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Original Research

Reliability of Body Landmark Analyzer (BLA) system for Measuring Hyperkyphosis and Hyperlordosis Abnormalities

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ABSTRACT

Among the several postural alterations, the thoracic hyperkyphosis and lumbar hyperlordosis are the most common ones. Hyperkyphosis is defined as an outward curvature of the thoracic spine and hyperlordosis is defined as an inward curvature of the lumbar. There are many methods as invasive and non- invasive for calculating of spinal column abnormalities. The purpose of the present research was to study the reliability of the Body Landmark Analyzer (BLA) method for measuring of the thoracic kyphosis and lumbar lordosis curvatures of the spinal column. Seventeen healthy males participated in this study. Intra-class correlation coefficient (ICC) two-way mixed model on absolute agreement was used to identify the inter/intra raters' reliability and 95% confidence intervals. Considering the results of this research indicated high Intra-class correlation coefficients for the thoracic kyphosis and lumbar lordosis 0.87- 0.90 and 0.84- 0.88 respectively, therefore it can emphasized that BLA method has succeeded to make a high reliability for both of the thoracic kyphosis and lumbar lordosis curvatures of the spinal column. Based on the mentioned capabilities and reliability of this method, it can suggest along with other non-invasive methods for diagnosing of kyphosis and lordosis abnormalities.

Keywords: Reliability, BLA system, Hyperkyphosis

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Introduction

The spine as a foundation of the body is a complex structure that has several functions due to its structural positioning and also connection of different muscles and ligaments (1). In this way, the following functions can be accounted for the spinal column: provide structural support and balance to maintain an upright posture, connection of the head to the rest of the body, and protection for the spinal cord. The spinal curvature can refer to the normal concave and convex curvatures of the spine, and it is very important to keep balance, flexibility, and absorption and distribution of the load applied to the spine. Although the spinal column reduces the pressures on the vertebrates, however, because of some factors such as wrong moving habits, weakness of extensor muscles and shortness of muscles, the spine could obtain abnormalities such as Kyphosis and Lordosis (1-3). Among the several postural alterations, the thoracic hyper kyphosis and lumbar hyper lordosis are the most common ones. Hyper Kyphosis is defined as an outward curvature of the thoracic spine (upper back) and hyper lordosis is defined as an inward curvature of the lumbar (1).

There are many methods as invasive and non- invasive for calculating of spinal column abnormalities (2, 3). In this way, Radiography is considered as a gold-standard invasive method (4, 5); however, this method is expensive and can expose the individual to radiation, therefore making it impossible to evaluate the people periodically. In order to diagnosis of spinal abnormalities, researchers usually apply non-invasive methods (3). Flexible ruler (Flexicurve) is used for measuring of thoracic kyphosis and lumbar lordosis, therefore it can considered among most commonly method to extract the spinal curve angles. In this method, one ruler gets the form of spinal curves and transfer on the paper to draw the arc of the spine including lumbar and thorax curvatures (3, 6). Although the flexible ruler has ability to measure both lumbar Lordosis and thoracic Kyphosis, however, the validity measurements of this device is higher for Kyphosis as compare to lumbar Lordosis angle. This could be due to the difference in more mobility of the intended areas. Other disadvantages of the flexible much more centered on the examiner such as: the contact of the examiner with the subject, the intervention of the examiner, and the examiner errors (2).

Moreover, the spinal mouse also is known as a non-invasive device for measuring the spinal abnormalities. During this method, the spinal column posture was measured by surface scanning of the skin. Therefore, beside of both Lordosis and Kyphosis angles, the angle of two adjacent vertebrate also can be measured. Moreover, some parameter such as, normal curvature of the lumbar, displacement of the vertebrates, pelvic tilt, hip displacement, spinal column deviation, and spinal column length can be compare with a standard position by using an algorithm way. However, it should be noted that the standard position that has been defined for this device is belonged to the Switzerland people and not specified for other nations (3).

As the same with flexible ruler, the spinal mouse method also has indicated several disadvantages. Firstly, it necessary to direct contact with the body of the individuals while it moved on the skin of the spinal column. The norm of the spinal abnormalities of this device is related to the Switzerland people, so, it is unusable for people of other countries. Moreover, there are little studies to indicate the validity of spinal mouse method whereas some indicated high correlation (7, 8), but some low (9).

Therefore, based on the need for an accurate and reliable tool, the innovative and intelligent method which named BLA (Body Landmark Analyzer) based on infrared waves was presented in this study. Hereby, the aim of the present research was to study the reliability of the BLA method for measuring of the thoracic kyphosis and lumbar lordosis curvatures of the spinal column.

Material and Methods

Participants

Seventeen males (average (SD) of age: 23.40 ± 1.70 years old, height: 176.32 ± 6.41 cm, weight: 72.25 ± 6.14 kg, and BMI: 22.33 ± 1.38 kg/m^2) recruited from physiotherapy department in Imam Hossein Hospital, Tehran, Iran. Sample size has been calculated by using of G*Power software (Effect size=0.6;β=0.8;α=0.05).The inclusion criteria were subjects who had a diagnosis of hyperkyphosis and hyperlordosis, had no surgical treatment, had a Cobb angle of less than 40°, and had a body mass index of less than 25 kg/m2. The exclusion criteria were any psychological diseases and traumatic injury.

The procedure of Body Landmark Analyzer method

The BLA system was comprised of a pen (transmitter) and camera (receiver) that both equipped with the IR sensor (Patent cod:93208). For setting up of system the calibration should be down at the beginning of the measurement. The necessity space for calibration is required with length, width and height of 2 m^3. The anthropometrical positions of the spinous processes of spine in the sagittal plane are needed to detect and calculate of the spine position. In this way, the anatomical landmarks were detected by palpation and then identified with a circular tape (Figure 1).

In the second stage, the subject stood posteriorly 2 meters away from the camera position. The main spinous process for detecting of contour of the spine was marked as described by Leroux et al. (2000) (T1, T3, T5, T9, T11, L1, L3, L5 and S1) (10).

In the third stage, the examiner located behind the subject in order to specify the identified spinous processes using pen (Figure 1). More specifically, all of the spinous processes marked with the tip of pen and the spacial coordinates of them were automatically sent to the computer system (BLA softwar has been made by Pouyanazma co.). Anthropometric thoracic and lumbar spine was calculated using a new algorithm with patent cod 93208 (Figure 1- Figure 5). For every subject, three observations were measured by experienced technicians of BLA and further the average of 3 trials were used for further analysis (11,12).

Figure 1. Main spinous processes for detecting the contour of the thoracic and lumbar spine

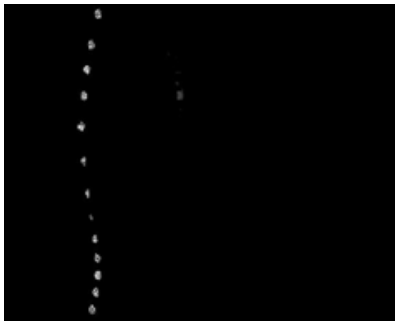

Figure 2. An example of adjusted images

Figure 3. An example of images to which rectangle operation is applied

Figure 4. An example of images to which disk operation is applied

Figure 5. An example of images in which the place of spinal column is cropped

Statistical Analysis

For statistical analysis, intra-class correlation coefficient (ICC) two-way mixed model on absolute agreement was used to identify the inter/intra raters' reliability and 95% confidence intervals. ICC values were interpreted as poor (<0.4), fair (0.41–0.59), good (0.6–0.74) and excellent (0.75– 1) (10). All statistics were carried out using the SPSS 25.0 with an overall significance level set at $p < 0.05$.

Results

The primary results including mean, standard deviation (Std.Deviation) and standard error (Std.Error) of the thoracic kyphosis and lumbar lordosis angles of the spinal column were indicated in Table 1.

Table1. Mean, Std.Deviation and Std.Error of the thoracic kyphosis and lumbar lordosis angles of the spinal column.

Method	Thoracic spine			Lumbar spine		
	Mean (degree)	Std.Devation (degree)	Std.Error (degree)	Mean (degree)	Std.Devation (degree)	Std.Error (degree)
BLA						
1st Rater	18.76	2.77	0.67	18.2941	2.05	0.49
2nd Rater	17.82	3.10	0.75	17.64	1.65	0.40
3th Rater	19.17	2.55	0.61	17.00	1.36	0.33

Inter rater reliability of the BLA method was classified as good to excellent class in Table 2.

Table 2. Inter-rater reliability of BLA method

Method	Thoracic spine		Lumbar spine	
	ICC	95%CI	ICC	95%CI
BLA 1st Rater-2nd Rater	0.84	(0.58 0.94)	0.85	(0.59 0.94)
BLA 1st Rater-3th Rater	0.82	(0.51 0.93)	0.78	(0.39 0.92)
BLA 2nd Rater-3th Rater	0.81	(0.48 0.93)	0.74	(0.29 0.90)
BLA Three Raters	0.87	(0.72 0.95)	0.82	(0.60 0.93)

Moreover, the relationships between measurements of each raters or Intra rater reliability were shown in table 3. We found excellent correlations between measurements for each rater.

Table 3. Intra-rater reliability of BLA method

Method	Thoracic spine		Lumbar spine	
	ICC	95%CI	ICC	95%CI
1st Rater Three measurements	0.88	(0.74 0.95)	0.85	(0.66 0.94)
2nd Rater Three measurements	0.90	(0.79 0.96)	0.84	(0.64 0.93)
3th Rater Three measurements	0.87	(0.72 0.95)	0.88	(0.73 0.95)

Discussion

The present study aimed to provide the reliability of the innovative and intelligent method for measuring the thoracic kyphosis and lumbar lordosis curvatures of the spinal column. Considering the results of this research that indicated high Intra-class correlation coefficients for the thoracic kyphosis and lumbar lordosis 0.87- 0.90 and 0.84- 0.88 respectively, therefore it can emphasized that BLA method has succeeded to make a high reliability for both of the thoracic kyphosis and lumbar lordosis curvatures of the spinal column.

Currently, for diagnosis of spinal column abnormalities, firstly, the intended arc must be extracted, and based on the arc angle that obtained the abnormalities of spinal column were diagnosed. In some invasive methods, based on the medical imaging (MRI, X-Ray and CT-Scan), as the same the intended arc is extracted, and then, using Cobb method, angle of the intended arc were calculated. Finally, medical specialists categorized the subject in normal or abnormal category based on the angle and standard norm available (3, 13).

Generally, non-invasive methods are preferred for diagnosing of spinal column abnormalities due to harmful nature of invasive methods. In this way, most commonly tool that used to extract arcs of spinal column is flexible ruler. In this method, the intended arc is extracted, and after drawing the arc on the paper, the mathematical formulae were used to obtain the angle of this arc. Having obtained the angle, researchers used the standard norm to categorize subjects into normal and abnormal categories (14, 15). Moreover, Flexible ruler has been frequently used by various researches and many researchers (15-25) have demonstrated its reliability. As already mentioned the spinal mouse also can be used to extract spinal angles and abnormalities. However, there are some limitation such as contradictory validity, inconsistency norm with other nation as Iranian population, and high cost of spinal mouse (3) for frequently using this device. Therefore, the new intelligent method was presented in this article may can considered as a non-invasive accurate method.

Regarding the results of Yousefi et al. (2012), the BLA method can be considered as a more precise as the spinal mouse and flexible ruler in extracting the kyphosis and Lordosis angles. Moreover, beside the above mentioned benefit of the image processing method many advantages were indicated for this method. 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 relevant errors. This could explain the precision of this method as 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.

Also, the feature vector of this device can considered among other capabilities of this method. Therefore, this ability can be a better describer, s compared with other non-invasive tools which describe the changes of spinal column only in one angle. The intelligent method that presented in this article, have both abilities including quantity and quality analysis of structure to calculate the amount of angle and also type of abnormality respectively.

The considerable point in the present study was the higher Intra-class correlation coefficient for measuring the thoracic kyphosis than Lordosis angle. This could be due to the mobility variation for two intended areas. Whereas, at the sagittal level of the chest, the flexion-extension can be limited due to the structures of the joints, while the back vertebrae can get more

benefit 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 at the thoracic Kyphosis is more precise as compared to the lumbar Lordosis (2, 10).

Some studies that have been selected in this article indicated different references regarding the ICC classification. In this way, Lee et al. (2013) classified the ICC agreement values as poor (between 0 and 0.2), fair (between 0.3 and 0.4), moderate (between 0.5 and 0.6), strong (between 0.7 and 0.8) and, near perfect (N0.8) (4). On the other hand, Lee et al. (2014) reported only what would be a strong reliability (index between 0.8 and 1) (24) and Kado et al. (2006) also found an ICC of 0.68 and defined it as an imperfect agreement and values (27). Therefore the proposed intelligent method that presented in this study can indicate a strong reliability for both of the thoracic kyphosis and lumbar lordosis curvatures of the spinal column, since the results of this study showed excellent inter/intra rater reliability (almost perfect agreement), which met requirements of reliability for classification systems.

This investigation, like all research has limitations. Firstly, in this study the Cobb angle of thoracic kyphosis extracted from the X-Ray image on the level of the T4-T12 while in the BLA method extracted from the T1-T12. Secondly, a physiotherapist has manually detected the Cobb angle. Therefore, based on the limitations, proposed to use digital X-Ray for extracting the Cobb angle for future study.

Conclusion

Based on the mentioned capabilities and reliability of this method, it can suggest along with other non-invasive methods for diagnosing of kyphosis and lordosis abnormalities.

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چکیده فارسی

پایایی دستگاه آنالیزور لندمارک های بدنی در اندازه گیری ناهنجاری های هایپر کایفوز و هایپر لوردوز

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هایپر کافیوزیس و هایپرلوردوزیس شایع ترین تغییرات پاسچرال در میان چندین اختلالات اسکلتی می باشند. هایپر کایفوزیس افزایش انحنای ستون فقرات سینه است و هایپرلوردوزیس افزایش انحنای ستون فقرات در ناحیه کمری می باشد. روش های اندازه گیری این اختلالات در دو دسته تهاجمی و غیر تهاجمی تقسیم می گردد. هدف از این مطالعه بررسی پایایی روش جدید BLA برای اندازه گیری ناهنجاری های هایپرکایفوزیس و هایپر لوردوزیس می باشد. تعداد ۱۷ آزمودنی مرد در این تحقیق شرکت کردند. برای تشخیص پایایی درون گروهی و بین گروهی از ضریب همبستگی درون کلاسی(ICC) و سطح اطمینان ۹۵٪ استفاده گردید. با توجه به نتایج این مقاله، ضریب همبستگی درون کلاسی برای هایپر کایفوزیس ۰/۸۷-۰/۹۰ و برای ناهنجاری هایپرلوردوزیس ۰/۸۴-۰/۸۸ به دست آمد. بنابراین با توجه نتایج تحقیق حاضر می توان بیان نمود که روش BLA پایایی مناسب برای استفاده در استخراج ناهنجاری های صفحه ساجیتال ستون فقرات دارد. بنابراین با توجه به پایایی مناسب این دستگاه ، می توان پیشنهاد کرد که در کنار سایر روش های غیر تهاجمی برای استخراج ناهنجاری های اسکلتی از این روش استفاده گردد

واژه‌های کلیدی: پایایی، روش BLA، هایپرکایفوزیس