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Repeatability and reproducibility of a topographic system to evaluate the spine

Repetibilidade e reprodutibilidade de um sistema topográfico para avaliar a coluna vertebral

Repetibilidad y reproducibilidad de un sistema topográfico para evaluar la columna

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Abstract
Objective: This study aimed to determine the repeatability and reproducibility of a topographic system for evaluating the spine in students. Methods: Thirty-seven students participated in this study. Participants were positioned with their backs facing the system, in orthostatic posture, with bare backs. The spinous processes of the seventh cervical vertebra (C7) and second sacral vertebra (S2), and the right and left posterior superior iliac spine (PSIS) were marked. Each student was evaluated five times, once on the first day and four times on the second day. The following variables were used for evaluation: kyphosis angle, lordosis angle, trunk length, and anterior and lateral perturbations. SPSS 17.0 (IBM, Armont, NY, USA) was used for performing statistical analyses, which included descriptive analysis, Intraclass Correlation Coefficient (ICC), and one-way ANOVA, with a significance level of 0.05. Results: topographic system showed excellent values, and a positive correlation was observed with reference to the ICC of reproducibility and repeatability for all analyzed variables. Conclusion: These results show that this system can be used to diagnose postural changes, and to estimate thoracic kyphosis and lumbar lordosis angles. It can also be used for providing additional information on the positioning of the surface of the back.
Keywords: Kyphosis; Spine; Lordosis; Posture; Topography.

Resumo
Objetivo: Este estudo teve como objetivo determinar a repetibilidade e reprodutibilidade de um sistema de avaliação da coluna vertebral em escolares. Métodos: Trinta e sete alunos participaram deste estudo. Os participantes foram posicionados com as costas voltadas para o sistema, em postura ortostática, com as costas nuas. Os processos espinhosos da sétima vértebra cervical (C7) e segunda vértebra sacral (S2), e da espinha ilíaca posterior superior direita e esquerda (EISP) foram marcados. Cada aluno foi avaliado cinco vezes, uma no primeiro dia e quatro no segundo dia. As seguintes variáveis foram utilizadas para avaliação: ângulo da cifose, ângulo da lordose, comprimento do tronco e perturbações anterior e lateral. O SPSS 17.0 (IBM, Armont, NY, EUA) foi utilizado para a realização das análises estatísticas, que incluíram análise descritiva, coeficiente de correlação intraclasse (ICC) e ANOVA one-way, com nível de significância de 0,05. Resultados: O sistema de topografia apresentou valores excelentes, e foi observada uma correlação positiva com referência ao ICC de reprodutibilidade e repetibilidade para todas as variáveis analisadas. Conclusão: Esses resultados mostram que esse sistema pode ser usado para diagnosticar alterações posturais e estimar os ângulos da cifose torácica e da lordose lombar. Também pode ser usado para fornecer informações adicionais sobre o posicionamento da superfície das costas.
Palavras-chave: Cifose; Espinha; lordose; Postura; Topografia.

Resumen
Objetivo: Este estudo teve como objetivo determinar una repetibilidad y reprodutibilidad de un sistema de evaluación de la coluna vertebral en escolares. Métodos: Trinta e sete alunos participaram deste estudo. Os participantes foram posicionados com as costas voltadas para o sistema, em postura ortostática, com as costas nuas. Os processos espinhosos da sétima vértebra cervical (C7) e segunda vértebra sacral (S2), e da espinha ilíaca posterior superior direita e esquerda (EISP) foram marcados. Cada aluno foi avaliado cinco veceses, uma no primeiro dia e quatro no segundo dia. Como seguintes variáveis foram used for avaliação: ângulo da cifose, ângulo da lordose, comprimento do tronco e perturbações anterior e lateral. O SPSS 17.0 (IBM, Armont, NY, EUA) foi utilizado para a realização das análises estatísticas, que incluíram análise descritiva, coeficiente de correlação intraclasse (ICC) e ANOVA one-way, com nível de significância de 0,05. Resultados: O sistema de topografia apresentou valores excelentes, e foi observada uma correlação positiva com referência ao ICC de reprodutibilidade e repetibilidade para todas as variáveis analisadas. Conclusión: Estos resultados muestran que el sistema puede ser usado para diagnosticar alteraciones de la postura y estimar los ángulos da cifose torácica e lordose lombar. También puede ser usado para fornecer informações adicionais sobre o posicionamento da superfície das costas.
Palabras clave: Cifosis; Columna vertebral; Lordosis; Postura; Topografía.

1. Introduction

Problems related to posture and spine pain are becoming increasingly common in today's society. Such problems are observed more frequently in the economically active population, hampering individuals' social and professional performance (Azevedo et al., 2020; Mendonça et al., 2020; Moreira et al., 2017; Sampaio et al., 2016; Santos et al., 2017; Vitta et al., 2017). Dorsal kyphosis and lumbar lordosis are some of the postural changes observed (Sampaio et al., 2016; Santos et al., 2017; Vitta et al., 2017). Although problems related to postural changes are widespread, most studies use visual and qualitative postural evaluation for collecting and analyzing data (Barreto et al., 2018; Noll et al., 2012; Sampaio et al., 2016).

The gold standard method used for evaluating physiological curvatures of the spine and spine pathologies is X-ray. However, this method has some disadvantages, such as the patient's exposure to ionizing radiation and poor image quality, which can make it difficult to perform the assessment and analyze the images (Bacchi et al., 2013; de Oliveira et al., 2012; Furlanetto et al., 2012). In addition to being a high-cost examination (Sampaio et al., 2016; Santos et al., 2017; Vitta et al., 2017), which limits access for some individuals, X-ray can cause damage to the patient's health due to the frequent exposure to radiation (Teixeira & Carvalho, 2007).

Therefore, the development of new tools for evaluating the spine is relevant in the clinical environment, indicating the need to conduct further research on this subject. Studies need to evaluate the use of more sophisticated methods, such as computerized photogrammetry and topographic evaluations, as they provide accurate and quantitative information (Achour et al., 2013; Carneiro, 2014; Pivotto et al., 2019).

Clinically, the use of these systems is vital because they allow faster and less invasive evaluations (Iunes et al., 2009). Systems using three-dimensional scanning enable an adequate analysis, free of exposure to ionizing radiation. One such method, the topographic system, meets all these criteria, bringing greater benefit to users (Sedrez et al., 2016).

The results of efficiency analyses of new technologies indicate the most appropriate techniques for evaluation, which in turn would enable professionals to obtain more accurate results and to accordingly select the most appropriate treatment. Therefore, the present study aimed to validate the topographic system by evaluating its repeatability and reproducibility for evaluating the spine in students.

2. Methodology

We performed a cross-sectional study with a quantitative approach based on the methodology used by (Sedrez et al., 2016) and (Sedrez et al., 2019). The sample comprised 37 students aged 18 to 28 years (24 males and 13 females), who attended courses at the Ceres Campus of the Federal Institute Goiano (Instituto Federal Goiano) during the evaluation period.

The following inclusion criteria were used for selecting the participants: being enrolled in a higher education course; being able to remain in orthostasis without aid or pain, and naturally; being interested in participating in the project; and not having undergone spinal surgery.

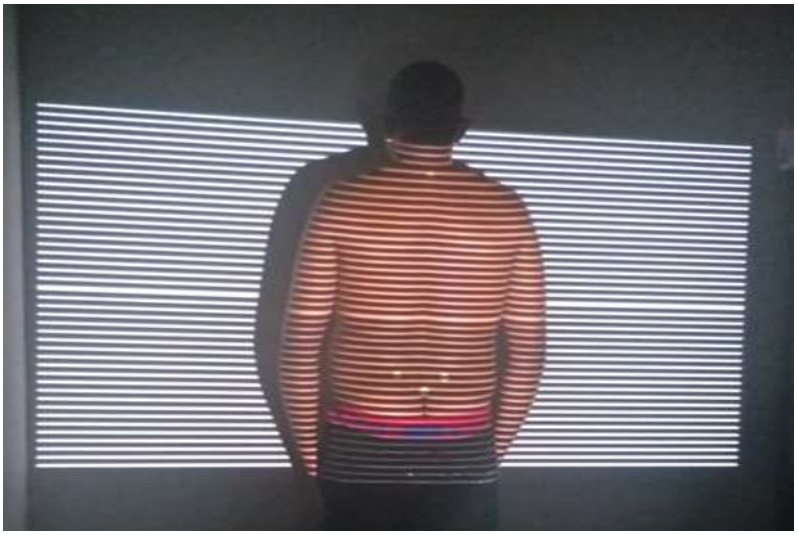
The project was approved by the Ethics and Research Committee of the Federal Institute Goiano (Opinion 35/2014). All the guidelines pertaining to conducting research with human subjects were followed. The researchers ensured that the confidentiality of personal data was maintained, that the study avoided embarrassment or harm to the participants, and that the obtained data were anonymized by using codes to represent participants' identifying information.

The study participants were subjected to a low degree of risk, considering that the data collection lasted only for a few minutes and the process was not invasive. Moreover, participants were free to choose to withdraw from the study at any point during the evaluation or data analysis period. The data will be stored for five years, after which they will be destroyed according to the instructions of the Resolution of the National Health Council (CNS 466/12).

Data Collection

The anthropometric evaluation consisted of measuring the body mass by using a weighing scale to assess weight and a tape measure to assess height, which were used to calculate the Body Mass Index (BMI). The BMI classification followed the standards described by (Cole, 2000). The topographic assessment was conducted using Vert 3D, with students being positioned as show in Figure 1.

Figure 1. Functioning of topographic system and student's positioning for postural evaluation.



Source: Authors (2019)

As can be seen, the students were placed in an orthostatic posture, with their bare backs facing the system, arms hanging down along the body, and bare feet. They were positioned using a positioner (Sedrez et al., 2016). The spinous processes of the seventh cervical vertebra (C7) and second sacral vertebra (S2), and the right and left posterior superior iliac spines (PSIS) were palpated and marked with adhesives.

Vert 3D system (Miotec Equipamentos, n.d.) is an interesting technology as it provides a three-dimensional view of the surface of the back, allowing evaluators to estimate spinal position, and enabling an examination free of exposure to ionizing radiation (Sedrez et al., 2016, 2017). Vert 3D provides a three-dimensional measurement of the back of patients with postural deviations. It uses a structured light projection to illuminate the patient's back while a camera captures the image from

another angle. The obtained three-dimensional surface is oriented towards the patient's body using adhesive markers previously applied to bone prominences identified by palpation **(**Figure 1**)** (Miotec Equipamentos, n.d.).

Repeatability and Reproducibility

The evaluations were conducted by a trained evaluator, and each student was evaluated five times, once on the first day and four times on the second day, with an interval of 7 days between the evaluation days. Reproducibility was determined by comparing results of the evaluation conducted on the first day with those obtained in the first evaluation conducted on the second day. This analysis was conducted one week (7 days) later. The results of the four evaluations conducted on the second day were used to calculate repeatability.

Values of the kyphosis angle, lordosis angle, trunk length, and anterior and lateral perturbations were obtained using the Vert 3D system. These variables were used for evaluating the reproducibility and repeatability of the evaluation system.

Statistical analysis performed using SPSS 17 included descriptive analysis, Intraclass Correlation Coefficient (ICC), and one-way ANOVA, with the significance level set at 5%. ICC values were classified as weak (ICC <0.40), moderate (ICC between 0.4 and 0.75), and excellent (ICC >0.75) (Guastala et al., 2016). The "*r"* values were classified as very low (<0.2), low (0.2 to 0.39), moderate (0.4 to 0.69), high (0.7 to 0.89), and very high (0.9 to 1) (Gaya, 2008).

3. Results

Participants (n=37) had an average BMI of 23.64±4.66 kg/m², and a mean age of 20.24±2.24 years. The sample comprised 24 males and 13 females.

Descriptive statistics were computed separately for Day 1 and 2 **(**Table 1). As mentioned earlier, one evaluation was conducted on Day 1, while four were conducted on Day 2. Means and ICCs were computed for each outcome variable (Table 2). Significant reproducibility (p<0.001) was found for kyphosis angle (ICC=0.850) and lordosis angle (ICC=0.822), and significant repeatability (p<0.001) was found for kyphosis angle (ICC=0.966) and lordosis angle (ICC=0.992).

Table 1. Topographic system results obtained from the evaluator's analysis on the reproducibility and repeatability of the vert angles of thoracic kyphosis and lumbar lordosis, trunk length, anterior and lateral perturbations in different nutritional profiles.

	Day 1 Evaluation 1	Day 2 Evaluation 1	Day 2 Evaluation 2	Day 2 Evaluation 3	Day 2 Evaluation 4
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Kyphosis angle	48.75 (9.84)	48.71 (8.58)	49.79 (8.76)	50.34 (10.33)	50.21 (8.45)
Lordosis angle	27.13 (10.15)	26.76 (10.87)	27.00 (10.51)	27.52 (10.72)	27.57 (10.83)
Trunk length	55.41 (9.49)	55.46 (8.84)	55.38 (8.51)	55.55 (8.74)	55.47 (8.72)
Anterior perturbation	5.00 (3.73)	4.44 (2.91)	4.64 (2.87)	4.74 (2.93)	4.37 (2.87)
Lateral perturbation	0.44 (1.27)	0.27 (1.40)	0.17 (1.53)	0.31 (1.53)	0.18 (1.30)

Source: Authors (2019).

Both reproducibility (ICC=0.847) and repeatability (ICC=0.997) of trunk length were significant. When evaluating anterior perturbation, reproducibility was ICC=0.786, and repeatability was ICC= 0.975, while in lateral perturbation, the reproducibility was ICC=0.856 and reproducibility was ICC=0.960. All findings were significant **(Table 2)**.

Table 2. Correlation between reproducibility measured on Day 1 and Day 2, and between the evaluations of repeatability performed on Day 2.

	Reproducibility Day 1 vs. Day 2		Repeatability Day 2 (Evaluation 1 vs. 2 vs. 3 vs. 4)	
	ICC	t-test	ICC	One-way ANOVA
Kyphosis angle	0.850*	0.967	0.966*	0.119
Lordosis angle	0.822*	0.783	0.992*	0.171
Trunk length	0.847*	0.963	0.997*	0.915
Anterior perturbation	0.786*	0.236	0.975*	0.267
Lateral perturbation	0.856*	0.290	0.960*	0.627

*Significant correlation. Source: Authors (2019).

4. Discussion

The results obtained with topographic system showed excellent levels of reproducibility and repeatability for all variables studied. Similar results were observed by (Sedrez et al., 2016) when evaluating the sagittal plane of children with different nutritional profiles using topographic system. These data support the efficacy of this instrument.

The ICC values for reproducibility obtained using topographic system were 0.850 and 0.822 for kyphosis and lordosis, respectively, in the present study, while (Sedrez et al., 2016) reported values of 0.821 and 0.786, respectively, in individuals with normal BMI. Regarding repeatability, the ICC values were 0.966 and 0.992 for kyphosis and lordosis, respectively, in the present study, while (Sedrez et al., 2016) reported values of 0.877 and 0.806, respectively.

The present results demonstrate that topographic system provided reliable results with low effective variations while evaluating students' spine profiles. Thus, topographic system emerged as an efficient system. Further, all values of repeatability were considerably high and within a desirable range, thus showing an excellent level of confidence in the system.

Chaise et al. (Chaise et al., 2011) acknowledged the importance of using repeatability as one of the parameters for evaluating the efficiency of a system considering its practicality and accuracy. Schmit et al. (Schmit et al., 2017) agreed with this statement, suggesting that excellent repeatability is indicative of efficiency of a system even if only one evaluation is performed.

High reproducibility is an important criterion for evaluating systems that fulfill a specific purpose. Borges et al. (Borges et al., 2019) support this statement in their study, where they evaluated a non-invasive system for monitoring blood pressure. They purported that the good reproducibility index obtained was indicative of the effectiveness of the system for hemodynamic monitoring. Similarly, in their study that evaluated a screening meter for assessing arterial hypertension, Bitencourt e Gottschall (Bitencourt & Gottschall, 2012) considered reproducibility as a parameter for validating an instrument.

Sedrez et al. (2019) used the Cobb method to measure lumbar lordosis in children, and they found excellent values when evaluating repeatability and reproducibility, showing that the efficacy of this method is comparable to that of topographic system. They also acknowledged the importance of experienced evaluators in obtaining reliable and efficient results.

The topographic system showed good results for all the variables analyzed in the present study, i.e., kyphosis angle, lordosis angle, trunk length, anterior and lateral perturbations. The reproducibility and repeatability of the assessment was confirmed, with significant results for repeatability, and ICC values above 0.95. These results suggest that this system can be

used to diagnose postural changes that may occur in the present sample, thus confirming the efficiency of this system in arriving at a preliminary diagnosis.

5. Final Considerations

In our study, the topographic system presented good results for all analyzed variables. Based on the discussion of the data and the bibliography consult, we can say that both the assessment was confirmed. Therefore, our objectives were reached and the system demonstrated that it can be used for the diagnosis of postural alterations in schoolchildren.

We hope that our study will support the development of new research in systems analysis and posture assessment procedures. We suggest carrying out future work that can analyze the reproducibility and repeatability of the topographic system in other target audiences. Furthermore, we encourage the development of studies that can compare the efficiency of different systems for different audiences.

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