Research Paper: The Validity and Reliability of Kinovea Software in Measuring Thoracic Kyphosis and Lumbar Lordosis

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ABSTRACT

Objectives: The present study evaluated the inter-rater and intra-rater validity and reliability of posturography by Kinovea software to measure the thoracic kyphosis and lumbar lordosis.

Methods: Eighteen subjects (10 females & 8 males) referring for radiographic imaging were included in this cross-sectional study. For evaluating the validity, the thoracic kyphosis and lumbar lordosis were measured according to the Cobb method and Kinovea in standing position. The inter-rater and intra-rater reliability of Kinovea were tested by 3 evaluators and one expert evaluator, respectively.

Results: Pearson correlation coefficient data suggested that the validity of measuring the thoracic kyphosis depends on the evaluator's expertise. Besides, the correlation was not significant in measuring the lumbar lordosis angle (P>0.05). The inter-rater and intra-rater repeatability revealed that the correlation was significant in all angles by the intraclass correlation coefficient (P<0.001).

Discussion: Posturography by Kinovea, as a noninvasive method presents an excellent inter-rater and intra-rater repeatability for measuring thoracic kyphosis and lumbar lordosis. This reliable method is simple, efficient, and inexpensive.

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Highlights

- Kinovea is clinically suitable for evaluating thoracic kyphosis.

- The inter-rater and intra-rater reliability of Kinovea were measured to be high.

- Kinovea is inexpensive and safe to evaluate kyphosis and lordosis.

Plain Language Summary

Evaluating thoracic kyphosis and lumbar lordosis in all age groups is important to diagnose and treat musculoskeletal problems. The standard method of evaluation is radiographic imaging, which can be harmful on multiple radiographs. Using a simple camera and free Kinovea software for such evaluations is simple and low-risk. In this method, side photos were taken and the angle of thoracic kyphosis and lumbar lordosis were evaluated by Kinovea software by 3 testers with different skill levels. The present study results suggested that this method is suitable for evaluating thoracic kyphosis. Besides, the evaluation results of all 3 testers were the same and reliable.

1. Introduction

The spinal structure is usually evaluated to help guide the diagnosis and treatment of musculoskeletal problems [1]. Thoracic kyphosis and lumbar lordosis are commonly evaluated when examining the spinal condition. Changes in the normal angle of thoracic kyphosis and lumbar lordosis are the most frequent spinal abnormalities [2]. Excessive kyphosis has been associated with musculoskeletal complaints, such as shoulder [3], cervical [4], and back pain [5], an increased risk of fracture [6], and impaired respiratory function [7]. Several studies signified a decreased lumbar lordosis angle as a leading cause of low back pain [8, 9], increased risk of falls [10], and reduced Quality of Life (QoL) [11].

The accurate, early, and timely identification of these abnormalities can prevent, stop progression, and correct musculoskeletal disorders. The assessment and measurement of spinal curvatures are significant factors in corrective exercises and physiotherapy treatments. Moreover, the extent of curvature or progress usually determines the appropriate treatment method [12]. Measuring the angles of thoracic and lumbar curvature is possible using various invasive and non-invasive methods [13, 14]. Some invasive methods include radiographic images, Computerized Tomography (CT) scans, and Magnetic Resonance Imaging (MRI) [14]. The gold standard for evaluating the spinal curvature is using radiographs and the Cobb method [13, 14]. Although this method is more reliable for assessing the spinal curvature, it is not especially suitable (due to its high cost, and radiation exposure) in pregnant women [15]. Studies suggested that

this method increases prostate cancer risk in men [16] and breast cancer in women [17].

There exist several non-invasive methods for measuring the angle of thoracic kyphosis and lumbar lordosis. The validity of the flexible ruler has been reported; however, the degree of its repeatability remains controversial among studies; or a spinal mouse that requires a fixed device. Another non-invasive approach is applying two digital inclinometers. Besides, the reproducibility of this device varied in different studies [13, 14, 18]. Therefore, a valid, reliable, rapid, and non-invasive method for assessing kyphosis and lumbar lordosis is useful in clinical and research practices.

Kinovea is a free 2D motion analysis software under the GPL v2 license, developed in 2009 by the non-profit collaboration of several researchers, athletes, coaches, and programmers. Kinovea is available for download on the web [19, 20]. It is portable, inexpensive, and feasible. Kinovea has been used along with 2D imaging by the digital camera for sports and clinical evaluations. The reliability and validity of this system were evaluated for measuring the range of motion in different joints of the body, including the shoulder [21], wrist [22], and cervical region [23]. Puig-Divi et al. examined the validity and reliability of this system for simultaneously evaluating different body angles [20]. However, this system's validity and reliability remain unevaluated for measuring the thoracic kyphosis and lumbar lordosis. Consequently, the current study aimed to evaluate the construct validity and inter-rater and intra-rater test-retest reliability of posturography by Kinovea to measure the thoracic kyphosis and lumbar lordosis.

2. Methods

In this cross-sectional study, individuals were selected by a simple non-probability sampling method. The study subjects were selected from patients presented to the physiotherapy, physical medicine and rehabilitation, and orthopedics specialists at Firozgar Hospital, Tehran, Iran. The study subjects were referred to radiology centers for obtaining a lateral-view spine radiograph.

Including participants had no age limit. Only patients who had balance disorders when standing or were unable to stand without assistance; those with a history of a spinal tumor, surgery, radiotherapy, trauma, spinal fracture or skeletal disease, scoliosis deviation, leg length discrepancy, and psychiatric disorders were excluded from this study. All steps of the procedure were explained to the research participants or their guardians, and an informed consent form was obtained from them for digital camera photography. The Ethics Committee of Iran University of Medical Sciences approved this study (Code: IR.IUMS.REC 1396.32599).

In the present study, α=0.05 and β=0.1 were considered and 3 testers performed the necessary assessments. Based on the previous studies, the minimum and the highest acceptable levels of reliability were determined as $\rho0=70$ and $\rho1=0.90$, respectively. These values were placed in a table provided by Walter et al. [24] to calculate the required sample size in reliability studies. As a result, the sample size of 18 participants was computed for this research.

Measuring the Cobb angle requires a full-body radiograph on the sagittal plane. The study subject was requested to stand barefoot with a comfortable and natural position on the cardboard, where the foot placement area was marked. They were also requested to keep their shoulders and elbows at 90° of flexion to avoid the spine's upper limb shadow [25]. The explored patient's code was then provided to a physical medicine and rehabilitation specialist; accordingly, after measuring the kyphosis and lordosis angle using a camera and Kinovea, the researcher was provided with the relevant results.

The Cobb method was employed to determine the angles and degrees of the kyphosis and lordosis in radiographs. Kyphosis was determined using a Cobb angle between the superior vertebral endplate of T4 and the inferior vertebral endplate of T12 [26]. Furthermore, lumbar lordosis was analyzed using lines drawn along the superior vertebral endplate of L1 and the inferior vertebral endplate of L5 [27]. Then, lines perpendicular to each of these lines were drawn, and the acute angle of their intersection was calculated, which indicated the degrees of kyphosis and lordosis (Figure 1) [9].

To measure the angle of kyphosis and lordosis by Kinovea, a complete image of the subject in the lateral view is required. For this purpose, the study subjects were instructed to take off their clothes, and a specialist marked bilateral earlobes.

The examined individuals were requested to stand sideways and barefoot on the back of the calibration plane with shoulders and elbows at 90°-flexion (similar to radiographs). Their legs were leveled and sided, and their weight evenly distributed on two legs, and they looked at a fixed point on the opposite wall. Each study subject had to remain in this position for 2 minutes to achieve their normal position; the shooting was repeated 3 times during this time.

The shooting was conducted using a Sony digital camera placed 1.5 meters away from the calibration plane and at a one-meter height from the ground on a tripod [22]. The camera was adjusted using the level placed on the tripod. The camera lens had to be placed perpendicular to the calibration plane. This is because the measurement was performed in 2D.

The angles of the kyphosis and lordosis were calculated using Kinovea. Initially, a line was drawn parallel to the calibration plane from the earmark, i.e., considered the plumb line. To calculate the kyphosis angle, the farthest point from the plumb line was determined. This point is considered the apex of the kyphosis angle. Then, two lines at the top and bottom were drawn parallel to the curvature of the back. These lines intersected at the apex of each other. The angle of intersection of the lines was measured by Kinovea and decreased from 180°. The calculated value was reported as the kyphosis angle (Figure 2).

To calculate the lordosis angle, the nearest point from the plumb line was determined. Then, two lines at the top and bottom were drawn parallel to the curvature of the lumbar. The angle of the intersection of the lines was measured by Kinovea and decreases from 180°. The calculated angle was reported as the lordosis angle (Figure 2).

First, one of the 3 images taken in the Kinovea evaluation process was randomly selected and anonymously provided to the evaluators. The 3 evaluators separately measured the angles of kyphosis and lordosis using Kinovea. The first evaluator was a specialist with >20 years of experience, the second evaluator was a special-
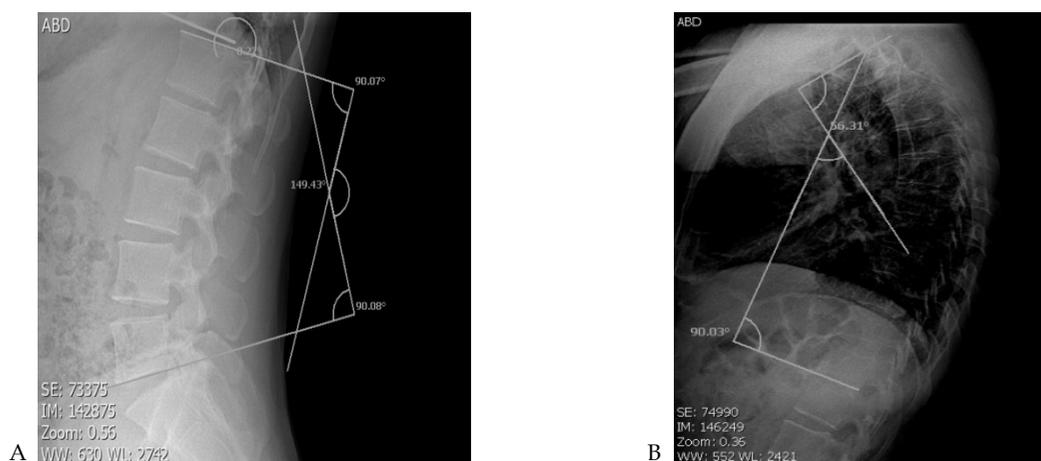
Sharifnezhad A, et al. Validity & Reliability of Kinovea. IRJ. 2021; 19(2):129-136.

131

Figure 1. Measuring thoracic kyphosis (A) and lumbar lordosis (B) by the Cobb method   **I**ranian **R**ehabilitation **J**ournal

ist with 5 years of experience, and the third evaluator was a trained expert. They worked separately and were unaware of the results of other Cobb angles.

Next, we evaluated the construct validity of the results obtained from calculating kyphosis and lordosis using Kinovea separately computed by 3 evaluators. Accordingly, the relevant data were compared with the results calculated by the physical medicine and rehabilitation specialist.

To evaluate the inter-rater repeatability of Kinovea, the results presented by the 3 testers were compared. To evaluate the intra-rater repeatability, the first evaluator calculated the kyphosis and lordosis with a mean value of the one-week interval using Kinovea.

The Kolmogorov-Smirnov test was employed to assess the normal distribution of the data. The Pearson correlation coefficient of kyphosis and lordosis angles (measured by the Cobb method from radiographs) was separately calculated by the mean angle obtained by the 3 testers to determine Kinovea software's construct validity. For evaluating the inter-rater and intra-rater reliability obtained from kyphosis and lordosis parameters, the one-way random Intra-Class Correlation Coefficient (ICC) was used. Based on Rosner's classification, ICC $\geq$0.75, 0.4$\leq$, ICC <0.75, and ICC <0.4 represent excellent, fair to good, and poor reliability, respectively [24]. The significance level in all tests was considered α=0.05. Furthermore, the statistical analysis was performed using SPSS.

3. Results

In this study, 18 subjects (10 females & 8 males), referring for radiographic imaging by physical medicine and rehabilitation specialists, and orthopedists were included. The demographic characteristics of the study

subjects are listed in Table 1. The Kolmogorov-Smirnov test data signified that the data had a normal distribution. The obtained Pearson correlation coefficient to determine the validity of Kinovea in measuring the thoracic kyphosis angles indicated that the validity of measuring the kyphosis depended on the evaluator's expertise. Besides, the correlation was not significant in measuring the lumbar lordosis angle (P>0.05) (Table 2).

The inter-rater and intra-rater repeatability calculated by Kinovea concerning kyphosis and lordosis angles revealed that the correlation was significant in all angles by the ICC (P<0.001). The results of inter-rater and intra-rater repeatability are presented in Table 3.

4. Discussion

The present study results suggested that using posturography by Kinovea for measuring the angle of kyphosis and lordosis presented a high inter and intra-rater repeatability; however, its validity depends on the examiners' skills, compared with the Cobb method. Exploring the validity and reliability of measuring methods plays an essential role in establishing a solid foundation for research results or clinical evaluation findings. Currently, the gold standard for measuring kyphosis and lordosis is the X-ray method. However, problems, such as cost, time-consuming, potential risks, and difficulty in the imaging's repetition have made it an unsuitable approach [13, 14].

A review by Barrett et al. classified 15 non-invasive methods for assessing thoracic kyphosis, ranging from simple to complex computer methods. In most of these methods, the reliability was high or very high; however, the validity of these techniques remains unexamined. Moreover, in the limited studied cases, this range has ranged from low to very high. It also does not seem that

Table 1. Demographic information of the study subjects

Variables	Mean±SD	Min.	Max.
Age (y)	42.64±21.67	9	73
Height (cm)	164.0±11.8	138	180
Weight (kg)	64.06±14.53	30	85
BMI (kg/m²)	23.48±3.62	15.75	29.38

Iranian Rehabilitation Journal

complicated computer methods are more valid and reliable than more straightforward approaches [18].

Kinovea is a free 2D motion analysis software. This inexpensive technology has been used in sports science as well as clinical and research studies. Studies using Kinovea to measure the joints' range of motion revealed that this system has a high inter-rater and intra-rater reliability. Besides, the testers' background and expertise present no effect on its reliability [20-23]. The present study results also indicated that the intra-group repeatability of Kinovea is high in measuring the kyphosis (ICC=0.90) and lordosis (ICC=0.91). The inter-group reliability of Kinovea in measuring the thoracic kyphosis (ICC=0.81) and lumbar lordosis (ICC=0.87) was also high.

A potential challenge in assessing reliability is the precise palpation of the spine. The accuracy of the palpation results throughout the spine has been reported to be low [18, 28]. This could also be affected by the examiner's skills [28]. In this study, spinal palpation and specialized marking were unnecessary. This is because only the earlobes were marked to determine the plumb line, which requires no expertise.

Another factor affecting the measuring methods' reliability is the changes that may occur over time, such as fatigue due to repeated tests or exercise between two repeated sessions [18, 29]. In this study, each subject was photographed only once. Besides, 3 evaluators examined the images, and the angle of kyphosis and lordosis were calculated. Therefore, environmental factors did not affect the repeatability of the data. However, it is better to repeat the imaging in different sessions to evaluate the reliability of Kinovea in measuring the angle of thoracic kyphosis and lumbar lordosis.

An advantage of Kinovea is that the examiner or measuring instrument does not contact the subjects; thus, it can reduce the odds of error. This is because some factors, like the pressure on the spine by a measuring instrument in tools, such as flexicurve and spinal mouse can affect the reliability [18, 29-31]. As a result, Kinovea seems to be more accurate than other contact methods; with one shot, the thoracic kyphosis and lumbar lordosis angles can be measured in this manner.

There are access restrictions and ethical issues regarding the use of X-rays to examine the validity of the

Table 2. Comparing correlation values between Cobb method and Kinovea software for all evaluators

Variables		Mean±SD	Pearson Correlation Coefficient	P
Thoracic kyphosis	First evaluator	29.0±7.35	0.48	0.049
	Second evaluator	28.5±7.43	0.59	0.013
	Third evaluator	31.5±7.78	0.317	0.21
	Cobb angle	49.4±13.13		
Lumbar lordosis	First evaluator	34.6±8.8	0.38	0.13
	Second evaluator	33.8±8.7	0.40	0.10
	Third evaluator	36.1±8.25	0.34	0.18
	Cobb angle	40.6±11.52		

Iranian Rehabilitation Journal

Sharifnezhad A, et al. Validity & Reliability of Kinovea. IRJ. 2021; 19(2):129-136.

133

Table 3. Reliability of the Kinovea software in measuring thoracic kyphosis and lumbar lordosis

Variables	Intra-rater		Inter-rater	
	ICC	P	ICC	P
Thoracic kyphosis	0.90	<0.001	0.81	<0.001
Lumbar lordosis	0.91	<0.001	0.87	<0.001

kyphosis and lordosis measurement method [32]. This study only included individuals referring for sagittal radiographs for clinical evaluation. The results indicated that the validity of Kinovea in measuring thoracic kyphosis depended on the expertise of the evaluator; only a specialist evaluator (r=0.48, P=0.049) and a trained expert with 5 years of experience (r=0.59, P=0.013) provided an acceptable validity, compared to the Cobb method. Furthermore, Kinovea has no acceptable validity in measuring the lumbar lordosis (P>0.05).

In measuring the angle of thoracic kyphosis and lumbar lordosis, vertebrae bodies are examined by the standard Cobb method; however, other non-invasive methods use the palpable vertebral spinous processes for the measurement [18, 30]. Muscles and the adipose tissue located on the vertebrae make it difficult to palpate the vertebrae and affect the measurement method's accuracy [30].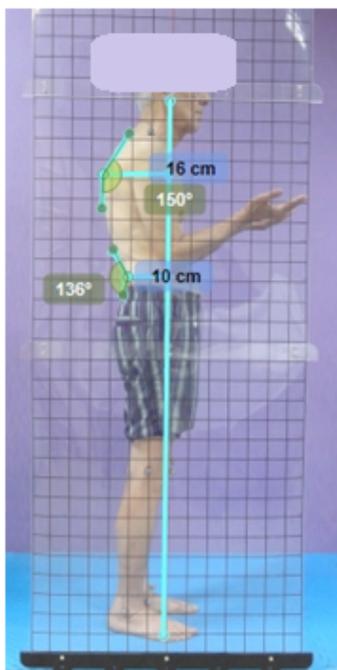 The Kinovea required no vertebrae palpation; however, the adipose tissue or muscle weakness was an influencing factor in measuring thoracic kyphosis and lumbar lordosis.

Most studies evaluated healthy individuals aged between 20 and 65 years. A healthy population in this age group does not necessarily represent a clinical population [33]; therefore, the results cannot be generalized to the clinical populations. Greendale et al. [34] and Yanagawa et al. [35] used Flexicurve in postmenopausal osteoporosis to assess its validity and reliability, thereby increasing the Flexicurve index's credibility. In the present study, individuals with different problems participated without age restrictions, which can affect the validity of the method.

The literature suggests that the accuracy of the lumbar lordosis angle measuring equipment is less than that of the thoracic kyphosis. This is because of the difference in the high mobility of the target areas [13, 25]. In the chest, flexion/extension at the sagittal plane is limited by the joints; however, the thoracic vertebrae benefit from a more extended flexion. Besides, as the measurement is not performed simultaneously, the lumbar lordosis is subject to much more changes, compared to kyphosis for the subject's movement [25]. However, in the present study, images were obtained while standing and simultaneously from the thoracic kyphosis and lumbar lordosis. Nevertheless, the collected results demonstrated that Kinovea presented no acceptable validity in measuring lumbar lordosis.

This study's main limitations were the small and heterogeneous sample size and the wide age range. This is because obtaining unreasonable X-rays is morally incorrect and may be harmful to the subjects. Therefore, in this study, only patients undergoing spine lateral view imaging for clinical reasons were included.

It is recommended to check the repeatability in repeated attempts. Additionally, evaluating the validity and reliability using larger sample size and selecting subjects with different age groups and problems are recommended. The validity and reproducibility of Kinovea can also

Figure 2. Measuring thoracic kyphosis and lumbar lordosis by Kinovea software

be evaluated for measuring other spinal abnormalities, such as scoliosis or lumbar lordosis.

5. Conclusion

Kinovea software has excellent inter-rater and intra-rater repeatability (ICC<0.80) for measuring kyphosis and lordosis. The advantage of using this reliable method is that it is simple, efficient, and inexpensive. This method's use is not affected by spinal palpation, applying force on the spine, or marking skills. This method can be employed in repeated follow-ups and the evaluation of the clinical treatment progress due to these positive features. This is the first study that has used this software to examine the thoracic kyphosis and lumbar lordosis; thus, further studies with a larger sample size are recommended to evaluate the validity and reliability of this method.

Ethical Considerations

Compliance with ethical guidelines

The Ethics Committee of Iran University of Medical Sciences approved this study (Code: IR.IUMS.REC 1396.32599).

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Authors' contributions

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Project Administration: Ali Sharifnezhad, Gholamreza Raissi, Bijan Forogh, Masumeh Bagherzadeh Cham.

Conflict of interest

The authors declared no conflicts of interest.

Acknowledgments

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135

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136

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