World Journal of Sport Sciences 4 (4): 416-422, 2011
ISSN 2078-4724

Is Reflective Markers Image Processing a Precise Method to Diagnose Lumbar Lordosis and Thoracic Kyphosis?

[1]*M. Yousefi,* [2]*N. Mehrshad,* [3]*S. Ilbeigi,* [4]*H. Piry and* [5]*M. Rahimi*

[1]Faculty of Physical Education, University of Birjand, Iran
[2]Faculty of Engineering, University of Birjand, Iran
[3]Faculty of Physical Education, University of Birjand, Iran
[4]Faculty of Physical Education, University of Tehran, Iran

Abstract: The present study proposed a noninvasive method (Reflective Markers Image Processing) (RMIP) for lumbar lordosis and thoracic kyphosis measurement. Fast measurement along with slight contact with subjects could be introduced as the main advantages of this method. 40 male volunteer students with age 26±2 years, weight 72±2.5 Kg and height 169±5.5 Cm were selected to participate in this study. Initially, the lumbar lordosis and thoracic kyphosis values of all subjects were measured via both the RMIP and the Flexi-curve and then they were compared. Pearson's correlation coefficient test was used for statistical analysis ($P \leq 0.05$). Based on this study results, the correlation value between the RMIP method and the flexi-curve method for lumbar lordosis and thoracic kyphosis was 0.95 and 0.97 respectively. The results also indicated that the suggested method (RMIP) could be used effectively for lumbar lordosis and thoracic kyphosis measurement and it is valid in comparison with flexible ruler. We postulated that the RMIP method can be used as a noninvasive method along with other methods.

Key words: Spinal Column · Reflective Markers Image Processing (RMIP) · Abnormalities · Thoracic Kyphosis · Lumbar Lordosis

INTRODUCTION

The spinal coronal alignment is completely defined whereas there is no clear-cut definition of the spinal sagital alignment. There are two kyphotic (between first and twelfth vertebra of thoracic) and lordotic (between first and fifth vertebra of lumbar) curves in the sagital view of spinal column. Differences between natural and pathological curves in sagital view are not defined as well as that of coronal view [1]. The natural curves of spinal column locate the head in alignment with pelvis, absorb the sudden shocks, control the mechanical forces and in general place the person in optimal postural position.

Deviation from the favorable postural position is not only visually unpleasant, but also has negative impacts on muscle performance and also causes the individual to be susceptible to musculoskeletal abnormalities and neural disorders [2].

Furthermore, it has been shown that if the body remains at an unfavorable position for long periods of time, some muscles remain at their elongated positions while others at their contracted positions, a condition to which the individual adapts and in which contracted muscles form knots and weakness forms in elongated muscles [3]. It is clear that excessive use of a particular group of muscles in a limited domain of movement leads to muscular imbalance and causes unfavorable postural changes [4 and 5]. Such unfavorable changes include abnormalities in lumbar and thoracic areas (lordosis and kyphosis).

Kyphosis and lordosis refer to thoracic and lumbar curves of the spinal column respectively [6]. Outward and inward curves of the spine result from and are formed by the effect of internal factors such as deformation of the vertebra, disks between vertebra and sacrum, as well as external factors such as the position of the center of gravity, body weight and muscle strength [7].

Diagnosis of spinal column abnormalities and measurement of angles of lumbar and thoracic is possible by invasive and noninvasive methods. The radiographic,

Correspondent Author: M. Yousefi, MA in Physical Education, Faculty of Physical Education, University of Birjand, Iran. E-mail: yousefi_mohammad2008@yahoo.com

fluoroscopic, CT scan and MRI images are some of the methods used for this purpose [8]. Noninvasive methods used are divided into two categories, namely contact methods (kyphometer, inclinometer, flexible ruler, spinal panthograph, electrogomiometer and spinal mouse) and non-contact methods (the New York test and audio or visual screening) [6]. One of the oldest and most popular invasive methods for the measurement of the spinal curve is the Cobb method. Most technicians measure the spinal curve on radiographic clichés using the Cobb method. The dangers of exposure to the X-Ray, the time consuming procedure for measurement, high expenses and most importantly the high probability of error due to the techniques and positions used for imaging and trained movements during imaging are of the drawbacks of this method [9]. Such invasive methods hold dangers such as bone cancer in men and breast cancer and miscarriages in women, as well as other such dangers [9]. Technological advances in measurement methods on one hand and the dangers of invasive methods for the measurement of the angles of spinal column on the other hand, have caused noninvasive methods to receive more and more attention today.

One of the highly used noninvasive methods in this field is flexible ruler. Limitations for subject as well as examiner during measurement and development of long distance measurement methods (based on visual machines) show the necessity of such methods in diagnostic and medical applications. With regard to this information, the image processing of reflective markers proposed in this article can be used as an innovative method of long distance measurement without direct contact with the subject (during measurement) by doctors and corrective exercise specialists. Therefore, the authors make an effort to compare the accuracy of the proposed method with the highly used flexible ruler method (as a norm that has a high validity).

MATERIALS AND METHODS

The present study was a descriptive-comparative in nature. The statistical population of this research consisted of all male students doing MA programs at the University of Birjand in one last year during the 2009-2010 educational year (n=108). Forty students were selected as the sample (using the simple random sampling method and based on KAKRON sample size formula). The angles of thoracic kyphosis and lumbar lordosis for each individual were calculated using both methods (the proposed method and flexible ruler method). Both the proposed method and flexible ruler were used for thoracic kyphosis and lumbar lordosis angles measurement. Angle measuring in both methods will be discussed in detail as follows.

The Procedure of Angle Measurement in Flexible Ruler Method: Flexible ruler was used for trunk curves (lordosis and kyphosis) measurement. Firstly, the subject stood barefoot on a piece of cardboard at a natural and comfortable position and the location of his feet had been marked. Then feet were spread out at the size of shoulder width and the subject was asked to stare forward at a horizontal angle. At this stage, technician stood behind the subject in order to find the reference points. These reference points are used to extract the local of spinus process. These reference points include posterior superior iliac spine, whose ocalization was made by thumb fingers in line with two hallows positioned at lower back area. After marking these points with a marker and connecting them with a straight line, the spinus process of the second sacral vertebra (S2) was selected as the midpoint of this line. In order to determine the spinus process of the fourth vertebra, at first the soft tissue should be moved aside by pressing the fingers on two sides of the subject’s body (above the iliac crest) and then by moving the two thumbs horizontally, the spinus process of the fourth vertebra is determined at the meeting point of the two thumbs. At this moment, by counting the spinus process in upward direction, the first spinus process of the vertebrae (L1) can be determined and marked by a marker. After obtaining L1 and S2 positions, the examiner can simply set the flexible ruler on these points and by applying pressure along the ruler, the ruler completely takes the form of spinal curve. In this stage, ruler is taken off from the subject’s lumbar slowly and carefully and the curve formed in ruler is drawn on a piece of paper. For next measurements, all marks remained from previous trial on subject’s skin were erased and after 1 minute of rest all previous steps were repeated [10]. To eliminate the effect of examiner's expectations, examiner was not informed of measured angles in previous trials. The lordosis angle was extracted and recorded in each of the 10 trials using number one equation. An average of the 10 trials is a relatively accurate value of lordosis angle.

$$\theta = 4\left[ARCtag\left(\frac{2H}{L}\right)\right] \quad (1)$$

In this equation, the length of curve (L) shows the distance between the first spinal vertebra and the second sacral vertebra and the height of curve (H) is a vertical line that has farthest distance from L [11]. In order to measure the kyphosis angle in subjects using the flexible ruler, C7 spinus process was first determined by palpation method and then marked. For C7 spinus process determination, the subject bended his head downward and the first bump in the lower part of the neck was found. The spinus process of C7 vertebra is usually the largest spinus process at the lower part of neck. Due to C6 and C7 spinus process resemblance, C7 spinus process is not easily found. In order to facilitate this procedure, we asked the subject to reposition his head slowly; during this movement the bump of C6 spinus process disappears sooner than C7. In this procedure, we determined and marked the C7 Spinus process after C7 spinus process marking. T12 spinus process also should be determined and marked. To determine T12 spinus process, we asked the subject to set his hands on the edge of table, in leaning forward position, in order to weight transferring to hand. Spinus process of T12 vertebra is at the same level as the lower edge of the 12th rib on both sides. Therefore, the edges of these ribs are simultaneously touched with tip of thumbs and their trace was followed in upward and inward directions until they disappeared in soft tissue. At this point, the location of T12 spinus process was estimated by drawing a straight line from the tip of one thumb to another. After the finding of this process, it was also marked and the flexible ruler was placed on two processes (C7 and T12) and after the ruler took the form of curve, it was transferred to a piece of paper and the resultant curve was drawn, then the kyphosis angle was calculated through equation (1) [6].

The Procedure of Angle Measurement in Proposed Method: The proposed method for thoracic kyphosis and lumbar lordosis measuring is based on determining the locations of reflective markers on spinus processes in relation to each other. Therefore, in the first stage of measurement, it is necessary to attach the reflective markers to the locations of spinus processes (including five thoracic vertebrae and sacral vertebrae and the first, third, fifth, seventh, ninth and eleventh thoracic vertebrae and the spinus process of the seventh vertebrae in the neck) using the palpation method [12]. C7 and T12 spinus processes are found as before mentioned using the flexible ruler method [6]. After T12 vertebra spinus process had been found, to determine the location of spinus processes of T11, T9, T7, T5, T3 and T1 vertebrates, spinus processes were counted in an upward direction. Also, to locate spinus processes of lumbar and sacral vertebrae, the flexible ruler method was used as explained above. After the locating of spinus processes of all mentioned vertebrae, reflective markers were applied. In the next step, the subject was positioned at a predetermined position (1 meter from the movement analysis camera and adjustment of the side view of subject based on the position of camera tripod and a predetermined position for subject); then 10 shots were taken from the side view of subject using the movement 1 analysis machine (the reflective markers are installed only once and 10 shots are taken of subject with 1 minute intervals). This stage is the most important stage in measurement and much care should be taken so that the subject remains at a completely natural position when the shots are taken. Moreover, to prevent the image processing algorithms from becoming too complicated, in the next stages of measurement it is necessary for the shots to be taken in controlled lighting and background color conditions. Images were taken with 1 minute intervals. After extraction of the images, each was entered in the proposed method and the angle of each of images was extracted. Eventually, the average of 10 angles was recorded as the final angle. In Fig. 1 an example of such images has been shown, taken with a dark background. As it can be seen in this figure, some markers cannot be completely seen. Therefore, if the point is to be selected as the position of marker in the image, it is better to select the farthest point of the marker from the spinal column as a location of marker. In these controlled conditions for imaging, the areas that are related to markers can be easily determined by applying a compatible domain as shown in equation (2).

$$f_{th}(x, y) = \begin{cases} 1, f(x,y) > 0.99\max(f(x,y)) \\ 0, f(x,y) \leq 0.99\max(f(x,y)) \end{cases} \quad (2)$$

The application of this compatible domain on the image shown in Fig. 1 extracts the areas that are related to markers as shown in Fig. 2. As it can clearly be seen in Fig. 2, by applying the compatible domain, all the pixels related to the area of one marker do not form a consistent area, whereas the next stages of processing require the consistency of the area for each marker to be distinguished from surrounding areas. To achieve this goal, morphological distribution operator 2 followed by erosive morphological operator 3 were applied to images after the application of compatible domain. By doing this, the points relating to each marker are represented as 1 in a binary image by a consistent area (Fig. 3).

Fig. 1: An example of image used for measurement of angles that are related to thoracic kyphosis and lumbar lordosis

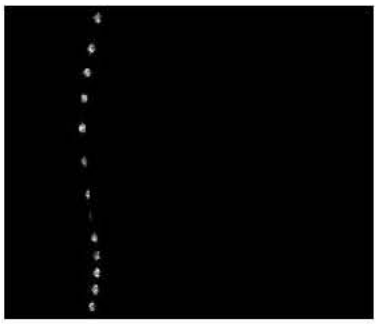

Fig. 2: Application of the compatible domain on image and extraction of points related to reflective markers

Fig. 3: Locating the positions of markers in a binary image with consistent areas formed by pixel of light intensity 1

After pinpointing the areas for reflective markers in the image, it is necessary to calculate the coordinates for each of these areas. For this purpose, in each area the coordinates of farthest pixel with light intensity 1 were selected. In other words, it is necessary for the point/points which has/have the least value of X coordinate to be chosen in the area for each marker and the average coordinate values for each of these points are selected as the coordinates for marker. In this stage, by having the coordinates for each of the markers, the thoracic kyphosis and lumbar lordosis angles can be calculated easily. If each of the markers are nominated M1, M2, ... and M13 from top to the bottom, the angle of thoracic kyphosis or the angle of curve at the location of M5 marker can easily be calculated using the locations of markers (M3 and M7). Also, the lumbar lordosis angle or angle of curve at the location of M11 marker can be calculated using the locations of M9 and M13 markers. If the location of marker *i* is shown as (xi,yi) from the top, the angle of thoracic kyphosis and lumbar lordosis (θ_i) is calculated as follows for *i*=0 and *i*=1:

$$l_1=\sqrt{\left(x_{3+6i}-x_{7+6i}\right)^2+\left(y_{3+6i}-y_{7+6i}\right)}^2$$

$$l_2=\sqrt{\left(x_{5+6i}-x_{7+6i}\right)^2+\left(y_{5+6i}-y_{7+6i}\right)}^2$$

$$l_3=\sqrt{\left(x_{3+6i}-x_{5+6i}\right)^2+\left(y_{3+6i}-y_{5+6i}\right)}^2$$

$$?_i=\frac{720}{p}\tan^{-1}\left(2l_2\sin\left(\cos^{-1}\left(\frac{l_1^2+l_2^2-l_3^2}{2l_1l_2}\right)\right)\right)$$

RESULTS

The average and standard deviation of thoracic kyphosis and lumbar lordosis angles have been shown in Table 1 for both measurement methods (proposed method and flexible ruler method).

With regard to this point that research design of this study is correlative and sample consisted of over 30 subjects, distribution of variables in study is natural [13]. Thus, to analyze the relationship between variables, Pearson's correlation coefficient test must be used. One of the requirements of using Pearson's correlation coefficient is that the variables have a linear relationship [13]. In order to prove the linear relationship between variables, scattered diagrams were used. Diagrams (1) and (2) show the linear relationship between variables.

The amount (degree) of correlation between variables has been shown in Table 2.

In this study, for each subject 10 measurements were carried out with each method and then the average of 10 measurements was recorded as the kyphosis or lordosis angle for each subject. The noteworthy point which can be seen in all subjects of this study is that despite the similarities in averages, standard deviation values for thoracic kyphosis and lumbar lordosis angles in each subject vastly differed in the proposed method and the flexible ruler method; two examples are shown in Table 3.

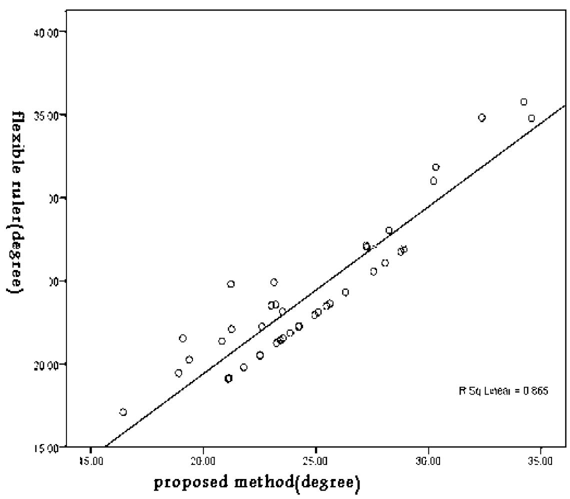

Diagram 1: The regression line resultant from the linear relationship between two variables in measurement of thoracic kyphosis

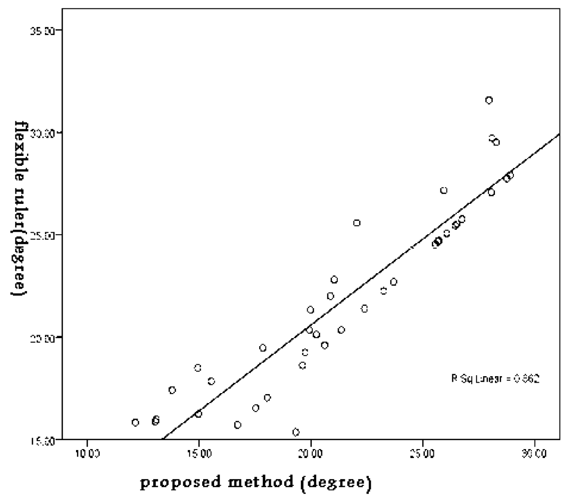

Diagram 2: The regression line resultant from the linear relationship between two variables in measurement of lumbar lordosis

Table 1: averages and standard deviation for variables of study

	Tools	
	Proposed method	Flexible ruler method
type of angles	Average and standard deviation	Average and standard deviation
thoracic kyphosis Angles	4.10±24.73	24.91± 4.43
Lumbar lordosis angles	4.98± 21.37	4.50± 21.98

Table 2: results of Pearson's correlation coefficient

	results	
method	Pearson's correlation coefficient	Significantlevel
Proposed and Flexible ruler methods (thoracic kyphosis)	0.97	0.001
Proposed and Flexible ruler methods (lumbar lordosis)	0.95	0.001

Table 3: average and standard deviation of thoracic kyphosis and lumbar lordosis angles for two subjects of the study

Method of measurement	subjects	Research variables	Mean	SD
Proposed method	Subject 1	Thoracic kyphosis	24.190	0.234
		Lumbar lordosis	26.811	0.379
	Subject 2	Thoracic kyphosis	23.154	0.305
		Lumbar lordosis	25.364	0.213
Flexible ruler method	Subject 1	Thoracic kyphosis	23.815	4.30
		Lumbar lordosis	25.935	5.017
	Subject 2	Thoracic kyphosis	23.736	5.078
		Lumbar lordosis	24.876	4.028

With a look at Table 3, we see that the standard deviation values for thoracic kyphosis and lumbar lordosis angles for number one subject (0.234 and 0.379 respectively) are far smaller than the same values for flexible ruler method (4.30 and 5.017 respectively). Also, the standard deviation values for thoracic kyphosis and lumbar lordosis angles for number two subject (0.305 and 0.213 respectively) are far smaller than the same values for flexible ruler method (5.078 and 4.027 respectively). The fact that these values are smaller indicates a source of error in the flexible ruler method which may have resulted from subject or examiner.

DISCUSSION

The accuracy of flexible ruler method in the measurement of thoracic kyphosis and lumbar lordosis has been proven in many domestic and foreign studies. Hart and Rose (1982) [14], Hart and Rose (1986) [15], Tilloston and Burton (1991) [16], Kahrizi *et al.* (1991) [17], Seidi *et al.* (2009) [18] reported the accuracy of the flexible ruler method for the measurement of lumbar lordosis in range of 0.72 to 0.92. Also, Khalkhali *et al.* (2006) [17] reported a high reliability (0.89) for flexible ruler method in measurement of thoracic kyphosis. With regard to the advantages of the flexible ruler method, researchers have benefited from this method as a noninvasive tool for clinical and research evaluation in healthy people and for the diagnosis of abnormalities of spinal column curves [19]. In addition, with regard to the results of mentioned studies, the flexible ruler method can be used as a secure as well as easy, economic and safe tool in comparison with X-Ray method for measurement of kyphosis and lordosis curves [17]. Therefore, in the present study, the degree of correlation obtained from the proposed method and the flexible ruler method (as a reliable method) was used to investigate the accuracy of proposed method in the extraction of thoracic kyphosis and lumbar lordosis angles. Results showed that the degree of correlation between the proposed method and the flexible ruler method in the extraction of thoracic kyphosis and lumbar lordosis angles was 0.97 and 0.95 respectively. Results obtained from the proposed method in comparison with the flexible ruler method indicate higher accuracy of the proposed method for the measurement of thoracic kyphosis and lumbar lordosis angles. Up to the present study, no research has compared these two methods (proposed method and flexible ruler method). However, the accuracy of the proposed method has been evaluated in a small number of studies in comparison with the X-Ray method. The studies of Learoux *et al.* (2000 and 2002) are examples of foreign research on the proposed method. In Learoux *et al.* (2000 and 2002) research, accuracy of proposed method in comparison with the X-Ray method for the measurement of thoracic kyphosis and lumbar lordosis was reported 0.89 and 0.84 respectively [12 and 20]. These results indicate higher accuracy of proposed method for extraction of thoracic kyphosis and lumbar lordosis angles. However, despite its high accuracy, this method holds the following advantages and disadvantages:

- With slight adjustments in the proposed method, measurement of other quantities (such as the amount of imbalance in the shoulders and pelvis and even abnormalities in lower parts of the body) becomes possible.
- Despite other measurement tools such as flexible ruler method, which involve constant direct contact with subject's body and may result in reactions from subject's body to pressure applied by examiner, in proposed method, after installing the reflective markers, no direct contact with subject's body is require during imaging and extraction of angles. Therefore, many potential sources of error are eliminated in this procedure.
- Based on the results of this study, standard deviation values for proposed method are less than flexible ruler method in all cases. Thus, the angle obtained in one measurement using the proposed method is more reliable than flexible ruler method.
- Although, preparation of subject (the step of installing the reflective markers) is a time consuming procedure, extraction process and calculation of angles quickly are carried out by computer. Unlike the proposed method, despite the fact that less time is spent for subject's preparation, calculation of the angles by drawing the curves on a piece of paper (in flexible ruler method) or by medical images is more time consuming.

Disadvantages of Image Processing Method:

- This method cannot be applied for women in Iran.
- The examiner who applies this method must have adequate information about how to find and install markers on spinus processes; otherwise, the procedure would carry error from installation of markers.

CONCLUSION

Based on the results obtained from this study, proposed method can be used as a measurement procedure along with other noninvasive approaches such as flexible ruler method. From the author's viewpoint, to eliminate the drawbacks of this method, more research should be carried out by future researchers.

ACKNOWLEDGEMENTS

The authors sincerely thank the officials of biomechanical laboratory of Birjand University for their cooperation in obtaining the data for this study and for providing the laboratory facility (movement analysis machine) for authors to obtain the images required for this study.

REFERENCES

1. Novak, C.B. and S.M. Mackinnon, 1997. Repetitive use and static postures: a source of nerve Compression and pain. Hand_Ther., 10: 151-159.
2. Bloomfield, J., 1994. Postural consideration in sport performance. Applied Anatomy and Biomech-In Sport, pp: 95-109.
3. Kendall, F.P., E.K. McCreary, Province, M.M. Rodgers and W.A. Romani, 2005. Muscles Testing and function, th edition, Williams and Wilkins.
4. Herbert, R., 1993. Preventing and treating stiff joints. Key Issues in Musculoskeletal Physiotherapy, _114_141.
5. Janda, V., 1993. Muscle strength in relation to muscle length, pain and muscle imbalance. Muscle Strength, pp: 83-91.
6. Rajabi, R. and H. Samadi, 2008. Corrective exercise laboratory guideline. Tehran University publication institute.first edition, Tehran (persian).
7. Twomey, L. and J.R. Taylor, 2000. Physical therapy of the low back. New York: Churchill Livingstone, 3: 66-70.
8. Elyasi, Z., 2008. Scoliosis and spinal column position measurement methods. Poyesh., 2: 16-19. (Persian).
9. Akbari, A., F. ghyasi, A. Aali, A. Habibinia, H. Khosravi zarandi and S. Afsharpour, 2008. A comparision between the clinical and radiography metods in lumbar curve measurement. Med. J. Ilam, 2: 26. (persian).
10. Magee, D.J., 2002. Orthopedic physical assessment. Philadelphia: Saunders WB Company, 4: 467-566.
11. Heart, D.L. and S.J. Rose, 1986. Reliability of a noninvasive method for measuring the lumbar curve. J. Orthop. Sports Phys. Ther., 8(4): 180-4.
12. Learoux, M.A., K. Zabjek, G. Simard and J. Badeaux, 2000. A Noninvasive Anthropometric Technique for Measuring Kyphosis and Lordosis. Spine, 25(13): 1689-1694.
13. Aliabadi, K.H. and A. samadi, 2003. Psychological data analyzing by use of SPSS program, 8,9,10,11 versions. Agah Publications. (persian)
14. Hart, D.L. and S.J. Rose, 1982. Reliability of a noninvasive method for measuring the lumbar lordosis curve. J. Orthop. Sports Phys. Ther., 8(4): 180-184.
15. Hart, D.L. and S.J. Rose, 1986. Reliability of a noninvasive method for measuring the lumbar lordosis curve. Phys. Ther., 62: 642-646.
16. Tilloston, K.M. and A.K. Burton, 1991. Noninvasive measurement of lumbar sagital mobility: an assessment of flexicurve technique. Spine, 16(1): 29-33.
17. Rajabi, R. and S. Latifi, 2008. Kyphosis and lordosis variables norm for Iranian's population in different age category, Research project in physical education institute.(persian).
18. Seidi, F., R. Rajabi, T.I. Ebrahimi, A.R. Tavanai and S.J. Moussavi, 2009. The Iranian Flexible Ruler Reliability and Validity in Lumbar Lordosis Measurements. World J. Sport Sci., 2(2): 95-99.
19. Youdas, J.W., J.H. Holloman and D.A. Krause, 2006. The effects of gender, age and body mass index on standing lumbar curvature in persons without current low back pain. Physiotherapy Theory and practice, 22(5): 229-237.
20. Learoux, M.A., K. Zabjek and G. Simard, 2002. Estimated Kyphosis and lordosis Changes at Follow-up in Patients With Idiopathic Scoliosis. Journal of pediartric orthopaedics, 22: 73-79.