometer and calculate the Cobb angle, which is the gold standard for diagnosing and following curvatures, without the need for excessive radiography.

The results of the present study showed that it is possible to identify 87% of the patients with idiopathic scoliosis with lateral curvatures greater than 10° Cobb and 100% of the patients with curves greater than 20° Cobb using 5°as the criteria for referral. The literature reported that increased ATR values do not lead to increased sensitivity of the scoliometer measurements. According to Bunnell[12], the 5° criteria for referral would permit the detection of 23% of patients measured by the scoliometer with Cobb angle greater than 20°, whereas Burwell et al.[18] proposed an 87% sensitivity for the referral criteria of 7.5° ATR. The use of ATR criteria for referral with greater sensitivity and smaller specificity examinations for idiopathic scoliosis is justified by the importance of detecting every individual with lateral curvature given the important consequences for the health of patients with skeletal immaturity[17]. Using a 5° ATR criterion for referral, two studies used the scoliometer to screen students and investigate the prevalence of idiopathic scoliosis[19,22].

A scoliosis diagnosis is confirmed when a curvature greater than 10° Cobb is determined by radiographic examination[23]. Curves smaller than 20° Cobb are rarely treated[12,19] and have not been included in previous studies[9,12,18]. However, patients with curves between 10° and 20° Cobb should be evaluated to eliminate factors that could lead to an increase in the curvature, such as the Risser index and the date of menarche in female patients[24]. We propose that patients with ATR values of at least 5° by scoliometer measurement should be referred for a more thorough clinical evaluation to identify those with a greater probability of the progression of the curvature of the lateral vertebral spine.

The scoliometric method for measuring the ATR is quick and easy to learn but requires a well-trained physical therapist to palpate the spinal levels, or the measurements can be made at the wrong anatomical marks, resulting in an unreliable angle value.

Further studies are needed to evaluate the capability of the scoliometer measurements in following the progression of the curvature of patients with idiopathic scoliosis of different magnitudes to confirm the use of the scoliometer as an instrument not only for screening but also for clinically following the scoliotic curvature and effectiveness of the treatments.

Scoliometer measurements, following the methodology proposed in this study, showed good correlation with the Cobb angle, the gold standard measurement. It had good intra- and interrater reliability and was sensitive in detecting curvatures greater than 10° Cobb using a referral criterion of 5° ART, indicating its potential for screening individuals with idiopathic scoliosis. Further studies should be performed to measure the test-retest reliability and the measurement responsiveness with the purpose of incorporating it into clinical practice as an alternative to radiographic exposure.

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