

## Comparative study of flexicurve ruler with Microsoft Kinect tool in spinal arch evaluation

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### Abstract

**Background and Aims:** Identifying spinal abnormalities and assessing the physical condition of people in the community with accurate and reliable tools is of great importance. The main purpose of this study was to compare the flexible ruler with Microsoft Kinect tool in spine arch evaluation. **Methods:** The present study is a descriptive study and for this purpose, 44 male athletes aged 20 to 42 years in Rasht who were purposefully selected participated in this study. First, a flexicurve ruler was used to evaluate the arch of the spine, and then the Microsoft Kinect tool was used. It was measured in three steps with an interval of 15 minutes. **Results:** Pearson correlation coefficient was used to investigate the relationship between flexicurve ruler and Microsoft Kinect measurements (for validity) and intragroup correlation coefficient was used to evaluate the reliability of kyphosis and lordosis measurements. The results showed that there was moderate validity between the measurements obtained by Microsoft Kinect and the flexicurve ruler ( $r = 0.407$  for kyphosis and  $r = 0.396$  for lordosis), but the in-test reliability of this device was very high (kyphosis ICC = 0/998 and lordosis ICC = 0/998) was obtained. **Conclusion:** The results of the present study showed that Microsoft Kinect is a reliable tool in evaluating and measuring the angle of kyphosis and lordosis and also has validity. Therefore, this device can be used quickly and accurately in the evaluation of the spine arch.

**Keywords:** kyphosis, lordosis, Microsoft Kinect, flexicurve

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## Introduction

The spine is a crucial part of the body's skeletal framework, characterized by its S-shape. This column provides the main support for the body during various activities and plays a primary role in maintaining body alignment [1], [2]. Kyphosis and lordosis are among the common spinal deformities, which are caused by various factors including poor habits and postures, neuromuscular diseases, fatigue, depression, and others [3]. The presence of these deformities can be the initial basis for the onset of var-

ious issues, such as back pain and respiratory problems. Accurate, early, and timely recognition of these deformities can be completely effective in their prevention, halting their progression, and correction [3]. The assessment and measurement of spinal curvature, especially in the thoracic and lumbar regions, is a considerable concern in corrective movements. Many methods exist for measuring spinal curvatures. Some of these methods include: the Arcometer [4], Ultrasound [5], Debrunner Kyphometer [6], Spinal

Mouse [7], Spinal Pantograph [8], Electrogoniometer [9], Flexible Ruler (Flexicurve) [10], and Inclinometer. To date, the gold standard for measuring spinal curves is the use of radiography and the Cobb method [7], [10], [11]. Although this method has high validity in measuring the curves, its use is consistently associated with disadvantages such as radiation exposure, high cost, and limited use by non-specialists [7], [10]–[12], which greatly restricts its application. Each of these non-invasive devices for measuring kyphosis and lordosis has its own advantages and disadvantages, making the measurement of thoracic kyphosis and lumbar lordosis challenging.

The results of any scientific research are reliable only when reliable, accurate, valid, and repeatable instruments are used [13]. One of the most important indicators in choosing a measurement tool is its level of validity.

The flexible ruler is inexpensive and portable, but its use, especially for large sample sizes, is laborious and time-consuming. Oliveira et al. reported its validity as  $r = 70\%$  [14]–[16]. The use of radiography is a reliable method but is invasive, costly, and hazardous [11]. The Spinal Mouse has not been widely adopted due to its high cost, complexity in measuring displacement, and difficulty of operation. Moreover, its validity is still questionable, and the current research group did not find any study on the validity of this device for measuring kyphosis and lordosis,

which limits its use in research [16]. Only one study exists regarding its reliability. Finally, visual tools and methods such as posture screens and the New York test have little value in scientific research due to the qualitative nature of their data [17].

Recently, motion sensing technologies have been used in various fields, including health and wellness. One such technology introduced for motion sensing and assessment is the Microsoft Kinect [1] device [18]. The Microsoft Kinect is a portable and automatic device that costs significantly less than other traditional instruments [18]. Microsoft Kinect uses infrared light and a video camera to create a three-dimensional map of objects in its path [19]. To create the 3D model, it automatically identifies and plots markers specified on the body's skeletal structure using a tree algorithm [20].

The advantages and applications of Microsoft Kinect have been studied in various fields, including security, sports, ergonomics etc. Past studies have referred to the validity of this tool for measuring human posture control [18], [21], [22]. In a review study, Castro [2] et al. (2016) assessed scoliotic posture of the spine using Microsoft Kinect. In this study, 98 male and female subjects were examined with a mean age of 24.7 years. The results showed that 38.37% of the subjects had a difference greater than 1 degree between the shoulders [23].

In another study, Ross A. Clark [3] et al. (2012) examined the validity of Microsoft Kinect for as-

sessing postural control [4]. This study involved 20 injury-free young adults with no history of disease. The results showed very good concurrent validity with the 3D camera method, with Pearson's  $r$  values of 90% for most measurements [18]. Furthermore, Erin [5] et al. (2017) investigated the reliability and repeatability of lower spine measurement using Microsoft Kinect. Thirty-seven subjects with a mean age of 51.7 years were included. The Microsoft Kinect device showed a high score of (ICC = 0.96–0.97) [24].

Based on the conducted research, few studies were found that examined the validity and reliability of the Microsoft Kinect device in kyphosis and lordosis deformities. Therefore, this study was designed and executed to determine the validity, reliability, and comparison of the Microsoft Kinect device with the flexible ruler [6] in kyphosis and lordosis deformities.

## Methods

The current research is a descriptive study given the nature of the topic and the aims pursued. After receiving the ethical code (Sports Science Research Institute IR.SSRI.REC.1398.543), the researcher selected the sample size, which consisted of 44 individuals.

The samples were selected from climbers and mountaineers who were referred to the Health Monitoring

Center of the Faculty of Physical Education at Guilan University by the Sports Medicine Board of Rasht city for spinal screening. Those who had no history of surgery, fracture, or deformity in the spine area were selected and entered the study after signing the consent form.

The sample size for the current study was determined using the G\*POWER software with  $\alpha = 0.05$ , an effect size of 0.60, and  $\beta = 0.85$  (statistical power of 0.85).

Exclusion criteria for the current research included: the presence of congenital deformities and spinal surgery. Based on the inclusion criteria (all subjects were in complete physical health, had at least 5 years of experience in their respective sport, and currently train regularly at least three sessions per week, which was obtained through a questionnaire), the sample was formed.

The subjects first voluntarily completed the individual information and consent form, including (age, weight, height, occupation, history of illness, injury, or deformity). The tester first explained the goal of the research, the method of measurement, and the tests to the subjects, and preliminary, verbal consent was obtained for participation. After ensuring that the samples were eligible as subjects, measurements and tests were conducted in the laboratory environment according to the inclusion and exclusion criteria.

In this research, a Flexible Ruler (Kidos [7] brand, made in Iran) was used to evaluate kyphosis and lordosis. After identifying the necessary bony and anatomical landmarks (T<sub>2</sub>, T<sub>12</sub>, S<sub>2</sub>) [25], the participants were asked to stand as naturally and comfortably as possible (dominant body posture), look forward, and distribute their weight evenly on both feet (feet distance of 10 to 15 cm). In this position, they waited for two minutes for the person's body to reach its normal and comfortable posture. Then, the flexible ruler was placed on the subject's back and lumbar region (each curve separately) to conform to the shape of the thoracic and lumbar curves [26].

After the flexible ruler was adapted to the curve, the location of the bony landmarks was marked on the ruler with a marker. Then, without any change in the flexible ruler, it was carefully and gently removed from the spine and placed on white paper. Both the thoracic and lumbar curves were drawn on the white paper. For the thoracic curve, points T<sub>2</sub> to T<sub>12</sub>, and for the lumbar curve, points T<sub>12</sub> to S<sub>2</sub> were connected with a straight line. Where the curve had the greatest depth, a vertical line was drawn from the curve to the straight line. These two lines were named L and H, respectively. After measuring the length of lines L and H with a millimeter ruler, their values were placed in the formula [8] written in an Excel program, and the angle of the thoracic and lumbar curves was calculated [27]. The formula used for calculating the angle  $\alpha$  based on L (chord length) and H (maximum depth/camber) is:

$$\theta = 4 \operatorname{Arctang} \left( \frac{2h}{l} \right)$$

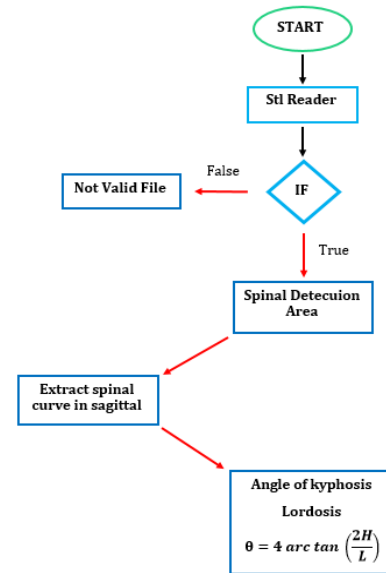
Measurement of the lumbar and thoracic curves using the Microsoft Kinect was performed as follows: Participants were asked to stand as normally as possible without an upper body covering. Then, the spinous processes of vertebrae C<sub>7</sub>, T<sub>12</sub>, and S<sub>2</sub> were identified using methods previously described by specialists in clinical settings [25]. Identifying the position of the T<sub>12</sub> vertebra was done by palpating the spinous process of the thoracic vertebrae. The evaluation process determined the vertebrae from C<sub>7</sub> to T<sub>12</sub> and the vertebrae above S<sub>2</sub>. Then, C<sub>7</sub>, T<sub>12</sub>, and S<sub>2</sub> were marked and specified with markers [28], [29].

Before the measurement and recording of the marked points, the Kinect device was calibrated [30]. Then, their spine was assessed using the Kinect kit connected to a laptop (SDK, Redmond, Washington, USA). The Kinect was placed 82 cm above the ground and at a distance of 180 cm from the participants [31]. Following the method of Mendleff et al., measurements from each subject were taken within 5 seconds, which included recording 5 consecutive frames of the depth of the thoracic and lumbar spine, as well as an image from the Kinect sensors [30]. (Figure 1)



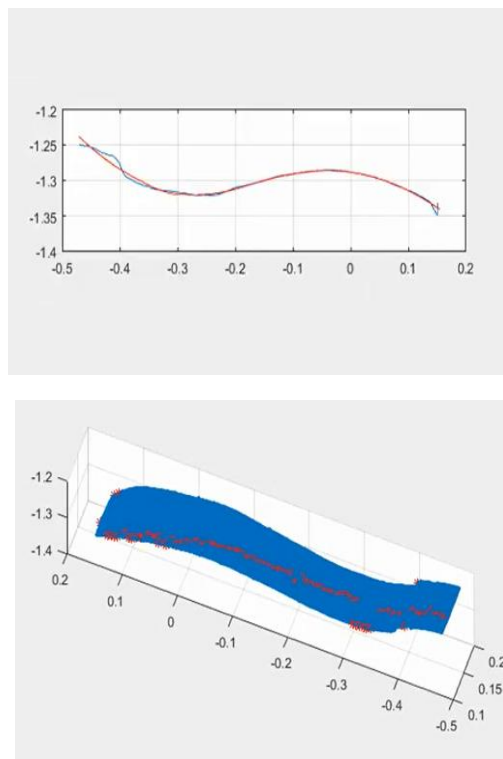
**Figure 1: measure the spine using the Kinect Marusoft camera**

The standing protocol described was performed three times with the Kinect, and the average was calculated. Using the Kinect Fusion Explorer software, a view of the posterior trunk was captured in space. Then, the collected data with the STL extensions were provided as input to the algorithm designed in the MATLAB software environment. The flowchart of this algorithm is shown in Figure 2.



**Figure 2: Flowchart of the algorithm for calculating kyphosis and lordosis angles**

- STL reader block: Imports the data stored by the Kinect into the MATLAB environment and creates an array of points in space. The algorithm then asks the user to specify the landmark [9] spinal range.
- Extract spinal curve in sagittal: In this block, the cloud space points are segmented along the sagittal plane axis and by the transverse plane. Then, the Savitzky-Golay filter is used to create a curve from the posterior trunk view and the transverse view. In the next step, the second derivative of the curve was used to determine the position of the spine in each section of the X, Y, and Z axes.



**Figure 3: Spinal Position Scan**

- After calculating the spine position in each section, the Savitzky-Golay filter was used again to create a curve, this time in the sagittal plane. In the next step, the kyphosis and lordosis angles were extracted from the created curve.

#### Statistical Method

The statistical methods used in this research included descriptive and inferential statistics. Descriptive statistics were used to determine central tendency and dispersion indices and to plot graphs. The type of data distribution was examined using the Shapiro-Wilk statistical test. Given the nature of the data (normality of the data distribution), Pearson's correlation coeffi-

cient was used to examine validity (the relationship between the two measurement methods), the Intra-class Correlation Coefficient (ICC) was used to examine the reliability of the measurement methods (repeatability of each measurement method), and the paired t-test was used to compare the measurement methods. All statistical analyses were performed using SPSS software version 23 at a significance level of 0.05.

## Results

A statistical analysis was conducted on 44 male samples to compare the validity and reliability of the Microsoft Kinect and the flexible ruler in measuring spinal curvature. The anthropometric data of the participants in this study are as follows (Table 1). The results of the Pearson correlation test for validity calculation and the paired t-test for comparison between the two measurement methods are reported in Table 2. The Bland-Altman graphical plots (Charts 2 and 3) also indicate a high agreement in the measurement methods for kyphosis and lordosis with Microsoft Kinect. Based on the calculated findings in Table 3, it can be stated with 95% confidence that the measurement of kyphosis and lordosis angles using the Kinect method has high repeatability. (Intraclass Correlation Coefficient for kyphosis angle = 0.998, Intraclass Correlation Coefficient for lordosis angle = 0.998).



**Table 1: Mean and Standard Deviation of Individual and Anthropometric Characteristics of Subjects**

VARIABLE	MEAN (M)	STANDARD DEVIATION (SD)	SIGNIFICANCE LEVEL (P)
AGE (YEARS)	27.20	4.83	0.001
HEIGHT (METERS)	1.76	0.08	0.698
WEIGHT (KILOGRAMS)	71	10.56	0.003
BODY MASS INDEX (KG/M2)	22.65	2.65	0.454

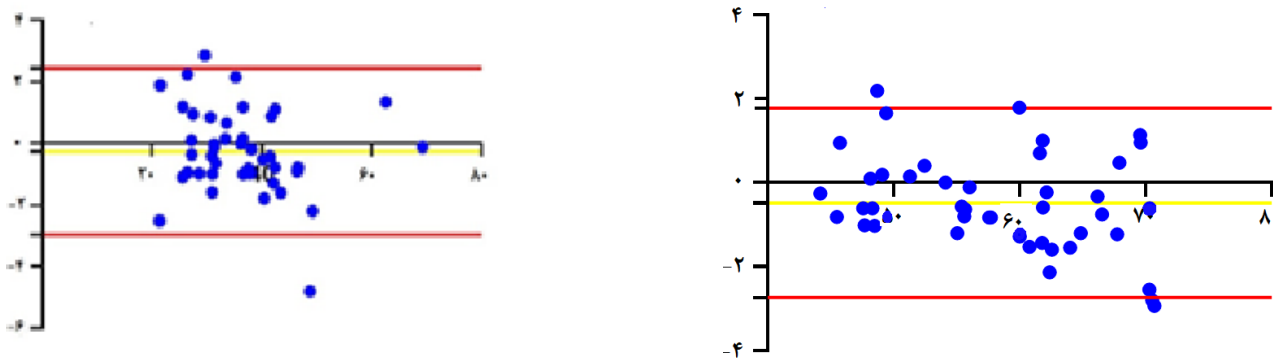
**Table 2: Results of Pearson Correlation Test, Validity Calculation, and Paired T-test in Two Measurement Methods**

VARIABLE	FLEXIBLE RULER (KYPHOSIS)	KINECT (KYPHOSIS)	FLEXIBLE RULER (LORDOSIS)	KINECT (LORDOSIS)
MEAN (M)	57.94	39.01	34.38	33.71
STANDARD DEVIATION (SD)	10.22	8.20	7.51	6.41
STANDARD ERROR OF MEASUREMENT (SEM)	1.42	1.21	1.20	0.96
95% CONFIDENCE INTERVAL (CI95%)	0.51–0.92	0.63–0.98	0.69–0.93	0.92–0.99
CORRELATION COEFFICIENT (R)		0.407		0.396
SIGNIFICANCE LEVEL OF CORRELATION (PR)		0.006		0.008
MEAN DIFFERENCE (MDF)		18.93		-0.67
STANDARD DEVIATION OF DIFFERENCE (SDDF)		9.58		8.02
T-STATISTIC (T)		13.09		-0.555
SIGNIFICANCE LEVEL OF T-TEST (PT)		0.001		0.582

**Table 3: Intraclass Reliability Among Three Repeated Measurements of Kyphosis and Lordosis Angle with Two Different Measurement Methods**

INSTRUMENT	VARIABLE	MEAN	STANDARD DEVIATION	STANDARD ERROR OF MEAN	INTRACLASS CORRELATION COEFFICIENT (ICC)	95% CONFIDENCE INTERVAL (95% CI)
FLEXIBLE RULER	Kyphosis 1st	57.93	8.09	1.53	0.982	0.973–0.992
	Kyphosis 2nd	58.37	8.40	1.53		
	Kyphosis 3rd	57.87	8.19	1.56		

KINECT MI-CROSOFT	Kyphosis 1st	38.43	\$10.15\$	1.22	0.998	0.997–0.999
	Kyphosis 2nd	38.60	10.18	1.26		
	Kyphosis 3rd	38.36	10.39	1.23		
FLEXIBLE RULER	Lordosis 1st	35.78	9.52	1.43	0.983	0.976–0.990
	Lordosis 2nd	35.87	9.54	1.44		
	Lordosis 3rd	35.48	9.51	1.43		
KINECT MI-CROSOFT	Lordosis 1st	34.92	6.85	1.03	0.998	0.997–0.999
	Lordosis 2nd	35.23	7.39	1.11		
	Lordosis 3rd	35.16	7.11	1.07		



**Figure 4: Bland-Altman plot to show the difference versus the mean of kyphosis results on a) Microsoft Kinect, b) Flexible Ruler**



**Figure 5: Bland-Altman plot to show the difference versus the mean of lordosis results on a) Microsoft Kinect, b) Flexible Ruler**

## Discussion

One of the important issues in the field of corrective movements is the measurement of spinal curves, especially kyphosis and lordosis. Knowing the exact degree of spinal curvature can be very effective in the prevention, diagnosis, and treatment of spinal deformities. One of the ways for accurate diagnosis of vertebral deformities is the use of the radiography technique, which is most widely used in spinal assessment and measurement and is known as the gold standard [32]–[34]. However, due to the risk of X-ray radiation, radiography cannot be considered the best method for patients whose body posture must be checked periodically [35].

This fact motivated researchers to introduce a safe and radiation-free tool for assessing various body postures [23], [24], [36], [37]. The purpose of the current study was to examine the validity and esti-

mate the reliability of the Microsoft Kinect compared to the flexible ruler.

Previous research has examined the validity of the Microsoft Kinect and referred to it as an accurate tool with acceptable validity for measuring spinal alignment (scoliosis, kyphosis). In the current study, the correlation coefficient between Microsoft Kinect and the flexible ruler on the body was found to be  $r = 0.407$  for kyphosis and  $r = 0.396$  for lordosis, which is a moderate correlation coefficient and can be reported in line with previous results [23], [24], [31].

Furthermore, the paired t-test results showed a significant difference between the two measurement methods for the kyphosis angle, but no significant difference was observed for the lordosis angle.

In addition to validity, having high reliability is of great importance. Reliability is a crucial and essen-

tial characteristic of any tool, as it shows the stability and repeatability of the measurements performed by that tool. As reliability increases, the measurement error of the measuring instrument decreases. The results of the current study showed that the Kinect has high intra- and inter-rater reliability for measuring the kyphosis and lordosis angles in adults (ICC = 0.998–0.998). An ICC greater than 0.90 indicates good reliability [38], [39].

Castro et al. (2017) examined 37 subjects aged 18 to 79 years with a mean age of 51.7 years and reported reliability and repeatability of (ICC = 0.96–0.97) [24]. Similarly, Quirk et al. (2017) studied 33 healthy subjects aged 21 to 64 years with a mean age of 31 years and reported reliability and repeatability of (ICC = 0.95–0.98) [31]. Carine et al.'s research (2020) also indicates that Microsoft Kinect has high reliability (ICC = 0.96–0.973) in both the thoracic kyphosis and lumbar lordosis regions; Erin et al. stated that this measurement method is fast, reliable, and safer than radiography [24]. The results of the current research also confirm the reliability of Microsoft Kinect and are consistent with previous results.

Therefore, it can be stated that if the measurement method and the selection of bony landmarks are correct, the measurements obtained from the Kinect will be consistent across different measurements. The high internal reliability of the Kinect means that

it can be used with high confidence and repeatability in repeated research with large sample sizes, where the spinal curve of individuals must be measured multiple times at different times.

Also, considering the Standard Error of Measurement (SEM) in the two measurement methods (flexible ruler and Microsoft Kinect) and the lower SEM for kyphosis and lordosis in the Microsoft Kinect method (Kyphosis = 1.21, Lordosis = 0.96) compared to the flexible ruler (Kyphosis = 1.42, Lordosis = 1.20), we can conclude that measurement with the Microsoft Kinect method has less error.

The difference between the Kinect and flexible ruler measurements is that the flexible ruler measures the degree of curve over the skin and soft tissues on the vertebrae, while the Microsoft Kinect measures the degree of curve over the spinous processes of the vertebrae. This leads to higher measurement accuracy and more precise angles. Dina et al. (2015) stated that Microsoft Kinect scans the anatomical points of the body in ideal conditions with greater clarity and a depth of several millimeters [40]. Oktavian et al. (2011) reported in their research that the use of the Microsoft Kinect camera is acceptable for assessing scoliosis and kyphosis deformities, and they also stated that the emergence of this generation of tools has the necessary accuracy in the assessment of anatomical surfaces of the body and ergonomics [41].

## Conclusion

These encouraging results provide new methods and pathways for researchers in the accurate and efficient measurement of kyphosis and lordosis. Furthermore, considering the results obtained in the current research, it can be stated that Microsoft Kinect has better and more advantages compared to the flexible ruler, which may overcome some of the disadvantages of the flexible ruler and facilitate the measurement of kyphosis and lordosis. Microsoft Kinect is a non-invasive, fast, reliable, and safe method for simultaneously measuring thoracic and lumbar spinal curvature. Other non-invasive methods also exist, but do not measure both kyphosis and lordosis curves simultaneously [24]. The most important advantage of Kinect over the flexible ruler is the ability to record measurement images and analyze the kyphosis and lordosis angles within a few seconds [24], [31]. In the flexible ruler method, the user needs to record the measurement on paper and input the obtained measurements into Excel software through the assessment of the Cobb angle to arrive at the kyphosis and lordosis angles [31], [42]. Therefore, given the overall simplicity of Kinect and its excellent accuracy, we predict that it will be reliable in clinical research. The only minor drawback that Microsoft Kinect may have compared to the flexible ruler is its cost, although it is affordable and accessible to many users. According to the findings of Castro et al. (2016), the Microsoft Kinect tool is a developed approach that has the potential to measure

and assess spinal curvature in scoliosis and other spinal curve issues and deformities [23]. Also, Carine et al. (2020) reported that Microsoft Kinect is a fast, reliable, and safe non-radiographic tool for simultaneously measuring thoracic and lumbar spinal curvature. Furthermore, according to the findings of these researchers, the scan recorded in the second stage of the three scans performed on the spinal curve is more reliable for measuring kyphosis and lordosis [24]. Therefore, according to the conducted studies and the results of the present study, the Microsoft Kinect tool for measuring spinal alignment and the kyphosis and lordosis angles is a reliable and highly valid, safe, very simple to use, and highly stable tool that can also be used in large sample sizes.

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### **Conflict of interest**

None.

### **Authors' contributions**

All authors contributed equally to the preparation of this article.

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