

## Comparing the Validity of Non-Invasive Methods in Measuring Thoracic Kyphosis and Lumbar Lordosis

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Article information	Abstract
<p>Article history: Received: 5 Apr 2011 Accepted: 13 July 2011 Available online: 18 Mar 2012</p> <p>Keywords: Validity Measuring Methods Kyphosis Lordosis</p> <p>*Corresponding author at: Department of Physical Education, Birjand University, Birjand, Iran. E-mail address: yousefi_mohammad2008@yahoo.com</p>	<p><b>Background:</b> the purpose of this article is to study the validity of each of the non-invasive methods (flexible ruler, spinal mouse, and processing the image versus the one through-Ray radiation (the basic method) and comparing them with each other.</p> <p><b>Materials and Methods:</b> for evaluating the validity of each of these non-invasive methods, the thoracic Kyphosis and lumbar Lordosis angle of 20 students of Birjand University (age mean and standard deviation: 26±2, weight: 72±2.5 kg, height: 169±5.5 cm) through four methods of flexible ruler, spinal mouse, and image processing and X-ray.</p> <p><b>Results:</b> the results indicated that the validity of the methods including flexible ruler, spinal mouse, and image processing in measuring the thoracic Kyphosis and lumbar Lordosis angle respectively have an adherence of 0.81, 0.87, 0.73, 0.76, 0.83, 0.89 (<math>p&gt;0.05</math>). As a result, regarding the gained validity against the golden method of X-ray, it could be stated that the three mentioned non-invasive methods have adequate validity. In addition, the one-way analysis of variance test indicated that there existed a meaningful relationship between the three methods of measuring the thoracic Kyphosis and lumbar Lordosis, and with respect to the Tukey's test result, the image processing method is the most precise one.</p> <p><b>Conclusion</b> as a result, this method could be used along with other non-invasive methods as a valid measuring method.</p> <p>Copyright © 2012 Zahedan University of Medical Sciences. All rights reserved.</p>

### Introduction

Wrong moving habits deform the spine and cause some malformations as thoracic hyperkyphosis or hyperlordosis [1,2,3]. The recognition of spine malformations and measuring the back curve angle is possible through a variety of invasive and non-invasive methods. Methods as CT Scan, MRI, and radiography images are among the invasive methods which facilitate such measurement [4]. The non-invasive methods are divided in two groups of contact methods (using kyphometer and inclinometer, flexible rulers, spinal panthograph, electro set-square meter, spinal mouse, and image processing methods), and non-contact methods (including NewYork Test, observational sieve ) [5]. So far, the validity of the flexible ruler has been reported as acceptable in various reports [6,7,8,9,10,11]. There have been various experiments in which the validity of spinal mouse was reported to be relatively high and acceptable [12,13]; though in some of these researches, the validity was not reported to be adequate enough [14]. The image processing method is a relatively recent method in which the some points on the body are marked by means of computer and after that through mathematical methods and computer programming, the deviation of the points, compared to the natural mode, is calculated and reported. There have been a limited number of experiments

studying the malformations of spine though the image processing method. Learoux et al. used image processing method and reported its validity as adequate [15,16]. According to the findings of Learoux et al. this method could be used as one of the non-contact methods in studying the malformations of spine. Regarding the limited number of experiments in this field, it seems necessary to conduct further investigations and studies on this method. Since the X-ray method is known as the golden method [10,17], the present study is to investigate the validity of the mentioned non-contact methods and compare them with each other based on the gained validity.

### Materials and Methods

The research method was that of correlation. The statistical population comprised of the boy students who were majoring at M.S. level at Birjand University during the academic year 2009-2010 (n=108). From among them, 20 students were selected as the samples through the Kakron Method. The thoracic Kyphosis and lumbar Lordosis angle was measured through the 4 methods of flexible ruler, spinal mouse, image processing and X-Ray. The measurement method of the thoracic Kyphosis and

lumber Lordosis angle through each of the above-mentioned methods were as follow:

1. The thoracic Kyphosis and lumber Lordosis angle measurement through Flexible ruler Method: the flexible method is used to measure the upper curves of the body including the kyphosis and lordosis. In this technique, the subject stands on a surface on which the feet place is marked bare footed in a natural and comfortable mode. The subject was asked to open his legs as wide as his shoulders facing forward. Then the examiner was placed behind the subject for determining the reference points. These points included the posterior superior iliac spines which were evaluated by the two hollow places on the lower part behind the face.

These points were marked by means of a marker. Then these points were connected through a line in a manner that the mid-point was placed on the Pin appendage of the second vertebrae Sacral Support S2. For finding the iliac crest the parts above the iliac crest were pressed by hand so that to make the muscles around it moves aside. The two thumbs reach each other behind the subject horizontally on the back of the subject, where the pin appendage of the first lumbar vertebrae is parallel with it. Then by counting the vertebral spine upwards, the pin appendage of the first lumbar vertebra was found and marked. Then the flexible ruler was placed on the L1 and S2 points and pressed tightly to the body so as to avoid any hollow space between the ruler and the subject skin and the ruler take the curve form of the subject back. Then the ruler is removed from the subject back and the curve is drawn on the paper. The note worthy point is that the line should be drawn from the side that the ruler was in contact with the skin of the subject[17].

Then the marks were cleaned away from the skin of the subject and after 1 minute of rest, the subject was asked to stand in the same position so as to have the measurement once again, following the same procedure. In order to avoid the influence of the examiner, he was not informed of the angles at the intervals at all. This was done 5 times for each subject and their average was recorded. Then the lordosis angle of the subjects was calculated through the following formula:

$$\theta = 4 \left[ \text{ARCtag} \left( \frac{2 H}{L} \right) \right]$$

In this formula, the curve length (L) indicates the distance between the first lumbar vertebra and the second vertebrae Sacral Support and the height of the curve (H0 is the vertical line with maximum distance from the L line. For measuring the kyphosis angle, the same route was followed but the part that the flexible ruler was placed between the redundancy vertebrae of the seventh cervical vertebra (C7) and the place of vertebra T12 and L1 was found and marked[5,18].

2. The thoracic Kyphosis and lumber Lordosis angle measurement through Spinal Mouse Method:

In order to extract the spine line, the spinal mouse which benefits of a high validity was used[19]. Prior to the experiment, the subjects received enough explanation on

the procedure by the examiner. Each of the subjects were asked to take off their shirts and stand normally in front of the examiner. Then the examiner marked the seventh cervical vertebra with a marker and measured the spinal line of the subject by placing the mouse wheel on the seventh vertebra and scrolling it down to the Vertebrae Sacral Support. The spinal data were sent to the note book in the form of radio waves and the Kyphosis and Lordosis angle was defined. The examiner repeated the same route for 5 times with 1 minute of interval between each time. Eventually, the average of the results was recorded as the final angle. In order to avoid the influence of the examiner, he was not informed of the angles at the intervals at all.

3. The thoracic Kyphosis and lumber Lordosis angle measurement through Image Processing Method:

This method of thoracic Kyphosis and lumber Lordosis angle measurement is based on finding the location of the reflective markers placed on the shock appendage in relation to each other. Therefore, at the first stage of measurement, it is required to place the reflective markers on the shock appendage (including T1, T3, T5, T7, T9, T11, L1,L2, L3, L4, L5, and S1, and C7) by touching[15]. For finding the above mentioned shock appendages, we acted as follow:

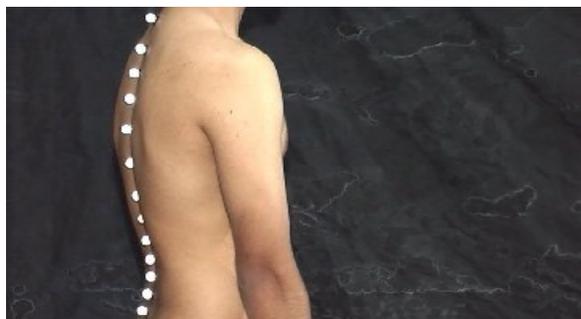
Spinal process of C7 and T12 were found according to the method introduced for the flexible ruler. After finding the Shock appendage of the seventh vertebrae, the Shock appendage are counted upwards for finding the Shock appendage of the T1, T3, T5, T7, T9, and T11 vertebrae. Similarly, for finding the Lumbar vertebrae spinal process, and Vertebrae Sacral spinal process, the same method of the flexible ruler was used[5]. After finding these processes, the reflective markers were placed on them.

At the next stage, the subject was located at a specific position, and 10 photos of his lateral dimension was taken by means of the motion analyzer (the indicators are put in place just once and the photos are taken with one minute intervals. This stage is the most important stage in measurement and it should be noted that the subject should be placed in position naturally. In addition, to avoid complexity of processing algorithms of the photos at the next stages, the photos are needed to be taken under control conditions of light and background color. The photos are taken with one minute intervals. After that the photos are entered into the processing program and the angle at each photo is extracted.

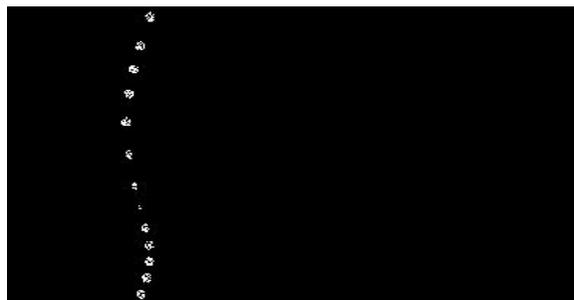
Eventually, the average of all these three angles is recorded as the final angle. Figure one illustrates a sample of such photos which is taken on a dark background. As it is evident in this figure, some of the indicators are not vivid clearly. Therefore, if we intend to select a point as the place of indicator in the photo, we would better select the furthest point from the spine as the place of the indicator.

Under such controlled conditions for taking photos, the places of indicators can be defined with applying a compatible threshold. Applying this compatible threshold

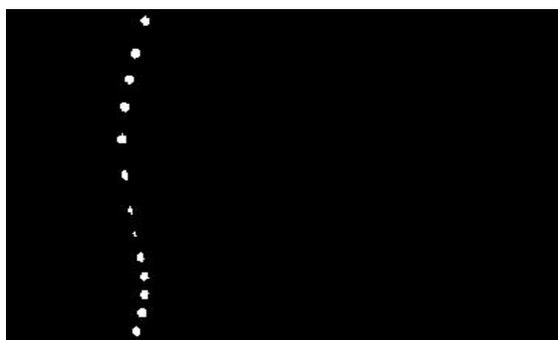
on the photo No. 1 leads to the extraction of the points as in the photo No. 2. As it is evident in photo No. 2, by applying the threshold, all the pixels of an indicator of a position do not make up a continuous line. That is while for the next stage of processing, the location of each indicator needs to be discriminated from the surrounding parts as a continuous one. For this purpose, the morphological dilation operator and the morphological erosion operators are applied to the picture resulted from applying the threshold. Accordingly, the points pertaining to each indicator is defined by a continuous area in the binary photo with the value of 1 (Fig. 3).



**Figure 1:** A sample photo which is used for measuring the kyphosis and lordosis angles



**Figure 2:** Applying the compatible threshold on the photo and extracting the points of the indicators



**Figure 3:** Locating the indicators on a binary photo with continuous areas, comprising of pixels with light intensity as great as 1

After locating the reflective indicators on the photos, we need to calculate the coordinates of these areas. For this purpose, we just need to select the furthest point from the

spine with the pixel intensity light of 1. In other words, we need to select the point(s) which are of the minimum X amount, and calculate the average coordinates of all these points as the final coordinate of the point at the area of an indicator. At this stage, we may manage to calculate the thoracic Kyphosis and lumber Lordosis angles easily with these coordinates at hand. If we name the indicators from the top point to the bottom, as M1, M2, ... M13, the amount of thoracic kyphosis at point M5 will be easily calculated by means of the points M3, and M7. Accordingly, the lordosis angle at point M11 will be calculated easily by means of the points M9 and M13.

4. The thoracic Kyphosis and lumber Lordosis angle measurement through X-ray Method:

The X-ray method was used to measure the lordosis and kyphosis arches. In this technique, having acquired the consent of the subject, he was asked to stand on a surface on which the feet place is marked bare footed in a natural and comfortable mode. In order to have all the components of the vertebrae lateral view in the X-ray photo, the subjects were asked to keep their arms at the flexion position[16]. At this situation, the X-ray photo was taken. Then the pertinent physician was provided with this photo and he extracted the lordosis and kyphosis angle by means of the Dicom-eye (MAT-8,  $p < 0.05$ ) through the Cobb method and presented the results to the researcher.

## Results

The mean and the standard deviation of the research variables through the image processing and X-ray methods are presented in table 1.

**Table 1:** Comparison of the mean and the standard deviation of the research variables

Measurement method	Kyphosis angle	Lordosis angle
X-ray (basic method)	27.59±5.77	23.74±5.04
Flexible ruler	24.85±5.37	21.37±4.98
Spinal mouse	19.71±4.65	18.93±4.32
Image processing	24.91±4.43	21.98±4.5

Before defining the applicable test, we need to assure the normal basis of the variables. If the variables are normal, we will use the parametric tests, otherwise, we will use non-parametric ones [20].

The Kolmogorov–Smirnov test (K–S test) indicated that the data distribution was normal.

Therefore, we could use the parametric methods for analysis of the data. Since the research is of –two-variable correlation nature, the applied test was the Pearson correlation coefficient. In order to be able to use the Pearson correlation coefficient to analyze relation between the variables, their relation needed to be a linear one. This linear nature was proved by means of a distribution diagram.

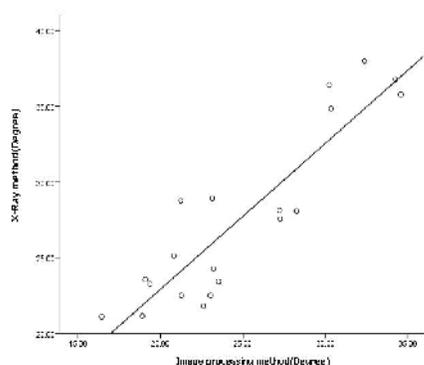


Figure 4. The regression line resulting from the linear relation between the two variables

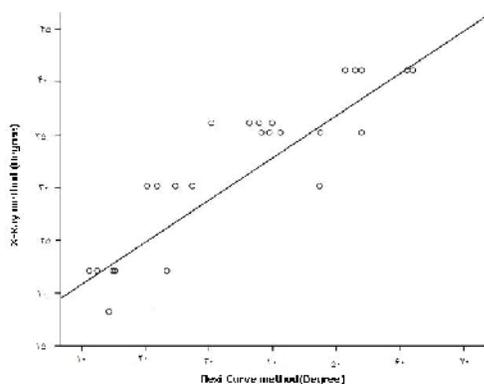


Figure 5. The regression line resulting from the linear relation between the two variables

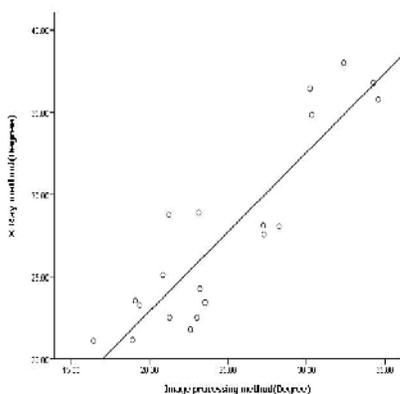


Figure 6. The regression line resulting from the linear relation between the two variables

According to the figures 4, 5, 6 and the drawn regression line for each variable, the relationship between the two variables in measuring the kyphosis and lordosis angles is a linear one. Therefore, we can use the Pearson correlation coefficient for investigating the intensity of the relation. The Pearson correlation coefficient in relation to the research variables is indicated in table 2.

Table 2. Results of Pearson correlation coefficient

Method	Correlation coefficient	p-Value
X-ray and image processing methods for kyphosis Measurement	0.89	0.001
X-ray and image processing methods for lordosis measurement	0.83	0.001
X-ray and flexible ruler methods for kyphosis measurement	0.87	0.001
X-ray and flexible ruler methods for lordosis measurement	0.81	0.001
X-ray and spinal mouse methods for kyphosis measurement	0.76	0.001
X-ray and spinal mouse methods for lordosis measurement	0.73	0.001

The correlation coefficient for each of the above-mentioned methods indicates that each of the methods, specially the image processing one benefits from an adequate validity for measuring the kyphosis and lordosis. In order to compare the above mentioned non invasive methods with each other, we used the one-way analysis of variance and Tukey methods were used. Regarding the results, there exist s a meaningful difference between the non-invasive measurement methods of thoracic kyphosis ( $p=0.009$ ) and lordosis ( $p=0.012$ ). At this stage, we used the Tukey's test in order to show which method has higher precision for measuring the thoracic kyphosis and lumbar lordosis. (Tables 3& 4).

Table 3. Binary comparison in Tukey Test in measuring the thoracic kyphosis

	Image processing	Flexible ruler	Spinal mouse
Image Processing	-	-	-
Flexible ruler	0.265	-	-
Spinal mouse	0.004	0.017	-

\* p-Value is meaningful at 0.05 level

Table 3. Binary comparison in Tukey Test in measuring the Lumbar Lordosis

	Image Processing	Flexible ruler	Spinal Mouse
Image processing	-	-	-
Flexible ruler	0.253	-	-
Spinal mouse	0.008	0.024	-

\* p-Value is meaningful at 0.05 level

Regarding the results of the Tukey's test (Tables 3 and 4), there exists a meaningful difference between the spinal mouse and the image processing methods, and with respect to the fact that the mean of the image processing method is greater than that of the spinal mouse (in both kyphosis and lordosis measurement), it could be stated that the image processing method has a better performance. There also exists a meaningful difference between the flexible ruler and the spinal mouse, and with respect to the fact that the mean of the flexible ruler method is greater than that of the spinal mouse, it could be stated that the flexible ruler method has a better performance.

There exists no meaningful difference between the flexible ruler and image processing methods, however, regarding the greater mean of the image processing method, it could be concluded that the image processing method is more precise than the flexible ruler method.

## Discussion

Regarding the results of this study, the equipments which are used for extracting the thoracic Kyphosis and lumber Lordosis angle measurement could be classified according to their correlation with the X-ray method. Since the acquired angles through the X-ray method were precise, the angles extracted by means of each of the methods were compared to that of the X-Ray. Accordingly, the classification of angle measurement methods is as follow:

Image processing method (0.83, 0.89), Flexible ruler (0.81, 0.87), and Spinal Mouse (0.73, 0.76).

Regarding the results of the methods, compared to the X-ray method, the higher correlation of the angles in the image processing method compared to other methods, indicates that in this method, the angles are closer together, rather than the other measurement methods. Since the validity of the angles extracted through the image processing method is greater than in other methods, it could be concluded that this method is the most precise one. The validity of the above-mentioned non-invasive methods have been reported in various studies. Lundon et al. conducted a research in which the subject involved 26 women (13 healthy and 13 suffering from back malformations). In this study, the two methods of X-ray and flexible ruler were used to measure the kyphosis angle and the reported correlation was  $r=0.87$ [6]. Hinman also conducted a research on 51 women (25 young and 26 old women) in which the correlation between the flexible ruler and the X-ray method was reported as .093[7]. However, in some researches as Hinman[11], and Loeble et al[22], the correlation between the two methods was respectively reported as 0.60 and 0.53. Arghavani et al., and Hart and Rose, calculated the correlation between the two methods of flexible ruler and X-ray methods for measuring the lordosis angle as 0.92, and 0.87[8, 9]. In a research by Seydi et al. named Validity and Reliability of the Iranian Flexible Ruler for measuring the lumbar lordosis, 55 healthy women were used. In this research, the correlation between the X-ray and Flexible ruler methods was reported as 0.91[10]. The correlation of 0.92 and the correlation of 0.72 were respectively reported by Nourbakhsh et al. and Kahrizi. Accordingly, there have been various studies both in Iran and out of Iran which brought about various results[11]. However, all of these studies prove the validity of this method, which is in line with the findings of the present study. There have been a few researches on the spinal mouse which indicated a

relatively high correlation, while in some others, the correlation is not trustable.

Ripani et al. achieved the validity of 0.62 for this equipment that is a relatively low correlation and renders this equipment as a faulty one in measuring the malformations' angles [14]. The results of the present study also prove this result. In other researches, the correlation is relatively high and acceptable. Kellis achieved the validity of 0.92 [12] for the Lordosis. Guerhazi et al. conducted a research for back flexion which resulted in the validity of 0.83 [13]. The correlations resulted from all the above mentioned researches indicate that this equipment benefits from acceptable validity for extracting the angles of kyphosis and lordosis. However, it is not fully trusted for the contradictory results ever achieved. There has been a few studied on the validity of the image processing method. In spite of this, the results are in line with the findings of the present study.

One of these studies was by learoux et al. which indicated the validity of 0.89 and 0.84 for kyphosis and Lordosis[15,16]. The note worthy point in both the learoux et al. study and the present study is that the precision of the equipment for measuring the thoracic Lordosis angle is less than that of the kyphosis. This could be due to the difference in high mobility of the intended areas. That is, at the chest, the extension flexion at the sagittal level is limited due to the joints, while the back vertebrae benefits from a more extended flexion, and since the measurement is not accomplished simultaneously, the lumbar lordosis is subject to much more changes rather than kyphosis for the movement of the subject. Therefore, the measurement in both methods at the lumbar Lordosis is less precise compared to the thoracic kyphosis[16]. Regarding the results of this study, the image processing method is more precise than the spinal mouse and flexible ruler in extracting the kyphosis and Lordosis angles. In addition to the above mentioned difference, the image processing method has many more advantages. One of the advantages is the minimum contact of the examiner with the subject, which reduces the intervention of the examiner, and eventually it omits the pertinent errors. This could explain the precision of this method compared to the other two methods. Another advantage is the non-invasive nature of this method and the simultaneous extraction of kyphosis and Lordosis angles [15].

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