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Evaluations of the spinal curvatures in the sagittal plane: reference measurements, categorization, discriminatory and diagnostic accuracy

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Abstract

Introduction. This study aimed to propose a categorization of body postures and to provide indexes/scores for the postural patterns.
Methods. The body posture of the 3 spinal regions in 180 asymptomatic young people, mean age: 16.1 (0.77) years, was evaluated quantitatively in the sagittal plane (cinemetry and the curvature index). The same images were presented to experts who, by way of qualitative analyses, provided the postural diagnosis of each curvature for all of the young people. Individuals with the same postural patterns were grouped together and the qualitative data were crossed with the quantitative values. Thus, scores were attributed to normal curvature, tendencies, and deviations. The one-way ANOVA test for independent samples was used to compare the patterns and the Bonferroni post-hoc test served to analyse effects between neighbouring changes. The mean difference and the 95% confidence interval were also calculated to compare the patterns. An alpha level of 5% was adopted for all analyses. The sensitivity, specificity, positive and negative likelihood ratios, and the predictive value for the suggested reference intervals were calculated to determine the diagnostic accuracy.
Results. Significantly different scores were attributed to the postural pattern curves: ≤ 0: curve inversion; 0.1–10: rectification; 10.1–11: tendency for rectification; 11.1–14: normal; 14.1–15: tendency for hyperlordosis/hyperkyphosis; > 15: hyperlordosis/hyperkyphosis. The scores presented great discriminatory capacity and diagnostic accuracy among the postural patterns.
Conclusions. This categorization could aid researchers and health professionals in evaluating postural deviations.
Key words: adolescent, kyphosis, lordosis, spinal curvatures

Introduction

Postural deviations amongst young people have been increasing in the recent decades, causing concern about the state of health and habits of this generation [1–3]. Postural alterations modify the orientation of the vertebras and the distribution of forces and tensions in the spine [3, 4], increasing the risk of paravertebral pain, injury, and degenerative processes of the vertebral structures [5, 6]. Early detection and treatment of postural problems could help avoid greater deformations of the spine and musculoskeletal perturbations [7, 8].

A variety of instruments have been developed for the detection of spinal curvature deviations using different physical principles, methodologies, and protocols, but visual observation and radiography are still used in clinical practice and research [9]. Visual observation is of low cost but only provides qualitative data on the surface evaluation of the spine; its subjectivity constitutes a limitation, and there is a need for a refined visual sensitivity of the examiner to perceive the deviations [9, 10]. Radiographs are considered a more objective method for the indication of treatment [9, 11, 12], but show restrictions for use with large populations [2] owing to the cost and logistics [2, 13]. They are also associated with problems concerning exposure to radiation [2, 14, 15], repeatability [9, 14], and imprecise representation of a 3-dimensional structure in a 2-dimensional image [11, 16]. Cobb's method is widely used to measure spinal curvature deviations in radiographic evaluations [11, 12]. However it is also questioned since it can present measurement errors caused by difficulty to visualize and identify the vertebras [17], problems with the characterization of the curves [16, 18], and a lack of consensus concerning the values of the curvatures [8, 17].

Thus, non-invasive instruments that offer quantitative data, such as kinematics/photogrammetry [2, 19, 20], and automatic measuring methods with direct measurements are more highly recommended [21]. Evaluating the length and arching of the curvature – curvature index – is considered adequate to quantify posture [13, 22, 23], but there are studies with different populations and no consensus exists concerning the values that designate normal and abnormal curvature patterns [22, 24]. The values presented as normal are those found for subjects considered healthy by the distribution of the majority or sample mean, and not those with adequate posture [17, 22, 24]. In turn, if one considers as normal the values attributed to the curvatures of individuals with no com-

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plaints of pain or diagnosis of physical problems, this can result in inadequate postural patterns being used as reference values. In addition, the studies that attribute values to curvatures and cut-off points to define postural patterns do not present tests for the diagnostic accuracy properties of these points. Thus, the objectives of the present study were: (1) to evaluate the spinal surface posture of asymptomatic young people in qualitative (normal, tendencies, and deviation postures) and quantitative (curvature indexes) ways in the sagittal plane; (2) to relate the qualitative to the quantitative evaluations, attributing reference scores to the postural patterns for normality, tendencies, and deviations; (3) to categorize the postural patterns; (4) to verify the discriminatory capacity of the scores of the postural patterns; (5) to evaluate the diagnostic accuracy of the scores of the postural patterns.

Subjects and methods

Participants: criteria for inclusion and exclusion

A total of 300 young people were evaluated; 180 asymptomatic individuals were selected (45 boys and 135 girls), aged 15–18 years, with a mean age of 16.1 (0.77) years and mean height of 1.65 m, to take part in the study, all from Florianópolis, Brazil.

The inclusion criteria involved age of 15–18 years, no complaints of pain, and no history of musculoskeletal injuries or cognitive, physical, or psychiatric problems that could prevent the subjects from taking part in the evaluation. The young people who agreed to take part in the study and signed the free and clarified term of consent for the research and whose parents or guardians also signed it were accepted for the study.

The exclusion criteria were as follows: physical health or cognitive problems which prevented the individuals from participating in the evaluation, as well as complaints of pain or musculoskeletal injuries which could alter the body posture at the moment of evaluation. Young people who did not sign the term of consent or whose parents or guardians did not sign it were also excluded.

Each participant (and legal guardian) received information about the objectives of the study and the form of participation (data collection procedure, associated risks, confidentiality information).

Procedures

The evaluations were carried out in the school environment in a room reserved for this purpose. The young people were first evaluated with respect to their anthropometric data and the inclusion and exclusion criteria. For the participants selection, before the postural evaluation, the individuals filled in a questionnaire which contained questions about the presence of musculoskeletal pain at the time of the evaluation. They were also questioned and evaluated for the existence of lesions and pathologies (strains, fractures, tendinopathies, or inflammatory/infectious processes, amongst others) that could interfere with the postural evaluation.

In sequence, marks were made on the following spinous processes: C2, C7/T1, T12/L1, and L5/S1, always by the same researcher (with 25 years of professional experience). The marking of bone processes presents adequate reliability [25, 26]. The young people were then filmed by using the Posture Evaluation Rotating Platform System [27], which includes a rotating platform, a camcorder (with a tripod), and a calibrator (Figure 1). During filming in the sagittal plane, the subject was asked to flex their elbows and join their hands in front of the chest, without changing their posture, to aid visualization of the outline of the curvatures. The participants were positioned standing on the rotating platform, which was switched. At the same time, the camcorder was switched on and vari-

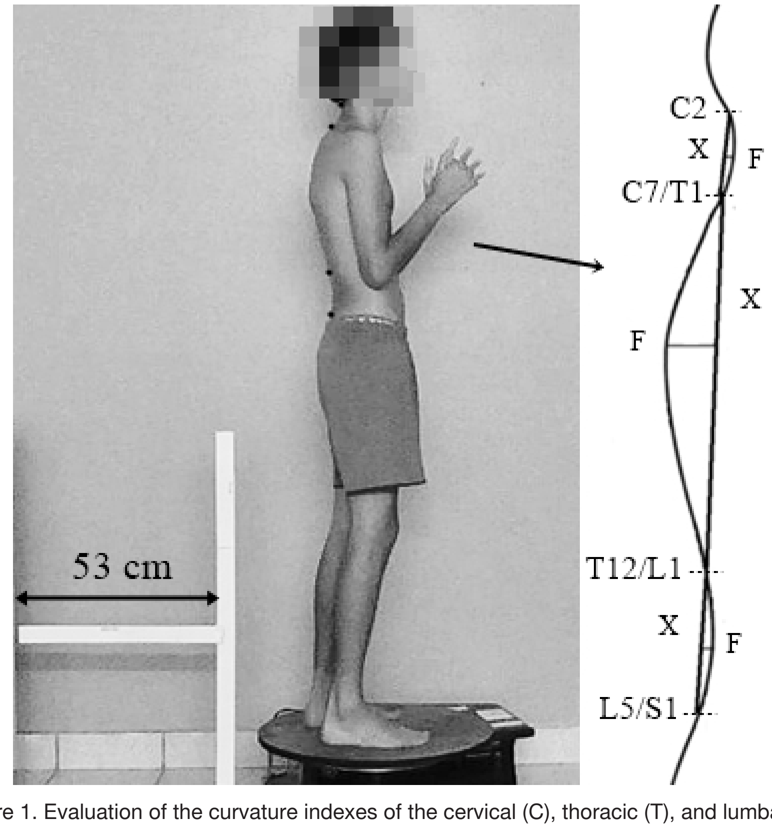

Figure 1. Evaluation of the curvature indexes of the cervical (C), thoracic (T), and lumbar (L) regions.
Curvature index = (F/X) × 100; 53 cm: measurement used to calibrate the system (x and y axes)

ous images of the subject were obtained. The system had been subjected to pilot studies, content validation, evaluation of its precision and reliability, and verification of the total number of images necessary to stabilize it [27].

Data analysis

The films were converted into frames by using the Kinovea® program, and 26 images of each subject in the sagittal plane were selected (13 on the right side and 13 on the left, practically in the same position to control the parallax) in order to calculate the curvature indexes (Figure 1) and allow for a qualitative analysis of the images by the evaluators.

Quantitative analysis

System calibration is an important step since it orientates the system with respect to the coordinates and real distances (important to provide real measurements for the x and y axes). In sequence, lines were created that joined the limiting vertebras of each region (cervical, thoracic, and lumbar), indicating the length of each curve (X), and other lines connecting the apexes of each curve to the straight line (X), representing the width of each curve (F) (Figure 1) – lengths all in centimetres. The curvature indexes were calculated with the following formula [22, 23]:

$$\text{Curvature index} = (F/X) \times 100$$

The curvature index values for each individual were obtained with the consideration of the average of the 26 frames [27].

Qualitative evaluation

The same images that were used in the quantitative evaluation were presented to 3 physiotherapists (each evaluator with a mean experience of 20 years), who had not taken part in the quantitative evaluation. The examiners analysed the postures of the individuals separately, classifying them as normal, inversion of the curve (kyphosis of the cervical or lumbar regions or lordosis of the thoracic region), rectified (flat back), tendency to rectification, tendency to hyperlordosis and hyperlordosis (cervical and lumbar regions), and tendency to hyperkyphosis and hyperkyphosis (thoracic regions). Each evaluator was blinded to the results of the other evaluators. Before carrying out the evaluations, the observers attended a meeting to standardize the procedures. Apart from the first meeting, they took part in another meeting to adjust the terminology used for the deviations.

Statistical analysis

A descriptive analysis of the data was obtained from the mean, standard deviation, standard error, and 95% confidence interval (CI) of the mean for the groups that presented normal, tendency, and deviation curves. Spearman's nonparametric correlation was used to analyse agreement between the evaluators. The one-way analysis of variance (ANOVA) test for independent samples served to compare the groups with reference to the alterations and/or normality presented. The test was applied to each spinal structure separately. The Bonferroni post-hoc test was used to analyse simple principal effects between limitrophe alterations, and other differences were only analysed when there was no difference between the limitrophe alterations. The mean difference and 95% CI were also calculated for the comparison between the groups, and an alpha level of 5% was adopted for all analyses. The analyses were carried out with the SPSS 17.0 software. The sensitivity, specificity, positive and negative likelihood ratios, and the predictive value of the reference intervals suggested [28, 29] were calculated by using the MedCalc 12.0 software to evaluate the diagnostic accuracy.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Committee of Ethics in Research of the Santa Catarina State University under the CAAE (Submission Certificate for Ethical Assessment) Process Number #35004014.4.0000.0118/2014.

Informed consent

Informed consent has been obtained from all individuals included in this study and their legal guardians.

Results

With respect to the qualitative evaluation, initially, the 3 evaluators agreed concerning the postural pattern in the cervical region in 102 young people (56.67%), in the thoracic region in 112 young people (62.22%), and in the lumbar region in 105 young people (58.33%). One should note that the more exacerbated and diminished curves presented a greater consensus amongst the evaluators, and that their greatest difficulty, as predicted in the preparatory meeting, was to evaluate what was normal (healthy). In the second meeting, the evaluators suggested the use of the term 'tendency' for those postural patterns where there were doubts as to whether they represented an adequate pattern or not. Table 1 shows the correlation amongst the evaluators before using the term 'tendency,' applied when the deviation was not pronounced.

After the meeting, the frames (images of the individuals) presenting inter-evaluator divergence were re-presented to the evaluators, and consensus was found between the 3 observers in most cases (except for 3 individuals in the cervical region, 2 in the thoracic region, and 3 in the lumbar region).

Table 1. Agreement between the evaluators with respect to the postural patterns

Observer	C normal (*r*)	C hyper/flat (*r*)	T normal (*r*)	T hyper/flat (*r*)	L normal (*r*)	L hyper/flat (*r*)
1 and 2	0.59	0.97	0.69	1	0.39	0.97
1 and 3	0.59	1	0.72	0.98	0.48	0.97
2 and 3	0.55	0.97	0.73	0.98	0.47	1

C – cervical, T – thoracic, L – lumbar, flat – rectification, r – Spearman's r
$p < 0.001$ between the evaluators for all regions

Table 2. Quantitative and qualitative comparison: curvature indexes and qualitative diagnoses

Parameter	Hyperkyphosis	Tendency for hyperkyphosis	Kyphosis	Rectification	Tendency for rectification	Normal	Tendency for hyperlordosis	Hyperlordosis
Cervical								
Mean ± *SD*			–3.82 ± 0.88	7.15 ± 2.85^{d,e}	10.55 ± 0.27^{b,e}	12.40^{n} ± 0.94^{c,d}	14.50 ± 0.36^{a,b}	19.33 ± 3.90^{a,c}
Standard error (95% CI: mean)	†	†	–	0.38 6.39–7.92	0.07 10.40–10.70	0.12 12.15–12.64	0.12 14.22–14.78	0.64 18.03–20.64
n (%)			2 (1%)	55 (31%)	15 (9%)	59 (34%)	9 (5%)	37 (21%)
Thoracic								
Mean ± *SD*	18.40 ± 2.70^{f}	14.58^{b} ± 0.27^{f,g}		7.95 ± 2.18^{h,i}	10.45 ± 0.36^{h,j}	12.56 ± 1.20^{g,j}		
Standard error (95% CI: mean)	0.32 17.75–19.04	0.07 14.42–14.74	‡	0.33 7.29–8.62	0.10 10.23–10.68	0.19 12.17–12.96	†	†
n (%)	70 (39%)	14 (8%)		44 (25%)	12 (7%)	38 (21%)		
Lumbar								
Mean ± *SD*			–4.31	7.69 ± 2.43^{n,o}	10.70 ± 0.24^{l,o}	12.24 ± 0.83^{m,n}	14.64 ± 0.30^{k,l}	20.46 ± 5.70^{k,m}
Standard error (95% CI: mean)	†	†	–	0.30 7.09–8.28	0.06 10.57–10.83	0.13 11.97–12.51	0.07 14.48–14.81	0.90 18.64–22.29
n (%)			1 (1%)	66 (38%)	16 (9%)	39 (22%)	15 (9%)	40 (23%)

Cervical: ^{a} hyperlordosis, ^{b} tendency for hyperlordosis, ^{c} normal, ^{d} rectification, ^{e} tendency for rectification
Thoracic: ^{f} hyperkyphosis, ^{g} tendency for hyperkyphosis, ^{h} tendency for rectification, ^{i} rectification, ^{j} normal
Lumbar: ^{k} hyperlordosis, ^{l} tendency for hyperlordosis, ^{m} normal, ^{n} rectification, ^{o} tendency for rectification
Negative values demonstrate that the curve was inverted. Letter pairs indicate paired differences.
† no deviation in this region, ‡ kyphosis in the thoracic region equal to normal

Non-consensual results were not considered in the statistical analysis of the qualitative evaluation to avoid compromising data normality. The data of individuals with kyphosis of the cervical and lumbar spinal regions were also removed from the analysis owing to the small number of participants.

Table 2 shows the patterns detected by the experts combined with the values obtained in the quantitative evaluation.

The statistical test revealed a significant interaction between the curvature index and the different diagnoses for all the structures evaluated ($p < 0.01$). For the cervical region, the curvature index for hyperlordosis was different from that for the tendency for hyperlordosis (mean difference [MD]: 4.83, 95% CI: 2.22–7.45, $p < 0.01$); the curvature index for the tendency for hyperlordosis was not different from that for normal, but presented a significant difference with respect to the tendency for rectification (MD: 3.95, 95% CI: 0.99–6.92, $p = 0.002$); the curvature index for normal was not different from those for the tendencies, but showed a significant difference with respect to the curvature index for hyperlordosis (MD: –6.94, 95% CI: –8.41 to –5.46, $p < 0.01$) and that for rectification (MD: 5.24, 95% CI: 3.93–6.56, $p < 0.01$); and, finally, the curvature index for the tendency for rectification exhibited a significant difference from that for rectification (MD: 3.40, 95% CI: 1.35–5.44, $p < 0.01$).

For the thoracic region, the curvature index for hyperkyphosis was different from that for the tendency for hyperkyphosis (MD: 3.82, 95% CI: 2.07–5.56, $p < 0.01$); the curvature index for the tendency for hyperkyphosis was different from that for normal (MD: 2.02, 95% CI: 0.15–3.88, $p = 0.02$); the curvature index for normal was different from that for the tendency for rectification (MD: 2.11, 95% CI: 0.13–4.09, $p = 0.03$); and the curvature index for the tendency for rectification was different from that for rectification (MD: 2.50, 95% CI: 0.56–4.44, $p = 0.003$).

With respect to the lumbar region, the curvature index for hyperlordosis was significantly different from that for the tendency for hyperlordosis (MD: 5.82, 95% CI: 3.12–8.52, $p < 0.01$); the curvature index for the tendency for hyperlordosis was not different from that for normal but was significantly different from that for the tendency for rectification (MD: 3.95, 95% CI: 0.74–7.15, $p = 0.006$); the curvature index for normal was not different from those for the tendencies, but showed a significant difference with respect to the curvature index for hyperlordosis (MD: –8.22, 95% CI: –10.23 to –6.21, $p < 0.01$) and that for rectification (MD: 4.56, 95% CI: 2.76–6.36, $p < 0.01$); and, finally, the curvature index for the tendency for rectification was different from that for rectification (MD: 3.01, 95% CI: 0.53–5.50, $p = 0.007$).

After stratifying the quantitative data in accordance with the qualitative evaluation and analysis of the descriptive distribution, cut-off points were suggested for the curvature index. Table 3 presents the respective diagnostic properties distribution of the descriptive data of the different groups and structures, and also a comparison of the groups concerning the qualitative diagnoses of the cervical, thoracic, and lumbar structures.

Discussion

The results showed that the curvature index values were different for the groups classified as normal, tendency, and deviation postures, determining diagnostics for the postural patterns of the spinal curvature surfaces in the sagittal plane.

The concern about the correct diagnosis of postural deviations in young people is justified by the need to plan the treatment and decrease the resulting musculoskeletal complications [7, 8]. When an individual maintains their spinal curvatures in the sagittal plane with adequate patterns, there is a better distribution of the loads on the vertebral structures and improved impact absorption capacity. In turn, changes in these curvatures cause an imbalance in the forces on the spine and can lead to injury [30].

Table 3. Cut-off intervals/scores suggested for the curvature index and their diagnostic measurements

Diagnosis	Cut-off intervals/scores	SEN (%) (95% CI)	SPE (%) (95% CI)	LR+ (95% CI)	LR– (95% CI)	PV+ (95% CI)	PV– (95% CI)
Cervical							
Kyphosis	≤ 0	100 (16–100)	100 (98–100)	x	0.0 (x)	100 (16–100)	100 (98–100)
Rectification	0.1–10	100 (94–100)	98 (94–100)	61 (15–241)	0.0 (x)	97 (88–100)	100 (97–100)
Tendency for rectification	10.1–11	100 (78–100)	99 (97–100)	162 (23–1143)	0.0 (x)	94 (70–100)	100 (98–100)
Normal	11.1–14	97 (88–100)	100 (97–100)	x	0.0 (0.0–0.1)	100 (94–100)	98 (94–100)
Tendency for hyperlordosis	14.1–15	100 (66–100)	100 (98–100)	x	0.0 (x)	100 (66–100)	100 (98–100)
Hyperlordosis	> 15	100 (91–100)	100 (97–100)	x	0.0 (x)	100 (91–100)	100 (97–100)
Thoracic							
Rectification	0–10	98 (88–100)	100 (97–100)	x	0.0 (0.0–0.2)	100 (92–100)	99 (96–100)
Tendency for rectification	10.1–11	100 (74–100)	100 (98–100)	x	0.0 (x)	100 (74–100)	100 (98–100)
Normal	11.1–14	97 (86–100)	100 (97–100)	x	0.0 (0.0–0.2)	100 (91–100)	99 (96–100)
Tendency for hyperkyphosis	14.1–15	100 (77–100)	100 (98–100)	x	0.0 (x)	100 (77–100)	100 (98–100)
Hyperkyphosis	> 15	100 (95–100)	98 (94–100)	54 (14–213)	0.0 (x)	97 (90–100)	100 (97–100)
Lumbar							
Kyphosis	≤ 0	100 (3–100)	100 (98–100)	x	0.0 (x)	100 (3–100)	100 (98–100)
Rectification	0.1–10	100 (95–100)	100 (97–100)	x	0.0 (x)	100 (95–100)	100 (97–100)
Tendency for rectification	10.1–11	100 (79–100)	99 (97–100)	161 (23–1136)	0.0 (x)	94 (71–100)	100 (98–100)
Normal	11.1–14	100 (91–100)	99 (95–100)	69 (17–273)	0.0 (x)	95 (84–99)	100 (97–100)
Tendency for hyperlordosis	14.1–15	100 (78–100)	100 (98–100)	x	0.0 (x)	100 (78–100)	100 (98–100)
Hyperlordosis	> 15	100 (91–100)	99 (96–100)	137 (19–966)	0.0 (x)	98 (87–100)	100 (97–100)

SEN – sensitivity, SPE – specificity, LR+ – positive likelihood ratio, LR– – negative likelihood ratio, PV+ – positive predictive value, PV– – negative predictive value, x – the calculation could not be carried out since some of the entered values included one or more zero instances

Some studies have provided reference values for postural patterns, but some left a void with respect to a definition of this parameter, since the lack of symptoms does not guarantee the absence of postural alterations [8, 17]. There can be errors in the diagnoses, classifying individuals with deviations as normal when based on reference values that use the mean or distribution of individuals without complaints or diagnosis of physical problems.

A support of consensus in the qualitative evaluation by examiners with considerable experience in classifying postural patterns was used in this study. Thus, the values for normal curvature were attributed to individuals with harmonious curves and the values for alteration to those with curvatures where the forces were distributed in an irregular way [2, 5]. As in previous studies, the sample was only made up of asymptomatic individuals [8, 17]; nevertheless, various postural alterations were detected, and about 90% of the sample presented some postural deviation in at least one region. There is evidence of an increase in postural deviations among young people over the last few decades [31] and this elevated prevalence has already been revealed in children younger than those investigated in the present study. A cross-sectional study with 637 Portuguese children aged 7–10 years determined postural deviations in the sagittal plane in 25.4% of these children [1]. Another more recent study with 257 Polish children aged 11–12 years using the Diers formetric III 4D optoelectronic method detected at least some deviation of the spine in the sagittal plane in 58.92% of these children [32]. These elevated postural deviation prevalence values imply a need for more studies to be carried out to accompany the evolution of these changes, their progression, and the consequences in young people and adults.

The present study, in addition to showing the relevance of identifying the appearance of postural changes, presented a way to categorize the postural patterns as adequate or as deviations (healthy or not) through the eye of experts. Scores were attributed to these postural patterns, which exhibited adequate capacity to detect and discriminate the different types of change in the spinal curvatures. This premise was ratified by the discriminatory capacity of the quantitative evaluation method applied, the use of groups with an appropriate number of cases being important. Despite the presence of many postural deviations, the prevalence of adequate postures was observed to be at least 20% in each region.

After dividing the groups in accordance with the qualitative evaluation, the curvature index values were significantly different between most of the limitrophe alterations. Only between the normal curvature index and those for the tendencies for the cervical and lumbar spinal regions were significant differences not found. These data, reinforced by the significant differences between the deviations and tendencies, could suggest that the tendencies belong to the classification of normal curves. On the other hand, the significant differences between the curvature index values for the tendencies for rectification and for hyperlordosis, as well as the discriminatory capacity of the cut-off points demonstrated that these postures were not part of the same behaviour, and considering them as normal postures could prevent the early detection of a postural deviation. Identifying tendencies is of clinical importance, since it can indicate the start of an injurious process with progressive consequences, and more studies are recommended to verify the distinction between the tendencies and normal postures. Although there was no significant difference between the groups cited above, the non-superimposition of the CI of the means allowed for the choice of cut-off intervals to serve as a guide during clinical evaluations. The suggested intervals were tested for their diagnostic properties and all presented values denoting high diagnostic power [28, 29] to identify individuals with and without alterations (sensitivity and specificity both close to 100%), adequate discriminatory probability (positive likelihood above 10 and negative likelihood below 0.1), and adequate predictive values with reference to the number of times the interval could identify subjects with alterations (positive predictive value) and subjects with no alterations (negative predictive value). Thus, on the basis of the adequate diagnostic properties, the cut-off intervals suggested could be used in evaluations as a guide to postural diagnoses.

Limitations

This study involved some limitations. The sample was small, only adolescents were included, and the analysis was carried out with the genders together. In some of the groups, the sample size could also have been limiting. However, considering that the sample studied was composed of asymptomatic individuals, each alteration occurred in a representative number, making it possible to characterize and distinguish the curvature index values. It should also be pointed out that the method used (surface evaluation) allowed one to detect the alignment of the body and its segments, and that the results of these evaluations only inferred the spinal position.

Conclusions

The quantitative evaluation of the curvature indexes showed discriminatory capacity between groups with different postural patterns, as categorized by the qualitative evaluation by experts. This categorization could aid researchers and clinical doctors in evaluating postural deviations.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Trigueiro MJ, Massada L, Garganta R. Back pain in Portuguese schoolchildren: prevalence and risk factors. Eur J Public Health. 2013;23(3):499–503; doi: 10.1093/eurpub/cks105.
2. Smith A, O'Sullivan P, Straker L. Classification of sagittal thoraco-lumbo-pelvic alignment of the adolescent spine in standing and its relationship to low back pain. Spine. 2008;33(19):2101–2107; doi: 10.1097/BRS.0b013e31817ec3b0.
3. Kratenová J, Zejglicová K, Malý M, Filipová V. Prevalence and risk factors of poor posture in school children in the Czech Republic. J Sch Health. 2007;77(3):131–137; doi: 10.1111/j.1746-1561.2007.00182.x.
4. Izzo R, Guarnieri G, Guglielmi G, Muto M. Biomechanics of the spine. Part I: spinal stability. Eur J Radiol. 2013;82(1):118–126; doi: 10.1016/j.ejrad.2012.07.024.
5. Adams MA, Dolan P. Spine biomechanics. J Biomech. 2005;38(10):1972–1983; doi: 10.1016/j.jbiomech.2005.03.028.
6. Vialle R, Ilharreborde B, Dauzac C, Lenoir T, Rillardon L, Guigui P. Is there a sagittal imbalance of the spine in isthmic spondylolisthesis? A correlation study. Eur Spine J. 2007;16(10):1641–1649; doi: 10.1007/s00586-007-0348-4.
7. Popova D, Mitova S, Gramatikova M. Research of innovative system abilities for postural analysis and postural disorders assessment. Act Phys Educ Sport. 2015;5(1):30–32.
8. Ghandhari H, Hesarikia H, Ameri E, Noori A. Assessment of normal sagittal alignment of the spine and pelvis in children and adolescents. Biomed Res Int. 2013;2013:842624; doi: 10.1155/2013/842624.
9. D'Osualdo F, Schierano S, Cisotti C. The evaluation of the spine through the surface. The role of surface measurements in the evaluation and treatment of spine diseases in young patients. Eur Med Phys. 2002;38(3):147–152.
10. Fedorak C, Ashworth N, Marshall J, Paull H. Reliability of the visual assessment of cervical and lumbar lordosis: how good are we? Spine. 2003;28(16):1857–1859; doi: 10.1097/01.BRS.0000083281.48923.BD.
11. Vrtovec T, Pernus F, Likar B. A review of methods for quantitative evaluation of spinal curvature. Eur Spine J. 2009;18(5):593–607; doi: 10.1007/s00586-009-0913-0.
12. Briggs AM, Wrigley TV, Tully EA, Adams PE, Greig AM, Bennell KL. Radiographic measures of thoracic kyphosis in osteoporosis: Cobb and vertebral centroid angles. Skel-

etal Radiol. 2007;36(8):761–767; doi: 10.1007/s00256-007-0284-8.
13. Tizabi AAT, Mahdavinejad R, Azizi A, Jafarnejadgero T, Sanjari M. Correlation between height, weight, BMI with standing thoracic and lumbar curvature in growth ages. World J Sport Sci. 2012;7(1):54–56; doi: 10.5829/idosi.wjss.2012.7.1.64109.
14. Roussouly P, Pinheiro-Franco JL. Sagittal parameters of the spine: biomechanical approach. Eur Spine J. 2011; 20(Suppl. 5):578–585; doi: 10.1007/s00586-011-1924-1.
15. Roobottom CA, Mitchell G, Morgan-Hughes G. Radiation-reduction strategies in cardiac computed tomographic angiography. Clin Radiol. 2010;65(11):859–867; doi: 10.1016/j.crad.2010.04.021.
16. Gstoettner M, Sekyra K, Walochnik N, Winter P, Wachter R, Bach CM. Inter- and intraobserver reliability assessment of the Cobb angle: manual versus digital measurement tools. Eur Spine J. 2007;16(10):1587–1592; doi: 10.1007/s00586-007-0401-3.
17. Mac-Thiong J-M, Labelle H, Berthonnaud E, Betz RR, Roussouly P. Sagittal spinopelvic balance in normal children and adolescents. Eur Spine J. 2007;16(2):227–234; doi: 10.1007/s00586-005-0013-8.
18. Been E, Kalichman L. Lumbar lordosis. Spine J. 2014; 14(1):87–97; doi: 10.1016/j.spinee.2013.07.464.
19. Somoskeöy S, Tunyogi-Csapó M, Bogyó C, Illés T. Accuracy and reliability of coronal and sagittal spinal curvature data based on patient-specific three-dimensional models created by the EOS 2D/3D imaging system. Spine J. 2012;12(11):1052–1059; doi: 10.1016/j.spinee.2012.10.002.
20. Fortin C, Ehrmann Feldman D, Cheriet F, Labelle H. Clinical methods for quantifying body segment posture: a literature review. Disabil Rehabil. 2011;33(5):367–383; doi: 10.3109/09638288.2010.492066.
21. Patias P, Grivas TB, Kaspiris A, Aggouris C, Drakoutos E. A review of the trunk surface metrics used as scoliosis and other deformities evaluation indices. Scoliosis. 2010; 5:12; doi: 10.1186/1748-7161-5-12.
22. Greendale GA, Nili NS, Huang M-H, Seeger L, Karlamangla AS. The reliability and validity of three non-radiological measures of thoracic kyphosis and their relations to the standing radiological Cobb angle. Osteoporos Int. 2011;22(6):1897–1905; doi: 10.1007/s00198-010-1422-z.
23. Harrison DE, Haas JW, Harrison DD, Holland B, Janik T. Sagittal skin contour of the cervical spine: interexaminer and intraexaminer reliability of the flexicurve instrument. J Manipulative Physiol Ther. 2005;28(7):516–519; doi: 10.1016/j.jmpt.2005.07.009.
24. Winter RB, Lonstein JE, Denis F. Sagittal spinal alignment: the true measurement, norms, and description of correction for thoracic kyphosis. J Spinal Disord Tech. 2009;22(5):311–314; doi: 10.1097/BSD.0b013e31817dfcc3.
25. Harlick JC, Milosavljevic S, Milburn PD. Palpation identification of spinous processes in the lumbar spine. Man Ther. 2007;12(1):56–62; doi: 10.1016/j.math.2006.02.008.
26. Hunt MA, Birmingham TB, Jenkyn TR, Giffin JR, Jones IC. Measures of frontal plane lower limb alignment obtained from static radiographs and dynamic gait analysis. Gait Posture. 2008;27(4):635–640; doi: 10.1016/j.gaitpost.2007.08.011.
27. Schwertner DS, Oliveira R, Mazo GZ, Gioda FR, Kelber CR, Swarowsky A. Body surface posture evaluation: construction, validation and protocol of the SPGAP system (Posture Evaluation Rotating Platform System). BMC Musculoskelet Disord. 2016;17:204; doi: 10.1186/s12891-016-1057-0.
28. Fritz JM, Wainner RS. Examining diagnostic tests: an evidence-based perspective. Phys Ther. 2001;81(9):1546–1564; doi: 10.1093/ptj/81.9.1546.
29. Jaeschke R, Guyatt GH, Sackett DL, Guyatt G, Bass E, Brill-Edwards P, et al. Users' guides to the medical literature. III. How to use an article about a diagnostic test. B. What are the results and will they help me in caring for my patients? JAMA. 1994;271(9):703–707; doi: 10.1001/jama.1994.03510330081039.
30. ElBayomi FEA, Ibrahim FF, Ibrahim MM. Corrective exercises specific for adolescent idiopathic scoliosis presented with bilateral leg pain: a case report describing an adaptive program and the recorded improvement as expressed by Cobb angle. Physiother Quart. 2020;28(4): 55–60; doi: 10.5114/pq.2020.96237.
31. Krawczky B, Pacheco AG, Mainenti MRM. A systematic review of the angular values obtained by computerized photogrammetry in sagittal plane: a proposal for reference values. J Manipulative Physiol Ther. 2014;37(4): 269–275; doi: 10.1016/j.jmpt.2014.01.002.
32. Wilczyński J, Lipińska-Stańczak M, Wilczyński I. Body posture defects and body composition in school-age children. Children. 2020;7(11):204; doi: 10.3390/children7110204.