ORIGINAL PAPER

Arch Phys Glob Res 2019; 23 (1): 13-20
DOI 10.15442/apgr.23.1.2

Psychometric Evaluation of Microsoft Kinect™ in Lumbar Spine Motion Assessment

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Abstract

Background and objective: Microsoft Kinect™ as a non-intrusive motion assessment device may solve the inherent limitations with goniometric and inclinometric approaches in range of motion (ROM) evaluations. This study assessed lumbar spine ROM using the inclinometer and Microsoft Kinect™ devices. It also examined the concurrent validity and intrarater reliability of the Microsoft Kinect™ in lumbar spine ROM assessment.

Methods: Four hundred consenting apparently healthy undergraduates from the Obafemi Awolowo University (OAU), Ile-Ife, Nigeria, participated in this cross-sectional study. Lumbar spine flexion and extension were assessed using the inclinometer and Microsoft Kinect™. Following the standardized procedure, the inclinometer was firmly strapped to each participant's spine at the level of the anterior superior iliac spine, the values on the inclinometer readings were recorded at the start and after each movement in flexion and extension. Moreover, flexion and extension motion of participants were evaluated with the Microsoft Kinect™ device using the Microsoft Software Development Kit (SDK), version 1.8 and MB ruler, an on screen protractor software solution. Every motion was evaluated twice with both devices and the average value used for statistical analysis. The anthropometric characteristics were recorded and body mass index calculated. Data was summarized using descriptive and inferential statistics. Alpha level was set at $p < 0.05$.

Results: The mean age, weight, height and body mass index of the participants were 21.0 ± 2.48 years, 61.3 ± 61.3 Kg, 1.60 ± 1.63 m, and 23.4 ± 4.10 Kg/m^2 , respectively. The mean values for lumbar flexion and extension were 116.32 ± 13.60 and 25.64 ± 7.90, and 66.10 ± 11.30 and 17.97 ± 5.70 for the Microsoft Kinect and the inclinometer, respectively. There was a significant poor correlation in the two lumbar spine range of motions evaluated for the Microsoft Kinect™ (flexion; $r = 0.14$, $p = 0.001$), (extension; $r = 0.023$, $p =- 0.001$). The intrarater reliability of both the Microsoft Kinect™ and the inclinometer in lumbar spine range of motion assessment was good. The ICC values for flexion and extension for the Microsoft Kinect™ was 0.77 and 0.87 while for the inclinometer was 0.72 and 0.65, respectively.

Conclusion: The Microsoft Kinect™ has good reliability but poor concurrent validity in comparison with the inclinometer in the assessment of lumbar spine movements in asymptomatic individuals.

Keywords: range of motion; lumbar spine; Microsoft Kinect™; inclinometry

Introduction

The measurement of lumbar spine range of motion (ROM) is important clinically for physicians and rehabilitation specialists in back care. Current clinical measurement techniques include the use of inclinometers, goniometers, and tape measures with each of the techniques having its own set of limitations. For information obtained from any of these measurement techniques to be useful, normative data for lumbar spine ROM using the specific measurement technique are needed. However, adequate documentation of normative data for the lumbar spine is lacking in the literature. Also spinal ROM varies with age, gender, and possibly race/ethnicity [1].

Limitations in ROM may indicate problems within the joint or capsular structures surrounding the joint. A limitation in Active Range of Motion (AROM) when Passive Range of Motion (PROM) is full may indicate diminished or loss of muscle power resulting from a nerve lesion. Range of motion assessment is central to understand health and its attendant dysfunctions. Also, limitations in range of motion (ROM) represent the most significant signs to consider in patients with spinal pathology [2]. Moreover, recognizing mobility impairments may assist clinicians in making diagnoses, identifying improvements or deteriorations in mobility, and in determining limitations in functional activities of daily living. Examination of joint integrity and mobility is necessary in order to select appropriate physical therapy interventions [3].

Traditionally, examination of spinal ROM is through visual observation, tape measure and goniometer. A goniometer has been used widely due to its portability and low cost [4], however, a potential limitation of goniometer is that it requires the clinician to use both hands, and locate anatomical landmarks, making stabilization of the subject's position more difficult, thus increasing the risk of error by inaccurate reading or incorrect placement [4]. Additionally, goniometry does not allow the differentiation between the pelvic and lumbar contributions to spinal mobility [4]. With the advancement in technology, a number of measurement instruments including linear measures, and inclinometry have evolved over time [5].

Inclinometry is considered an alternative to goniometry as it incorporates the use of constant gravity as a reference point [6]. Nonetheless, inclinometry still has significant disadvantages which include Zero offset (Drift), linearity, and vibration shock, cross axis sensitivity, angle of measurement. Precision and accuracy may also contribute to alterations in inclinometry measurements. Samo et al. [7] have found that the greatest variability of inclinometric measurements may be caused by the examiner and/or technical errors. Procedural errors, such as wrong placement of the inclinometer at a region distant to the landmark, failure to maintain constant pressure during movement, and technical errors, such as holding the inclinometer slightly off plumb, could also give inaccurate readings [7].

Consequent to the foregoing, there is still the need for an instrument with requisite clinimetric properties. Human motion analysis is receiving increasing attention from computer vision researchers. This interest is motivated by a wide spectrum of applications, such as athletic performance analysis, surveillance, man–machine interfaces, content-based image storage and retrieval, and video conferencing [8]. The Microsoft Kinect is gaining attention as a new motion detecting device that is non-intrusive and easy to use [9]. The use of Kinect in the assessment of spinal ROM may represent an important medical breakthrough that may solve the inherent limitations in the goniometry and inclinometry approaches [10]. The psychometric properties of the Microsoft Kinect™ has been tested in the measurements of cervical spine ROM among healthy individuals [11], but yet to be tested in the lumbar spine. This study assessed lumbar spine ROM using the inclinometer and Microsoft Kinect™ device, and examined the concurrent validity and intrarater reliability of the Microsoft Kinect™ in lumbar spine ROM assessment in apparently healthy individuals.

Materials and methods

Four hundred apparently healthy undergraduates of the Obafemi Awolowo University

(OAU), Ile-Ife, Nigeria were purposively recruited into this cross sectional study. Ethical approval was obtained (IPH/OAU/12/1002) from the Health, Research and Ethics Committee, Institute of Public Health, Obafemi Awolowo University, Ile-Ife, Nigeria. Spine ROM in flexion and extension were assessed using the Inclinometer and Microsoft Kinect™, respectively for all participants after signing an informed consent form.

Inclusion criteria

Eligible for participation in this study were:

I. Individuals with no positive report of low-back pain for no less than three months,
II. Individual without an apparent spinal deformity, and
III. Individuals with no pain on repeated flexion and extension of the spine during assessment.

Exclusion criteria

Eligible participants excluded from this study were:

I. Those involved in competitive athletics and elite sports.

Procedure

All participants were asked to stand erect during the assessment of lumbar spine ROM. The purpose and procedure was explained to each participant. The participants completed two sets of two lumbar flexion and extension movements. Each movement was recorded while the movement was being performed. For the lumbar flexion and extension, two consecutive values were obtained for all participants using the inclinometer and Microsoft Kinect™.

Assessment of lumbar spine range of motion using the inclinometer

The lumbar spine inclinometry was performed using a Polycast Magnetic Protractor inclinometer made by Empire, United States. The measurement was made according to the guidelines elucidated by Norkin and White [2]. The inclinometer landmarks were straight palpation of the posterior superior iliac spine (PSIS) and L1. Upon land marking, the adhesive tape was used to hold the inclinometer in place (see fig. 1a). For flexion, the participants were asked to bend forward attempting to touch the floor with their hands while maintaining knee extension (Fig 1b), and for extension, the participants were asked to bend backward as far as possible (see fig. 1c) maintaining knee extension while the angle was recorded. Two trials of flexion and extension readings were recorded.

Assessment of lumbar spine range of motion using the Microsoft Kinect™

The Kinect camera (Prime Sense's 3D sensor) was used as a markerless motion capture device. The skeleton model (stick figure composed of 20 points) used to estimate the segment length and orientation was obtained using the Microsoft Kinect SDK software (Beta 1) installed on a laptop HP G4 (Intel (R) Pentium (R) @1.9GHz, 4GB RAM, Windows 8 Professional). The sensor was placed on a tripod 1.5 meter from the ground, and the subjects were positioned using a flexible meter ruler at a distance of 2 meters from the camera, as recommended by the manufacturer. The Kinect camera does not require any calibration; whenever a subject was in the camera's field of view, his/her stick figure skeleton was automatically created. The Kinect displays the 3D representation of the participant's body image as shown in figure 2a. The displayed body image was boldly repressed on the laptop screen while the subject was told to perform the flexion and extension movement, respectively as in inclinometry.

The displayed stickman model on the computer screen was captured and recoded in real time as seen in figures 2b, for flexion, and 2c for extension. The stickman imitates the participant's movement pattern in flexion and extension; the angular displacement is estimated using an app MB ruler software that measures angles between a desired point when a participant performs flexion and extension movements as displayed on the computer. The hip centre was used as the reference on the stickman model for lumbar spine motions measurement. The MB (software by Markus Barder) ruler works similar to a protractor, and can measure angles up to 360 degrees. The reliability and validity of the MB ruler has been previously confirmed to be near excellent (ICC>0.972) (12). The lumbar spine flexion and extension were measured from the pelvis centre of the Kinect stickman.

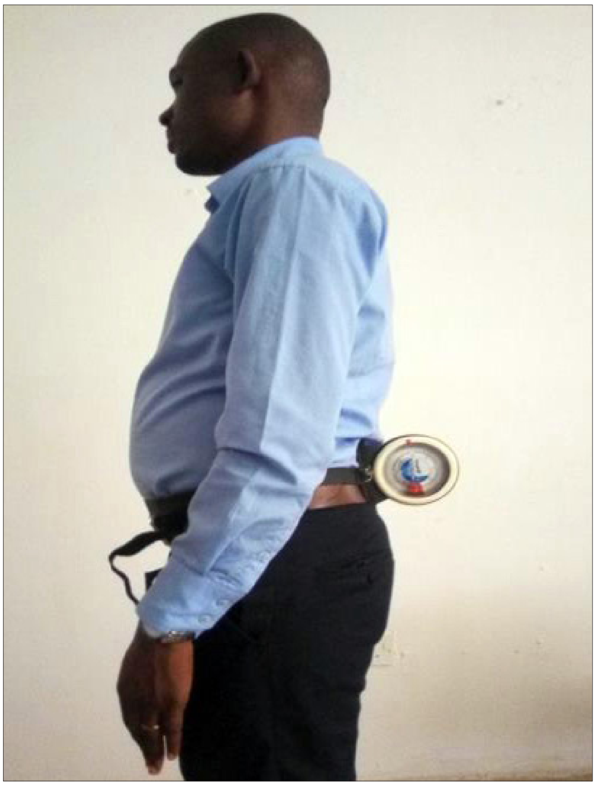

Fig. 1a. Strapping of the inclinometer to a participant

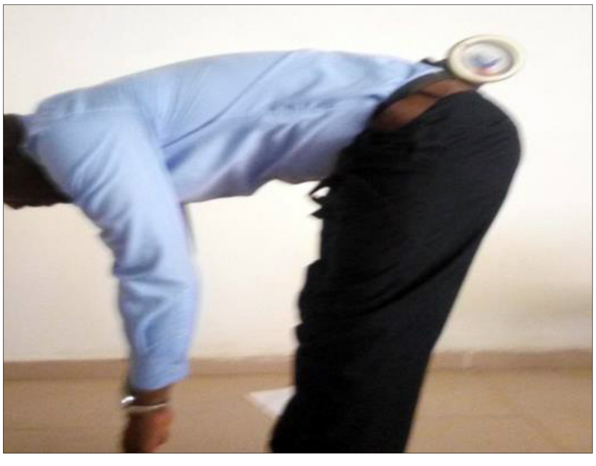

Fig. 1b. Measurement of back flexion with the inclinometer

Fig. 1c. Measurement of back extension with the inclinometer

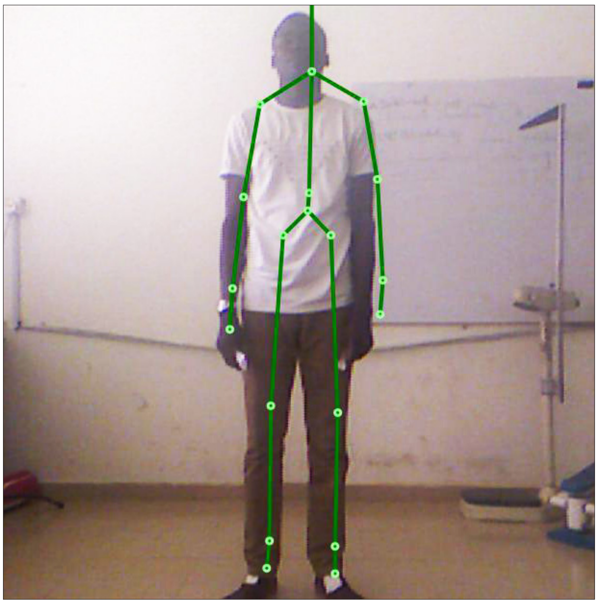

Fig. 2a. The stickman model of Microsoft Kinect

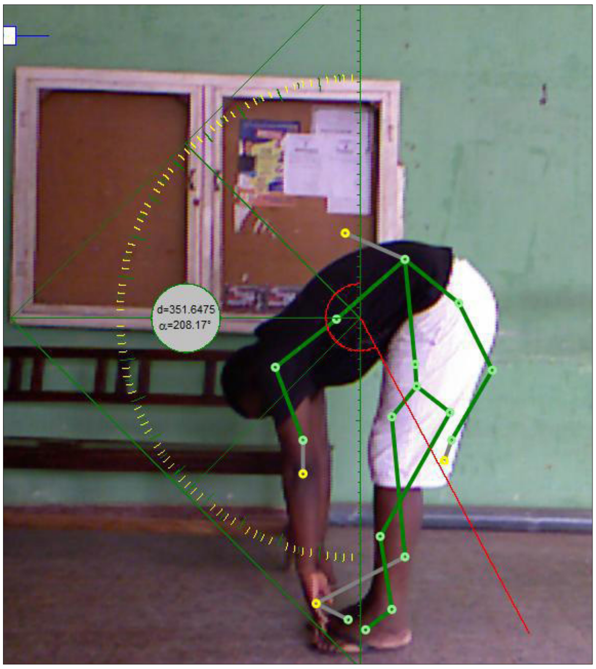

Fig. 2b. Measurement of lumbar spine flexion using the Kinect with a M.B ruler superimposed

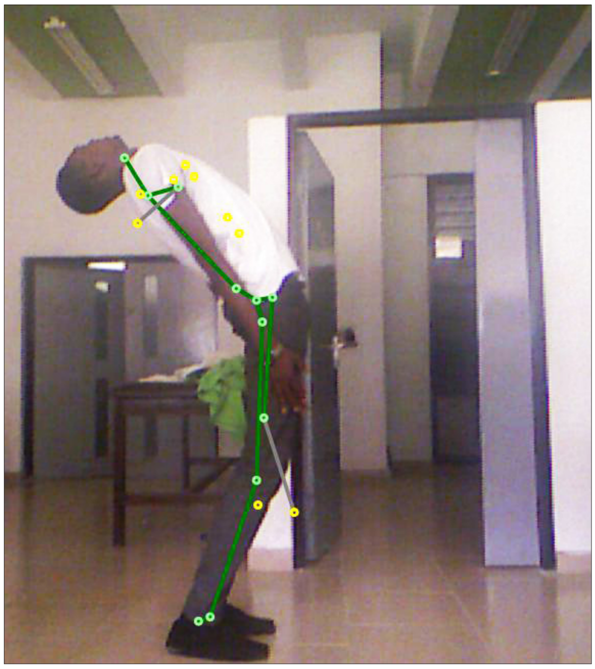

Fig. 2c. Measurement of lumbar spine extension using the Kinect

Data analysis

The data was analyzed by descriptive statistics of mean and standard deviation. The intra- class correlation coefficient (ICC) was used to assess the relationship between the variables obtained using the inclinometer and Microsoft Kinect™. The reliability of the Microsoft Kinect™ in lumbar spine motion assessment was calculated by intra-class correlation coefficient. An alpha level was set at $p < 0.05$. The Statistical Package for Social Sciences (SPSS Inc., Chicago, USA) version 21 was used for data analysis.

Results

The general characteristics of participants are shown in Table 1. The mean age, weight, height and body mass index of the participants were 21.0 ± 2.48 years, 61.3 ± 9.10Kg, 1.60 ± 0.80m, and 23.4 ± 4.10 Kg/m^2, respectively. The frequency of male participants was higher (352) than that of female participants (48). The mean lumbar spine range of motion for flexion and extension using the Microsoft Kinect were 116 .± 13.6 degrees and 25.64 ± 7.9 degrees while the mean lumbar spine range of motion for flexion and extension using the inclinometer were 66.10 ± 11.2 degrees and 17.69 ± 5.6 degrees, respectively as shown in table 2.

Table 3 shows the concurrent validity of lumbar ROM assessment of the Microsoft Kinect™ and inclinometer. The correlation (r) for lumbar flexion ($r = 0.14$, $p = 0.001$) was lower than that of lumbar extension ($r = 0.23$, $p = 0.001$). The intra-class correlation coefficient (ICC) for lumbar flexion using the Kinect and inclinometer was 0.773 and 0.871 respectively while for lumbar extension, the test retest reliability was 0.728 for the Kinect and 0.659 for the inclinometer, as shown in table 4.

Table 1. Physical characteristics of participants (n = 400)

Variables	Mean	±SD
Age (yrs)	21.0	2.48
Height (m)	1.60	0.80
Weight (kg)	61.3	9.10
BMI (kg/m^2)	23.4	4.10

Key: Yrs-Years; M-Meter; Kg-Kilogram; BMI- Body Mass Index; SD-Standard deviation.

Table 2. Mean values and standard deviations of lumbar spine range of motion assessment obtained using the Microsoft Kinect and inclinometer (n = 400).

Variables	Device	All participants Mean ± SD
Flexion (⁰)	Kinect	116.32±13.6
	Inclinometer	66.10±11.2
Extension (⁰)	Kinect	25.64±7.9
	Inclinometer	17.69±5.6

Key: SD-Standard deviation

Table 3. Concurrent Validity of the Microsoft Kinect in the assessment of lumbar ROM.

Variable	Correlation (r)	95% confidence interval		p-value
		Lower class	Upper class	
Flexion (⁰)	0.141	0.045	0.294	0.001
Extension (⁰)	0.023	0.063	0.367	0.001

Table 4. Test–retest reliability of lumbar ROM using the Microsoft Kinect and inclinometer.

Variable	Device	Test-retest (ICC; 95% CI) Reliability (r)	p-value
Flexion (⁰)	Kinect	0.773	0.001
	Inclinometer	0.728	0.001
Extension (⁰)	Kinect	0.871	0.001
	Inclinometer	0.659	0.001

Key: ICC-Intra-class Correlation; CI-Confidence Interval

Discussion

This study investigated the concurrent validity and reliability of the Microsoft Kinect device for assessment of the lumbar spine range of motion among apparently healthy undergraduates. The spinal movements measured were lumbar forward flexion and extension using the Microsoft Kinect and the Inclinometer. According to the findings,, the Microsoft Kinect™ had poor concurrent validity when compared with the inclinometer. While there is an apparent dearth of studies to compare the present findings with, previous investigators have attempted to establish the validity of the Microsoft Kinect™ in various contexts. For example, Reither et al. [13] have investigated the reliability and validity of Kinect for the upper extremity and demonstrated good reliability for the Kinect within a day, while results within days were inconclusive with moderate validity. Another study by Seung et al [14] has found excellent agreement when the Kinect was used for measurements of the shoulder active and passive range of motion in patients with adhesive capsulitis. Moreover, Hawi et al. [15] have reported a poor to moderate correlation between the Kinect and the universal goniometer in the assessment of elbow range of motion. Ademoyegun et al. [11] have reported the poor correlation and excellent intra-rater reliability when the Kinect was compared with the goniometer in the assessment of cervical spine range of motion among healthy individuals.

The poor correlation of the Kinect can be attributed to the differences in the extent of ROM assessment between the two devices. The use of different intermediate software devices, such as the MB ruler, may contribute to variability in outcomes of various studies. The spinal range of motion differs during flexion and extension movements, as each movement is hard to replicate exactly after the initial movement is done [16]. Several factors which may also be responsible for the poor correlation between the Kinect and the inclinometer may involve lightning, clothing, body somatotype and the ability to detect the exact landmark for repeated measure. Most studies have reported that the Kinect is clinically applicable to detect the range of motion which frequently is critical to diagnosing pathology or proffering a solution. The Kinect has largely been found to be reliable but low in validity [14, 17], which is likely to indicate that its approach to measuring ROM as a construct is different from that of the inclinometer or the goniometer. The Kinect estimates ROM based on the line of coordinates while the other method follows body landmarks. The Kinect approach may be more specific than gross movement assessment involved in inclinometry.

With regard to reliability, both the Kinect and the inclinometer showed good intra-rater reliability in lumbar spine ROM assessment. For the inclinometer, previous studies have reported good ICC values when using similar assessment protocols in lumbar ROM assessment [2]. Unfortunately no data is available to compare the reliability findings in this study when using the Kinect to assess the lumbar ROM. To the best of our knowledge, the present study is the first to assess concurrent validity and reliability of the Microsoft Kinect™ in lumbar spine ROM measurements. Moreover, all the researches have stated that the Kinect shows good to excellent intra-rater reliability in joint angular measurements, which is consistent with our results. The Kinect showed superior intra-rater reliability in the two lumbar motions evaluated, as compared to the inclinometer. The lower reliability values obtained for the inclinometer when compared to the Kinect may be caused by the differences in handling of the two devices.

The small age range distribution is one of the limitations of this study as age has been determined to affect the lumbar spine ROM [12]. Furthermore, our findings need to be validated in patients with health challenges (e.g. non-specific low back pain) as AROM of individuals with lumbar pathology may not be similar to that in apparently healthy individuals. The healthy population was chosen for this study as the participants were asked to hold their end lumbar ROM for a few seconds prior to assessment, which may not have been feasible with symptomatic participants.

Conclusion

The Microsoft Kinect™ has good reliability but poor concurrent validity in comparison with the inclinometer in the assessment of lumbar spine movements in asymptomatic individuals.

Competing interests:

The authors declare no conflict of interest

Funding:

We do not have any financial disclosure

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