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Original research

Evaluating the Validity and Reliability of Thoracic and Lumbar Curvature Measurements Using Image Processing Software (IPSO)

Kobra Soufi [1], Seyed Kazem Mousavi Sadati [2*], Abdolrasoul Daneshjoo [3]

1. *Department of Physical Education and Sport Sciences, East Tehran branch, Islamic Azad university, Tehran, Iran.*
2. *Department of Physical Education and Sport Sciences, East Tehran branch, Islamic Azad university, Tehran, Iran.*
3. *Department of Physical Education and Sport Sciences, East Tehran branch, Islamic Azad university, Tehran, Iran.*

ABSTRACT

The present study aimed to evaluate image processing software (IPSO) for physical abnormalities compared to standard Cobb measurements when measuring thoracic and lumbar curvature. This was a correlational study. The participants included 56 healthy male and female volunteers visiting the radiology centers at Firoozgar and Bahonar hospitals in Tehran with a mean age of 45.2±13.9 years, mean weight of 76.1±12.3 kg, mean height of 1.67±0.13 m, and mean body mass index (BMI) of 27.4 ± 5.7 kg/m^2. Before the study, the participants were briefed on the significance, purpose, and process, completed a medical-sports record questionnaire, and consented to participate in the study. Thoracic and lumbar curves were measured using radiography (the Cobb measurement) and image processing software. The results showed that the thoracic (ICC=0.65) and lumbar curve (ICC=0.61) measurement data obtained using the image processing method had moderate validity relative to the Cobb method. Moreover, lumbar (ICC=0.98) and thoracic (ICC=0.96) curves measured with the test-retest software had excellent reliability. The reliability of the thoracic and lumbar curve measurements using the two testers with the image processing software were respectively (ICC=0.91) and (ICC=0.84). The good to excellent reliability and moderate validity of thoracic and lumbar curve measurements using image processing software for physical abnormalities and its ease of use, lower cost, and more features mean that it can be used to examine thoracic and lumbar skeletal deformities.

Keywords: Validity, Reliability, Image Processing Software (IPSO), Cobb method

Corresponding Author: Seyed Kazem Mousavi Sadati, Department of Physical Education and Sport Sciences, East Tehran branch, Islamic Azad university, Tehran, Iran.. Email: drmousavisadati@gmail.com, Tell: +989126240125

INTRODUCTION

Skeletal deformities are an important factor in various musculoskeletal pain syndromes and can cause secondary discomfort and impair respiratory function, range of motion, muscle strength and endurance, and ultimately reduce the musculoskeletal system's efficiency and increase early spine fatigue (1). Meanwhile, thoracic kyphosis and lumbar lordosis are common spinal deformities, and measuring their curves is a routine stage of postural evaluation in corrective movements (2). Presently, radiography is the gold standard in spine on sagittal plane evaluation (3); but is unsuitable due to potential risks and high costs, especially in repeated measurements for preliminary diagnoses of spinal disorders (4). In clinics, radiography procedures are undesirable due to their high cost and risk of hazardous radiation (5, 6). Methods based on 3D imaging and sonography have their specific advantages and disadvantages (7). There are easier methods proposed for use in clinics, such as digital imaging (8), the Debroner Kyphometer (9), Body landmark Analyze (BLA) (10) and the spinal mouse (11).

Low back pain is one of the most frequent musculoskeletal disorders that affects different populations (12). Epidemiological studies suggest that 50 to 80% of people are likely to suffer from low back pain in their lifetime. In 2002, studies in the United States showed that with a frequency of 4.26%, low back pain was the most common pain reported by individuals in the final three months of the year (13). Several studies on low back pain treatment costs have estimated that in the United States, the total cost of low back pain treatment from 1997 to 2007 was $6.19 billion to $8.624 billion (13). This medical condition generally related to abnormality and deformity in vertebra. This deformity may seem insignificant, but it predisposes many lumbar, thoracic, and cervical spine disorders. Any visual change in a spinal musculoskeletal unit will extensively change the upper and lower areas, which means that lordosis is not independent (14). The most common cause of lower back pain is mechanical pain (strain, sprain, intervertebral disc herniation, etc.) (12).

In the sagittal view of the spine, there are two kyphotic (between the first and twelfth thoracic vertebra) and lordotic (between the lumbar's first and fifth vertebra) curves (15). As a children grow, stand, and walk, lumbar curvature increases until puberty, allowing the spine to transfer torso weight to the pelvis (16). Hyperlordosis is defined as an abnormal increase in the lumbar arch of >40° (17) that caused by internal factors such as vertebrae deformity, intervertebral disc, and sacrum, as well as external factors such as the center of gravity, body weight, and muscle strength (14), also this deformation can impair the postural balance and muscle function (18).

Early, accurate, and timely diagnoses of these disorders can help prevent, stop the progression, and correct musculoskeletal abnormalities. Examination and measurement of spinal curves are important to corrective movements and physiotherapy (4, 19). Moreover, the suitable treatment is often determined by curve extension or progression. The lumbar and thoracic curves are usually measured with various methods, and this measurements are valuable for planning of orthopedical surgical procedures, monitoring the progression and treatment of spinal deformities, and for determining reference values in normal and pathological conditions (20). Some methods include radiographic imagery, CT scan, and MRI (14, 21). Radiography is common, highly reliable, and valid but unsuitable for regular use because of radiation exposure and cost (22). The digital imaging method (photogram) and image processing of physical abnormalities is a new method that records images and detects specific body parts (landmarks) and uses mathematics and computer programming to examine the deviations of different body parts from the natural state (23). Physical abnormalities are diagnosed and evaluated using different software; and one such software registered in Iran for image processing of physical abnormalities is IPSO corrective exercises (24).

Research on the validity and reliability of image processing method of spinal deformities have been limited, and each have evaluated a specific software. Lerox et al. (2002), Yousefi et al. (2020), and Gheitasi et al. (2021) used the image processing method and reported its suitable validity (10, 25, 26). However, searching the databases of studies on the validity of results obtained from image analysis software, both in smartphones and in gold standard computer software, does not indicate consensus in measuring thoracic and lumbar curvature (27). Given the gap in research and the inconsistent results of studies on the validity of image processing software for physical abnormalities, further research on this method seems necessary (28). Since the X-Ray-based Cobb method is the gold standard, the present study seeks to check the validity and reliability of IPSO using the Cobb method.

METHODOLOY

Participants

This was a correlational study. In the present study, the statistical population consisted of 56 males and females aged 17 to 55 visiting the orthopedic and neurology clinics of Firoozgar Hospital in Tehran with moderate spine pain. Sample size was determined using GPOWER 3.1 according to the study, significance level of 0.05, effect size of 0.3, and test power of 0.75, as well as referring to the literature (1-4). The participants had a mean age of 45.2±13.9 years, mean weight of 76.1±12.3 kg, mean height of 1.68±0.13 m, and mean BMI of 27.4±5.7 kg/m^2. This study was conducted in the radiology centers of Firoozgar and Bahonar hospitals and the physiotherapy center in Tehran in July and August, 2021. Due to the Covid-19 pandemic, health protocols (using masks, gloves, and disinfectants) and social distancing were observed in all research stages to collect and measure the research variables. Also, the participants considered for this study received no rehabilitation or regular corrective movements for six months. Before the study, the participants were briefed regarding the significance, purpose, and process, and were assured that the study would not interfere or create any problems in the treatment process (5). Exclusion criteria included participants' dissatisfaction, acute and chronic illness, and musculoskeletal abnormality. The study protocol was approved by the Human Research Ethics Committee of Islamic Azad University under the IR.IUA.SRB.REC.1400.143 code of ethics.

This study determined the validity and reliability of open measurements methods through physical abnormality image processing software using three datasets: 1. The accuracy of lumbar and thoracic curves obtained by sagittal-level image processing was compared with measurements from radiological imaging using the Cobb method (ICC=0.98). ; 2. Inter-tester reliability was calculated according to lumber and thoracic angles using image processing software with two examiners and the same length of time. 3. Intra-tester reliability was obtained according to measurements obtained from lumber and thoracic angles using image processing software and one examiner in two different states with a one-week interval (5).

Lumber and Thoracic Measurement Process Using Image Processing Software for Physical Abnormalities

In this study, the anthropometric variables of participants, including height, weight, and body composition was measured first with minimal clothing and no shoes. Height was measured using the Seca 216 height measurement device (manufactured in Germany) with a 0.01 cm accuracy while standing next to a wall without shoes and normal shoulders. Body composition was evaluated using InBody 520 (manufactured in Korea). Then, the lumber and thoracic curves were measured using software (Fig. 1).

With this technique, the participants would stand comfortably and naturally with bare feet on the spot marked on the ground. They were asked to spread their legs shoulder-width apart and look ahead. The researcher then stood behind the participant to find the reference points behind T1, T12, and the most prominent thoracic vertebra, and T12, S2, and the most depressed lumbar vertebra. First the most prominent 7th cervical vertebra, was identified by lowering the neck, and the lower vertebrae, or T1, was marked. To determine L1 and T12, the fingers were pressed on both sides of the participant's waist above the pelvis to push aside the soft tissue (6). Then, the two vertical thumbs on the participant's back would mark the thorny appendage of the fourth lumbar vertebrae. Then, the L1 and T12 vertebrae were identified and marked by counting the vertebrae to the top (7).

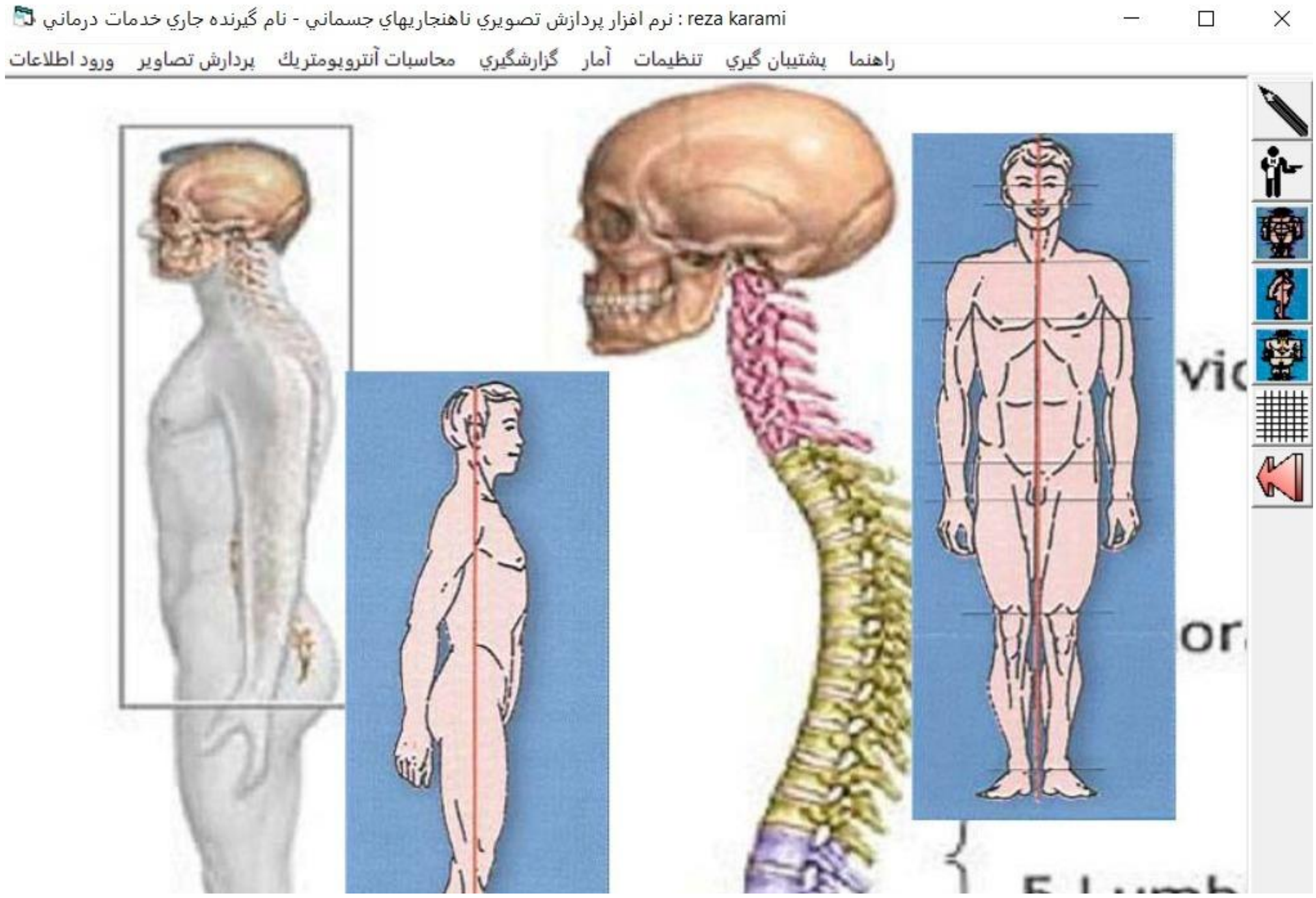

Fig. 1. Application Environment in Image Processing Software

To identify the S2 vertebrae, there are two indentations in the hip area corresponding to the posterior superior iliac spine, which the two indentations are connected to (6). The most prominent thoracic vertebrae and the most depressed lumbar vertebrae are identified visually. After determining these points and marking them (Fig. 2), the participant was asked to stand in front of the camera, taking into account the dimensions of the body until the whole body and spinal markers were placed in the camera frame, and hold their elbow in the Flexion position to clearly show the markers. The camera was mounted on a tripod with alignments on the sagittal and frontal plates, that it was possible to fasten and stabilize them on the ground. Also, the surface on which the camera and the subject were placed was completely flat and horizontal. The camera was mounted on a perfectly vertical tripod. In this position, the participants' image (The resolution of the images will be at a maximum level and the dimensions of the images will be 640 by 480 pixels) was captured with the markers and transferred to the software to measure lumber and dorsal angles. Image processing software for physical abnormalities-corrective movements has been registered by the research team of Mousavi et al. (2002) and has received a certificate of approval from Iran University of Medical Sciences. To prevent the complexification of image processing algorithms in later stages of measurement, it is necessary to take images with controlled lighting and background color (8). The following formula was used to calculate lumber and thoracic angles: $\theta = 4\mathrm{Arctan}2h/L$.

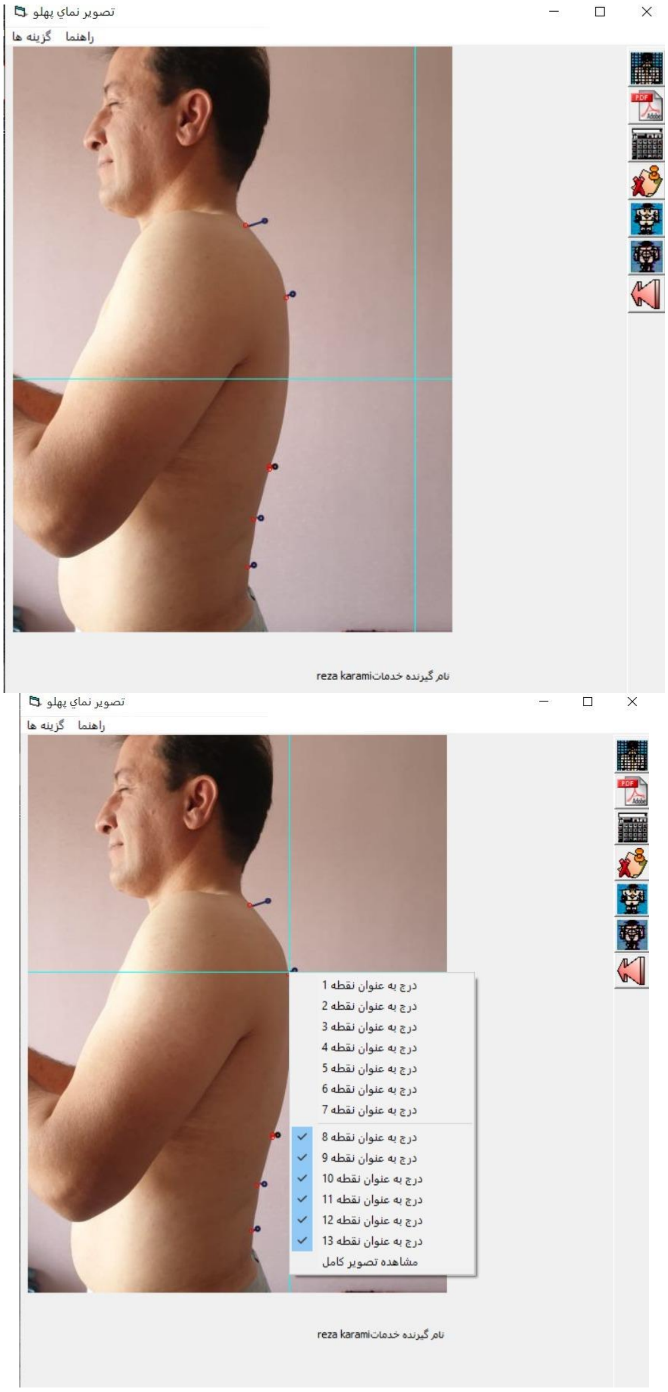

Fig. 2.point marked for calculating lumbar and thoracic curvatures

The Lumber and Thoracic Curve Measurement Using the Cobb Method

The lordosis and kyphosis curves were measured using the Cobb method with X-Ray (9, 10). First, the participant was asked to stand comfortably and naturally with bare feet on the cardboard marked with the foot position. To make all vertebral bodies visible to the lateral X-Ray, participants were asked to keep their hands somewhat in flexion from their shoulder (Fig. 3). The device would then capture the X-Ray image (9). In the lateral view of the spine on the radiographic image, tangent lines were drawn to the upper surface of the first thoracic vertebra (T1) and the lower surface of the twelfth thoracic vertebra (T12). Then a perpendicular line was drawn on each line to form an angle, which was measured at the intersection of the perpendicular line using the Cobb conveyor. To measure the lordosis cob angle, tangent lines were drawn on the upper surface of the first lumbar vertebra (L1) and the lower surface of the second sacral vertebra (S2) in the lateral view of the radiograph. Then, a vertical line was drawn on each of these two lines, and the angle formed at the intersection of the vertical lines was measured using a conveyor (11).

Fig 3. Radiographic image to assess lumbar and thoracic angles

Analysis Method of Research Findings

In this study, the natural distribution of data was first investigated using the Kolmogorov-Smirnov (K-S) test. The correlation between thoracic and lumbar angles was identified using the Pearson correlation test, mixed intra-class correlation coefficient (ICC) on absolute agreement was used to evaluate inter-tester and intra-tester reliability (12). The significance level of all statistical calculations is P≤0.05.

RESULTS

Before choosing standard static analyses method normality tests for all variables was performed. Table 1 shows the mean±SD of lumber and thoracic angles measured with image processing software and the Cobb technique. The results showed that the measured data of lumbar and thoracic angles with IPSO method have high validity when results of both methods showed acceptable correlation (table 2). The results showed that the thoracic (*r*=0.48) and lumbar (*r*=0.45) angles data measured with IPSO method had a significant relationship with the Cobb method. In addition, the measured data of lumbar (*r*=0.93) and thoracic (*r*=0.97) angles had test-retest reliability. Thoracic (r=0.79) and Lumbar (r=0.85) angles measured with image processing software had inter-tester reliability.

Table 1. Mean ± Standard Deviation of Participants' Lumber and Thoracic Curve Data According to the Cobb Method and Image Processing Software

	The Cobb method	First image processing	Second image processing	Second test image processing software
Thoracic curve	41.7±2.8	39.7±7.4	40.7±0.6	40.8±6.2
Lumber curve	47.9±8.2	44.7±6.8	44.7±8.6	41.9±9.3

The K-S test results showed the natural distribution of all data.

Table 2. Validity, Reliability, and Objectivity of Thoracic and Lumber Curve Measurements

Variable	Method	r Value	Significance Level	Correlation Coefficient	ICC Value	0.95 Confidence Interval	Significance Level

						Lower Limit	Upper Limit	
Thoracic Curve	Physical Abnormality Image Processing Software - Cobb Method	0.48**	P<0.001	0.23	0.65*	0.39	0.48	P<0.001
	Image Processing Software (Test-Retest)	0.97**	P<0.001	0.93	0.98***	0.99	0.98	P<0.001
	Image Processing Software (Two Testers)	0.85**	P<0.001	0.72	0.91***	0.85	0.95	P<0.001
Lumber Curve	Physical Abnormality Image Processing Software - Cobb Method	0.45**	P=0.001	0.20	0.61*	0.33	0.76	P<0.001
	Image Processing Software (Test-Retest)	0.93**	P<0.001	0.86	0.96***	0.94	0.97	P<0.001
	Image Processing Software (Two Testers)	0.79**	P<0.001	0.62	0.84**	0.63	0.92	P=0.015

*** Excellent Validity, ** Good Validity, * Moderate Validity

** Significance at the 0.01 level

According to the ICC estimation and 95% confidence interval, values less than 0.5, between 0.5 to 0.75, between 0.75 and 0.9, and over 0.90 were respectively indicative of poor, moderate, good and excellent reliability (12). Table 2 shows that all correlations are significant. According to the ICC values, the physical abnormality image processing software has moderate validity and good to excellent inter-tester and intra-tester reliability. The measured data of lumbar (ICC=0.98) and thoracic (ICC=0.96) angles have test-retest Excellent reliability. thoracic (ICC=0.84) and Lumbar (ICC=0.91) angles measured with image processing software had good to excellent inter-tester reliability. The thoracic (ICC=0.65) and lumbar (ICC=0.61) angles data measured with IPSO method had a moderate reliability with the Cobb method.

DISCUSSION

This study aimed to validate physical abnormality image processing software to measure the angle of thoracic and lumbar curvature compared to standard Cobb measurements. The results showed a significant correlation between the two measurement methods, and the ICC showed that the software had moderate validity compared to the gold standard Cobb method. To explain this finding, the Cobb and software methods use two computational methods to calculate the curves. As explained in Methodology, the Cobb method measures the lumbar and thoracic curves directly using a conveyor, whereas the software considers it as a slice of a circle and obtains the corresponding angle, and since the lumbar and thoracic curves do not exactly match the slice, the two methods produce different results. Grindel et al. (2020) evaluated the validity of flexible rulers and image processing techniques for measuring thoracic kyphosis versus standing radiographic measurements, and concluded according to the inter-class correlation (ICC) and the root mean square of errors (RMSEs) for radiographic and non-radiographic measurements that most non-radiographic estimates of kyphosis have poor to moderate reliability compared to radiographic measurement.These non-radiographic measurements can be applied to clinical practice or to clinical studies with recognition of specific limitations. (36). Gheitasi et al. (2021) evaluated the validity and reliability of digital imaging in determining thoracic hypokyphosis and lumbar hyperlordosis in Iranian adolescent girls and boys, and concluded that the digital imaging method had good validity and reliability in measuring thoracic and lumbar spine curvature, and specialists can use this method to reduce reliance on X-rays for the treatment of hypokyphosis and hyperlordosis (26). This discrepancy in research can be partly attributed to the interpretation of correlation findings, and partly to the fact that in digital imaging, thoracic kyphosis and lumbar lordosis curves are measured differently. In comparing with body land mark analyses method based on yousefi and et al (2020) present data of our study is in line with BLA method, and IPSO can be considered as a precise as the BLA, spinal mouse and flexible ruler in extracting the kyphosis and Lordosis angles (10).

The results of the present study showed that using posturography software to measure kyphosis and lordosis curves is highly reproducible and objective. This high validity and inter-tester and intra-tester reliability means that the proposed method is recommended for evaluating thoracic and lumbar curvature using spinal imaging software on the sagittal plane. Several researchers have also reported that photogram methods have high reproducibility and objectivity (10, 26, 37). However, some researchers have advised against the use of photogrammetric measurement data for research (38). It should be noted, however, that validity is more dependent on the tester's skills than the Cobb method. Currently, the radiographic method is the gold standard for measuring kyphosis and lordosis. However, it is also costly, time consuming, potentially hazardous, and has problems in repeated imaging, rendering it unsuitable (39). Since software image processing methods do not expose people to hazardous radiation and can easily calculate the kyphosis and lordosis angles with acceptable accuracy and repeatability using captured images, it is recommended as a fast, non-invasive, and economical method for more accurate measurement of the lumbar and thoracic curves. Due to these features, Penha et al. (2008) recommend using photogrammetry to analyze stature and apply early interventions (40). The use of image processing software for physical abnormalities also allows for re-evaluation of the entire spine without requiring the participant's presence, and provides a more complete image of the entire spine in relation to other structures. This provides an intelligent method for describing the abnormality, quantitative and qualitative analysis, and better evaluation of the entire spine compared to the Cobb method and other non-invasive instruments (10, 11).

However, like all studies, this research has limitations. Firstly, thoracic and lumbar kyphosis curves were obtained from the X-ray image at the T4-T12 level, while in the image processing software, it was obtained from T1-T12. Secondly, a physiotherapist manually measured the cob angle, which may reduce its accuracy. Therefore, it is recommended to calculate the Cobb kyphosis and lordosis curves from the image file using Dicom-eye (MAT-8).

CONCLUSION

The results showed that the image processing of corrective movements had moderate validity, whereas the reliability of test-retest and inter-tester objectivity of the software in evaluating thoracic and lumbar angles was excellent. Accordingly, image processing software for physical abnormalities can be used as a new and easy method of evaluating and imaging the curvature of the thoracic kyphosis and lumbar lordosis at the sagittal level in medical centers for corrective movements.

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چکیده فارسی

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کبری صوفی[1]، سیدکاظم موسوی ساداتی[2*]، عبدالرسول دانشجو[3]

۱.دانشجوی کارشناسی ارشد آسیب شناسی ورزشی، واحد تهران شرق، دانشگاه آزاد اسلامی، تهران، ایران.

۲.استادیار رفتار حرکتی، گروه تربیت بدنی و علوم ورزشی، واحد تهران شرق، دانشگاه آزاد اسلامی، تهران، ایران.

۳.استادیار بیومکانیک ورزشی، گروه تربیت بدنی و علوم ورزشی، واحد تهران شرق، دانشگاه آزاد اسلامی، تهران، ایران.

هدف تحقیق حاضر اعتبارسنجی نرم افزار پردازش تصویری ناهنجاری جسمانی (آی پی سو) برای اندازه گیری زاویه انحنای قفسه سینه و کمر در مقایسه با اندازه گیری‌های بدست آمده از روش‌های استاندارد کاب بود. تحقیق حاضر از نوع همبستگی بود. شرکت‌کنندگان ۵۶ نفر مرد و زن سالم مراجعه کننده به مراکز رادیولوژی بیمارستان‌های فیروزگر و باهنرتهران، با میانگین سنی ۱۳/۹± ۴۵/۲ سال، وزنی ۱۲/۳±۷۶/۱ کیلوگرم، قد ۰/۱۳±۱/۶۷ متر و شاخص توده بدنی ۵/۷±۲۷/۴ کیلوگرم برمترمربع بودند که به طور داوطلبانه در تحقیق حاضر شرکت نمودند. قبل از شروع مطالعه آزمودنی‌ها در یک جلسه توجیهی از اهمیت، هدف، روند اجرای کار آگاه شدند، همچنین از طریق پرسشنامه سوابق پزشکی-ورزشی مورد ارزیابی قرارگرفتند و رضایت نامه شرکت در تحقیق از آن‌ها اخذ شد. زاویه های پشتی و کمری با استفاده از عکس رادیوگرافی (روش کاب) و نرم افزار پردازش تصویری اندازه‌گیری شد. نتایج تحقیق نشان داد که داده‌های اندازه‌گیری شده زاویه پشتی (ICC=۰/۶۵) و زاویه کمری(ICC=۰/۶۱) با روش پردازش تصویری در مقایسه با روش کاب، از روایی متوسط برخوردار است. علاوه‌بر این زوایای پشتی (ICC=۰/۹۸) و کمری(ICC=۰/۹۶) اندازه‌گیری شده به روش آزمون- آزمون مجدد با نرم افزار از پایایی عالی برخوردار است. پایایی زاویه پشتی، و زاویه کمری اندازه گیری شده توسط دو آزمونگر با نرم افزار پردازش تصویری به ترتیب(ICC=۰/۹۱) و (ICC=۰/۸۴) بود. به نظر می رسد با توجه پایایی خوب تا عالی و روایی متوسط اندازه‌گیری قوس‌های پشتی و کمری با نرم افزار پردازش تصویری ناهنجاری‌های جسمانی،آسان بودن کار با نرم افزار، هزینه کمتر و حتی امکانات بیشتر، می توان از آن برای ارزیابی ناهنجاری های اسکلتی پشت و کمر استفاده کرد .

واژگان کلیدی: روایی، پایایی، نرم افزار پردازش تصویری، روش کاب