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ORIGINAL RESEARCH

Validation of a topography system for evaluation spine in sagittal plane for children in different nutrient profiles

Validação de um sistema de topografia para avaliação da coluna vertebral no plano sagital de crianças em diferentes perfis nutricionais

Validez de un sistema de topografía para evaluación de la columna vertebral en el plano sagital de niños con distintos perfiles nutricionales

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ABSTRACT | The objective of this study was to determine the validity, repeatability and inter-evaluator reproducibility of the Vert 3D system in evaluating thoracic and lumbar curvatures of children with different nutritional profiles. A total of 115 children participated, which were divided into 3 groups: low weight and eutrophic, overweight, and obese. Each child underwent a panoramic radiography exam of the spine in right profile, from which we obtained Cobb angles for thoracic kyphosis and lumbar lordosis, in addition to being evaluated with the Vert 3D topography system, five times in the same day, immediately after radiological evaluation. Evaluations were conducted by three independent evaluators and provided the Vert angles for thoracic kyphosis and lumbar lordosis. Using the SPSS software, data were submitted to Pearson Product-moment Correlation Coefficient, Intra-class Correlation Coefficient, paired t-test and one-way ANOVA. Vert 3D system presented excellent levels of repeatability and inter-evaluator reproducibility, regardless of the nutritional profile evaluated, for angles of thoracic kyphosis and lumbar lordosis, but showed low correlation with Cobb angle for thoracic kyphosis and moderate correlation for lumbar lordosis. These results indicate that this system can be used in the clinical follow-up of postural alterations of spine in sagittal plane, of children with all nutritional profiles, but cannot be used as a means of diagnosis or for the purpose of estimating the Cobb angle.

Keywords | Reproduicibility of Results; Spine; Child.

RESUMO | O objetivo deste estudo foi verificar a validade concorrente, a repetibilidade e a reprodutibilidade interavaliador do sistema Vert 3D na avaliação das curvaturas torácica e lombar de crianças com diferentes perfis nutricionais. Participaram 115 crianças, divididas em três grupos: baixo peso e eutróficos, sobrepeso e obesos. Cada criança fez uma radiografia panorâmica da coluna vertebral na incidência perfil direito, de onde foram obtidos os ângulos de Cobb de cifose torácica e lordose lombar. Além disso, cada participante foi avaliada com o sistema de topografia Vert 3D cinco vezes no mesmo dia, imediatamente após a avaliação radiológica. As avaliações foram realizadas por três avaliadores independentes e forneceram os ângulos Vert de cifose torácica e lordose lombar. No software SPSS os dados foram submetidos ao Coeficiente de Correlação Produto-momento de Pearson, Coeficiente de Correlação Intraclasse, teste t pareado e ANOVA one-way. O sistema Vert 3D apresentou excelentes níveis de repetibilidade e reprodutibilidade interavaliador, independente do perfil nutricional avaliado, para os ângulos de cifose torácica e lordose lombar, mas apresentou correlação fraca com o ângulo de Cobb para cifose torácica

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e moderada para lordose lombar. Esses resultados sinalizam que esse sistema pode ser utilizado no acompanhamento clínico de alterações posturais da coluna vertebral no plano sagital de crianças de todos os perfis nutricionais, mas não pode ser utilizado como forma de diagnóstico ou com o objetivo de estimar o ângulo de Cobb.
Descritores | Reprodutibilidade dos Testes; Coluna Vertebral; Criança.

RESUMEN | Este estudio se propone a verificar la validez concurrente, la repetibilidad y la reproductibilidad interevaluadora del sistema Vert 3D en la evaluación de las curvaturas torácica y lumbar de niños con distintos perfiles nutricionales. Han participado del estudio 115 niños, y se los dividieron en tres grupos: bajo peso y eutróficos, sobrepeso y obesos. Cada participante realizó una radiografía panorámica de la columna vertebral en el lateral derecho, de la cual se obtuvieron los ángulos de Cobb de cifosis torácica y lordosis torácica. Además, a cada participante se les evaluaron con el sistema de topografía Vert 3D cinco veces al día, tras evaluarles radiológicamente. Las evaluaciones las realizaron tres evaluadores independientes, las cuales fornecieron los ángulos Vert de cifosis torácica y lordosis lumbar. En el *software* SPSS, se sometieron a los datos al coeficiente de correlación de Pearson, coeficiente de correlación interclase, prueba t pareada y ANOVA One-Way. El sistema Vert 3D presentó excelentes niveles de repetibilidad y reproductibilidad interevaluadora, independiente del perfil nutricional evaluado, para los ángulos de cifosis torácica y lordosis lumbar, en cambio, presentó una débil correlación con el ángulo de Cobb para cifosis torácica y moderada correlación para lordosis lumbar. Esos resultados apuntan que este sistema puede utilizarse en el seguimiento clínico de alteraciones posturales de la columna vertebral en el plano sagital de los niños de todos perfiles nutricionales, en cambio, no se lo puede como forma de diagnosticar o de proponer el ángulo de Cobb.
Palabras clave | Reproducibilidad de Resultados; Columna Vertebral; Niño.

INTRODUCTION

The vertebral column, in physiological conditions, consists of a succession of harmonious sagittal curves of opposite directions: lumbar lordosis, thoracic kyphosis, and cervical lordosis[1]. Alterations of curvatures in sagittal plane are characterized by increase or reduction of magnitudes of these curves and often there are reports of functional impairments associated with, for example, increased thoracic kyphosis and with reduction of lumbar lordosis. In several studies, increased thoracic curvature has been associated with the reduction of spine mobility[2], to the presence of back pain[3], and increased risk of fractures[4] and falls[5], in addition to causing reduced quality of life[2,6]; and increased mortality[7]. Reduction of lumbar lordosis has also been associated to the presence of lumbar pain[8], to higher risk of falls[9] and to reduction of quality of life[6].

Therefore, spinal evaluations have a relevant role, in clinical and school environment, as well as in research. Clinically, it assists in choosing treatment techniques, because the therapies are proposed based on the degree of curvature or progression of the same. In the school context, it is a screening tool for early detection of alterations, and, in research, evaluation of curvatures is fundamental so the effects of treatments in studies can be reported adequately[10].

However, tools of easy handling that enable quantifying sagittal curvatures of spine are scarce and not studied adequately[11]. To fill this gap, a three-dimensional scanning system was developed for topographic evaluation of dorsum, named Vert 3D. This system enables radiation-free examination and provides a three-dimensional view of the surface of the back, allowing to estimate the position of spine[12]. However, no reference was found indicating that this system has been submitted to validation procedures.

Importantly, in studies that use the surface of the back as reference for evaluation of spinal column, no mention has been found for anthropometric characteristics of the population under study, which, supposedly, comprises individuals within a range of normality[13-15]. Thus, as far as is known, the questioning about the validity of the noninvasive instruments for three-dimensional evaluation of spine in the population of individuals with overweight and obesity remains unanswered. Therefore, the objective of this study was to determine the concurrent validity, repeatability, and inter-evaluator reproducibility of the Vert 3D system version 1 in evaluating thoracic and lumbar curvatures of children with different nutritional profiles.

METHODOLOGY

Sample

Sample size was determined based on the study of Thometz et al.[16], assuming a 5% margin of error and confidence interval of 95%. Participants attended schools registered in a Family Health Strategy (FHS) of Porto Alegre, and those who had medical referral for panoramic Radiology exam of the spine were invited to participate in the study. They should meet the following inclusion criteria: chronological age from 6 to 13 years, conditions to remain in orthostasis, no history of spinal surgery, medical request for spinal radiography exam, and participate in five exams with Vert 3D. Initially, the study had the participation of 119 children, but there was loss of four: two due to radiological examination with poor positioning and two due to no completion of five exams with Vert 3D. Thus, the sample comprised 115 children, mean age 10.93±2.50 years, 53.9% (n=62) male, mean weight 42.5±14.5kg, and mean height 1.43±0.15 m.

The children were divided into three groups: 1) low weight and eutrophic; 2) overweight; and 3) obese. They were stratified according to the state percentage of children in these nutritional profiles[17].

This study was approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul, under number 19685 and was conducted according to Resolution No. 466/12 of the National Health Council. The children were included after agreeing to participate in the study and after their parents or guardians signed the informed consent.

Anthropometric evaluation

Measurement of mass and stature of the children, to calculate body mass index (BMI). BMI classification followed the international standard, stratified according to age[18].

Radiographic evaluation

Digital panoramic radiography exams of spine in right profile were conducted with children in orthostasis, with flexion of shoulder and elbows to avoid overlapping the humerus on the spine.

Based on the radiographs, Cobb angles were calculated in MATLAB® 7.9. To calculate thoracic kyphosis, we marked the upper vertebral plateau of T1 and the lower vertebral plateau of T12[19] and, to calculate lumbar lordosis, the upper vertebral plateau of L1 and the lower vertebral plateau of L5[20]. However, if the ends of the selected vertebrae were not clearly visible, the adjacent vertebrae above or below were used as alternatives to define the curvature angle.

All these calculations were carried out by two independent evaluators, and when the measures between the evaluators differed by more than five degrees, a third evaluator conducted a new evaluation.

Topographic evaluation

The children were positioned facing away from the Vert 3D equipment in orthostatic posture, with bare back, pending arms along the body, barefoot and positioned with the aid of a positioner (Figure 1A). We palpated and marked the spinous processes of the seventh cervical vertebra (C7) and of the second sacral vertebra (S2), as well as the posterior-superior iliac spines (PSIS) right and left.

These evaluations were performed by three independent evaluators, properly trained, and each child was evaluated five times on the same day, immediately after radiological evaluation.

Vert 3D system (Miotec Biomedical Equipment Ltda, Porto Alegre)

The system consists of a computer, a projector and a camera, coupled to a tower of adjustable height (Figure 1A), which projects a structured light pattern on the dorsum of individuals (Figure 1C). The image is captured and analyzed by the system, which generates a map of relief (Figure 1D) and a map of curvature (Figure 1E). Based on this information, the system provides the three-dimensional symmetry line (Figure 1B and 1E), which represents an estimate of the location of spinous processes. Based on the points of the symmetry line, the system calculates the inclination of the line portions between each two consecutive points (Figure 1B). The two largest inclinations calculated in each region of the spine will compose the Vert angle of the respective region.

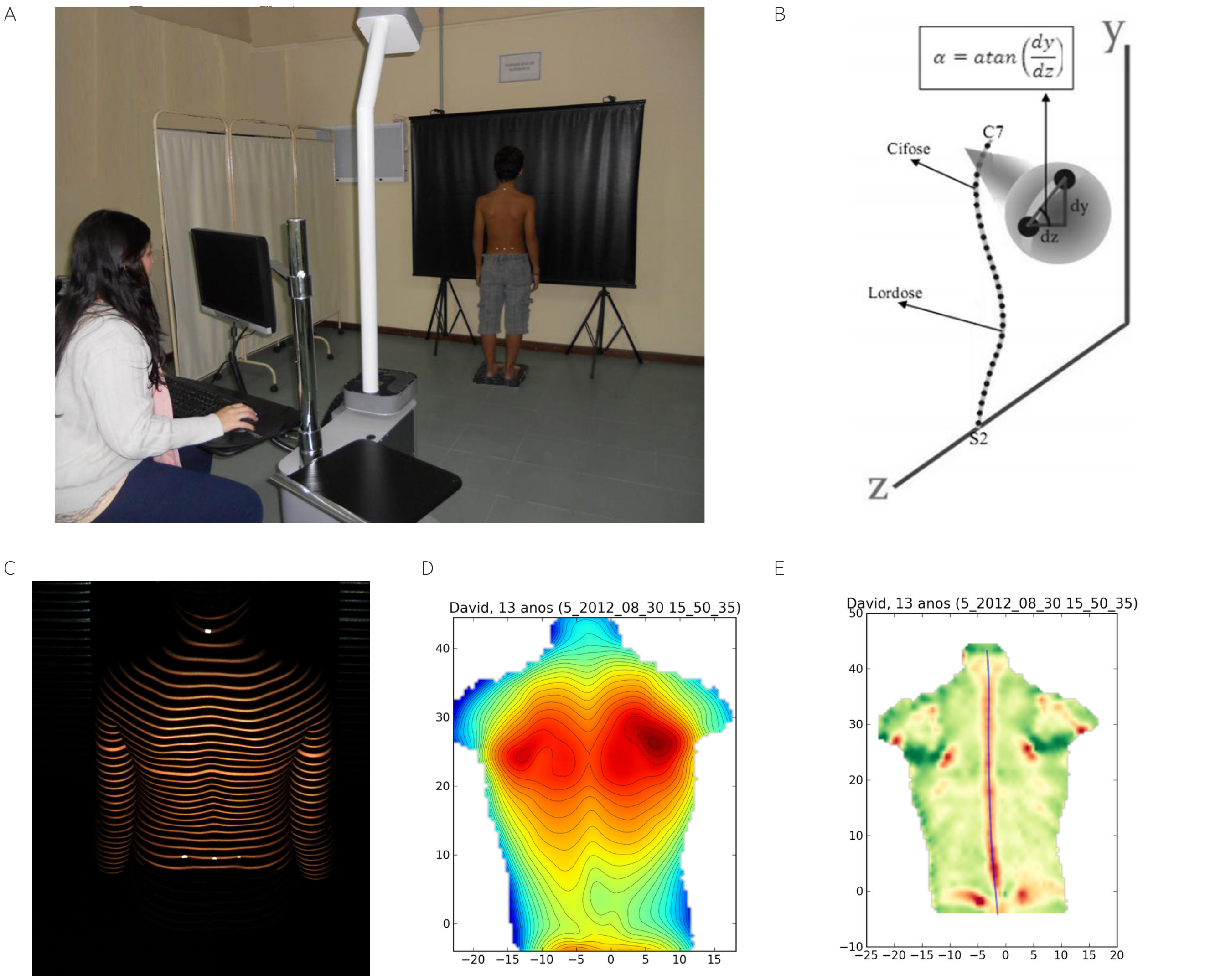

Figure 1. (A) Physical structure of the Vert 3D system and positioning of child to conduct postural evaluation; (B) representation of symmetry line analysis in sagittal plane to obtain Vert angles for thoracic kyphosis, with dy and dz being the measure in the vertical and antero-posterior axes, respectively; (C) image of fringe projection; (D) relief map; (E) curvature map with symmetry line

Statistical treatment

Performed in software SPSS 17, through descriptive data analysis, Intra-class Correlation Coefficient (ICC), Pearson Product-moment Correlation Coefficient (r), paired t-test, and one-way ANOVA. The significance level adopted was 0.05. To analyze the degree of agreement between the angles of Vert and Cobb we used the graphical method of Bland and Altman[21].

ICC values were classified as weak (ICC<0.40), moderate (ICC 0.4-0.75), and excellent (ICC>0.75)[22]. Values for r were classified as very low correlation (<0.2), low correlation (0.2-0.39), moderate correlation (0.4-0.69), high correlation (0.7-0.89), and very high correlation (0.9-1.0)[23].

RESULTS

When assessing BMI: the group composed of eutrophic or low-weight children (n=69) presented mean BMI of 17.8±2.3 kg/m^2; the overweight group (n=32), BMI of 22.6±2.2 kg/m^2; and the group classified as obese (n=14), BMI of 26.6±4.0 kg/m^2.

In evaluating the total sample, we obtained, for thoracic kyphosis, excellent repeatability (ICC 0.85-0.89; p<0.001) and inter-evaluator reproducibility (ICC=0.83; p<0.001). However, in evaluating concurrent validity, we obtained low correlation (r=0.30; p=0.001) and significant difference between Vert and Cobb angles (p<0.001). In evaluating lumbar lordosis, we obtained excellent repeatability (ICC 0.75-0.85; p<0.001) and inter-evaluator reproducibility (ICC=0.84; p<0.001), moderate concurrent validity (r=0.43; p<0.001), with no significant difference between Vert and Cobb angles (p=0.51). The graphical analyses of Bland and Altman[21] were performed only with the results from the evaluation of lumbar lordosis, since only this evaluation presented adequate levels of concurrent validity (Figure 2).

To evaluate the influence of BMI on the Vert 3D system measurement, we evaluated the system's repeatability (Table 1), inter-evaluator reproducibility (Table 2), and concurrent validity (Table 3). Vert system 3D presented excellent repeatability and inter-evaluator reproducibility of thoracic kyphosis for subjects with normal BMI or overweight, and moderate levels in obese subjects. However, the validity maintained weak levels in the normal and overweight nutritional profile, and moderate level in the obese nutritional profile. For the evaluation of lumbar lordosis, we obtained excellent levels of repeatability and inter-evaluator reproducibility, in addition to moderate level of validity for all nutritional profiles.

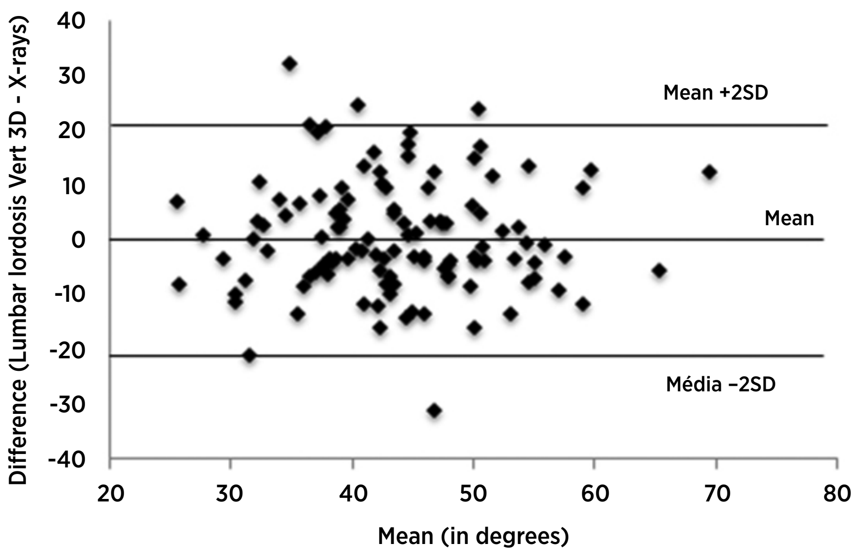

Figure 2. Graphical method of Bland and Altman between measures for lumbar lordosis obtained with Vert 3D system and x-ray exam, corresponding to the first measurement of evaluator A

Table 1. Vert 3D System results obtained in measurements of evaluators A and B, corresponding to repeatability of Vert angles for thoracic kyphosis and lumbar lordosis in the different nutritional profiles

Vertebral level	Evaluator A					Evaluator B				
	1st evaluation Mean±SD	2nd evaluation Mean±SD	p (t Test)	ICC (95%CI)	p	1st evaluation Mean±SD	2nd evaluation Mean±SD	p (t Test)	ICC (95%CI)	p
Normal BMI (n=69)										
Kyphosis (º)	44.3±8.3	45.0±9.0	0.239	0.848 (0.766–0.867)	<0.001*	44.6±9.0	45.4±9.2	0.195	0.877 (0.808–0.922)	<0.001*
Lordosis (º)	41.±8.7	42.8±10.2	0.331	0.795 (0.689–0.868)	<0.001*	41.6±9.7	40.8±9.4	0.279	0.806 (0.704–0.875)	<0.001*
Overweight BMI (n=32)										
Kyphosis (º)	45.5±10.2	45.1±8.8	0.608	0.915 (0.833–0.957)	<0.001*	45.7±9.7	45.0±8.7	0.390	0.880 (0.768–0.939)	<0.001*
Lordosis (º)	46.9±9.7	47.2±10.1	0.535	0.947 (0.894–0.974)	<0.001*	47.5±9.8	47.2±9.1	0.772	0.862 (0.736–0.930)	<0.001*
Obese BMI (n=14)										
Kyphosis (º)	50.8±9.1	49.3±10.4	0.510	0.658 (0.217–0.876)	0.004*	48.2±6.9	50.1±11.6	0.357	0.705 (0.299–0.895)	0.002*
Lordosis (º)	48.2±11.5	47.8±12.9	0.645	0.962 (0.886–0.988)	<0.001*	46.1±11.3	46.9±12.8	0.376	0.959 (0.878–0.987)	<0.001*

*Significative correlation

Table 2. Results from Vert 3D system obtained in measurements of three evaluators, as for inter-evaluator reproducibility of Vert angles for thoracic kyphosis and lumbar lordosis in the different nutritional profiles

Vertebral level	Evaluator A Mean±SD	Evaluator B Mean±SD	Evaluator C Mean±SD	p (Anova)	ICC (CI 95%)	p
Normal (n=69)						
Kyphosis (º)	44.3±8.4	44.6±9.0	43.8±9.2	0.846	0.821 (0.747–0.878)	<0.001*
Lordosis (º)	41.7±8.7	41.7±9.7	41.1±9.8	0.913	0.786 (0.702–0.854)	<0.001*
Overweight (n=32)						
Kyphosis (º)	45.5±10.2	45.7±9.7	45.2±10.1	0.977	0.872 (0.785–0.931)	<0.001*
Lordosis (º)	46.9±9.8	47.5±9.8	47.1±9.2	0.971	0.875 (0.789–0.932)	<0.001*
Obese (n=14)						
Kyphosis (º)	50.8±9.1	48.2±6.9	50.5±9.8	0.704	0.723 (0.465–0.890)	<0.001*
Lordosis (º)	48.2±11.5	46.1±11.3	48.7±12.3	0.822	0.909 (0.795–0.967)	<0.001*

*Significant correlation

Table 3. Correlations between Cobb angles and Vert angles in measurements of Evaluator A, for thoracic kyphosis and lumbar lordosis in the different nutritional profiles

X-rays	BMI Classification	Vert 3D Kyphosis		
		p (t Test)	r	p
Cobb Thoracic kyphosis	Normal (n=69)	<0.001**	0.25	0.036*
	Overweight (n=32)	0.136	0.38	0.032*
	Obese (n=14)	0.542	0.57	0.034*
		Vert 3D Lordosis		
		p (t Test)	r	p
Cobb Lumbar lordosis	Normal (n=69)	0.232	0.40	0.001*
	Overweight (n=32)	0.053	0.55	0.001*
	Obese (n=14)	0.064	0.60	0.024*

*Significant correlation; **Significant difference.

DISCUSSION

The main findings demonstrate that: 1) Vert 3D presented excellent repeatability and inter-evaluator reproducibility levels for evaluation of thoracic kyphosis and lumbar lordosis; 2) weak concurrent validity for thoracic kyphosis and moderate for lumbar lordosis; and 3) there was significant difference between the angles for thoracic kyphosis obtained with the Vert 3D system and with the radiographs.

Regarding the evaluation of curvatures in sagittal plane, the literature is scarce as to validation procedures for topography instruments, as many studies focus on evaluating the frontal plane. However, the studies that present these data corroborate the results of this study. Mohokum et al.[24], when using the Jenoptick Formetric system, also obtained excellent repeatability and inter-evaluator reproducibility for the angle of thoracic kyphosis and lumbar lordosis. Goh et al.[25], using the same system, reported ICC ranging from 0.98 to 0.99, for all thoracic kyphosis parameters measured.

The Milwaukee topography instrument presented excellent inter-evaluator reproducibility for thoracic kyphosis and weak inter-evaluator reproducibility for lumbar lordosis. However, in determining repeatability, we found lower levels for thoracic kyphosis, with correlation ranging from moderate to excellent and excellent for lumbar lordosis[26].

The Quantec topography system was also evaluated as for repeatability; however, only the standard deviation values of these measures were presented, and we observed standard deviation of ±4.2° for lumbar lordosis and standard deviation of ±3.6° for thoracic kyphosis[16]. However, these data are insufficient to demonstrate that this instrument presents repeatability. Furthermore, important questions concerning validation of the Quantec system have yet to be studied, since this technology presents no results as for its intra- and inter-evaluator reproducibility[27].

Even considering the clinical importance of the variables involved in a new instrument's validation process, such as repeatability and inter-evaluator reproducibility, we found no studies reporting these evaluations in sagittal plane for the other topography systems; therefore, a gap remains in the literature regarding these aspects of validity.

In analyzing the concurrent validity of Vert 3D system, we observed that there is correlation with x-rays; however, this correlation presents weak level for thoracic kyphosis and moderate level for lumbar lordosis. In Figure 2, it is observed that, in spite of the mean difference of 0.63° between the two evaluation methods and of the small number of individuals out of the limits of agreement, it is not possible to affirm that there is agreement between them, considering that the magnitude of the standard deviations presents a clinically important magnitude. Based on these results, it is suggested that the Vert 3D system should not be used to estimate the Cobb angle, not even in lumbar curvature.

There are few studies that investigate the concurrent validity of the topography methods in sagittal plane. Fortin et al.[28] reported high correlations between the InSpeck 3D digitizer system and radiographs in evaluating thoracic kyphosis and lumbar lordosis. Kovac and Pecina[29] also reported excellent correlation between the Moiré Topography system and radiological exams, in evaluating thoracic kyphosis. Importantly, in both studies the mean age of the individuals evaluated was 16.4 years (10 to 26 years) and 15.7 years (10 to 20 years), which is higher than that of those evaluated in this study, with mean age of 10.9 (6 to 13 years). Probably, physical characteristics, such as size and width of trunk, differ between the samples of the studies, which can be important factors in the evaluations, considering that the surface topography generates information based on fringe projections on the dorsum of the individual evaluated and, therefore, trunks with smaller size could hinder the system's analysis.

According to D'Osualdo et al.[30], agreement with x-rays is not the only relevant issue in surface measurements; on the contrary, reproducibility is at least as important, since only one method that allows for reproduction of its data can be used both in screening program and follow-up of changes over time and in evaluating the alterations produced by the treatment.

Thus, based on the results obtained in this study, it is possible to affirm that the Vert 3D topography system can be used for follow-up of thoracic and lumbar curvature, both by a single evaluator and by different evaluators, since it presents adequate repeatability and inter-evaluator reproducibility.

In evaluating the aspects of validation in the different nutritional profiles, we observed that the excellent levels of repeatability and inter-evaluator reproducibility are maintained for all profiles only for lumbar lordosis. For evaluation of thoracic kyphosis, excellent levels were obtained only for normal and overweight subjects, whereas moderate levels were obtained for obese subjects.

The only study found in the literature that conducted this type of analysis used the Jenoptic Formetric system and found no significant association between BMI and levels of repeatability and inter-evaluator reproducibility, which remained excellent for the normal group and for the overweight or obese BMI group[24]. However, in this study[24], the analyses were divided only into two groups (normal and overweight/obese), differently from this study, in which the three groups were analyzed separately. It is suggested that the fact of collectively analyzing the overweight and obese groups may have limited the study in determining the levels of repeatability and inter-evaluator reproducibility in the obese group.

Despite this small influence caused by obesity in the results for repeatability and inter-evaluator reproducibility, the Vert 3D system maintained levels ranging from moderate to excellent in all nutritional profiles; therefore, this instrument can be a good alternative for the evaluation of thoracic and lumbar curvatures in the cases of overweight or obese individuals, since it is automated, with no critical dependence on palpation of anatomical points, which may facilitate this type of evaluation. And, considering that currently there is an increasing number of individuals with body weight above the normal range, there is also a growing concern by health professionals, especially with regard to comorbidities associated with this condition. Within the scope of physiotherapy, taking into consideration the increase of overload on the musculoskeletal segments, the use of reproducible evaluation methods that also present conditions to analyze these individuals, as in the case of Vert 3D system, acquires importance. It is noteworthy that intra-evaluator reproducibility at different times was not evaluated. It is recommended that future studies organize the logistics of data collection so the participants are evaluated at different times with at least 24 hours of difference between each evaluation.

CONCLUSION

The Vert 3D System presented excellent levels of repeatability and inter-evaluator reproducibility for evaluation of thoracic kyphosis and lumbar lordosis, proving viable in the follow-up of the spine sagittal curvatures of children of all nutritional profiles, when utilized by different evaluators or by a single evaluator. However, it presented poor concurrent validity for thoracic kyphosis and moderate concurrent validity for lumbar lordosis; thus, to date, it is not possible to diagnose postural alterations using this system, not even to estimate the Cobb angle for thoracic kyphosis and lumbar lordosis. Therefore, it is suggested that the Vert 3D system can be utilized as an instrument to provide additional information concerning the positioning of the dorsal surface, aiding in the clinical follow-up; however, it presents no conditions of replacing the use of radiographic examination.

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