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ARTICLE

# Non-ionizing method of screening adolescent idiopathic scoliosis in schoolchildren

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**Abstract** *Adolescent idiopathic scoliosis (AIS) affects 2% to 4% of young people in Brazil. Repeated exposures to radiation used in the monitoring of the deformity can be harmful to the health. This study aimed to present a photogrammetry protocol as a non-ionizing method to quantify scoliosis and relate it to the Cobb radiological method. Sixteen individuals with idiopathic scoliosis (age: 21.4 ± 6.1 years, body mass index: 19.8 ± 0.2 kg/m2) underwent standing posteroanterior X-ray examination of the trunk. Additionally, markers were placed on the spinal processes of the C7 to L5 vertebrae, and posterior trunk photographs were taken. All images were sent for independent analysis by two examiners who were trained in the quantification of scoliosis. The average of the thoracic curvature evaluated through the photogrammetry and Cobb methods were 36.43° and 36.14°, respectively. With an average difference of 4.1°, the methods were not statistically different (p < 0.05). As a non-ionizing method that is low cost and portable, photogrammetry may represent a suitable alternative to the radiological method. Further studies are needed for the improvement of non-ionizing techniques in AIS screening.*
**Key words** *Adolescent idiopathic scoliosis, Diagnosis, Non-invasive method, Adolescent health*

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## Introduction

Vertebral deformity is highly prevalent among young people and has been the subject of numerous investigations. Scheuermann's kyphosis, spondylolisthesis, and adolescent idiopathic scoliosis (AIS) are deformities related to vertebral growth that can affect healthy children at the beginning of the growth spurt[1]. Overall, AIS is the most common vertebral deformity found worldwide and comprises 80% of all types of scoliosis.

The Scoliosis Research Society defines AIS as an unknown spinal deformity, characterized by changes in three planes: lateral curvature with a Cobb angle ≥ 10°, thoracic lordosis, and axial rotation. This disease primarily affects children of 10 years and older whose skeletons are still developing[2]. Although scoliosis has a very low life-threatening index, social, familial, and surgical factors can lead patients to develop mental disorders and can even increase the risk of suicide[3,4]. A study by Payne et al.[3] indicated that the presence of spinal deformity in adolescents constitutes a risk factor for psychological depression independent of the treatment received by the patient. According to Han et al.[2], adolescence is a sensitive period of personal and psychological maturation, and both the vertebral deformity and the physical discomfort generated by it can affect the patients' quality of life.

Konieczny et al.[5] study showed an overall prevalence of AIS between 0.47 - 5.2%. The prevalence and severity are higher in girls than in boys at a rate of 3:1 between 11 and 12 years and increase with age. In Brazil, according to Souza et al.[6], the prevalence of AIS ranges from 2% to 4% between the ages of 10 and 16 years. According to Konieczny et al.[5] there are few studies that provide relevant data in relation to the prevalence of AIS. These studies present varied definitions for scoliosis in addition to several study protocols and age groups with inclusion of scoliotic curves < 10 °, although it is an international consensus that, by definition, scoliosis is a deformity with an angle ≥10 °. In addition, according to the authors, the efficacy of the widely used Adams[7] test was considered low and would be more effective if associated with trunk rotation or Moiré topography evaluations. Fong et al.[8] state that no evaluation of scoliosis has yielded substantial benefits and sufficient levels of evidence to date.

The Cobb method, developed in 1948 by a researcher of the same name, is still considered the "gold standard" for scoliotic curve measurement[9]. This method is used for diagnosis, follow-up, and definition of the treatment to be instituted. However, several studies have presented the deleterious effects of numerous ionizing radiation sessions on young people with incomplete bone maturation during the follow-up period for idiopathic scoliosis[10-15]. During this follow-up, the adolescent may be submitted to more than 25 trunk radiographs. One study revealed that approximately 15% of the patients underwent 50 or more radiographic examinations with an accumulation of estimated ionizing radiation doses of 20 cGy or more[12]. Non-radiographic examinations aimed at postural evaluation, which allow for the topographic investigation of asymmetries related to vertebral deformities, are not common practice in the daily clinic. According to Brink[16], postural assessment should be a routine examination for individuals with neuromusculoskeletal disorders. In the study by Kowalski et al.[17], postural monitoring tests performed in schoolchildren revealed that 50-60% of the adolescents had postural abnormalities, 10% of them being at risk of progressive deformity of the spine. For Cheung et al.[18], early postural screening and observation of scoliosis may apparently mitigate the surgical risk. In addition, early diagnosis of AIS can prevent excessive progression and pathological postural adaptations. In the study by Aroeira et al.[19], individuals with similar Cobb angle values may present different asymmetries throughout the body; on the other hand, significant asymmetries may be present in those with low Cobb angle values. As a consequence, there is a gap in the proposed treatment for cases of scoliosis classified as "mild"; that is, between 10 and 25 ° of Cobb value. Because they are not eligible for treatment according to radiological criteria, they are deprived of an early therapeutic approach and adequate functional treatment. Han et al.[2], in a quality of life study of post-operative scoliosis patients, stated that radiological examination should not be the only therapeutic indicator in AIS, and that new evaluation systems should be developed with a focus on the quality of life of patients.

In the last 20 years, a great scientific effort has been devoted to the development of non-ionizing computational methods for the evaluation of vertebral deformities in young people. Several techniques have been proposed to overcome the limitations of the traditional methods of visual evaluation and the deleterious effects of the ionizing method. The reconstruction of the surface topography of the body's anatomy, based on computer vision, is the method most widely used by the proposed technologies[20]. Five technologies have stood out: 3D ultrasound system, 2D computerized photogrammetry, technologies based on laser projection or structured light, and Moiré projection[19]. The great motivation of the new studies lies in the search for a reduction in the number of radiographic examinations in the monitoring of these deformities that reach young people without complete bone maturation. In addition, the search for exams that assess asymmetries in their entirety, not only in the trunk, is equally relevant.

Thus, the objective of this study was to present a non-ionizing method, based on 2D photogrammetry by computer vision, for the angular measurement of vertebral deviations, aiming at the diagnosis and follow-up evaluation of AIS.

## Materials and methods

The method of measurement proposed in this study for the calculation of vertebral deviations in scoliosis using computerized photogrammetry was patented at INPI under n. 14110002335[21]. An observational and cross-sectional study was conducted to compare this new non-radiographic method with the traditional Cobb method using a direct numerical correlation between both methods. In addition, a nonparametric test was performed to describe the intensity of agreement between the Cobb methods and computerized photogrammetry at the location of the apical vertebra of the scoliotic curve.

### Field study

After approval by the Research Ethics Committee (COEP), patients who were in conservative treatment for AIS during the study period and who had a medical request for radiological monitoring of scoliosis were invited to participate in the study. All included participants gave their free and informed consent. After the adoption of the exclusion criteria for individuals submitted to resection surgery of spinal processes of the vertebrae and those who had difficulty maintaining orthostatism, 16 patients were included in the study.

### Radiological examination

A single anteroposterior x-ray of the trunk was obtained in the standing posture using the Toshiba KXO15R radiographic generator (Toshiba, Tokyo, Japan) and the Agfa Health System digital radiography (AGEA, Mortsel, Belgium). The scanned images were printed on 35.6 × 43.2 cm film and sent to the Cobb angle measurement. This angle is obtained by the intersection of two lines perpendicular to the tangents of the upper plateau of the upper terminal vertebra and the lower plateau of the lower terminal vertebra of the curve presented by the vertebral column. With the objective of not marking on the printed radiography, which could interfere with the other measurements, the lines drawn with a ballpoint pen and a 30-cm ruler aid were made on transparent sheets positioned on the radiographs. A protractor was used to obtain the angle of curvature. Five measurements were performed for each patient at different times, and the mean of the five values were used in the statistical analysis. In addition to the Cobb angle measurement, the apical vertebra of the curve was identified; that is, the vertebra that presented the greatest distance from the vertical axis of the spine. All measurements were performed by a single examiner.

### Computerized photogrammetry examination

Immediately after the radiological examination, an examiner experienced in palpatory anatomy performed the marking of the spinal processes of the vertebrae from C7 to L5, using dermographic pencil. Next, to promote the external identification of each vertebra and its displacement in the three planes of the space, anatomical landmarks vector type 45 mm long and 5 mm in diameter, specially developed for this study, were positioned in the respective spinous processes of said vertebrae. After this procedure, each patient was photographed standing in the front position, with the arms hanging over the body and standardizing the position of the feet at 36º (Piok position). A transparent acrylic symmetry graph was used as background, measuring 2.05 m in height and 0.72 m in width and squared in the dimensions 10 × 10 cm mark CARCI® for calibration. Photographs were taken using a tripod-mounted (GREIKA WT3750) Olympus 7.1-megapixel camera at 3072 × 2304 resolution, without zoom positioned at 1.3 m distance. The images were sent for the independent analysis by the examiner trained in the protocol for the quantification of scoliosis by photogrammetry as proposed in this study. A two-dimensional vector drawing software, CorelDRAW13®, was used to identify the arc, or scoliotic arcs and subsequent angular measurement. The first step was to accurately highlight the center of the surface markers using the ellipse feature in the CorelDraw13® toolbar. Next, the first phase of the photointerpretation was carried out, consisting of the identification of the apical vertebra and the upper limit vertebra of the scoliotic curve. This procedure was performed by tracing two vertical lines, one tangential to the convex face of the curve and another to the vertical axis of the C7 vertebra, as shown in Figure 1. The apical vertebra of the curve gives rise to the phenomenon of scoliosis. It is the vertebra farthest from the vertical axis of C7 and, generally, is the one that presents greater rotation of its body, which is visualized by the change of direction of the body of the vector. The upper limit vertebra is the first vertebra emerging from the vertical alignment of C7 and undergoing rotation, identified by the positioning of the landmark.

Then, angular measurements of the vertebral deviations with the vertical Y axis of each segment of two adjacent vertebrae from the upper limit vertebra to the apical vertebra, referred to as angles R1, R2, R3, etc., were performed. The sum of the angles collected determines the angle of scoliosis, termed MR. This angle corresponds to the Cobb angle measured by radiography (Figure 2).

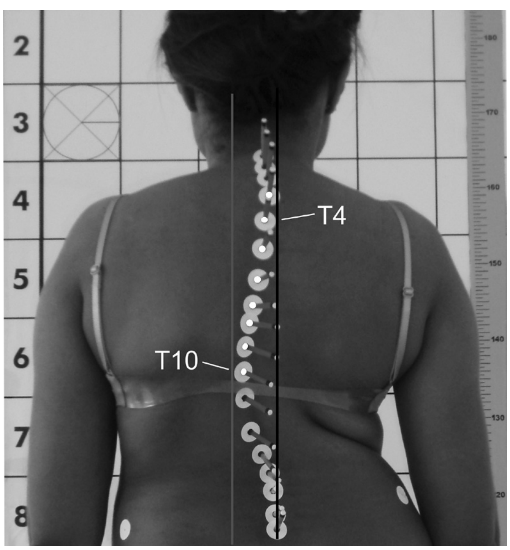


**Figure 1.** 1st phase of the photointerpretation: the white vertical line, to the left of the column, identifies the apical vertebra through the vertical tangentiating the curve convexity (T10 vertebra). The gray vertical line, to the right of the column, identifies the upper boundary vertebra by the vertical passing through the C7 vertebra and the first vertebra breaking with this vertical alignment (T4 vertebra).

Computed photogrammetry, through the identification vectors of each vertebra, also allowed the generation of three-dimensional virtual images of the spatial behavior of the vertebral column[22].

It was possible to mathematically correlate the angular measurements of the scoliotic curve obtained by the Cobb method (MC) and by the method of the present study (MR). If we define the scoliotic curve as consisting of segments of circle arcs, as shown in Figure 3, it is possible to consider that the MC measure is the sum of the angles C1, C2, C3, and C4 obtained between the consecutive spinous processes found in this measurement. Thus, if the angles C1, C2, C3, and C4 are equal to each other and equal to C, then the sum of these angles obtained in the Cobb method interval will be equal to 4C (Figure 3a and b).

Considering that the scoliotic curve is composed of segments of circle arcs, the triangles ABD, ADE, FGH, and FHJ will be isosceles triangles (Figure 3b). Therefore, the angle X will be indicated by EQ (1):

$X = (180-C) / 2$ (1)

In addition, the relationships between the angles of deviation of the Y-axis (R1, R2, R3, and R4) obtained by the method proposed in this study with the angles (C) of each vertebral segment obtained by the Cobb method are shown, as indicated by EQs (2), (3), (4) and (5).

$R1 = 90-X = 90 - (180-C) / 2 = C / 2$ (2)

$R2 = R1 + C = C / 2 + C = 3C / 2$ (3)

$R3 = R4 + C = C / 2 + C = 3C / 2$ (4)

$R4 = 90 - X = 90 - (180 - C) / 2 = C / 2$ (5)

Thus, the MR measurement will be indicated by EQ (6):

$R 2 = C 4 + C 2 + C 2 = 4C$ (6)

Therefore, in this case, the value of the measurement obtained by the present study will be equal to that obtained by the Cobb method.

It is important to point out that this demonstration does not represent a general solution; however, it provides an understanding of the phenomenon observed in this experimental and statistically proven study, highlighting the equivalence between the measurement obtained in this study and that obtained by the Cobb method.

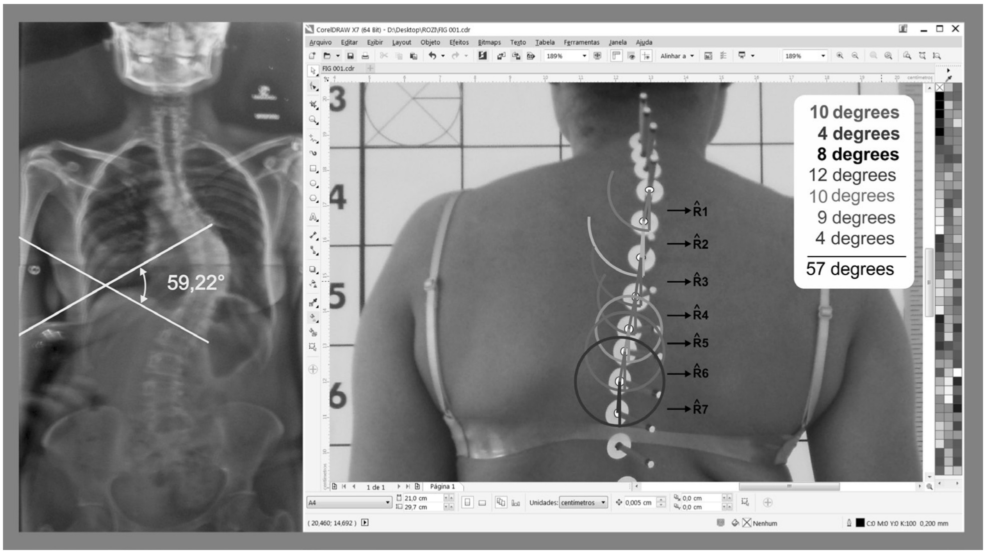


**Figure 2.** 2nd phase of the photointerpretation, angular measurement, performed in the CorelDraw13® software, of a volunteer AIS carrier with left main convex thoracic curve. Measure of the angles of deviation of the spinal balance in the Y axis between the upper limit vertebrae (T4) and the apical vertebra (T10): R1 (10°), R2 (4°), R3 (8°), R4 (12°), R5 (10°), R6 (9°) and R7 (4°). On the left, measure of the Cobb angle to the X-ray of the same patient.

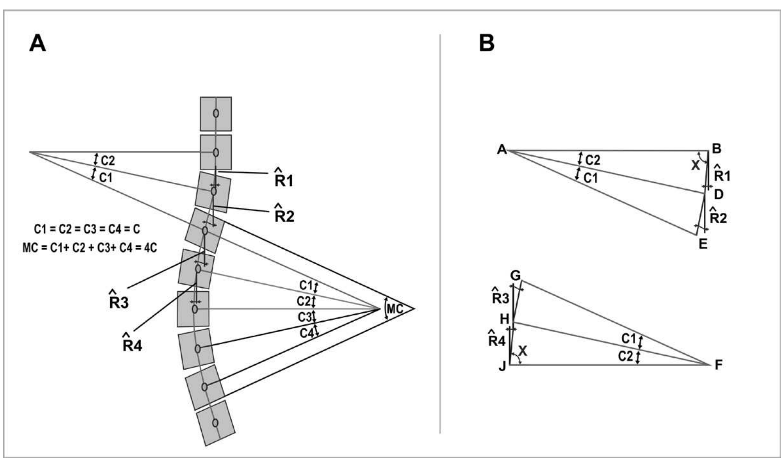


**Figure 3.** (a) Schematic demonstration of the scoliosis arc and its Cobb angle equivalence (MC) and the respective angles R1, R2, R3 and R4, which together form the angle MR of the present method; (b) geometric demonstration of the equivalence of angles C and R.

### Agreement test for the location of the apical vertebra of scoliosis

The Kappa measure was used to describe the intensity of agreement between the two methods, Cobb and computerized photogrammetry, to locate the apical vertebra of the curve. This measure consists of the degree of interobserver agreement beyond what would be expected by chance alone. Its maximum value is 1, which represents total agreement, and values close to and below zero indicate no agreement, or that agreement was exactly as expected by chance. The Kappa coefficient was indicated by the EQ (7).

$$\kappa = \frac{C_o - C_e}{1 - C_e} \qquad (7)$$

In which:

$C_o$ Observed agreement

$C_e$ Expected Concordance

The level of significance adopted for all tests was 5%.

## Results

In a population composed of 16 individuals with AIS, with 21.4 ± 6.1 years of age, 52.9 ± 5.8 kg body weight, 1.63 ± 0.05 m height, and 19.8 ± 0.2 body mass index (BMI), 12 individuals presented a double curve (dorsal and lumbar), three individuals with a single lumbar curve, and one individual with a single dorsal curve, with a dorsal Cobb angular mean of 36.14° ± 16.38° and mean angle of Cobb lumbar of 27.20° ± 10.05°. General characteristics and measurements using the Cobb method and the computerized photogrammetry method for lumbar and thoracic curves are presented in Table 1.

According to the descriptive statistics and the graphs presented in Figure 4, there was no statistically significant difference between the measurements in the two methods. Thus, it can be stated that regardless of the adopted method, the measurements of both dorsal and lumbar curvature will be similar.

The Cohen's Kappa statistical study revealed a general index of 0.92 for the location of the thoracic apical vertebra and 0.825 for the location of the lumbar vertebra. With a significance level of 5% the null hypothesis is rejected, which shows that the agreement between the two tests is different from zero; that is, they are concordant. The values obtained for the thoracic and lumbar Kappa index were very high and were considered excellent.

## Discussion

A 2D computerized photogrammetry protocol was proposed as a non-ionizing method for the diagnosis and follow-up of AIS in schoolchildren. Other non-ionizing technologies have been proposed as an alternative to radiological examinations for this purpose[19]. However, no method has so far reached routine clinical use. The lack of objectivity and numerical correlation with Cobb's "gold standard" method may be contributing to the low adherence to the proposed methods[23].

The values of the curves obtained by the computerized photogrammetry method were similar to the values obtained by the Cobb method. The difference between the two methods was lower for thoracic curves than for lumbar curves, with values of 2.9° and 5.1°, respectively. The mean difference of 4.1° for both methods, which includes all thoracic and lumbar curves, was compatible with the intrinsic error of the Cobb method in an inter- and intra-observer analysis[24], in which the variability of Cobb angle measurements was between 4° and 8°[25,26]. The location of anatomical structures by palpatory anatomy is impaired in individuals with a very high BMI, due to the difficulty in identifying the bony prominences located below the skin. The location of the bony prominence of the spinal processes of the vertebrae is indispensable in the application of the method proposed in this study. During the recruitment of the study volunteers, two subjects with AIS had a BMI above 24 kg/m$^2$ (above ideal weight) but were included in the study. Subjects who had previous surgery of resection of these processes were excluded from the study due to the impossibility of applying these landmarks. It would be plausible, then, to suppose that the most discordant results in the measurements of the lumbar angles were related to the individuals with higher BMI, as in the case of subjects of n.1 and n.4 shown in the table of results. Despite the great difference presented in the lumbar angles of these two subjects (8°), the greatest disagreement between the lumbar results was found in the subject of n.5 (23.8°), whose body mass index is within normal limits. Although the sample of this study is considered representative of the scoliotic population, which is sent to public medical services in the southeast region of the country, it may differ from other regions or countries where childhood obesity is more prevalent. Thus, a study with a larger number of subjects would be necessary for a conclusive evaluation of the possible causes of the difference between the means of the thoracic and lumbar angles presented in this study. A new study using the same methodology presented in this article was conducted by Leal[27] that included 161 adolescents between 10 and 18 years old with AIS. In the mentioned study, the accuracy, sensitivity, specificity, and predictive values of photogrammetry in the progression of the AIS were evaluated. The computerized photogrammetry and Cobb methods were compared in two cycles of measurements, with a mean interval of 8.6 months, and the Wilcoxon test was used to compare the means of the scoliosis angles obtained in both methods. There was no difference between the means obtained by both methods. The averages of the curves by the photogrammetry and radiographic method were 36.9° and 36.6°, re-

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**Table 1.** General characteristics of each individual included in the study and their angular measurements obtained by the Cobb method and by the computerized photogrammetry method in the thoracic and lumbar regions.

| Subjects | Age | Sex | BMI | Scoliosis level | Cobb Method | | | | Photogrammetry Method | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Thoracic | Lumbar | ATV | ALV | Thoracic | Lumbar | ATV | ALV |
| 1 | 39 | F | 28.8 | T e L | 59.8° | 26.0° | T10 | L4 | 57.4° | 17.6° | T10 | L3 |
| 2 | 15 | M | 17.1 | T e L | 32.0° | 15.0° | T9-T10 | L2-L3 | 34.4° | 17.2° | T9 | L3 |
| 3 | 22 | F | 18.3 | T | 27.0° | _ | T9-T10 | _ | 25.8° | _ | T9 | _ |
| 4 | 13 | F | 25.5 | T e L | 30.4° | 32.0° | T7-T8 | L3 | 22.6° | 24.0° | T8 | L2 |
| 5 | 12 | F | 21.7 | T e L | 39.6° | 33.8° | T8 | L2 | 40.8° | 10.0° | T7 | L2 |
| 6 | 19 | F | 22.9 | T e L | 28.2° | 38.4° | T8 | L1 | 22.4° | 35.4° | T8 | L2 |
| 7 | 16 | F | 22.2 | T e L | 42.2° | 22.8° | T9 | _ | 47.0° | 22.8° | T7 | L2 |
| 8 | 14 | F | 17.4 | T e L | 22.4° | 27.0° | T9 | L2-L3 | 23.0° | 30.0° | T9 | L3 |
| 9 | 11 | F | 19.0 | T e L | 50.4° | 48.6° | T7 | L2 | 51.0° | 55.0° | T7 | L2 |
| 10 | 25 | F | 19.8 | T e L | 21.4° | 18.8° | T8 | L2 | 26.4° | 16.8° | T9 | L3 |
| 11 | 45 | F | 23.4 | T e L | 25.6° | 26.4° | T7 | L2 | 29.0° | 27.8° | T7 | L3 |
| 12 | 46 | F | 18.9 | T e L | 73.0° | 41.8° | T6-T7 | L2 | 74.2° | 39.4° | T7 | L2 |
| 13 | 14 | F | 17.8 | L | _ | 19.8° | _ | L2-L3 | _ | 22.0° | _ | L3 |
| 14 | 13 | F | 15.9 | L | _ | 14.0° | _ | L1 | _ | 26.0° | T12 | _ |
| 15 | 15 | M | 16.9 | L | _ | 18.4° | _ | L1 | _ | 17.8° | _ | L1 |
| 16 | 25 | F | 23.1 | T e L | 17.8° | 25.5° | T5 | L2 | 19.6° | 23.8° | T5 | L1 |

Legend: BMI: body mass index; F: female; L: lumbar; ALV: apical lumbar vertebra; M: male; T: thoracic; ATV: apical thoracic vertebra.

spectively. The differences between the means of the two measurements were 0.34 [95% = -0.153 to 1.807], close to zero. The Pearson coefficient for the 161 volunteers was r = 0.82 [95% CI = 0.77 – 0.86]. These results corroborate with the findings presented in the current study. Photogrammetry showed an accuracy of 86.7%, sensitivity of 94.4%, specificity of 86.7% and predictive value of 75.5% in the aforementioned study. The differences between the angular means of the thoracic and lumbar curves were not reported.

The identification of the apical vertebra of the scoliotic curve was an important step in the proposed method, and the use of this specific landmark to identify vertebral alterations in the various planes of space had an important role in this analysis. The statistical study to evaluate the agreement of both methods in the identification of the apical vertebra of the scoliotic curve presented excellent concordance between them. However, the Kappa index was higher in cases of thoracic scoliosis when compared to lumbar scoliosis (0.92 and 0.825, respectively). Considering the Kappa index for the general location of all the vertebrae involved in the study, the T5 and T8 thoracic vertebrae and the L3 lumbar vertebra had a value of 1, that is, maximum agreement. In addition, the possibility of finding three-dimensional coordinates from the base to the tip of this landmark vector type made it possible to visualize the angular variation of this vector in any of the three spatial planes, enabling the 3D reconstruction of the deformity. Thus, a major step was taken to reproduce the deformity across the surface, usually visualized only by invasive methods.

Although the cost comparison between the two methods is not an objective in this study, some considerations are relevant. The total cost of photogrammetric equipment (computer, software license, camera, tripod, and markers) was valued at USD 1,826. Strictly for comparative use, the cost of installing radiological equipment used in this study was estimated at USD 216,238. The basic skills for applying the proposed method are: basic knowledge of palpatory vertebral anatomy, photography, and image software. The time spent with the radiographic method in a typical patient was 13 min (positioning, exposure to radiological imaging, and Cobb measurement), while the time spent in the photogrammetric method was 28 min (landmark positioning, photographic exposure, and curve measurement).

Mrozkowiak et al.[28] made the following considerations about methods of measuring vertebral deformities: 1- the measurement examination should work according to how the measurement result is used (e.g. as a basis for decision-making for surgery) and should be portable for preventive examinations (detection of

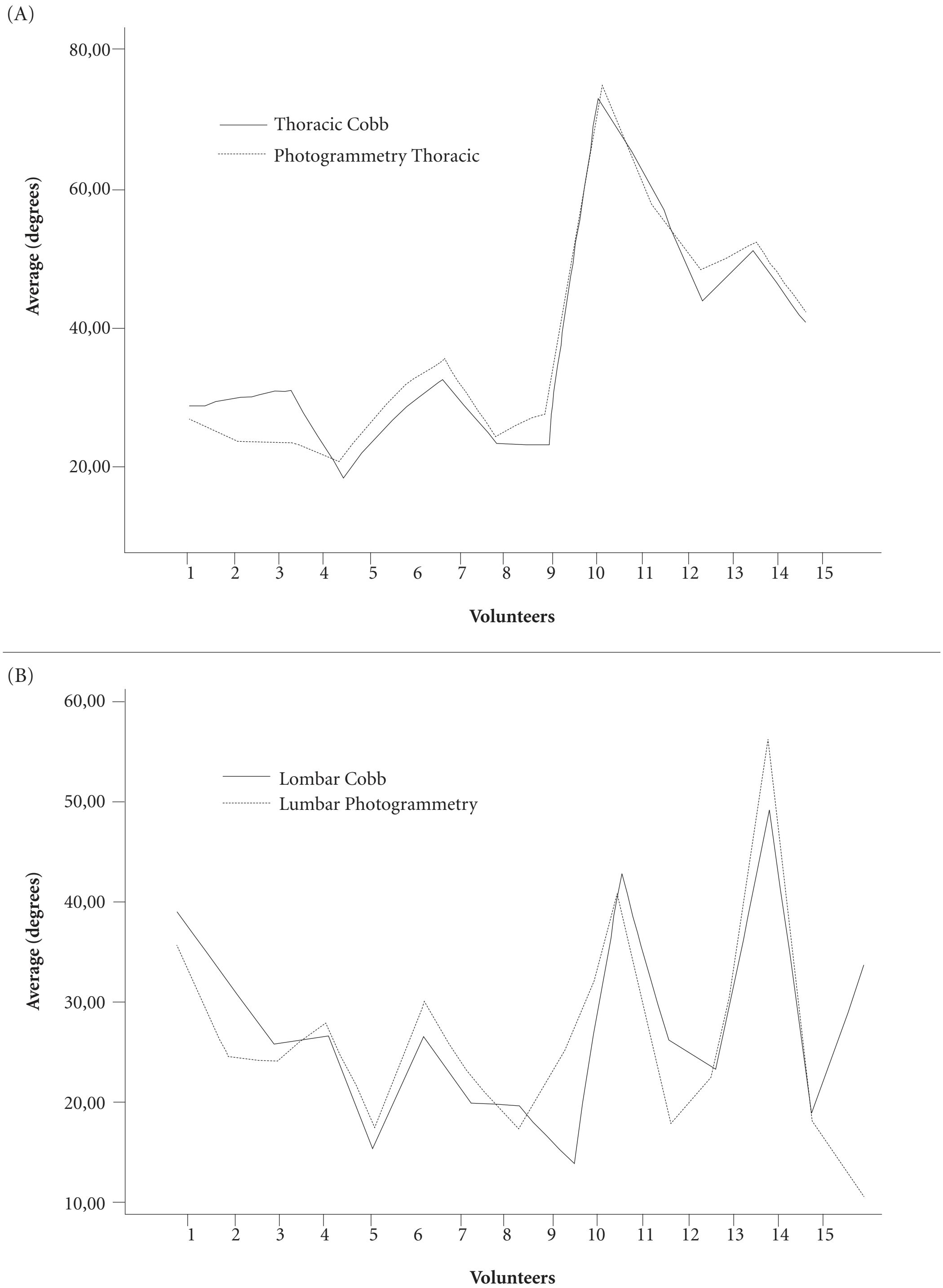


**Figure 4.** Comparison between the measurements of the scoliotic curves obtained by the Cobb method and the computerized photogrammetry method for (A) thoracic curves and (B) lumbar curves.

scoliosis in pre-school or school children); 2- the acquisition of images and the processing of data should be fast enough to provide results during the visit of the health professional responsible for the case; 3- the measurement results should be presented in a readable form, not only for the

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health professional but also for the patient, and should be compared with specific medical knowledge standards, preferably in terms of graphics and images; 4- the measurement should be simple enough, particularly in terms of automation, so that it can be operated by a health professional; 5- the system must be reliable, error-resistant in its operation, and should not require constant intervention from a specialist.

In a review study, Aroeira et al.[19] presented the five main non-ionizing technologies for the evaluation of scoliosis in studies obtained in the literature from 2011 to 2015. The study showed that the same technology was used with different measurement protocols as, for example, the use of the 3D laser scanner without the use of a reference marker, applied in the studies of Komeili et al.[20,29], and using 11 reference markers in the studies of Parent et al.[30]. These results showed analysis parameters with different maps of surface topography. Likewise, 2D computerized photogrammetry was used in four studies with different protocols. In this category, Fortin et al.[31] used topographic whole-body tracing, with measurements of angular deviations in the trunk and limbs. In a different way, Saad et al.[32] used 2D computerized photogrammetry only, in the posterior trunk, using different measurement protocols. These various protocols applied to different technologies make a comparative analysis difficult. Studies using technologies based on ultrasound, structured light, lasers, and fringe projection have been shown to be of moderate to high quality. These techniques allow the evaluation of a large number of individuals in a reduced time, making them attractive for scoliosis screening in schoolchildren. However, the high cost and low objectivity of the results, based on color maps, can be a restriction factor for large scale use.

The 2D computerized photogrammetry protocol presented in this article provides the following advantages: the low cost of implementing the system; the transportability of the instruments that comprise it; the possibility of visualization of the whole body posture, allowing for correlation of dysfunctions associated to the body segments adjacent to the deformity of the spine, increasing the possibility of success in the diagnosis and the therapy used; and, finally, the reduction in the exposure of youths without complete bone maturation to the ionizing rays of the radiographs in the tracking and follow-up of the AIS. However, the method can be improved with its automation and, consequently, reduced exam time.

Recent technological advances point to deep cameras, which allow the acquisition of dense 3D scans of an area in real time, without the need for multiple cameras, at a low cost and portability[33-37]. The use of 3D scanners offers new opportunities for the collection of anthropometric data in a wide range of applications. However, existing studies with the use of depth sensors in the analysis of human activity have focused only on the qualitative estimation of body part positioning and on the knowledge of human action. A study using this technology for quantitative evaluation of the surface topography in AIS should be performed.

The search for non-ionizing methods of evaluation of vertebral deformities does not intend to replace radiological examination, which is important in the identification of congenital bone malformations and evaluation of skeletal maturity. However, new technologies introduce a new approach, not only for diagnosis, but mainly for the periodic monitoring of the developmental deformities of the adolescent's spine, with the possibility of also identifying compensatory asymmetries through reliable diagnoses. Low-cost and non-invasive diagnoses can be considered of relevance in public policies considering, mainly, public health needs in Brazil. Considering the high prevalence of AIS and the fact that these are mainly preventive tests, which seek to avoid invasive and costly procedures such as surgeries, these tests are relevant in large-scale application for tracking vertebral alterations in schoolchildren as a measure of public health. The right to health of children and adolescents is State policy, as the Brazilian constitution norm ratifies the principle of absolute priority of the protection of children and adolescents. The chapter on the right to life and health, in its Article 11, § discusses vertebral deviations in other areas of the body. In this context, the 2nd paragraph of "Search for technologies and methods" says:

"It is incumbent upon the public authority to provide, free of charge, to those in need, medicines, orthotics and other assistive technologies related to the treatment, habilitation or rehabilitation for children and adolescents, according to the lines of care directed to their specific needs."

**Limitations**

The computerized photogrammetry protocol for measuring the angle of scoliosis may be difficult in individuals with a very high BMI, due to the difficulty in locating the spinous processes by palpatory anatomy. In addition, the method cannot be applied in individuals who have undergone surgery for resection of the spinous processes of the vertebrae involved in the analysis, due to the absence of the anatomical structure object of method analysis.

## Collaborations

RMC Aroeira collaborated in the design, study design, data collection and final writing; JS Leal in the interpretation of the results of medical imaging tests; AEM Belongs in the delineation of the mathematical study, creation of figures and aid in the statistical analysis of the data; EB Las Casas in the critical review of the study; and M Greco in the critical review of the study and final approval of the version to be published.

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