ISSN 1413-3555
Rev Bras Fisioter, São Carlos, v. 13, n. 2, p. 103-9, mar./apr. 2009
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Evaluation of lumbar concavity using a radiographic method and kypholordometry

Avaliação da concavidade lombar pelo método radiográfico e pela cifolordometria

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Abstract

Background: Clinical evaluation is the basis for making decisions regarding treatments. When radiographic images cannot be obtained, few resources allow physical therapists to quantitatively evaluate an individual's condition. One of these is the kypholordometer, a low-cost noninvasive instrument proposed for measuring spinal curvature in the sagittal plane. **Objectives:** To evaluate the intra- and inter-examiner reliability of the kypholordometer, to investigate its agreement with radiography, and to determine whether there is any correlation between measurements of lumbar curvature using the radiographic method and the kypholordometer. **Methods:** Twenty healthy individuals of both sexes aged between 21 and 27 years were evaluated. They underwent radiographic examination of the lumbar spine in right lateral view while standing up. The radiographic images were evaluated by a radiologist using Cobb's method, with T12 and S1 as the reference points. The kypholordometry was carried out in the same position by three evaluators on two occasions, with the same vertebrae as the reference points. A straight line was drawn from T12 to the least prominent vertebra and another from S1 to the same vertebra, thus identifying the degree of lumbar concavity. **Results:** The results demonstrated that kypholordometry presented excellent levels of reliability (both intra- and inter-examiner), but low agreement with radiography. However, there was a statistically significant positive correlation between the two methods studied (r=0.88). **Conclusion:** Kypholordometry is a quantitative method with excellent intra- and inter-examiner reliability for evaluating lumbar curvature. It may contribute greatly towards the clinical practice of physical therapists.

Key words: evaluation; spine; radiography; posture.

Resumo

Contextualização: A avaliação clínica é a base para tomada de decisão referente ao tratamento. Quando não é possível obter a radiografia, poucos recursos permitem ao fisioterapeuta avaliar quantitativamente o estado do indivíduo, um deles é o cifolordômetro, um instrumento não invasivo, de baixo custo, proposto para mensuração das curvas da coluna vertebral no plano sagital. **Objetivos:** Avaliar a confiabilidade intra e interexaminador do cifolordômetro, verificar sua concordância com a radiografia e se há correlação entre a medida da curva lombar pelo método radiográfico e pelo cifolordômetro. **Métodos:** Foram avaliados 20 indivíduos saudáveis de ambos os sexos, com idade entre 21 e 27 anos. Os voluntários foram submetidos à radiografia da coluna lombar, incidência perfil direito e em ortostatismo. As radiografias foram avaliadas por um radiologista pelo método de Cobb, tendo como pontos de referência T12 e S1. A cifolordometria foi realizada no mesmo posicionamento e por três avaliadores em dois momentos, tendo como referência as mesmas vértebras. Foi traçada uma reta de T12 à vértebra menos proeminente e outra de S1 à mesma, identificando o grau de concavidade lombar. **Resultados:** Os resultados demonstram que a cifolordometria apresenta níveis excelentes de confiabilidade, tanto inter quanto intraexaminador, baixa concordância com a radiografia, porém há correlação positiva, estatisticamente significativa entre os dois métodos estudados (r=0.88). **Conclusão:** A cifolordometria apresentou-se como um método quantitativo, com excelente confiabilidade intra e interexaminador para a avaliação da curvatura lombar, podendo contribuir de sobremaneira para a prática clínica do fisioterapeuta.

Palavras-chave: avaliação; coluna vertebral; radiografia; postura.

Received: 17/12/2007 – **Revised:** 23/06/2008 – **Accepted:** 21/11/2008

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Introduction

Several methods to quantify body posture and spinal curvatures have been described in the literature. Among them, the radiography stands out as the "gold standard" for such evaluations. This method is also the most requested by medical professionals[1]. However, its application is not very common in the physical therapy clinical practice, either because the equipment is not available to the physical therapist or because not all health plans cover radiographic examinations. The most common procedure for measuring the angles of the spinal curvatures is Cobb's method, carried out by means of radiographic studies[2].

Radiographic examinations can have harmful effects on the body that may lead to somatic diseases such as cancer, leukemia, and even cataracts; it can also have genetic consequences, such as trisomy in newborns. In addition, the low-quality of the images often hinders examination analysis, and the procedure has to be repeated, which increases exposure to radiation and its consequences[3-5].

In a retrospective study, Levy et al.[6] observed 2039 adolescents with idiopathic scoliosis diagnosed through radiographic examination and reported that constant, small doses over months and years may take 20 years or more to show harmful effects on an individual. The subjects under study were observed over the course of 40 years, and later post-mortem examinations showed that the incidence of cancer was greater when compared to the general population.

To minimize the harmful effects of repeated radiographic examinations over a lifetime while keeping the changes in the spine under control, some techniques have been presented as noninvasive methods, such as: the pantograph, the DeBrunner kyphometer, the biophotogrammetry, the spondylometer, the flexible ruler, and the kypholordometer[1,7-12]. The kypholordometer was created by Baraúna and patented at the Instituto Nacional de Patentes Industriais (INPI) under protocol number PI 9905389-6[7].

The use of kypholordometry to evaluate spinal curvatures in different situations has been studied by various researchers. Adorno[11], using noninvasive methods such as biophotogrammetry and the kypholordometer carried out a study on the lumbar concavity of pregnant women and showed that both are precise methods of quantifying the angles of the lumbar concavity and those of the thoracic convexity. It must be noted that these instruments allow the professional to evaluate the lumbar and thoracic curvatures in order to observe the individual's response to interventions. Not only are these instruments noninvasive but they are also inexpensive and easy to use.

In another study, Baraúna et al.[7] tested the thoracic convexity of 30 subjects of both sexes aged 13 to 56, using the radiographic method and kypholordometry. The results showed that the measures obtained through the kypholordometer had a positive correlation with the radiographic examination, confirming the parallel, intra-examiner and inter-examiner reliability. The authors concluded that the kypholordometer is an efficient instrument for thoracic curvature measurement, and it can be used as often as necessary with no harm to the patient.

For the physical therapist, it is important to use noninvasive methods of evaluation because they provide planning and follow-up criteria for interventions[13]. Therefore, the aims of the present study were: to analyze the intra- and interexaminer reliability of the lumbar concavity evaluation using kypholordometry; to verify the agreement between the radiographic method and kypholordometry; and to determine whether there is a correlation between the lumbar curvature measured by the radiographic method and by kypholordometry.

Methods

The study was carried out at Centro Universitário do Triângulo (Unitri) after approval by the Research Ethics Committee of that institution under protocol number 650217.

Twenty-eight healthy subjects were evaluated, of which 8 were excluded due to the poor quality of the radiographic images. The following exclusion criteria for exclusion were also used: previous surgery or history of fracture of the spine, pelvis, or lower limb, spondylolisthesis, spondylolisis, scoliosis, sixth lumbar vertebra, history of neoplasy, multiparity, pregnancy or suspected pregnancy.

Thus, the sample for the study consisted of 20 individuals, all of them university students, including 7 men and 13 women, aged 21 to 27. The mean height was 1.68±0.10m and the mean weight was 68.26±11.60kg. All subjects were informed about the procedures and goals of the study before signing the consent form.

Kypholordometry

Kypholordometry is an evaluation method that uses an apparatus which consists of a vertical aluminum pole (39x58mm thick by 197cm tall) that supports 39 horizontal ¼-inch rods (40cm long). These rods are mobile, unbendable, equidistant and 4cm apart. The vertical pole is fixed on an orthostatic support platform lined with adjustable, non-slip material (73x56cm). There is also a level that allows corrections to the support platform, even when the floor is not completely flat. Attached to the pole, there is a lateral support made from acrylic to hold the sheet of paper where the analyzed curve is recorded[7].

To evaluate the lumbar curvature using the kypholordometer, palpation was necessary to identify spinous processes T_{12} to S_1. These vertebrae were chosen according to the criteria suggested by Stagnara et al.[3], Bernhardt and Bridwell[13], Korovessis, Stamatakis and Baikousis[14], and Vedantam et al.[15].Next, the subject was positioned on the kypholordometer with bare feet and trunk (except for the private parts), arms relaxed next to the body and gazing horizontally, as shown in Figure 1. After that, the points projected by the horizontal rods closest to T_{12} and S_1 and the least prominent point between them were marked on the recording paper, as observed in Figure 1. The subject then stepped off the kypholordometer and, after one minute, a second evaluation was carried out by the same examiner, following the same procedures. Thus, each subject was evaluated by three different examiners, each of whom executed the evaluation and the angle measurements twice. Once the three points had been recorded, a straight line was drawn from the top point to the least prominent point and another from the bottom point to the least prominent point. The angle formed by the intersection of these lines was measured at the vertex using the goniometer; thus identifying the degree of lumbar concavity (two-line method).

Radiographic examination

All subjects underwent the lumbar curvature radiographic examination, carried out by the same technician, on the same apparatus and evaluated by the same radiologist. Shea et al.[8] showed that errors are less likely to occur when the angle measurement by Cobb's method is taken by a single examiner. The position for the radiographic examination was standardized according to the criteria used by Propst-Proctor and Bleck[4], Bernhardt and Bridwell[13], Gelb et al.[16] and Leroux et al.[17] who recommend a right lateral radiograph, with a horizontal gaze, extended knees and parallel feet.

To measure the lumbar curve, Cobb's method was applied to the same vertebrae marked in the kypholordometer. The following lines were drawn: a parallel line below the T_{12} and another parallel line above the S_1. Perpendicular lines were drawn and their intersection was recorded (four-line method). The angle value was measured with a goniometer. The radiographic examination was analyzed by a radiologist who did not have access to the data obtained by kypholordometry. Thus, there was no mutual knowledge of the recorded values[4,7,14,16-20].

Statistical analysis

After descriptive analysis the information was processed in the computer package SPSS for Windows, version 13.0. The measures are presented as means and standard deviations. After applying the Kolmogorov-Smirnov test, it was observed that the data follow the normal curve. Thus, in order to check the reliability of intra- and interexaminer kypholordometry, the Intraclass Correlation Coefficient (ICC) was applied, where an ICC less than 0.4 indicates poor reproducibility; between 0.4 and 0.75, acceptable reproducibility; and greater than 0.75, excellent reproducibility.

To determine a single value for the analyses involving kypholordometry, we calculated the means of the two values for each examiner, and then the overall mean, that is, the mean of the values obtained by each of the three examiners. Next, to analyze the agreement between the kypholordometry and radiography measurements, we used the Bland-Altman method, as described by Rankin and Stokes[21]. It consists in

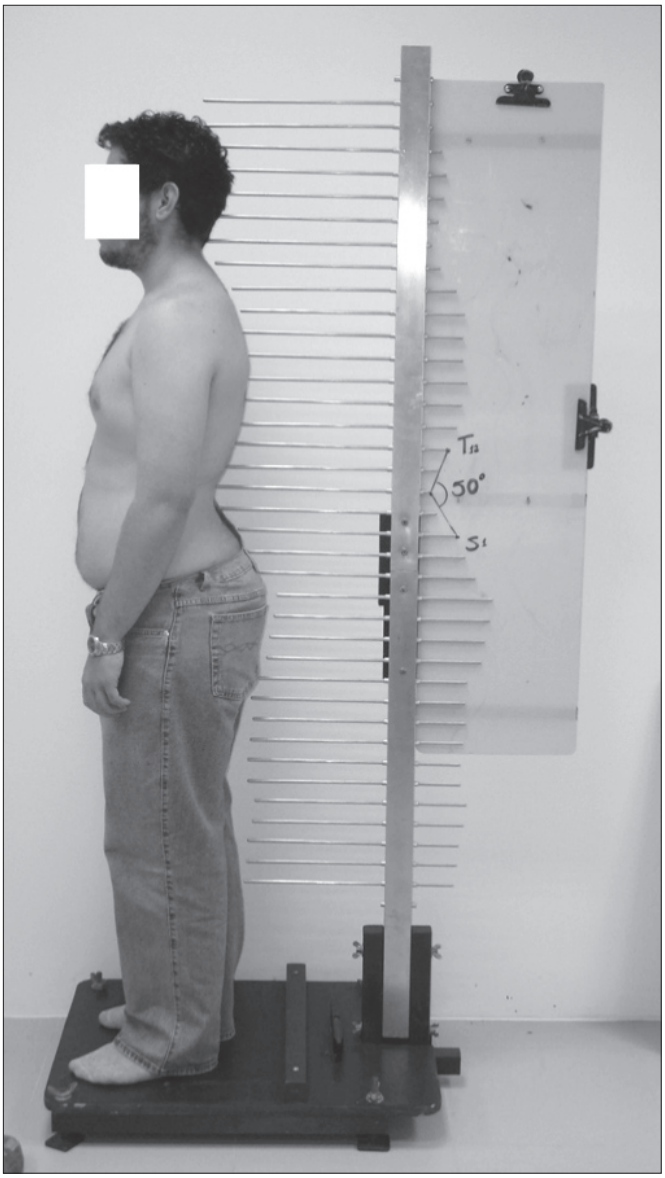

Figure 1. Kypholordometer - The subject's position and the demarcation of the most prominent points, regarding T12 and S1, and the least prominent points of the lumbar curvature.

graphically representing the differences of the measures in relation to their mean (where d=mean difference between the measures). A reliability interval of 95% was adopted. Pearson's correlation was applied to verify the existence of correlation between the lumbar curve measures as evaluated by kypholordometry and radiography.

Results

The 20 subjects evaluated had a mean age of 22.7±2.3 years and BMI of 21.2±2.3Kg/m^2. The mean lumbar concavity measured by kypholordometry was 19±8 degrees, and by radiography was 70.5±15 degrees. In the case of kypholordometry, the first examiner obtained a mean of 20±9.4 degrees in the first measurement and 19.6±8.6 degrees in the second. The second examiner obtained a mean of 19.2±10-degrees in the first measurement and 19±8.7 degrees in the second. The third examiner obtained a mean of 18.3±7.7 degrees in the first measurement, and 18.5±7.4 degrees in the second measurement.

In the reliability evaluation (reproducibility of the method) for all analyses, both intraexaminer (Table 1) and interexaminer (Table 2), the ICC showed very good coefficients, which shows the excellent reliability of the method of lumbar curvature evaluation through kypholordometry.

Table 1. Intraexaminer reliability for the first and second measurement of each examiner (ICC).

Analyzed variables	ICC	Reliability level
1st X 2nd measure - examiner 1	0.98	Excellent
1st X 2nd measure - examiner 2	0.97	Excellent
1st X 2nd measure - examiner 3	0.99	Excellent

Table 2. Interexaminer reliability (ICC).

Analyzed variables	ICC	Reliability level
1st measure - examiner 1 X 1st measure - examiner 2	0.94	Excellent
1st measure - examiner 1 X 1st measure - examiner 3	0.94	Excellent
1st measure - examiner 2 X 1st measure - examiner 3	0.89	Excellent
2nd measure - examiner 1 X 2nd measure - examiner 2	0.95	Excellent
2nd measure - examiner 1 X 2nd measure - examiner 3	0.98	Excellent
2nd measure - examiner 2 X 2nd measure - examiner 3	0.93	Excellent
1st measure - examiner 1 X 2nd measure - examiner 2	0.94	Excellent
1st measure - examiner 1 X 2nd measure - examiner 3	0.95	Excellent
2nd measure - examiner 1 X 1st measure - examiner 2	0.93	Excellent
2nd measure - examiner 1 X 1st measure - examiner 3	0.97	Excellent
1st measure - examiner 2 X 2nd measure - examiner 3	0.90	Excellent
1st measure - examiner 3 X 2nd measure - examiner 2	0.92	Excellent

As can be seen in Figure 2, the Bland-Altman plot[21] shows that there was a great dispersion in relation to the *y*-axis, indicating that there is a low agreement between the kypholordometry and the radiography data (d=5.4).

After analyzing the relationship between the lumbar concavity measurements by kypholordometry and the Cobb measurements by radiography, it was possible to detect a statistically significant correlation between the methods (r=0.88), as observed in the plot displayed in Figure 3.

Discussion

The results of the present study show that kypholordometry, the proposed method of quantitative evaluation of the lumbar curvature, showed high levels of intra- and interexaminer reliability and reproducibility. This is highly relevant to the physical therapist because it is important to use noninvasive quantitative methods of evaluation that provide criteria for intervention planning and follow-up[7,13].

The mean value found in the lumbar curvature evaluation by radiography was 70.5±15.2 degrees. This agrees with the values reported in the literature, which range from 35 and 90 degrees[22]. However, several studies on the sagittal alignment of the spine did not define normal lordosis; on the contrary, they

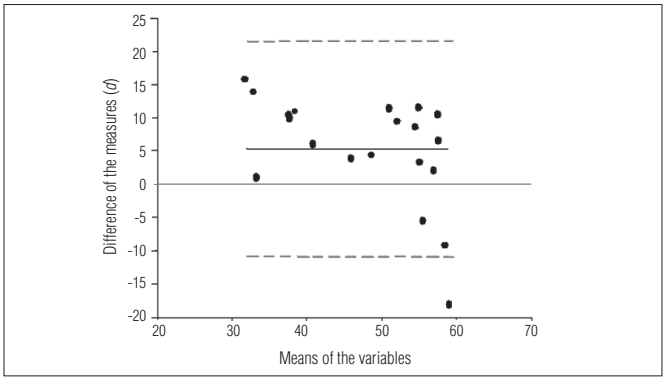

Figure 2. Agreement between kypholordometry and radiography measures - Bland-Altman plot.

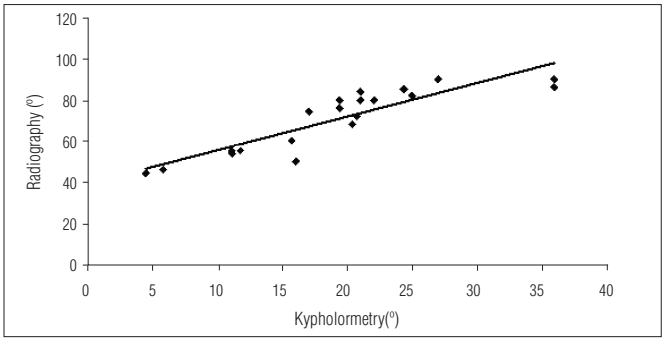

Figure 3. Relationship between the lumbar curvature measures by kypholordometry and radiography – Positive correlation.

are more concerned with the frequency distribution of these data in and between the groups being studied. Hence, it is difficult to set a standard of normal angles, either by kypholordometry or radiography[23,24].

The present study also evaluated the reliability of the measurements obtained in the lumbar curvature evaluation with the kypholordometer. The results show that the proposed method for lumbar curvature evaluation is reliable when carried out by a single examiner at different moments or by several examiners. Thus, the present work is in line with other studies on kypholordometry, which allows safe monitoring even when conducted by different examiners[7,11].

The low agreement observed when the Bland-Altman[21] agreement test was applied is due to the fact that these results may have been influenced by the angle evaluation method since Cobb's angle is drawn along the upper and lower edges of the vertebrae that limit lumbar curvature. After that, perpendicular lines are also drawn and their intersection is analyzed. This is the four-line method[19], which differs from the angular evaluation by kypholordometry that uses the two-line method. These two lines are drawn from the end points of the lumbar curvature to the less prominent point[7]; thus, the angle is defined by the vertex of that intersection. Due to this vertex-based analysis, the angle tends to be smaller, even when using the same vertebrae as a reference, which is easily understood when observing the means of the lumbar concavity evaluations. The mean for kypholordometry was 19±8 degrees, whereas the mean for radiography (Cobb's angle) was 70.5±15 degrees.

However, there is no reason to discredit the kypholordometry method because, despite the disagreement between the measures obtained by either method, there is a positive correlation between kypholordometry and the radiographic examination in the lumbar curvature evaluation, i.e. the greater the values obtained by kypholordometry, the greater the values obtained by the radiography, although not necessarily the same for each individual. In a similar study, Baraúna et al.[7] detected a significant positive correlation between kypholordometry and radiographic examination in thoracic concavity evaluation. The results also confirmed the parallel reliability of kypholordometry.

Ward and Tidswell[25] cite the spondylometer, a similar apparatus to the kypholordometer, although it only monitors the evolution of ankylosing spondylitis. The distances between the most prominent and the least prominent points are measured and recorded on paper. The spondylometer does not include a level and does not allow the measurement of spinal curvature because there is no acrylic lateral support to hold the recording paper such as the one used in kypholordometry to draw the evaluated curve and measure the angle. In addition, the spondylometer rods are 5cm apart, whereas the kypholordometer rods are positioned 4cm apart, which allows a greater proximity of the vertebrae to be examined, and therefore more precise angular measurements of the spine[7].

Oi et al.[26] developed an apparatus called posture-measuring device. It uses a system of wooden rods that move inside aligned metal tubes. The distance between the rods is small but not specified. The authors showed that this method is very similar to kypholordometry, although it has a serious limitation because its only purpose is visual evaluation and classification of the individual into four types of proposed postures, making it a subjective method. The authors claim that this method revealed postural deformity in older adults based on comparisons between radiographic examinations and the spinal outlines obtained with the posture-measuring device. However, the method does not evaluate that posture quantitatively, but only qualitatively.

After studying the reliability of the flexible ruler for lumbar curvature measurement, Hart and Rose[10] stated that noninvasive techniques for spinal evaluation in the sagittal plane characterize its shape, but may not be as precise as radiographic measurements. However, the radiographic examination may also present angle variations of up to 8 degrees, depending on the focus of the apparatus, time of the day, and radiologist interpretation[27].

Harrison et al.[28] compared the measures of the lumbar curvature by using Cobb's two-line method (one line was drawn parallel to and below the T_{12} body and another line parallel to and above the S_1 body) with the four-line method (four perpendicular lines are drawn starting from parallel lines). The intersection was recorded and Cobb's angle was measured. Compared to the four-line method, the two-line method had a smaller absolute difference and a greater correlation coefficient between examiners. Nevertheless, in clinical practice, there are instances where Cobb's two-line method cannot be used because the lines do not converge in the radiography itself, hence the preference for the four-line method, as carried out in the present study.

Radiographic examinations require a specialized team, including the technician who conducts the procedure, the doctor who reads the examination, and a professional who services the equipment. Investing on radiographic equipment is very costly and increases the cost of the examination for the patient. There is also the need for facilities with suitable internal lining of the walls[29,30].

Kypholordometry is easy to carry out, and the data are collected quickly and objectively. It is not necessary to recruit a multi-professional team to take the measurements, although there must be at least one trained examiner. The kypholordometer is an inexpensive apparatus, which requires little space. Once placed inside the clinic, it can be used whenever necessary to quantify the lumbar concavity

angle in evaluations and to monitor the progress of postural treatments, particularly in cases involving pathologies or provisional health conditions that do not allow radiography, such as pregnancy.

The use of kypholordometry offers immediate access to the results and low costs[7]. In contrast, it is a method that may result in variations in the measures collected by the examiners due to palpation, drawing and angle measurement method. These factors, however, are not restrictive when one considers the benefits the apparatus brings not only to the patient, but also to the physical therapist, who can rely on it as a primary clinical evaluation measure. In the event of substantial variations, the physical therapist can request a radiographic examination however the use of kypholordometry would avoid unnecessary exposure to radiation by the patient and the expenses related to radiography, given that most health plans do not cover radiographic examinations requested by the physical therapist.

This study corroborates the efficacy, simplicity and precision of kypholordometry as a method of lumbar curvature evaluation and leads to the conclusion that there is a correlation between the angular measurements by radiographic examination and by kypholordometry. Furthermore, kypholordometry allows quantitative evaluation of the lumbar curvature with excellent levels of intra- and interexaminer reliability.

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