PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

NOVO MÉTODO PARA MEDIÇÃO DA ESCOLIOSE DA COLUNA HUMANA COM BASE EM FOTOGRAFIA

NEW METHOD FOR MEASUREMENT OF HUMAN SPINE SCOLIOSIS BASED ON PHOTOGRAPHY

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RESUMO

Introdução: O ângulo de Cobb é amplamente utilizado para medir curvaturas escolióticas. Mas este método exige que os pacientes sejam submetidos a radiografia. **Objetivo**: neste trabalho, apresenta-se uma nova metodologia de mensuração do desvio da coluna vertebral humana como forma de melhor acompanhamento clínico da evolução da escoliose. **Método**: o método proposto consiste em rotinas de medição de curvaturas e ângulos, que podem ser implementadas em programas de computador. A nova metodologia pode ser aplicada a fotografias da coluna do paciente, necessitando apenas da identificação dos pontos que definem cada vértebra por marcadores. O desvio é determinado em fotos bidimensionais, embora as rotinas aqui apresentadas possam ser adaptadas para dados tridimensionais. **Resultados**: os resultados obtidos até o momento apontam para um método robusto e adequado para uso clínico, com incertezas condizentes com as obtidas com o método de Cobb, evitando assim o uso recorrente de exames caros e exposição deletéria à saúde do paciente aos raios X. **Conclusões**: o método de avaliação do ângulo escoliótico apresentado neste estudo pode ser uma alternativa mais objetiva, simples de usar e de baixo custo em relação ao método de Cobb e, embora ainda necessite de acompanhamento e análise por profissional de saúde qualificado, pode reduzir a exposição aos raios X de pacientes em tratamento para desvios da coluna vertebral.

Palavras-chave: *Novo método, software, postura, escoliose, mediçãoNovo método, software, postura, escoliose, medição*

ABSTRACT

Background: The Cobb angle is broadly used for measuring scoliotic curvatures. But this method requires patients to undergo radiography. **Objective**: in this work, a new methodology for human vertebral spine deviation measurement is presented as a way to better the clinic monitoring of the evolution of scoliosis. **Method**: the proposed method consists of routines for measuring curvatures and angles, which can be implemented in computer programs. The new methodology can be applied to photographs of the patient column, needing only the identification of the points that define each vertebra by markers. The deviation is determined on two dimensions photos, though the routines presented here can be adapted to three-dimension data. **Results**: the results attained so far point to a robust method and suitable for clinical use, with uncertainties consistent with those obtained with the Cobb method, thus avoiding the recurrent use of expensive examinations and patient health deleterious exposition to X-rays. **Conclusions**: the method for evaluating the scoliotic angle presented in this study may be a more objective, simple to use, and low-cost alternative compared to the Cobb method, and although it still requires follow-up and analysis by a qualified healthcare professional, it can reduce x-ray exposure of patients being treated for spinal deviations.

Keywords: *New method, Software, Posture, Scoliosis, Measurement.*

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1. INTRODUCTION

Scoliosis is characterized by lateral deviation of the spine in the coronal plane. Idiopathic, congenital, neuromuscular, and degenerative are among the main types of scoliosis.

Idiopathic scoliosis affects 2-3% of the working-age population, is a three-dimensional deformity as it presents a vertebral rotation as well as a lateral curvature. It is responsible for geometric and morphological changes in the trunk and rib cage (Kapandji, 2000; Bricot, 20001; Gstoettner *et al.,* 2007).

The Cobb method, described in 1948 by John Cobb, despite its limitations, is considered the "gold standard" for measuring the bending angle in the coronal plane through radiographs. It is based on the measurement of the angle between the two tangential lines drawn along the outer ends of the spline curve. The more severe the angle, the larger the surface of the pronounced deformity (Srinivasalu *et al.,* 2008; Godinho et al.,2001; Hay, Hershkovitz and Rivlin, 2009).

The exact evaluation of the degree of the spine curvature is essential to the decision on how to treat an individual with scoliosis. According to Gstoettner Sekyra, Walochnik, Winter, Wachter, and Bach, despite the availability of digital radiographs that facilitates the measurement of the Cobb angle, still occurs inaccuracies in this technique due to a variety of causes, for example, the method is based on a two-dimensional image for three-dimensional evaluation, not to say all (Gstoettner *et al.,* 2007; _ 2001; Appel, 2002).

According to Santos, all clinical procedures for making diagnoses either on a good or a bad postural alignment must be gathered, discussed, accepted, and applied by all professionals dedicated to studying the problem(Santos, 2001; Smith, Weiss, and Lehmkuhl, 1997)

A proper postural assessment should be initiated by static inspection to reveal changes in the three anatomical planes since scoliosis can cause asymmetry between the ears, shoulders, ribcage, and pelvis (Gstoettner *et al.,* 2007; Santos, 2001; Smith, Weiss, and Lehmkuhl, 1997).

Even with a standardized schedule of assessment, the inspection may be subjective since it varies with the observer (Smith, Weiss, and Lehmkuhl, 1997; Sutherland, 2005).

Other issues involving the application of the Cobb method for measuring the angle of scoliosis are the quality of the images, the degree of curvature, dependence on the investigator, variations in the method, among other things (Srinivasalu *et al.,* 2008; Langensiepen *et al.,* 2013; Horng *et al.,* 2019; Greiner, 2002; Wang *et al.,* 2018; Sun *et al.,* 2021).

From the foregoing, it is necessary to create a system for evaluating scoliosis that reduces the dependence for determining the deviation angle on a radiography-based method and the individual observer variation.

This study had as its main objective the creation and validation of a methodology for measuring scoliotic deviations of the spine from a clinical examination by a physician or physiotherapist, based on photographic images of the patient and a measuring algorithm. The specific objectives consisted of identifying anatomical landmarks for the analysis of the human spine and providing these collected data and measurements for evaluation by the developed software.

The scoliotic angle of deviation obtained by the new methodology is here called SAL angle (Silva, Avila, and Lorenzini angle). To validate the proposed methodology, the angles of SAL from digital photography were compared with the values of the respective Cobb angles obtained manually from further X-ray examination. These angles were calculated and compared using the software developed by the authors that was able to report such deviation.

2. MATERIALS AND METHODS:

2.1. Methodology

The research consisted of five steps: 1) identification of the objectives and the appropriated methodology, 2) standardization of the acquisition of the images and identification of the relevant characteristics to the methodology, 3) formulation of the software, 4) development of software and 5) validation.

Step 1) identification of the objectives and the appropriated methodology:

1. The new methodology aimed to evaluate scoliosis through photographs, reducing the need for x-ray examinations during the treatment of spinal pathologies.

Step 2) standardization of the acquisition of the images and identification of the characteristics relevant to the methodology:

2. For the development of the methodology, radiological images, and digital photographs of the patients with postural alterations of the vertebral column were used. Those were provided by the Rehabilitation Clinical Centre of the São Lucas Hospital of PUCRS (HSL);

3. The standardized protocol for capturing the images from digital photographs, as regards distance, height, lighting, and digital camera configuration, observed the following recommendations:

   - the total distance from the camera to the opposite wall was established as three meters;

   - the participants were positioned halfway of that distance, i. e., one and a half meters from the camera;

   - the height of the camera until the ground was established as one meter and thirty centimeters;

   - it was used artificial environment lighting;

   - it was adopted a 7.2 megapixels digital camera in automatic mode with flash on and timer set to 10 seconds;

   - It was used black fabric as a background.

4. To obtain the photographs used in the proposed method, it was fundamental to correctly demarcate the spinous processes of the vertebrae of the patients submitted to the study. Opaque black circular stickers were used for this (Figure 1).

Figure 1. General care to obtain the digital photographs used in this work.

Step 3) mathematical formulation of the method:

For the formulation of the software, the graphic marking, usually made by doctors to calculate the angle of Cobb in radiography, was considered. These appointments could not be adopted in the new method, as the contours of the vertebrae are not seen in photographs. Instead of it, a new graphical way of measuring such information was adopted, enabling the calculation of the curvature of the spine, in certain positions related to where the vertebrae were.

It was noted that the measurement of the deviation is related to the measurement of the angle of inclination between two vertebrae curvatures, the two most extreme measure curvature of the spine.

In the case of the SAL angle, the object of this methodology, to get the right segments that define the angle, it was necessary to define the point of intersection between the two lines formed between the central point, identified in the extreme curvature vertebrae, and the center of the circle passing through three points, given by the points that define the chosen and its neighboring vertebrae.

For the measurement of the angle between three points, A, B, and C, which define two straight segments, BA and BC: when calculating the angle between these lines, the definition of the scalar product between the vectors formed by the points received, was used:

$$\vec{BA}\,.\,\vec{BC} = |\vec{BA}|\,|\vec{BC}|\,.\cos\alpha$$

(Eq. 1)

Applying the law of cosines, we have:

$$\cos\alpha = \frac{|\vec{BA}|^2 + |\vec{BC}|^2 - |\vec{AC}|^2}{2.|\vec{BA}|.|\vec{BC}|}$$

(Eq. 2)

In this way, choosing two vertebrae, two lines were drawn. The angle in question is made by these lines, according to the previous expression.

Step 4) software development:

- The software (Figure 2), in its first version, had tools to name and identify the points pretended, but the user must point to the vertebrae involved in scoliotic curvature.

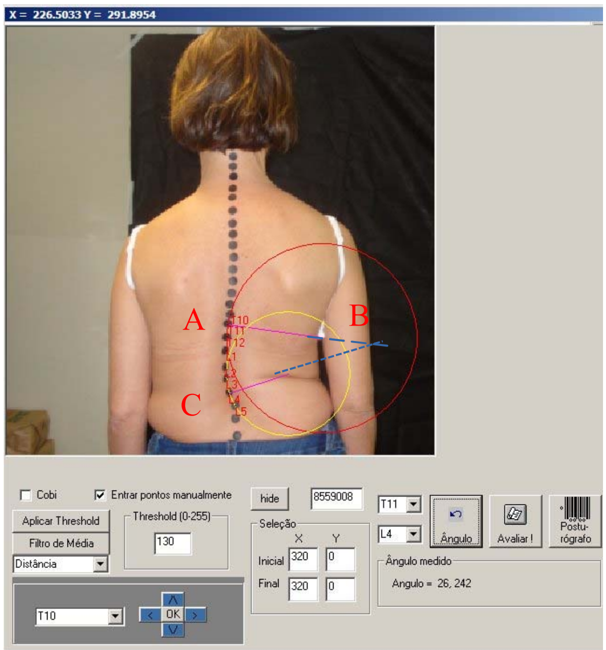

Figure 2. The main screen of the software.

Step 5) validation:

Digital photographs were selected as samples for the method validation, using quality as a criterion for selection. Distorted images that were not in the established protocol were excluded, resulting in eight photographs, leading to 10 column deviations. The complementary examinations (x-ray) that were opaque and those where it has not been possible to identify the vertebral levels were also excluded. The data and images collected were provided to the developed software, which analyzed and compared the angles of lateral deviations of the spine.

- The manual measurement from an X-ray of the Cobb angle was considered the "gold standard" for comparison and validation purposes.
- The interpretation held by the software consisted of obtaining the angle of SAL, being this a new measurement of the scoliosis curvature, which replaces the tangents mentioned in the literature when using the method of Cobb. The SAL angle still shows two ways to be calculated, towards the inner and outer side of the scoliotic curve, through delimitation of the vertebrae involved in lateral deviation considered. The software produces a circle using their respective neighbors, generating straight segments of BA and BC that allow the software to calculate the angle in question. This form permits the measurement of the average angle of deviation, which was used as a scoliotic index for comparison with the Cobb angle. In that way, the specific difference between the results from the two methods occasioned a percentage error of the method proposed here.

3. RESULTS AND DISCUSSION:

Eight digital photographs were selected to be entered the software, leading to ten scoliotic curves. The software performed the calculation of the average SAL angle, from the average angles provided by both the inner and the outer measurements of the bend, to then compare it with the Cobb angle calculated manually by a doctor.

The results are summarized in Table 1.

Table 1. Comparison between the Cobb and the SAL angles.

	Manual Cobb	Mean SAL	SAL Error (%)
Scoliosis1	50°	48,9°	2
Scoliosis2	62°	52,3°	16
Scoliosis3	49°	46,5°	5
Scoliosis4	38°	34°	11
Scoliosis5	33°	34,3°	4
Scoliosis6	21°	20,5°	2
Scoliosis7	60°	52°	13
Scoliosis8	48°	53,5°	11
Scoliosis9	50°	58,5°	17
Scoliosis10	10°	9,4°	7

The total average error of the SAL angle in comparison to the Cobb angle was calculated as 8.8% when considering the 10 measurements. The Cobb angle itself showed a 7.6% error when submitted to a new evaluation by a different professional. While the proposed SAL angle obtained a maximum error of 17%, the Cobb angle, which is also subject to uncertainties of subjective character, got a maximum error of 16%. In this way, it appears in the new methodology proposed here, an enough competitive alternative with the existing Cobb method, winning in aspects such as rapidity of diagnosis, low cost, the possibility of implementation in Office, not to mention the no need for patient exposure to radiation. A comparison chart between the two methodologies, existing and proposed, are shown in Table 2.

Table 2. Comparative table of the adopted methodology with the technique that requires an x-ray.

	Radiography (Cobb)	Photographs (SAL)
Scoliosis diagnosis	Yes	Yes
Other pathologies diagnosis	No	No
Cost	High	Low
Speed	Low	High
Clinical application	No	Yes

This work demonstrated the effectiveness of the SAL angle, according to the methodology proposed here, for the evaluation of scoliosis curvature, to facilitate and enhance the diagnosis, leading to early intervention.

In Table 1, it was presented the results calculated by the developed software, through the points marked by a physiotherapist. It can be noticed that the differences between the angular values calculated by both Cobb and SAL methods, the former one obtained by the proposed methodology, present uncertainties of human nature in its procedures, which are consistent in magnitude.

It is believed that the discrepancies in the new procedure may be linked to factors that interfere with the angle measurement in digital photography, as there are errors on palpation to determine the spinous processes, size of the markers used and resampling by the software of the vertebrae.

In Table 2, one can see the advantages of using the methodology here studied. Especially when compared to x-rays based techniques that require patients' frequent exposure to ionizing radiation, in addition to the high costs of such examination. The use of photographs is low-cost, easy accessibility, does not expose the patient to harmful effects on his/her health and can be done as many times as necessary to obtain an immediate diagnosis.

The results achieved so far point to a robust and appropriate method to clinical use, with uncertainties that are compatible with those obtained by the method of Cobb, dispensing, and the use of more costly and patient health deleterious examinations.

4. CONCLUSIONS:

A new method for evaluating the scoliotic angulation presented in this study may be an alternative, more objective, simple, and low cost compared to the Cobb method and can be used in the future for healthcare professionals, after further validation experiments.

The main advantage of the new method is the reduction of unnecessary exposure of patients to X-rays, reducing their exposure to mutagenic agents.

The proposed method errors were compatible with the ones of the reference method. As future works, the group intends to adapt the methodology for three-dimensional measurements, allowing a complete diagnosis of the column deviations.

5. DECLARATIONS

5.1. Study Limitations

No limitations were known at the time of the study.

5.2. Acknowledgements

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5.3. Funding source

This research was funded by the authors and the related institutions.

5.4. Competing Interests

The authors declare no competing interests.

5.5. Open Access

6. HUMAN AND ANIMAL-RELATED STUDIES

6.1. Ethical Approval

Ethical approval was provided by the Research Ethics Committee of PUCRS, under the ethics protocol reference number of CEP 06/03004.

7. REFERENCES:

1. Kapandji, A. I. Fisiologia Articular. Vol.: 3. Rio de Janeiro: Guanabara Koogan, 2000.
2. Bricot, B. Posturologia. São Paulo: Ícone, 2001.
3. Gstoettner M, Sekyra K, Walochnik N, Winter P, Wachter R, BachCM. Inter- and intraobserver reliability assessment of the Cobb angle: manual versus digital measurement tools. Eur Spine J. 2007; 16:1587–1592
4. Srinivasalu S, Modi HN, Mehta SS, Suh SW, Chen T, Murun T. Cobb Angle Measurement of Scoliosis Using Computer Measurement of Digitally Acquired Radiographs-Intraobserver and Interobserver Variability. Asian Spine J. 2008; 2 (2): 90-93.
5. Godinho RS,Alvioni RS, Curto D, MartinsDE, HenBerg M, Puertas EB. Measurement of the scoliotic curve by cobb technique for intra-observer And inter-observer and its clinical significance. Coluna/Columna. 2001; 10(3): 216-20.
6. Hay O, Hershkovitz I, Rivlin E. Spine Curve Modeling for Quantitative Analysis of Spinal Curvature. Conf Proc IEEE Eng Med Biol Soc. 2009;2009:6356-9.
7. _ Aula de Revisão. Mensuração da angulação frontal: Método de Cobb. Rev. Coluna fisioterápica, 2001;1: 16- 17
8. Appel, F. (org.) Coluna Vertebral - Conhecimentos Básicos. Porto Alegre: AGE, 2002.
9. Santos, A. Diagnóstico Clínico Postural – Um guia prático. São Paulo: Summus Editorial, 2001.
10. Smith, L.K.; Weiss, E.L.; Lehmkuhl, L.D. Cinesiologia clínica de Brunnstrom. São Paulo: Manole, 1997.
11. Sutherland, H. D. The evolution of clinical gait analysis part III – kinetics and energy assessment. *Gait e Posture*. 2005; 21: 447- 461
12. Srinivasalu, S., Modi, H. N., Smehta, S., Suh, S. W., Chen, T., Murun, T. Cobb Angle Measurement of Scoliosis Using Computer Measurement of Digitally Acquired Radiographs Intraobserver and Interobserver Variability. Asian Spine Journal Vol. 2, No. 2, pp 90~93, 2008;
13. Langensiepen, S., Semler, O., Sobottke, R., Fricke, O., Franklin, J., Scho¨nau, E., Eysel, P. Measuring procedures to determine the Cobb angle in idiopathic scoliosis: a systematic review. Eur Spine J (2013) 22:2360–2371;
14. Horng, M. H., Kuok, C. P., Fu, M. J., Lin C. J., Sun, Y. N. Cobb Angle Measurement of Spine from X-Ray Images Using Convolutional Neural Network. Computational and Mathematical Methods in Medicine Volume 2019, Article ID 6357171, 18 pages https://doi.org/10.1155/2019/6357171;
15. Greiner, A. K. Adolescent Idiopathic Scoliosis: Radiologic Decision-Making. American Family Physician. May 15, 2002 / Volume 65, Number 9
16. Wang, J., Zhang, J., Xu, R., Chen, T. G., Zhou, K. S., Zhang, H. H. Measurement of scoliosis Cobb angle by end vertebra tilt angle method. Journal of Orthopaedic Surgery and Research. (2018) 13:223. https://doi.org/10. 1186/s13018-018-0928-5.
17. Sun. Y., Xing, Y., Zhao, Z., Meng, X., Xu G., Hai, Y. Comparison of manual versus automated measurement of Cobb angle in idiopathic scoliosis based on a deep learning keypoint detection technology. European Spine Journal. https://doi.org/10.1007/s00586-021-07025-6