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Validity of computed photogrammetry for detecting idiopathic scoliosis in adolescents

Validade da fotogrametria computadorizada na detecção de escoliose idiopática adolescente

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Abstract

Introduction: Adolescent idiopathic scoliosis (AIS) is a three-dimensional abnormality of the spine, of unknown etiology. It starts at the beginning of puberty and its progression is associated with the growth spurt. Analysis of angular movement and body posture through the static imaging method known as photogrammetry could allow physical therapists to quantify and qualify their body posture/movement assessments. Objective: This study was carried out to evaluate the sensitivity of this instrument for detecting AIS in examinations in schools. Methods: This was a school-based cross-sectional study among fifth to eighth-grade elementary school students in public and private schools in Pelotas. Digital images were collected and radiographic examinations were performed in the anteroposterior and lateral planes. The sensitivity and specificity of the photogrammetry were investigated using three and two degrees of margin for the body surface asymmetry. Results: Two hundred twenty four students underwent the photogrammetry and standard radiological examinations at the schools. The prevalence of AIS was 4.5% (n=10), in eight girls and two boys with mean Cobb of 13.3°; mean vertebral rotation of 1.1 (Nash-Moe); dorsal kyphosis of 29.5° Cobb; iliolumbar angle of 3.6°; and Risser sign of 1.6. With three degrees margin, the sensitivity was 21.4% and the specificity was 90.7%. With two degrees margin, the sensitivity was 50% and the specificity was 61.2%. Conclusions: Based on these results, it was found that computerized photogrammetry could not be used as a screening method for detecting mild scoliosis in schools.

Key words: idiopathic scoliosis; photogrammetry; posture; physical therapy.

Resumo

Introdução: A escoliose idiopática adolescente (EIA) é uma alteração tridimensional da coluna vertebral. Sua etiologia é desconhecida e seu início ocorre no início da puberdade, tendo sua progressão associada ao estirão de crescimento. A análise angular de movimento e postura corporal através da imagem estática, conhecida como fotogrametria, permite ao fisioterapeuta quantificar e qualificar sua avaliação da postura/movimento corporal. Objetivo: Este estudo foi realizado para avaliar a sensibilidade deste instrumento na detecção da EIA no exame escolar. Métodos: Estudo transversal de base escolar sobre alunos de 5ª a 8ª série do ensino fundamental das redes pública e particular de Pelotas. Foram realizados coleta de imagem digital e exame radiográfico em postura antero-posterior e perfil. A sensibilidade e especificidade da fotogrametria foram verificadas utilizando três e dois graus de margem para desnivelamento da superfície corporal. Resultados: Duzentos e vinte e quatro alunos realizaram o exame de fotogrametria na escola e o exame radiológico padrão. A prevalência de EIA foi de 4,5% (n=10), sendo oito meninas e dois meninos, com média de 13,3° Cobb; média de 1,1 para rotação vertebral (Nash-Moe); 29,5° Cobb para cifose dorsal; 3,6° para ângulo íleo-lombar; e sinal de Risser em 1,6. Para três°, a sensibilidade foi de 21,4% e a especificidade de 90,7%. Utilizando dois graus, a sensibilidade foi de 50% e a especificidade de 61,2%. Conclusões: Com base nestes resultados, verificou-se que a fotogrametria computadorizada não pode ser realizada como screening para detecção de escoliose de grau leve nas escolas.

Palavras-chave: escoliose idiopática; fotogrametria; postura; fisioterapia.

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Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional abnormality of the spine, of unknown etiology. It starts at the beginning of puberty and its progression is associated with the growth spurt. The prevalence of scoliosis among adolescents ranges from 1 to 3% of the population[1,2] and girls are more affected than boys, in proportions of approximately four to one[2]. Many associated factors have been correlated with the progression of the curvature[3], such as the presence of double curvatures, high magnitudes of curvature, early diagnosis, diagnosis before menarche, low Risser sign and the female gender.

The vast majority of AIS cases are asymptomatic until high angulations are reached, normally more than 40º Cobb, and early detection of scoliosis gives rise to a threefold increase in the number of patients conservatively treated, thus reducing the percentage of patients who need surgery[4].

The Cobb method continues to be the standard clinical measurement for evaluating the magnitude of scoliosis[5]. Other non-radiological methods have been used in attempts to achieve early detection of AIS among school children. Amendt et al.[6] used the Scoliometer®, an instrument created in 1984 by Bunnell, to measure asymmetries or axial rotations of the trunk. Velezis, Sturm and Cobey[2] used the Adams test (forward bending test with anterior spine flexion) to observe gibbosity on the back, resulting from vertebral torsion. Thulbourne and Gillespie[7] and Burwell et al.[8] recorded the outline of the back by using a gibbogram[1,2]. Turner-Smith Harris e Thomas[9] proposed an integrated shape imaging system (ISIS), while Stokes and Moreland[10] used a Raster stereograph to study back shape abnormalities.

Over the last few years, many authors have questioned the existing models for scoliosis examinations among schoolchildren[1-3]. Although conventional radiography identifies spine deformities, it is not recommended for basic examinations in schools. The risks involved in exposing the child to radiation and the high costs have justified attempts to develop other methods for detecting and documenting scoliosis.

For some years now, physical therapists and other professionals within the field of human movement studies have devoted themselves to kinematics: the angular analysis of movement and body posture through images[11-14]. When separately considered, such images (photograms) can be analyzed with what is conventionally termed photogrammetry. Recent studies have tested the reliability of this examination technique applied to conventional postural evaluation and for measuring anterior trunk flexion, showing good intra- and inter-examiner reliability[15-19]. Evaluation of scoliosis through computed photogrammetry can make it possible to analyze the shape of the child's back, determine deformities and quantify in degrees the unevenness found and may be a useful tool for scoliosis examination[14].

Thus, the purpose of this study was to investigate the sensitivity of computed photogrammetry for examinations in schools to detect early adolescent idiopathic scoliosis. It was also intended to determine the validity of angular kinematics as a diagnostic and analytical examination for scoliosis, compared to radiological examinations, and to establish cross-validation between the angular measurements by means of a surface protocol, through angular kinematics, versus the Cobb angle from radiological images. The hypotheses were that, compared with conventional radiological examinations, angular kinematics would demonstrate high sensitivity and specificity and that there would be positive and significant correlations between the surface angular kinematic analysis and the Cobb angle.

Materials and methods

Between March and July 2005, a school-based cross-sectional study was carried out among fifth to eighth grade elementary school students in the urban zone of Pelotas, Rio Grande do Sul. The sample size was calculated through the Epi-Info software, estimating a sensitivity of 90% with a margin of error of 3.5 percentage points, thus resulting in 279 students. For an estimated specificity of 80%, with the same margin of error, 492 adolescents would be necessary. Adding 30% for losses and refusals, 650 students would be necessary. From a list containing all the schools in the urban zone of the municipality, 20 schools providing either a complete elementary level course or the final four years were eligible. To ensure representativeness among all students from the target population, the schools were stratified by type: public (municipal and state) and private. Six hundred and fifty students were initially selected from eight schools. In each school, one class was randomly chosen from each of the last four years of elementary school and 20 students per class were consecutively selected according to the attendance list. One hundred and fifty-eight students did not participate in the study because of lack of authorization from their parents or other responsible adults. Another 178 students did not attend school on the appointed day to sit for the examination. Of the 314 students who underwent the photogrammetry at school, 224 also did the radiological examination and these, therefore, formed the final sample.

Five interviewers were recruited among the second-year undergraduate physical therapy students of the Universidade Católica de Pelotas (UCPel) and were trained over a six-month period to carry out photogrammetric examinations, as well as in semiology and palpatory anatomy. Of these, three of the interviewers were women, to carry out examinations on the girls, and two were men, for examinations on the boys. The research project was approved by the Ethics Committee of UCPel, through report nº. 2006/51.

After student selection, a written consent statement was sent to the parents or other adults responsible for the children, to obtain authorization for performing the photogrammetric examinations at school and the radiological examination in a specialized location.

The inclusion criteria consisted of prior parental authorization and that the child was included on the list of selected students. The exclusion criteria were lack of prior authorization, inadequate clothing for the examination to be performed and not undergoing both selected examinations (*id est*, photogrammetry and X-ray).

The digitized images were gathered at school, in a room set aside for this purpose. Crosses formed by adhesive tape on the floor marked the correct positions for the feet and alignments for the camera, at pre-established distances. There was adequate natural and artificial light, and a large enough physical area for image gathering, perpendicular to the student under examination. The surface markers that were used were standardized: self-adhesive, white and spherical (13mm in diameter). They were placed at anatomical points, from which the symmetry of the body surface was delineated (Table 1). A digital camera (DSC-P73, Sony®) with a resolution of 2592x1944 pixels was used, and placed upon a photographic tripod at a height of 85cm from the floor, with levels for image alignment, autozoom and focal distances of 2.40m for the anterior-frontal, posterior-frontal and sagittal (right and left) planes, and 1.80m for the anterior flexion-posterior trunk position. According to a study found in the literature[14], the degree of distortion in the distance interval between 1.20 and 2.40m for angular measurements is the same. The image-gathering angle was 90º, at a height of 85cm from the floor, with a degree of distortion of approximately 1% for these parameters. Male students underwent the image gathering while wearing trunks, and the female students wore bikinis and the subjects were barefoot. The digital images were stored on a CD for subsequent analyses and the symmetry and alignments measurements were carried out using the CorelDRAW 9.0 software.

In Figure 4, the symmetry and alignments measured in the different planes can be seen.

The biomechanical basis selected was that all the paired bone contralateral anatomical reference points were leveled, to form lines parallel with the floor, ***id est***, with symmetry angles of 0º between each other and both at 90º to the floor. Unpaired homolateral reference points also needed to be aligned with each other, forming perpendiculars with the floor, ***id est***, with symmetry angles of 0º between each other and both at 90º in relation to the longitudinal x-axis, parallel to the ground. Functional tolerance measurements of two and three degrees were used. A pathological condition was considered to be present when the angles were lower than 88 and 87º or greater than 92 and 93º, respectively, in relation to the 90º marks on the ordinate (y) and abscissa (x) axes.

The photographic interpretations of the Thales triangles (ΔThales) used the formula: $\Delta Thales = Thales_{Right} - Thales_{Left}$. When the result of the equation was positive, there was a trunk/scapular waist inclination to the right; when negative, it was to the left. The same calculation was applied to define the Head-Shoulder relationship (HSR) and the Head-Malleolus relationship (HMR), defining occurrences of rotation of the evaluated segments by using the following formulae, respectively: $\Delta HSR = HeadShoulder_{right} - HeadShoulder_{left}$ and $\Delta HMR = HeadMalleolus_{right} - HeadMalleolus_{left}$. The measurement references for ΔHSR, were the internal auditory canal and lateral shoulder acromion. For the ΔHMR measurements, the internal auditory canal and lateral ankle malleolus were used. For calculating the angle of gibbosity, the following formula was used: $\Delta Gibbosity = \Delta Gibbosity_{right} - \Delta Gibbosity_{left}$.

Table 1. Anatomical points and alignment levels* used for photogrammetric examination.

Pattern	Anatomical points	Alignment/Symmetry
Anterior frontal plane	• Anterior border of acromion	Shoulders: 90º±2 and 3º
	• Glabella-jugular vein incision	Omphalic: 90º±2 and 3º
	• Anterosuperior iliac spines	Pelvis: 90º±2 and 3º
	• Anterior tibial tubercles	Knees: 90º±2 and 3º
Sagittal	• External acoustic meatus – lateral border of acromion	Head-shoulder relationship (HSR)
	• External acoustic meatus – lateral malleolus of ankle	Head-malleolus relationship (HMR)
	• Cervical lordosis apex – dorsal kyphosis apex – external vertex	Cervical-thoracic lordosis plane
	• Lumbar lordosis apex – dorsal kyphosis apex – external vertex	Lumbar-thoracic lordosis plane
Posterior frontal plane	• Posterior acromion	Shoulders: 90º±2 and 3º
	• 7th cervical vertebra – 9th thoracic vertebra	Upper spine: T9-C7 x-axis abscissa: 90º±2 and 3º
	• 9a thoracic vertebra - 5a lumbar vertebra	Lower spine: T9-L5 x-axis abscissa: 90º±2 and 3º
	• Inferomedial angle of scapula	Scapula: 90º±2 and 3º
	• Posterosuperior iliac spines	Pelvis: 90º±2 and 3º
	• Angle between x-axis and line tangential to gibbus y-axis	Gibbosity angle – *Adams*

*Proposed by the authors for this study.

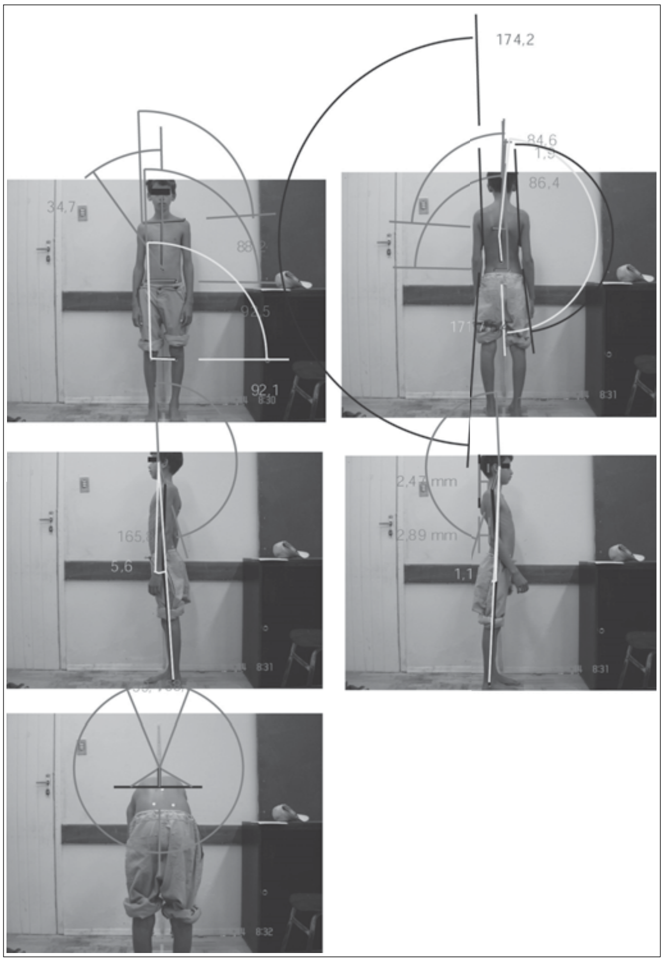
To define the physiological curvature measurements in the sagittal plane, the distances of the thoracic-cervical lordosis plane and the thoracic-lumbar lordosis plane were used, in which the thoracic-cervical lordosis plane was the distance in mm between the line tangential to the dorsal kyphosis apex and the line tangential to the cervical lordosis apex. The thoracic-lumbar lordosis plane was the distance in mm between the line tangential to the dorsal kyphosis apex and the line tangential to the lumbar lordosis apex.

To determine the existence of any dorsal scoliosis, the upper spine alignment, anterior shoulder symmetry and posterior scapula symmetry were used. However, for scoliosis of lumbar form, the lower spine alignment and anterior and posterior pelvis symmetry were used. Dorsal-lumbar curvatures and double curvature were classified in consideration of all the above variables. The determining factor for defining the side was the infra- or supra-symmetry of the anterior surface measurements. During the training, it was attempted to standardize the procedures for anatomical palpation when positioning the surface markers on overweight or obese children, so as not to distort the image gathering.

After the image gathering, all the students were referred to a radiology institute for standard radiological examination, *id est*, total vertebral column in postero-anterior and lateral planes (both in the orthostatic position). From these, the following variables were analyzed: localization (lateral curvature or not); type (functional or structural); Cobb angle for lateral deviations and dorsal kyphosis; initial specific vertebral rotation angles (obtained by means of the Nash-Moe method); Risser sign (amount of calcification present in the iliac apophysis which measures the progressive ossification associated with the closing of bone growth) and the iliolumbar angle. Lateral curvatures with Cobb angles greater than or equal to 11º were considered to be true scoliosis. Students with curvatures between 5 and 10º Cobb were classified as having a propensity for curve progression and development of scoliosis. The radiological examinations were analyzed by two different examiners and, if there was any discordance regarding any of the variables, a third examiner was asked to give the final opinion. The sensitivity was defined as the percentage of patients with scoliosis who were also positive in the computed photogrammetry, while the specificity was the percentage of students who underwent radiography without showing scoliosis and who had a negative test results from the photogrammetry.

The statistical analyses were predominantly descriptive, with observations of central trends and dispersion measurements for the quantitative variables. In the analyses of measurements according to gender, Student's t-tests were used for comparisons between the means, and differences with p values less than 0.05 were taken to be significant.

Figure 4. Body symmetry and alignments measured by computer aided photogrammetry. Pelotas, RS, 2005.



Results

From the whole sample, just over half was male and the mean age was 12.3 years at the time of the examination at school (sd=1.6), without differences between the genders. Just under half of the students were from state schools, and the others were equally divided between municipal and private schools. Among the girls examined using photogrammetry, 85 (59.4%) had already had their first menstruation, at a mean age of 11.8 years (sd=1.2). None of these characteristics demonstrated any differences in relation to either the whole sample or the radiographed sample (Table 2).

By means of computed photogrammetry, the prevalence of any type of scoliosis was 45.5% (143/314). All symmetry and alignment measurements were compared according to gender, and only the alignments of the upper and lower spine resulted in greater separations for the boys ($p<0.05$), who also obtained larger measurements in the thoracic-cervical lordosis plane, as confirmed by the Cobb angle measurement for kyphosis (32.4±9.7 for the boys and 27.9±9.6 for the girls).

Table 2. Distribution of sample of school children according to gender, age and type of school.

	n (total)	% (total)	n (Radiography)	% (Radiography)
Gender				
Male	171	54.5	116	51.8
Female	143	45.5	108	48.2
Age (years)				
9 and 10	42	13.4	32	14.3
11	65	20.7	49	21.9
12	54	17.2	36	16.1
13	89	28.3	64	28.6
14	41	13.1	31	13.8
15 and 16	23	7.3	12	5.3
Type of school				
State	136	43.3	102	45.6
Municipal	73	23.2	61	27.2
Private	105	33.4	61	27.2
Total	314	100.0	224	100.0

The prevalence of adolescent idiopathic scoliosis was 4.5% (10/224), and it was four times more common for girls than boys. Eight% (18/224) of the students showed scoliosis classified as functional and 110 demonstrated curvatures with angulations ranging from 5 to 10º (Table 3).

The mean Cobb angle of the idiopathic scoliosis found by means of the radiological examinations were 13.3º Cobb, while for the functional scoliosis cases, 12.5º Cobb were found. The mean Cobb angle for dorsal kyphosis was 30.3º, and it was 29.5º among children with idiopathic scoliosis. The mean Risser sign was 1.6, without variations for the idiopathic scoliosis group (Table 4).

Among the curvatures, 77 were located in the dorsal region, 49 were in the lumbar region and 12 were double curvatures. Dorsal curvature predominated among the cases of functional scoliosis (13/18) and inclined scoliosis (62/110). For the idiopathic scoliosis cases, the predominant location was lumbar and with double curvature (4/10). Analysis of the side of the convexity, the right side prevailed for the dorsal form curves (40/77) and the left side for the lumbar form curves (38/49).

Table 3. Prevalence of scoliosis among school children, according to radiological examinations.

	Idiopathic Scoliosis		Functional Scoliosis		Propensity to develop		Without Scoliosis	
	n	%	n	%	n	%	n	%
Gender								
Male	2	20.0	11	61.1	62	53.4	41	47.7
Female	8	80.0	7	38.9	48	46.6	45	52.3
Age (years)								
9 and 10	1	10.0	3	16.6	15	13.6	13	15.1
11	3	30.0	4	22.2	15	13.6	27	31.4
12	1	10.0	4	22.2	23	20.9	8	9.3
13	2	20.0	7	39.0	35	31.8	20	23.3
14	2	20.0	0	0	18	16.4	11	12.8
15 and 16	1	10.0	0	0	4	3.6	7	8.1
Type of School								
State	6	60.0	3	16.6	56	50.9	37	43.1
Municipal	0	0	7	39.0	20	18.2	34	39.5
Private	4	40.0	8	44.4	34	30.9	15	17.4
Total	10	100.0	18	100.0	110	100.0	86	100.0

Table 4. Final results and comparisons with other studies in the literature.

	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
The present study	21 to 50	61 to 89	16 to 50	90 to 97
Burwell, 1986 (20º Cobb minimum)	38 to 69	84 to 96	18 to 56	–
Howell, Craig and Dawe, 1978 (10º Cobb initial)	29 to 74	42 to 81	–	–
Amendt et al., 1990 (20º a 30º Cobb)	76 to 100	54 to 90	–	40 to 100
Sahlstrand, 1986 (5º Cobb minimum)	97 to 99	57 to 64	–	–
Lauland, Søjbjerg and Hørlycke, 1982 (10º Cobb minimum)	–	–	18 to 29	97 to 100

The mean iliolumbar angle was 3.6º for all of the idiopathic scoliosis cases, and 2.4 among those with functional scoliosis. Taking all the scoliosis cases with a single lumbar curvature, it was found through X-rays (n=9), that the mean iliolumbar angle was 4.1º, rising to 4.5º when analyzing only the idiopathic cases.

Observation of the sagittal physiological curvatures in the thoracic-cervical lordosis and thoracic-lumbar lordosis planes for all the children who underwent the radiological examination, it was found that the distances between these planes increased in the same proportions in which the Cobb angle increased for dorsal kyphosis, as shown in Figure 1. Using the f test for linear trends, for differences between the means of two variables according to the Cobb angle, it was observed that both showed statistical significance (p=0.001 and p=0.015, respectively).

Using three degrees of asymmetry as the maximum measurement for body surface symmetry in photogrammetry, when cross-referenced with the radiological data, sensitivity of 21.4% was found for all scoliosis curvatures, 16.7% for functional scoliosis and 30.0% for structural scoliosis. By using two degrees as the measurement reference, the sensitivity increased to 50.0%, 61.1% for functional scoliosis, while structural scoliosis remained at 30.0% (Figure 2). The total specificity was 88.8%, it was 90.7% for the group without scoliosis and 87.3% for those with a propensity towards it. By reducing the maximum symmetry measurement to two degrees of asymmetry, the total specificity obtained was 61.2%, while for the group without scoliosis it was 68.6% and for those with a propensity, it was 55.5% (Figure 3). The positive predictive values were 16.0% (6/28) with three degrees as the asymmetry measurement and it rose to 50.0% using two degrees (14/28). The negative predictive values were 97.0% and 90.0%, respectively using three and two degrees as the body surface asymmetry measurements.

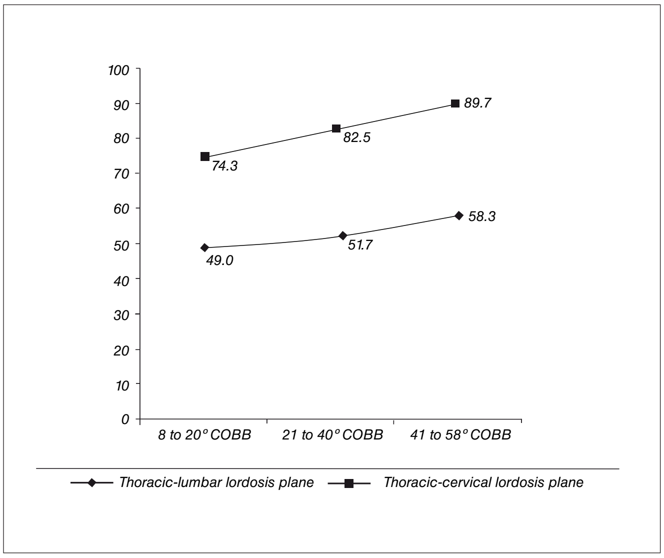


Figure 1. Mean distance (mm) of the thoracic-lumbar lordosis plane and thoracic-cervical lordosis plane in relation to Cobb angle measurements.

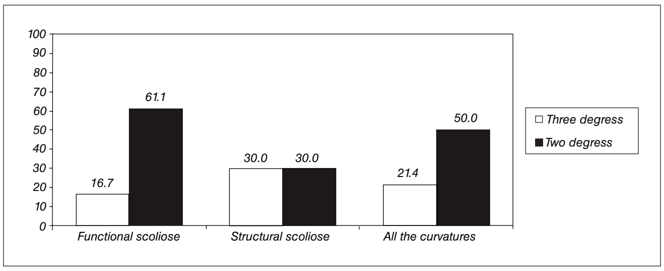


Figure 2. Sensitivity (%) of computed photogrammetry with leveling of three and two degrees.

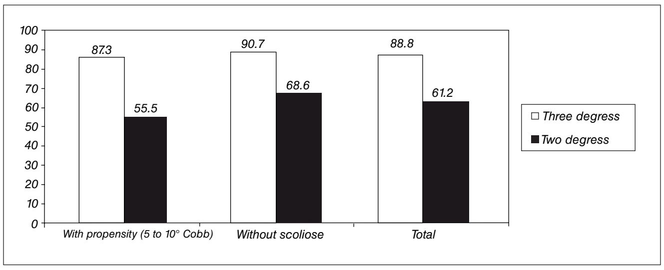


Figure 3. Specificity (%) of computed photogrammetry with symmetry of three and two degrees.

Discussion

Although the losses were notable both for the photogrammetry and for the radiological examinations, they did not create differences in the characteristics of the group that followed through with the study. One of the limitations of this study was to have six different examiners for gathering the digitized images and placing the surface markers. Even with a significant period of training for these interviewers, inter-observer measurement errors may have occurred. It is understood that examinations should be carried out by the same interviewers but, for ethical reasons, female interviewers were chosen for the girls and male interviewers for the boys. Another difficulty was the placement of surface markers on obese children. Angular measurement errors due to difficulties in correctly marking the anatomical points because of the greater quantities of adipose tissue and skin were minimized by the standardization of point marking and image gathering carried out during the training and fieldwork, since there is no mention in the literature that there should be any exclusion of overweight or obese individuals from examinations in schools for detecting scoliosis.

The prevalence of adolescent idiopathic scoliosis, in this study, was within the rates found in the worldwide literature, which ranges from 2 to 4%. As reported in other studies, the girls showed a four times greater prevalence than did the boys. Among the students who demonstrated scoliosis, the segmental extension component (lordosis) was not observed, in comparison with the other children studied, because the mean Cobb angle for kyphosis was 30.3º for the group without scoliosis, and 29.5º for the group with idiopathic scoliosis. The scoliosis found among the students who were examined was all of a mild degree, with a mean Cobb angle of 13.3º and mean vertebral rotation of 1.1. The students examined were skeletally immature, with a mean Risser sign of 1.6. The predominant locations of the idiopathic scoliosis were double curvature and lumbar, followed by dorsal. In the functional scoliosis cases, the dorsal form prevailed followed by the lumbar form.

By analyzing the sensitivity, specificity and positive and negative predictive value results, in comparison with other studies, variations were observed regarding the specificity and sensitivity, according to the type of examination performed and the symmetry measurement criteria used. Burwell[15] assessed 102 children with scoliosis with Cobb angles of at least 20º using the Scoliometer® to measure trunk axial rotation, finding sensitivity ranging from 38 to 69% and specificity ranging from 84 to 96%. Howell, Craig and Dawe[16] assessed 54 children with idiopathic scoliosis with an initial Cobb angle of 10º by means of photogrammetry and forward bending tests applied by physical therapists and nurses, finding sensitivity levels of 29, 87 and 74% and specificity of 81, 42 and 49%. Amendt et al.[6] used a Scoliometer® on 65 patients with idiopathic scoliosis with 20 to 30º Cobb, and found sensitivity of 76 to 100% and specificity of 54 to 90%. It is very likely that such results are due to the fact that in all of these studies, the evaluated subjects had a confirmed diagnosis of adolescent idiopathic scoliosis, *id est*, a Cobb angle greater than 11º.

In this study, the sensitivity ranged from 21 to 50%, and the highest value occurred when using two degrees as the symmetry measurement (50%), while the specificity ranged from 61 to 89%, and the highest values occurred when using three degrees as the symmetry measurement (89%) (Table 4). It seems that the parameters used as significance measurements (two and three degrees) with photogrammetry in this study, together with a sample composed mostly of individuals without scoliosis, or with slight scoliosis, may have been overestimated.

The clinical use of an examination is not only determined by its sensitivity and specificity, but also by its predictive value. Although these two indicators are very important, an examination can also supply clinical evaluation and diagnostic information. Physical therapy professionals need to know the likelihood that computed photogrammetry might be positive or negative in the presence of scoliosis. By applying this principle, a relatively low positive predictive value was found, *id est*, the number of students with scoliosis divided by the total number of students with positive photogrammetry with or without scoliosis (true ones and false positives), with the symmetry measurement equal to two degrees (50%) and three degrees (16%). In the study carried out by Burwell[15], the positive predictive values ranged from 18 to 56%. In the study by Lauland, Søjbjerg and Hørlycke[17]who evaluated 195 children with scoliosis and a minimum Cobb angle of 10º by means of Moiré topography and the forward bending test, the positive predictive value ranged from 18 to 29% (Moiré topography).

Inversely, the negative predictive value was observed to be extremely high, ranging from 90% to 97%, signifying that the proportion of students without scoliosis divided by the total number of students with negative photogrammetry (true ones and false positives). The studies by Lauland, Søjbjerg e Hørlycke[17] and Amendt et al.[6] found negative predictive values ranging from 97 to 100% and 40 to 100%, respectively. It seems that this high negative predictive value could have been overestimated because, in the present study, a higher level of significance was used (two and three degrees).

Computed photogrammetry in the present study, using three and two degrees for body surface symmetry, was not shown to be sensitive and specific enough to be recommended alone as a school screening method for adolescent idiopathic scoliosis. It seems that using two degrees as an unevenness measurement level has been shown to be more reliable, given that it noticeably decreases the chance of not detecting a child with mild idiopathic scoliosis. In comparison with other studies, the mean Cobb angle found was one of the lowest (5.5º Cobb), which could in a way explain the tendency towards decreased sensitivity. It is believed that other studies will need to be carried out, with greater scoliosis curvatures and image gathering carried out by the same examiner, in order to verify these percentages. Another factor is the number of subjects examined, since our study reported a higher number of subjects examined and, of these, only 4.5% presented idiopathic scoliosis, all in a mild form. Most of the studies used smaller samples and only subjects with scoliosis, with a minimum Cobb angle ranging from 5 to 30º Cobb, which seems to limit the predictive implications of the examination to a general population. For detecting physiological curves in the sagittal plane, this examination was shown to be effective among this population.

The objective of examining schoolchildren was to achieve early identification of scoliosis, *id est*, before curve progression and before reaching skeletal maturity. Traditionally, classical school examination programs use the forward bending test. Computed photogrammetry allows quantification of body surface symmetry that is not measured through the subjective clinical examination. These data may contribute towards better monitoring of the progression, stabilization or reduction of scoliosis curvature over the course of therapy and bone growth, as well as helping to document the curvature.

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