Reliability and Validity of the Photogrammetry for Scoliosis Evaluation: a Cross-Sectional Prospective Study

Karen Ruggeri Saad, MA,[a] Alexandra S. Colombo,[b] and Silvia M. Amado João, PhD[c]

Abstract

Objective: The purpose of this study was to investigate the reliability and validity of photogrammetry in measuring the lateral spinal inclination angles.
Methods: Forty subjects (32 female and 8 males) with a mean age of 23.4 ± 11.2 years had their scoliosis evaluated by radiographs of their trunk, determined by the Cobb angle method, and by photogrammetry. The statistical methods used included Cronbach α, Pearson/Spearman correlation coefficients, and regression analyses.
Results: The Cronbach α values showed that the photogrammetric measures showed high internal consistency, which indicated that the sample was bias free. The radiograph method showed to be more precise with intrarater reliabilities of 0.936, 0.975, and 0.945 for the thoracic, lumbar, and thoracolumbar curves, respectively, and interrater reliabilities of 0.942 and 0.879 for the angular measures of the thoracic and thoracolumbar segments, respectively. The regression analyses revealed a high determination coefficient although limited to the adjusted linear model between the radiographic and photographic measures. It was found that with more severe scoliosis, the lateral curve measures obtained with the photogrammetry were for the thoracic and lumbar regions (R = 0.619 and 0.551).
Conclusions: The photogrammetric measures were found to be reproducible in this study and could be used as supplementary information to decrease the number of radiographs necessary for the monitoring of scoliosis.
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Key Indexing Terms: *Scoliosis; Photogrammetry; Reproducibility of Results; Physical Therapy*

The evaluation of scoliosis, as well as the objective measurements of the aspects of trunk deformity, plays key roles for the diagnosis, planning, and follow-up of prescribed therapeutic interventions.[1] Traditionally, radiographic examinations are both the most well-known and applied evaluation methods in clinical practice. The Cobb method has been applied to measure the curve progression, to select the type of intervention, and to evaluate its efficacy.[2]

Patients who had idiopathic scoliosis who are submitted to physiotherapy treatments, with or without the use of braces, often undergo radiographic evaluations every 3, 6, or 12 months according to the Society on Scoliosis Orthopaedic and Rehabilitation Treatment (Guideline Committee of 2005).[1] However, health professionals have been worried about the adverse effects of high doses of radiation. It is well known that children and adolescents have higher risks of the development of cancer with radiation.[3,4] Thus, over the last few decades, research has been conducted with the aim to lower, as much as possible, these patients' exposure to x-rays.[4]

Older methods of evaluation[5-7] that collect data from trunk deformity observations have been discussed, and others with improved technology have been created.[8-20] Some of these methods, such as the scoliometer and observational postural evaluations, are recognized as appropriate methods to detect postural alterations related to scoliosis and, consequently, are widely used in annual assessments of adolescents and preadolescent students.[21-24]

Other scoliosis evaluation methods, such as scanners, stereophotogrammetry, as well as the use of special software,

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have been applied high-technology tools, with the objective of measuring trunk deformities, so that these methods could replace, or at least someday may decrease, periodic radiographic evaluations.[9-19,25] However, in spite of all of these methods that show moderate agreement with radiographic aspects, as well acceptable reliability, all authors agreed that they could not replace radiographic measurements.

Digital photogrammetry has been considered an alternative to the quantitative evaluation of postural asymmetries and may be used for angular and linear variable measurements.[26-33] According to the American Society for Photogrammetry and Remote Sensing,[34] photogrammetry is the science and technology to obtain reliable information through pictures of physical objects and the environment, which may be measured and interpreted.[28,34]

One advantage of photogrammetry is the possibility of the recording of subtle changes.[35] Besides, it quantifies the morphological variables related to posture and provides more reliable data than those obtained with the observational evaluations.[28] Another advantage of photogrammetry is the possibility of saving the files digitally with an economy of space and easy access to these records.

A limited number of studies were found using photogrammetry as a methodology of quantitative postural evaluation for patients with scoliosis. There is also a need for healthcare providers to have an instrument that is capable of providing objective information on the evolution of posture. It is also necessary for follow-ups or as a prognostic tool that could be used more frequently than conventional radiographic evaluations. Therefore, the aim of this study was to test the reliability and the validity of photogrammetry in assessing the lateral spinal angular inclination.

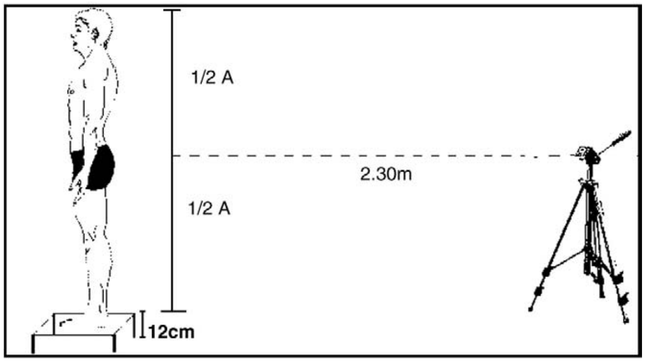

Fig 1. *Positioning of the patient during the photography session.*

Methods

The records of 129 patients with diagnosis of scoliosis for the last 5 years were studied; these patients were in treatment at the orthopedic clinic of the university hospital. Forty-eight subjects were excluded because their scoliosis was due to lower limb discrepancies, neurologic diseases, hemivertebrae, fractures, previous spine surgery, degenerative changes of the intervertebral disks, and scoliosis less than 10°, as determined by the radiographic Cobb method. The other 81 patients were contacted by telephone and invited to participate in the study, but only 40 agreed to participate. All subjects had a diagnosis of idiopathic scoliosis confirmed by anterior-posterior radiographs of the trunk. All control radiographs were taken a maximum of 1 month before the photogrammetry, and all Cobb angular measures were obtained by the same investigator who was previously trained.

All subjects or their legal guardians signed the consent form, which was approved by the Ethical Committee for Analysis of Research Projects of the Board of the University Hospital of Sao Paulo University (protocol no. 0187/07). All subjects were interviewed to obtain their ages, diagnosis times, and therapeutic treatments, along with their body mass and height to calculate their body mass index (BMI).

Two photographic sessions for each patient were performed on different days. During the first session, the subject was prepared and photographed by 2 examiners. During the second photographic session, which was 15 days apart, the patient was photographed again by the first examiner. Both examiners were physiotherapists and experienced with postural assessment and treatment. The training for the determination of the bony references, the photographic sessions, and the use of Corel Draw 11.0 (Corel, Ottawa, Ontario, Canada) was carried out in a pilot study, when both examiners previously together assessed 2 subjects. For this study, the investigators independently recorded the measurements without communicating their results to each other.

Each photographic session consisted of recording the digital photos in the frontal and sagittal planes, which were standardized for the individual's positioning, photographic camera positioning (Sony P200 7.2.mp; Sony, Tokyo, Japan), and the distance between the camera and the subject (Fig 1). All sessions were carried out in the physiotherapy outpatient clinic of the university hospital, with the same light and temperature conditions. All sessions were carried out in the afternoon (between 1:00 and 5:00 PM).

The subjects' preparation was composed of the identification of the anatomical landmarks, with round tape of 1 cm in width (3M), which were placed on the subject's skin after careful palpation to identify the spinal processes of the T1 to L5 vertebrae. The markers were placed on the subjects while in the standing position and wearing appropriate clothes.

The subjects were positioned behind a symmetrograph apparatus (CARCI, São Paulo, Brazil) and over a 12-cm-high wooden platform. Their feet were always placed in the same way with the aid of 2 reference lines marked on the platform. The wooden platform, the symmetrograph, as well as the tripod on which the camera was fixed had a leveling system to correct support differences, and the tripod heights

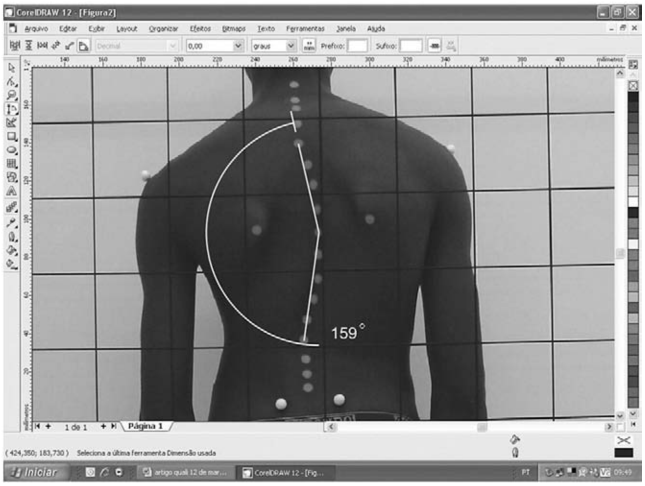

Fig 2. *Measurement of the lateral spinal curvature using method 1 of photogrammetry.*

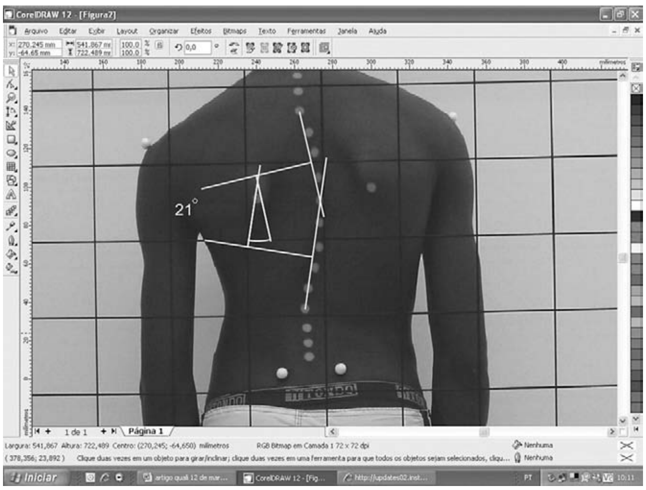

Fig 3. *Measurement of the lateral spinal curvature using method 2 of photogrammetry.*

were regulated at half of the subject's height. At the end of the procedure, the digital pictures were transferred to the Corel Draw program, which enabled the researchers to measure the scoliosis curve angles in the frontal plane in 2 different ways:

- *Method 1.* The scoliosis angle: the measurement of the angles between the apical vertebrae (the furthest marked vertebra from the midline) and the superior and inferior limit vertebrae (vertebrae near the midline) (Fig 2).
- *Method 2.* The Cobb photos: similar measurements of the radiographic Cobb angle (Fig 3).

The lateral spinal curvatures in this study were classified as thoracic, when the apical vertebrae were above T10; the lumbar, when they were below the L2; and thoracolumbar, when the apical vertebrae were between T11 and L1. During the analysis of the photos, the researchers had no previous knowledge of the radiographic Cobb angle measurements. The Cobb angle was determined by means of an anterior-posterior radiograph, following the instructions of Amendt et al.[21]

All statistical analyses were carried out with the SPSS version 13.0 (SPSS Inc, Chicago, Ill) with the significance level set at $\alpha < .05$. The Cronbach α statistics was used to evaluate the internal consistency, whereas the Pearson correlation coefficients were calculated to evaluate the photogrammetry reliability ($r > 0.7$, strong correlations; $0.3 > r < 0.7$, moderate correlations; and $r < 0.3$, poor correlations).[36] Regression analyses were used to evaluate the levels of agreement between the radiographic and photographic measurements and Spearman correlation coefficients to verify the associations between the variables.

Table 1. *Sample characteristics (n = 40)*

	Age (y)	BMI (kg/m^2)	Time from diagnosis (y)	Cobb (°) thoracic	Cobb (°) lumbar	Cobb (°) thoracolumbar
Average	23.4	21.67	5.9	29.1	25.2	16.6
SD	11.17	4.82	6.21	15.8	12.9	7.8
Min	10	14	0.1	9	10	35
Max	52	36.8	25	60	50	10

Table 2. *Intrarater reliability with method 1 (scoliosis angle) and with method 2 (Cobb photo)*

Vertebral column segment	Correlation coefficients method 1	Correlation coefficients method 2
Thoracic (n = 20)	+0.963 ($P < .001$)	+0.942 ($P < .001$)
Lumbar (n = 20)	+0.975 ($P < .001$)	+0.928 ($P < .001$)
Thoracolumbar (n = 20)	+0.945 ($P < .001$)	+0.935 ($P < .001$)

Table 3. *Interrater reliability with method 1 (scoliosis angle) and with method 2 (Cobb photo)*

Vertebral column segment	Correlation coefficients method 1	Correlation coefficients method 2
Thoracic (n = 20)	+0.942 ($P < .001$)	+0.932 ($P < .001$)
Lumbar (n = 20)	+0.564 ($P = .010$)	+0.459 ($P = .042$)
Thoracolumbar (n = 20)	+0.879 ($P < .001$)	+0.966 ($P < .001$)

Results

Of the 40 participants, 32 were female and 8 male, with their ages ranging between 10 to 52 years (23.4 ± 11.2 years). Twenty-four had single and 16 had double lateral spinal curves. All 56 curves, measured by the radiographs, had a Cobb angle of 29.1° ± 15.8° for the thoracic, 25.2° ± 12.9°

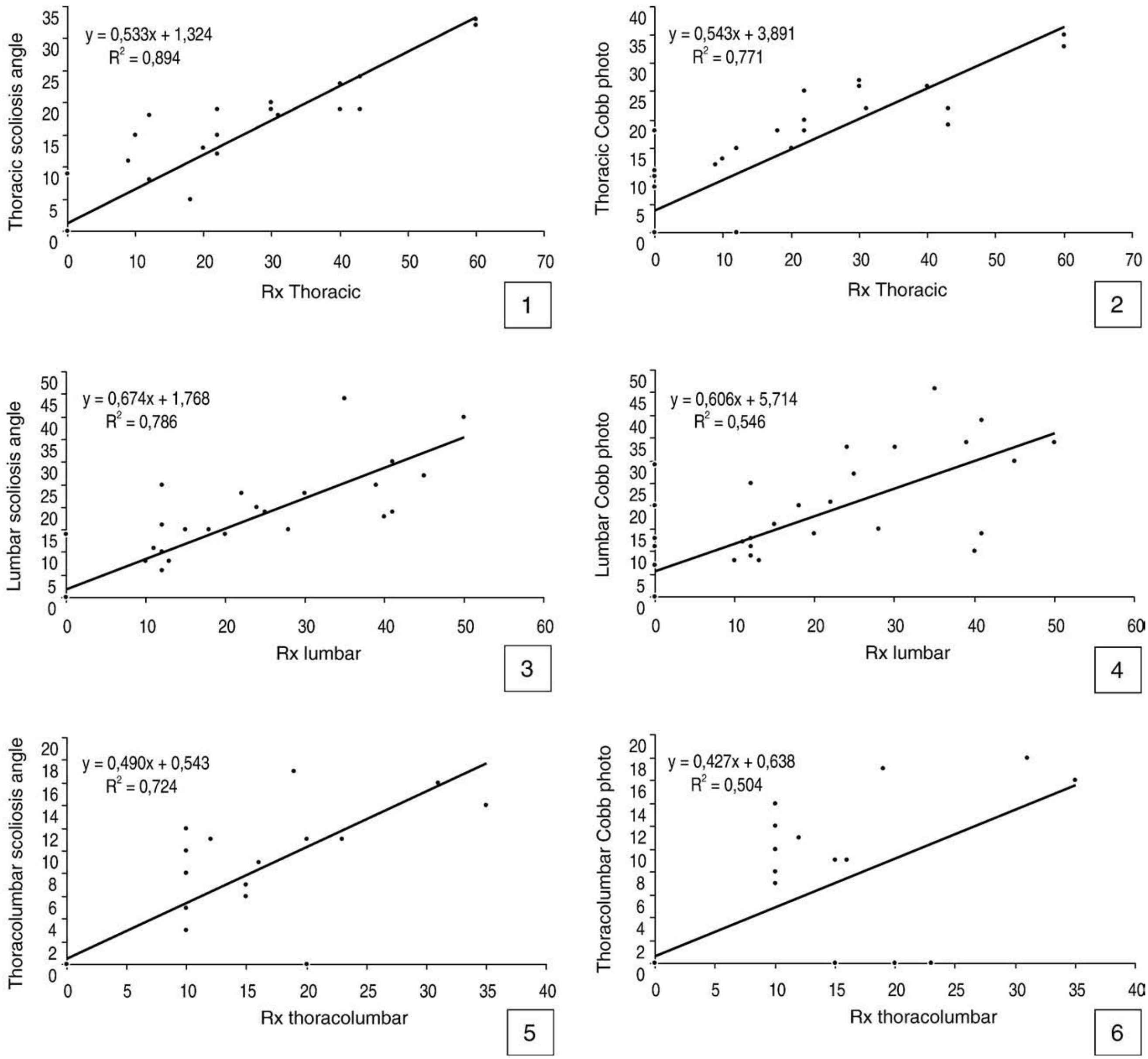

Fig 4. *Determining coefficients between the measurements of lateral spinal curvature by means of photogrammetry (method 1) and the Cobb radiographic angle (x-axis).*

for the lumbar, and 16.6° ± 7.8° for the thoracolumbar curve. The subject characteristics are given in Table 1.

The internal consistency of the observed values revealed high statistical relevance for the thoracic segment angles (Cronbach α = .97), lumbar (Cronbach α = .705), and thoracolumbar (Cronbach α = .932) for the photographic measures of method 1 and for the thoracic segment angles (Cronbach α = .961), lumbar (Cronbach α = .604), and thoracolumbar (Cronbach α = .934) for the photographic measures obtained with method 2. According to the Yu[37] and Churchil[38] classifications, the reliability degrees of the sample was considered between "satisfactory" and "high," which indicated that the sample was unbiased.

As can be seen in Table 2, regarding the photogrammetric measures, high intrarater reliability coefficients were found for methods 1 and 2, as well as for the results concerning the interrater reliability, except for the measures of the lumbar spine obtained with both measures (Table 3). The validity of the photogrammetry was assessed by the relationships between the photographic and radiographic measures. The determination coefficients were calculated and are illustrated in Figure 4. It was not possible to apply a correction factor to the photographic measures to approximate the radiographic measures, because the relationships between their measures were not linear. In addition, they showed heterogeneous behaviors in relation to the curve spinal segment.

Table 4. *Correlations between age, BMI, gravity of scoliosis, and variability between radiographic and photographic measurements (n = 40)*

		Delta RX thoracic photo	Delta RX lumbar photo	Delta RX thoracolumbar photo
Age	*R*	−0.032	−0.015	+0.071
	P	.845	.929	.662
BMI	*R*	−0.035	−0.045	+0.213
	P	.831	.783	.187
Gravity of scoliosis	*R*	+0.619	+0.551	−0.171
	P	<.001	<.001	.291

Delta RX indicates the numerical difference between radiographic measurement and photographic measurement.

The Spearman correlation analyses (Table 4) indicated that the age and BMI variables did not interfere with the photographic measurements of this sample. However, significant positive correlations were found, considered to be from moderate to weak, between the magnitudes of the thoracic and lumbar curves (R = 0.619 and 0.551). The differences between the radiographic and photographic measurements indicated that when the scoliotic curve magnitudes were larger in the thoracic and lumbar segments, the differences between the radiographic and photographic measurements were greater.

Discussion

These results indicate acceptable reliability of the photogrammetric measurements. However, linear relationships between the photogrammetric and radiographic measures were not observed, which compromised the validity of this tool to evaluate the magnitude of the lateral spinal curvatures in scoliosis.

High intraobserver correlation values were found in the current study (r = 0.928) between the angular measures of the lateral curvature through photogrammetry. These results differed from previous findings,[26] which reported intraobserver agreement indices ranging from poor to moderate for lateral deviations of the thoracic region in women. The authors affirmed that the poor results were caused by the physiologic body sway showed by the individuals during the image acquisitions and by the lack of training and expertise of the examiners in the image preparation, acquisition, and analyses with the computer systems. It is known that trunk sway when standing up is mainly anterior-posterior and increases when the person remains in the same position, but it does not influence the results in angular measurements.[39] Zabjek et al[39] reported that the angular measures are less influenced by body sway when compared with the linear measures. The examiners in the present study were physiotherapists and experts in postural evaluation. In addition, they attended a specific training course for the computer program used to collect these measures and that may have affected these acceptable results. The angular measures were obtained in the posterior view (frontal plane), which could have minimized the influence of body sway.

Iunes et al[28] found acceptable repeatability indices (intraclass correlation coefficient = 0.70) for angular postural measurements in the frontal plane. However, the researchers have limited themselves to evaluate the reliability of the angular measurements by using a computer program. This avoided the precision of evaluations during the preparation of the individual, their positioning, and the image acquisitions, because the same photographs were used for all measurements.

The present study also showed high interobserver correlation indices, except for the lateral curvature measurements in the lumbar region for both methods used in the photogrammetry (0.564 and 0.459). These results corroborated the results of the previous study,[19] which used an electrogoniometer to assess the lateral spinal curvature and highlighted the fact that this region of the shown spinal lordosis makes palpation of the spinal processes rather difficult. As a result, the placing of the reference points on the spinal processes is quite difficult and not free from errors, which is common to all of the used methods. One option would be to identify the lumbar spinal processes with the trunk partially flexed to decrease the lordosis, and after identification, the subjects could slowly return to the standing position.

Herzenberg et al[40] already determined that the lateral curvature measurements in scoliosis, which result from methods that use the spinal processes of the vertebra as reference points, is necessarily different from the radiographic measurements, which uses the vertebrae body as reference points. The authors stated, however, that it is possible to predict radiographic Cobb angle values by adding a correction factor to the measures obtained with noninvasive methods.

Based on these data, the present study evaluated the validity of the photogrammetry in assessing the lateral curvatures found in individuals with scoliosis through regression analysis, which graphically showed the relationships between the photographic and radiographic measurements. As expected, all photographic measurements underestimated the radiographic Cobb angles.[13,19,25] For the thoracic curves (methods 1 and 2), the lumbar, and the thoracolumbar with method 1, the determination coefficients were considered high, which permitted the conclusion that method 1 was more precise than method 2. Both methods assessed the spinal lateral deviation in relation to the median line; however, the number of parallel and perpendicular lines drawn in method 1 were less and, therefore, made this method much simpler and precise and with less chance of errors.

The first graph in Figure 4 shows a regression coefficient of r^2 = 0.894 for the thoracic angular curves, which meant that 89.4% of the relationships between the photogrammetric and radiographic measures showed a linear relationship, but only for the curves with Cobb angles greater than 25°. On the other hand, for the lumbar curves measured with method 1, the coefficient was $r^2 = 0.786$, indicating that the linearity was weaker for angles greater than 35° (Fig 4, graph 3). For the thoracolumbar curves assessed by method 1, weak relationships were found for the angles less than 15° (Fig 4, graph 5) and for the Cobb angles of 10°, and the photogrammetric measures that ranged from 3° to 12°.

Mior et al[19] also tried to establish a linear relationship between scoliosis measurements from the Metrocon Skeletal Analysis Systems and the radiographic measurements. Just as in the present study, the use of a correction factor was not possible because the differences between the radiographic and the derivative method of trunk evaluation were not sufficiently constant.

The present findings showed that the relationships between the photogrammetric and radiographic measures were different for the lateral curves in each spinal segment. This does not allow the confirmation of the concurrent validity of the photogrammetric measures in relation to those obtained with radiography, even though high determination coefficients were individually found.

The literature is still divergent regarding the correlation between traditional scoliosis radiographic measurements and the angular measurements from trunk topography. Some studies that have used stereophotogrammetry and digitized pantographs[7,14,17] found acceptable accuracy of these instruments in relation to the radiographic measures. Other studies that have used rastersterephotogrammetry and trunk scanners observed only moderate correlation between the thoracic and lumbar measures of these instruments and the Cobb radiographic angle.[9,11,18]

The Spearman correlation analysis showed that when the Cobb angle in the dorsal and lumbar segments was larger, the differences between the radiographic and photographic measurements were greater. Such findings have also been observed in other studies[9,10] and may be explained by the fact that the larger the spinal inclination, the greater the rotation of the vertebral bodies. Therefore, for very severe scoliosis, with large vertebral rotations, the use of the spinal processes as reference points for measurements will result in much smaller angle measurements than the radiographic ones, that is, the larger the vertebral rotations found in severe scoliosis, the greater will be the limitations of the photogrammetry in assessing the lateral curves.

D'Osualdo et al[15] questioned the studies of the relationships between topographic and radiologic measurements of the trunk. For these authors, the reproducibility of a tridimensional evaluation method is more important than their agreement with radiographic standards. Stokes[41] affirmed that in the future, surface topography is likely to replace radiographic evaluations, once one puts aside the idea that both methods of measurement need to be in agreement. Yet, there is a consensus that the evaluation of the results of scoliosis treatments should be complemented with trunk photographs, in addition to the fact that all images and measurements resulted in a system that can be rapidly recorded and resulted in maintaining a permanent history of the deformity.[10,17,42]

The postural evaluation by photogrammetry is widely used in our country. Modern and high-cost methods, which require specific training, are only found in major rehabilitation centers. Therefore, it is important to build valid, user-friendly, and low-cost assessment tools that are more adequate and available.

Although the current study did not show the validity of photogrammetry as a measure of the lateral spinal curvature in scoliosis, high reliability coefficients were observed. It is possible to affirm that the photogrammetry can offer a quantitative documentation of this deformity not provided by the subjective clinical examinations alone, besides offering the monitoring of cosmetic deformities, and may be used as supplementary information in deciding the treatment of scoliosis.

Limitations

Although, even with the methodological care used in this study, some limitations need to be pointed out. One of the major limitations in the assessment of scoliosis by photogrammetry is that it refers to a 2-dimensional measure of a tridimensional postural alteration. Therefore, the assessment of the vertebral rotation should be included in future studies by using the scoliometer with the subject in a forward bending position.

Another limitation was the transversal nature of the study's design. The measurement of the spinal inclination angle was obtained just once during the progression of the scoliotic curve. The scoliosis evaluation requires serial assessments, and a study evaluating serial measures would need to be performed in a longitudinal design. Therefore, future longitudinal designs should be conducted to investigate whether photogrammetry would be sensitive to changes associated with the progression of the scoliotic curvature.

The limitations inherent in the technique included the limitation of the measurements of severe curves, those with greater rotational component, and those of the lumbar region.

Conclusions

Photogrammetry showed a high repeatability index to evaluate scoliosis for the thoracic and thoracolumbar curves. However, it was not possible to show its validity in the assessment of the lateral spinal curvature. Therefore, clinicians should not use photogrammetry to evaluate the scoliotic curve in patients with idiopathic scoliosis with the methodology used in the present study (Cobb method adapted to photogrammetry), which cannot replace radiographic assessments. Nonetheless, it possibly can be used as supplementary information in the decision making for therapeutic interventions, which could decrease the number of radiographs necessary for the follow-up of scoliosis.

Practical Applications

- Photogrammetry appears to be a reproducible method for scoliosis evaluation.
- Photogrammetry provides quantitative information regarding trunk deformities.
- Evaluation by means of photogrammetry may decrease the number of radiographs obtained during the follow-up of scoliosis.
- The limitations of photogrammetry for the evaluation of scoliosis are the measurements of curves with great rotational components and those in the lumbar region.
- Studies need to be carried out to verify whether photogrammetry would be sensitive to the progression of scoliosis.

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References

1. Weiss HR, Negrini S, Rigo M, Kotwicki T, Hawes MC, Grivas TB, et al. Indications for conservative management of scoliosis (guidelines). Scoliosis 2006;1:1-5.
2. Carman DL, Browne RH, Birch JG. Measurement of scoliosis and kyphosis radiograph: intraobserver and interobserver variation. J Bone Joint Surg Am 1990;72:328-33.
3. Almén AJ, Mattsson S. Dose distribution at radiographic examination of the spine in pediatric radiology. Spine 1996;21: 750-6.
4. Levy AR, Goldberg MS, Mayo ME, Hanley JA, Poitras B. Reducing the lifetime risks of cancer from spinal radiographs among people with adolescent idiopathic scoliosis. Spine 1996; 21:1540-8.
5. Denton TE, Randall FM, Deinlein DA. The use of instant Moiré photographs to reduce exposure from scoliosis radiographs. Spine 1991;1:509-12.
6. Korovessis PG, Stamatakis MV. Prediction of scoliotic Cobb \angles with the use of the scoliometer. Spine 1996; 21:1661-6.
7. Stokes IAF, Moreland MS. Concordance of back surface asymmetry and spine shape in idiopathic scoliosis. Spine 1989; 14:73-7.
8. Willner S. Spinal pantograph. Acta Orthop Scand 1981;52: 525-9.
9. Thometz JG, Lamdam R, Liu XC, Lyon R. Relationship between Quantec measurement and Cobb angle in patients with idiopathic scoliosis. J Pediatr Orthop 2000;20:512-6.
10. Hackemberg L, Hierholzen E, Potzl W, Gotze C, Liljeenqvist U. Rasterstereographic back shape analysis in idiopathic scoliosis after anterior correction and fusion. Clin Biomech 2003;18:1-8.
11. Jarenko JL, Poncet P, Ronsky J, Harder J, Dansereau J, Labelle H, et al. Estimation of spinal deformity in scoliosis from torso surface cross sections. Spine 2001;26:1583-91.
12. Zabjek KF, Leroux MA, Coillard C, Rivard CH, Prince F. Evaluation of segmental postural characteristics during quiet standing in control and idiopathic scoliosis patients. Clin Biomech 2005;20:483-90.
13. Pazos V, Cheriet F, Song L, Labelle H, Dansereau J. Accuracy assessment of human trunk surface 3D reconstructions from an optical digitising system. Med Biol Eng Comput 2005;43: 11-5.
14. Ovadia D, Bar-On E, Fragnière B, Rigo M, Leitner J, Wientroub S, et al. Radiation-free quantitative assessment of scoliosis: a multi center prospective study. Eur Spine J 2007;16: 97-105.
15. D'Osualdo F, Schierano S, Soldano FM, Isola M. New tridimensional approach to the evaluation of the spine through surface measurement: the BACES system. J Med Eng Technol 2002;26:95-105.
16. Mínguez MF, Buendía M, Cibriàn RM, Salvador R, Languía M, Martín A, et al. Quantifier variables of back surface deformity obtained with a noninvasive structured light method: evaluation of their usefulness in idiopathic scoliosis diagnosis. Eur Spine J 2007;16:73-82.
17. Goldberg CJ, Kaliszer M, Moore DP, Fogarty EE, Dowling FE. Surface topography, Cobb angles, and cosmetic changes in scoliosis. Spine 2001;26:E55-E63.
18. Dawson EG, Kropf MA, Purcell G, Kabo JM, Kanin LEA, Burt C. Optoelectronic evaluation of trunk deformity in scoliosis. Spine 1993;18:326-31.
19. Mior SA, Kopansky-Giles DR, Crowther ER, Wright JG. A comparison of radiographic and electrogoniometric angles in adolescent idiopathic scoliosis. Spine 1996;21:1549-55.
20. Ramirez L, Durdle NG, Raso VJ, Hill DL. A support vector machine classifier to assess the severity of idiopathic scoliosis from surface topography. IEEE Trans Inf Technol Biomed 2006;10:84-91.
21. Amendt LE, Ause-Ellias KL, Eybers JL, Wadsworth CT, Nielsen DH, Weinstein SL. Validity and reliability testing of the scoliometer. Phys Ther 1990;70:108-17.
22. Grivas TB, Vasiliadis ES, Koufopoulos G, Segos D, Triantafyllopoulos G, Mouzakis V. Study of trunk asymmetry in normal children and adolescents. Scoliosis 2006;1:19.
23. Vercauteren M, Van Beneden M, Verplaetse R, Croene P, Uyttendaele D, Verdonk R. Trunk asymmetries in Belgian school populations. Spine 1982;7:555-62.
24. Penha PJ, João SMA, Casarotto RA, Amino CJ, Penteado DC. Postural assessment of girls between 7 and 10 years of age. Clinics 2005;60:9-16.
25. Turner- Smith AR, Harris JD, Houghton GR, Jefferson RJ. A method for analysis of back shape in scoliosis. J Biomech 1988; 21:497-509.
26. Dunk NM, Chung YY, Compton DS, Calghan JP. The reliability of quantifying upright standing postures as a baseline diagnostic clinical tool. J Manipulative Physiol Ther 2004;27:91-6.
27. Lima LCO, Baraúna MA, Sologurem MJJ, Canto RST, Gastaldi AC. Postural alterations in children with mouth breathing assessed by computerized biophotogrammetry. J Appli Oral Sci 2004;12:232-7.

28. Iunes DH, Castro FA, Salgado HS, Moura IC, Oliveira AS, Bevilaqua-Grossi D. Confiabilidade intra- e inter-examinadores e repetibilidade da avaliação postural pela fotogrametria. Rev Bras Fisioterapia 2005;9:327-34.
29. Guimarães MBB, Sacco ICN, João SMA. Caracterização postural da jovem praticante de ginástica olímpica. Rev Bras Fisioterapia 2007;11:213-9.
30. Sato TO, Vieira ER, Gil Coury HJC. Análise da confiabilidade de técnicas fotométricas para medir flexão anterior do ombro. Rev Bras Fisioterapia 2003;7:53-9.
31. Sacco ICN, Alibert S, Queiroz BWC, Pripas D, Kieling I, Kimura AA, et al. Confiabilidade da fotogrametria em relação à goniometria para avaliação postural de membros inferiores. Rev Bras Fisioterapia 2007;11:411-7.
32. Leroux MA, Zabjek K, Simard G, Badeaux CC, Rivard CH. A noninvasive anthropometric technique for measuring kyphosis and lordosis. Spine 2000;25:1689-94.
33. Braun BL, Amundson LR. Quantitative measures of head and shoulder posture. Arch Phys Med Rehabil 1989;70:322-9.
34. ASPRS-American Society for Photogrammetry and Remote Sensing. What is ASPRS—definition [homepage in internet]. Bethesda: American Society for Photogrammetry and Remote Sensing; 2000 [updated on 16/11/2006; access in 21/12/2007]. Available at: http://www.asprs.org/society/about.html.
35. Watson AW, MacDoncha C. A reliable technique for the assessment criteria for aspects of posture. J Sports Med Phys Fitness 2000;40:260-70.
36. Cohen J. Statistical power analysis for the behavioral sciences. New Jersey: Lawrence Erlbaum Associates; 1988.
37. Yu CH. An introduction to computing and interpreting Cronbach coefficient alpha in SAS. Proceedings. Of the 26th SAS User Group International Conference. Available at: http://www2.sas.com/proceedings/sugi26/p246-26.pdf. Accessed July 22, 2009.
38. Churchil G. Marketing research: methodological foundations. Orlando: The Dryden Press; 1995.
39. Zabjek KF, Simard G, Leroux MA, Coillard C, Rivard CH. Comparaison de la fidélité de deux systèmes d'acquisition 3D sur l'étude de paramètres anthropométriques et posturaux. Ann Chir 1999;53:751-60.
40. Herzemberg JE, Waanders NA, Closkey RF, Schultz AB, Hensinger RN. Cobb angle versus spinous process angle in adolescent idiopathic scoliosis: the relationships of the anterior and posterior deformities. Spine 1990;15:874-9.
41. Stokes IAF. Point of view. Spine 2001;26:1591.
42. Oxborrow NJ. Current topic: assessing the child with scoliosis: the role of surface topography. Arch Dis Child 2000;83:453-85.