Clinical and Experimental
Health Sciences

Reliability, Concurrent Validity, and Minimal Detectable Change of a Smartphone Application for Measuring Thoracic Kyphosis

Ertan Şahinoğlu[1], Gülbin Ergin[2], Serkan Bakırhan[3], Bayram Ünver[4]

[1] Mavi Physiotherapy, İzmir, Türkiye.
[2] İzmir Bakırçay University, Faculty of Health Sciences, Department of Physical Therapy and Rehabilitation, İzmir, Türkiye.
[3] Ege University, Faculty of Health Sciences, Department of Physical Therapy and Rehabilitation, İzmir, Türkiye.
[4] Dokuz Eylül University, Faculty of Physical Therapy and Rehabilitation, İzmir, Türkiye.

Correspondence Author: Ertan Şahinoğlu
E-mail: ertan.sahinoglu@hotmail.com
Received: 17.12.2021 **Accepted:** 17.02.2023

ABSTRACT

Objective: To assess the intra – and inter-rater reliability and concurrent validity, and to estimate minimal detectable change of a smartphone application for measuring thoracic kyphosis angle.

Methods: A total of 80 healthy university students were evaluated. Two raters measured the thoracic kyphosis angle using a digital inclinometer and the smartphone application. Intra – and inter-rater reliability were assessed using the intraclass correlation coefficient (ICC) with 95% confidence interval. The standard error of measurement (SEM) and the minimal detectable change at the 95% confidence level (MDC_{95}) were also calculated. The concurrent validity between the digital inclinometer and the smartphone application was assessed by the linear regression analysis and Bland and Altman's 95% limits of agreement method.

Results: The intra – and inter-rater reliability were excellent for the digital inclinometer and the smartphone application (ICC > 0.75). The SEM values for the digital inclinometer and the smartphone application were close together. The MDC_{95} values for the smartphone application were 5.11 and 6.30 degrees, and 9.02 degrees for intra – and inter-rater, respectively. The digital inclinometer and the smartphone application showed a positive correlation ($R^2 = 0.85$). The Bland-Altman plot showed a good agreement between the instruments.

Conclusion: The smartphone application used in this study is a cost-effective, practical, reliable, and valid instrument for measuring the thoracic kyphosis angle. More than 9 degrees in the value of the thoracic kyphosis angle measured by the smartphone application can be considered as a true change.

Keywords: Reliability; validity; kyphosis; smartphone; spine

1. INTRODUCTION

Thoracic kyphosis is defined as spinal angulation between the T1 and T12 vertebrae in the sagittal plane (1). An increase or decrease in the thoracic kyphosis angle may cause adverse changes in the shoulder range of motion (2), balance (3–5), pulmonary functions (6), and quality of life (5); therefore, evaluation of the thoracic kyphosis angle is important to determine the negative effects caused by the changes in the thoracic kyphosis angle and to identify appropriate treatment strategies (7).

The gold standard method to measure the thoracic kyphosis angle is measurement of the Cobb angle on lateral radiographs (8). The disadvantages of radiographic methods are clinical impracticality, high cost, and high exposure to radiation (7). Hence, indirect measurement methods and instruments, such as Debrunner kyphometer (9), flexible electrogoniometers (1), Flexicurve index and Flexicurve angle (10), Spinal Mouse (11), goniometers (12), seventh cervical vertebrae wall distance (13), are applied. The digital inclinometer is one of these methods. The validity and intra – and inter-rater reliability of the digital inclinometer compared with the Cobb angle measurement on lateral radiographs were found to be high (14).

In recent years, one of the methods used to measure range of joint motion is smartphone applications. The use of software applications in clinical practice has increased because they are fast and practical (15). The reliability and validity studies were conducted on the use of smartphone applications for measuring range of motion of different joints (16–18). In addition, the reliability and validity of smartphone applications to measure thoracic kyphosis angle were investigated (19,20); however, the reliability and validity of a measurement instrument are not enough for an interpretation of change scores, the standard error of measurement (SEM) and the minimal detectable change should be determined (21). A smaller SEM is an indicator of a good reproducibility (22). The minimal detectable change is also an important benchmark associated with reliability, and shows the smallest change in score that can be interpreted as a true change beyond measurement error (21).

ISSN:2459-1459

DOI: 10.33808/clinexphealthsci.1038122

The aim of this study was to assess the intra – and inter-rater reliability, and concurrent validity, and to estimate the minimal detectable change of a smartphone application for measuring the thoracic kyphosis angle.

2. METHODS

2.1. Participants

In this cross-sectional study, a total of 80 healthy university students participated. The inclusion criteria were as follows: older than 18 years, and able to stand independently without using any auxiliary devices. The exclusion criteria were as follows: any pain or pathology of the musculoskeletal system of the spine, and lower and upper extremities; low back pain; and having a previous surgery of the musculoskeletal system.

All participants were informed about the study, and they signed the informed consent form before participating in the study. The Non-Interventional Research Ethics Committee of European University of Lefke (17/07/2018 and UEC/17/02/07/1718/01) approved the study.

2.2. Instruments

A digital inclinometer (Baseline, 12-1057, Fabrication Enterprises, NY, USA) and a smartphone application (Clinometer, Plaincode) were used to measure the thoracic kyphosis angle of the participants.

2.3. Procedures

The measurements were performed by two physiotherapists with 13 and 19 years of experience. Before the study began, the physiotherapists practiced the procedures on volunteer subjects. As recommended in the literature, two reference points were determined to measure the thoracic kyphosis angle: the spinous processes of the 1st and 2nd thoracic vertebrae (the first reference point), and the spinous processes of the 12th thoracic and 1st lumbar vertebrae (the second reference point) (23). The total thoracic kyphosis degree was obtained by summing the angle values for each reference points (23).

The thoracic kyphosis angle was measured with the digital inclinometer and the smartphone application by each rater. Once the first rater completed the first session, the participants were rested for ten minutes prior to performing the measurement with the second rater. The second session was performed on the same day. The first and second sessions were performed three times for each instrument by each rater, and a mean value of the three measurements was used for further analysis.

2.3.1. Digital inclinometer measurement

The participants were asked to remove outer clothing to identify the spinous processes, and to assure proper positioning of the instruments. The participants were requested to stand in their normal postures and with their arms resting alongside their bodies, and remain as still as possible to avoid deviation from the angular values during the measurement. The reference points were determined by palpation, and marked. The feet of the inclinometer was initially placed at the first reference point, and a value was recorded. The inclinometer was then placed at the second reference point to measure a second value. The thoracic kyphosis angle was the sum of the values (Figure 1).

Figure 1. *The measurement of the thoracic kyphosis angle with the digital inclinometer.*

2.3.2. Smartphone application measurement

The instructions to the participants were as stated previously. The top side of the smartphone was placed at the first reference point with screen facing laterally, and a value was recorded. A second value was obtained from the second reference point in the same way, and the sum of both values was deemed the thoracic kyphosis angle (Figure 2).

Figure 2. *The measurement of the thoracic kyphosis angle with the smartphone application.*

2.4. Sample size estimation

The sample size was calculated based on the sampling method recommended by Walter et al. for reliability studies using the intraclass correlation coefficient (ICC) (24). The minimal acceptable and expected levels of ICC were set at 0.70 and 0.85, respectively. From this calculation, with α = 0.05 and b = 0.20 for two raters, the minimum number of participants required was 43. Assuming a drop-out rate of 20%, the final sample size was calculated to be 54 participants.

2.5. Statistical analysis

All statistical analysis and graphical representations were performed using the SPSS 25.0 software (SPSS Inc., Chicago, IL, USA). Variables determined by the measurement were expressed as arithmetic mean and standard deviation.

The intra – and inter-rater reliability of the instruments were examined by calculating the ICC with 95% confidence interval. The ICCs were calculated based on a two-way mixed model (3, k) with an absolute agreement type (25). The ICC values were interpreted as follows: < 0.40, poor; 0.40–0.59, fair; 0.60–0.74, good; and 0.75–1.00, excellent (26). The SEM for the intra – and inter-rater were calculated by √mean square error and √(mean square error) + (mean square subjects × raters), respectively (27). The minimal detectable change at the 95% confidence level (MDC_{95}) was calculated by 1.96 × SEM × √2 (28).

The concurrent validity between the digital inclinometer and the smartphone application was assessed by the linear regression correlation and the limits of agreement proposed by Bland and Altman (29). The 95% limits of agreement were calculated as mean difference ± 1.96 × SD (29).

3. RESULTS

The demographic characteristics of the participants are presented in Table 1. The measurement results of both raters are given in Table 2. The intra – and inter-rater reliability are presented along with the SEM and MDC_{95} values in Table 3 and Table 4, respectively. The intra – and inter-rater reliability were excellent for the digital inclinometer and the smartphone application.

Table 1. *The demographic characteristics of the participants.*

	N = 80
Age (years) (Mean±SD)	20.42±1.40
Gender (in %) Male Female	 42 (52.5) 38 (47.5)
Weight (kg) (Mean±SD)	66.58±13.39
Height (m) (Mean±SD)	1.71±0.09
Body mass index (kg/m²) (Mean±SD)	22.58±3.16

SD, standard deviation

Table 2. *The measurement values of the digital inclinometer and the smartphone application for the first and second raters.*

	First session Mean±SD (range)	Second session Mean±SD (range)
First rater		
Digital inclinometer (°)	30.01±6.65 (14.30–48.10)	29.58±6.53 (14.20–47.70)
Smartphone application (°)	30.47±6.74 (15.20–49.40)	29.93±6.84 (14.10–49.30)
Second rater		
Digital inclinometer (°)	29.01±5.39 (15.60–44.80)	28.66±5.72 (15.40–44.10)
Smartphone application (°)	28.73±5.36 (16.90–44.80)	28.40±5.17 (17.10–44.30)

SD, standard deviation

Table 3. *The intra-rater reliability of the digital inclinometer and the smartphone application.*

	Digital inclinometer			Smartphone application		
	ICC (95% CI)	SEM (°)	MDC_{95} (°)	ICC (95% CI)	SEM (°)	MDC_{95} (°)
First rater	0.92 (0.88–0.95)	2.44	6.76	0.94 (0.90–0.96)	2.27	6.30
Second rater	0.94 (0.91–0.96)	1.81	5.04	0.93 (0.89–0.95)	1.84	5.11

ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC95, minimal detectable change at the 95% confidence level

Table 4. *The inter-rater reliability of the digital inclinometer and the smartphone application.*

	ICC (95% CI)	SEM (°)	MDC_{95} (°)
Digital inclinometer	0.82 (0.73–0.89)	3.03	8.39
Smartphone application	0.80 (0.68–0.88)	3.25	9.02

ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC95, minimal detectable change at the 95% confidence level

Figure 3 and Figure 4 provide graphical representations of the linear correlation and the limits of agreement, respectively. The linear regression correlation between the digital inclinometer and the smartphone application showed a positive correlation (R^2 = 0.85) (Figure 3). A mean difference on the Bland-Altman plot was –0.46 degrees, and the limits of agreement ranged from –5.60 to 4.67 degrees (Figure 4). When interpreted according to Bland and Altman (29), it can be said that the Bland-Altman plot showed a good agreement between the instruments.

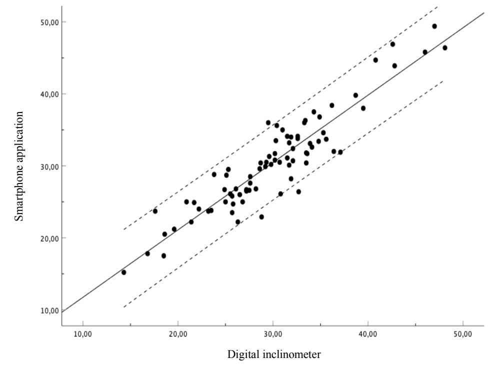

Figure 3. *The linear correlation between the digital inclinometer and the smartphone application (y = 2.38 + 0.94*x, R^2 = 0.85). The solid line is the linear regression line, the dashed lines are the 95% confidence limits.*

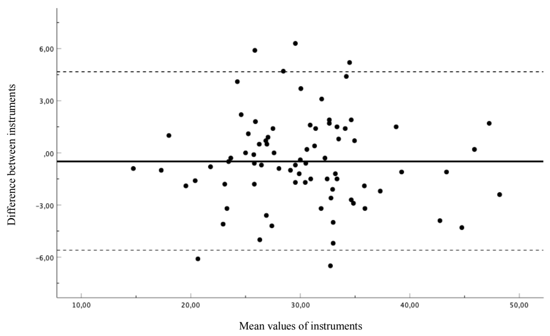

Figure 4. *The Bland-Altman plot comparing the measurements of the digital inclinometer and the smartphone application (SD = 2.62). The solid line is the mean difference (–0.46), the dashed lines are the 95% limits of agreement (–5.60 to 4.67).*

4. DISCUSSION

The present study shows that the smartphone application used in this study has high reliability and concurrent validity for measuring the thoracic kyphosis angle, and hence is an appropriate instrument to be used in clinic practice as an alternative to other instruments.

This study provides novel findings about the reliability of a smartphone application for measuring the thoracic kyphosis angle. In clinical practice, reproducibility of a measurement is an important concern when assessing a patient. A high ICC value and a smaller SEM in repeated measurements reflect a greater reproducibility (22). This study revealed that reproducibility of measuring the thoracic kyphosis angle with the smartphone application is high. Furthermore, the SEM values for the smartphone application were very close to those of the digital inclinometer (see Table 3 and Table 4); therefore, it can be argued that the smartphone application is an instrument as precise as the digital inclinometer for measuring the thoracic kyphosis angle. In this study, the MDC_{95} values of the smartphone application for intra-rater were 5.11 and 6.30 degrees, and for inter-rater was 9.02 degrees, meaning that if a clinician detects a change of more than 9 degrees in the value of the thoracic kyphosis angle measured by the smartphone application in a patient, the clinician can assume it as a true change.

The intra – and inter-rater ICC values determined by the present study are consistent with a recent study with a similar age group (20). In another study evaluating the intra-rater reliability of a smartphone application for measuring the thoracic kyphosis angle, the ICC and SEM values were found as 0.80 and 11.80 degrees, respectively (19). These findings are pretty different from those in the present study. There could be several possible explanations for discrepancies between studies. Firstly, in the mentioned study, the first and second measurement were made in standing and sitting positions, respectively (19). The angles in the vertebral arrangement showed a significant difference in sitting and standing positions (30). The different position of the participants in repeated measurements would probably affect the results. Secondly, the time period between the repeated measurements was different in studies. The second measurement was performed one week later in the mentioned study (19), while it was performed on the same day in the present study. This factor also could explain this difference.

The smartphone application showed similar reliability levels for measuring the thoracic kyphosis angle compared to other indirect measurement instruments which have been previously studied. Greendale et al. found the intra – and inter-rater ICC values as between 0.96 and 0.98 for the Debrunner kyphometer, the Flexicurve kyphosis index, and the Flexicurve kyphosis angle (10). Similarly, Roghani et al. found the intra-rater ICC value for the Spinal Mouse measurement instrument as 0.89 in subjects with normal kyphosis and as 0.94 in subjects with hyperkyphosis (11); however, while the population of the present study consisted of young and healthy subjects, the average age of subjects was ≥ 60 years in the mentioned studies (10,11). Elderly subjects showed more postural stiffness in the thoracic region compared with younger subjects (31). This factor might make a difference in repeated measurements; therefore, the differences in characteristics of the study population between the present study and the mentioned studies should be considered when comparing results. This issue should be addressed in future studies.

In previous studies, the concurrent validity of some indirect measurement methods and instruments has been studied (1,13). In these studies, the validity among methods or instruments was assessed with a correlation analysis (1,13). Such an approach has not been followed in the present study because Bland-Altman analysis is recommended to compare methods instead of correlation analysis (29). In the present study, the coefficient of determination obtained by using the linear regression was used to reveal the proportion of variance that the two instruments, but in addition, the Bland-Altman plot was presented to describe agreement between the instruments. In this study, the Bland-Altman analysis demonstrated a small mean difference with narrow limits of agreement. This means the smartphone application can be used instead of the digital inclinometer for measuring thoracic kyphosis angle. Shahri et al. compared a smartphone application with the Cobb angle on lateral radiographs and reported that an acceptable agreement between the smartphone application and the Cobb angle (20); however, the limits of agreement were wider than those calculated in the present study, and in our opinion, reported intervals in the mentioned study were not small enough to reach a conclusion that the methods could be used interchangeably. It was probably caused by a small sample size (n = 31) of the mentioned study; sample size is a factor that affects the limits of agreement (29,32). If it was performed with a larger sample size, in our opinion, the limits of agreement would come closer to the intervals obtained the present study.

Smartphone applications has a substantial advantage in clinical practice. It is not as expensive as other indirect measurement instruments. Applications can be downloaded for free via the Internet. Clinicians, on the other hand, may not want their personal phone to come in contact with others' skin (33). This may be a barrier to use of smartphone applications in clinical practice.

This study has some limitations. Firstly, the concurrent validity of the smartphone application was not assessed by comparing measurement of the Cobb angle on lateral radiographs, which is accepted as the gold standard method for measuring the thoracic kyphosis angle. The radiographic method was not preferred in the present study because it would expose participants to excessive radiation and, in turn, pose ethical problems (1). Nevertheless, the digital inclinometer was used as a reliable and valid indirect instrument for measuring the thoracic kyphosis angle (14). Furthermore, the generalizability of the results is limited to a young, active, and healthy population, so the findings may not apply to other populations.

5. CONCLUSION

The smartphone application used in this study is a cost-effective, practical, reliable, and valid instrument for measuring the thoracic kyphosis angle in clinical practice. More than 9 degrees in the value of the thoracic kyphosis angle measured by the smartphone application can be considered as a true change. Future studies should assess the reliability and validity of smartphone applications for measuring thoracic kyphosis angle in different populations.

Funding: *The author(s) received no financial support for the research.*
Conflicts of interest: *The authors declare that they have no conflict of interest.*
Ethics Committee Approval: *This study was approved by European University of Lefke Non-Interventional Research Ethics Committee of (Approval date: 17.07.2018 and number: UEC/17/02/07/1718/01)*
Peer-review: *Externally peer-reviewed.*
Author Contribution:
Research idea:EŞ,GE,SB
Design of the study: EŞ,GE,SB,BÜ
Acquisition of data for the study: GE,SB
Analysis of data for the study: EŞ,GE
Interpretation of data for the study: EŞ, GE, SB, BÜ
Drafting the manuscript: EŞ,GE
Revising it critically for important intellectual content: EŞ,GE,SB,BÜ
Final approval of the version to be published: EŞ,GE, SB,BÜ

REFERENCES

[1] Perriman DM, Scarvell JM, Hughes AR, Ashman B, Lueck CJ, Smith PN. Validation of the flexible electrogoniometer for measuring thoracic kyphosis. Spine (Phila Pa 1976) 2010;35(14):E633–640.

[2] Barrett E, O'Keeffe M, O'Sullivan K, Lewis J, McCreesh K. Is thoracic spine posture associated with shoulder pain, range of motion and function? A systematic review. Man Ther 2016;26:38–46.

[3] Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. Osteoporos Int 2005;16(8):1004–1010.

[4] Kim DY, Moon ES, Park JO, Chong HS, Lee HM, Moon SH, et al. The thoracic lordosis correction improves sacral slope and walking ability in neuromuscular scoliosis. Clin Spine Surg 2016;29(8):E413–E420.

[5] Ishikawa Y, Miyakoshi N, Hongo M, Kasukawa Y, Kudo D, Shimada Y. Relationships among spinal mobility and sagittal alignment of spine and lower extremity to quality of life and risk of falls. Gait Posture 2017;53:98–103.

[6] Kado DM, Lui L-Y, Ensrud KE, Fink HA, Karlamangla AS, Cummings SR, et al. Hyperkyphosis predicts mortality independent of vertebral osteoporosis in older women. Ann Intern Med 2009;150(10):681–687.

[7] Barrett E, McCreesh K, Lewis J. Reliability and validity of non-radiographic methods of thoracic kyphosis measurement: a systematic review. Man Ther 2014;19(1):10–17.

[8] Briggs AM, Wrigley T v., Tully EA, Adams PE, Greig AM, Bennell KL. Radiographic measures of thoracic kyphosis in osteoporosis: Cobb and vertebral centroid angles. Skeletal Radiol 2007;36(8):761–767.

[9] Lundon KM, Li AM, Bibershtein S. Interrater and intrarater reliability in the measurement of kyphosis in postmenopausal women with osteoporosis. Spine (Phila Pa 1976) 1998;23(18):1978–1985.

[10] Greendale GA, Nili NS, Huang MH, Seeger L, Karlamangla AS. The reliability and validity of three non-radiological measures of thoracic kyphosis and their relations to the standing radiological Cobb angle. Osteoporos Int 2011;22(6):1897–1905.

[11] Roghani T, Khalkhali Zavieh M, Rahimi A, Talebian S, Dehghan Manshadi F, Akbarzadeh Baghban A, et al. The Reliability of standing sagittal measurements of spinal curvature and range of motion in older women with and without hyperkyphosis using a skin-surface device. J Manipulative Physiol Ther 2017;40(9):685–691.

[12] Gravina A, Ferraro C, Poli P, Barazzuol M, del Felice A, Masiero S. Goniometric evaluation of the spinal sagittal curves in children and adolescents: A reliability study. J Back Musculoskelet Rehabil 2017;30(2):325–331.

[13] Suwannarat P, Amatachaya P, Sooknuan T, Tochaeng P, Kramkrathok K, Thaweewannakij T, et al. Hyperkyphotic measures using distance from the wall : validity , reliability , and distance from the wall to indicate the risk for thoracic hyperkyphosis and vertebral fracture. Arch Osteoporos 2018;13(1):25.

[14] Azadinia F, Kamyab M, Behtash H, Ganjavian MS, Javaheri MRM. The validity and reliability of noninvasive methods for measuring kyphosis. J Spinal Disord Tech 2014;27(6):E212–218.

[15] Otter SJ, Agalliu B, Baer N, Hales G, Harvey K, James K, et al. The reliability of a smartphone goniometer application compared with a traditional goniometer for measuring first metatarsophalangeal joint dorsiflexion. J Foot Ankle Res 2015;8:30.

[16] Milanese S, Gordon S, Buettner P, Flavell C, Ruston S, Coe D, et al. Reliability and concurrent validity of knee angle measurement: smart phone app versus universal goniometer used by experienced and novice clinicians. Man Ther 2014;19(6):569–574.

[17] Werner BC, Holzgrefe RE, Griffin JW, Lyons ML, Cosgrove CT, Hart JM, et al. Validation of an innovative method of shoulder

range-of-motion measurement using a smartphone clinometer application. J Shoulder Elb Surg 2014;23(11):e275–282.

[18] Charlton PC, Mentiplay BF, Pua YH, Clark RA. Reliability and concurrent validity of a Smartphone, bubble inclinometer and motion analysis system for measurement of hip joint range of motion. J Sci Med Sport 2015;18(3):262–267.

[19] Waś J, Sitarski D, Ewertowska P, Bloda J, Czaprowski D. Using smartphones in the evaluation of spinal curvatures in a sagittal plane. Postep Rehabil 2016;30(4):29–38.

[20] Shahri YFK, Hesar NGZ. Validity and reliability of smartphone-based Goniometer-Pro app for measuring the thoracic kyphosis. Musculoskelet Sci Pract 2020;49:102216.

[21] de Vet HC, Terwee CB, Ostelo RW, Beckerman H, Knol DL, Bouter LM. Minimal changes in health status questionnaires: distinction between minimally detectable change and minimally important change. Health Qual Life Outcomes 2006;4:54.

[22] Terwee CB, Bot SDM, de Boer MR, van der Windt DAWM, Knol DL, Dekker J, et al. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol 2007;60(1):34–42.

[23] Lewis JS, Valentine RE. Clinical measurement of the thoracic kyphosis. A study of the intra-rater reliability in subjects with and without shoulder pain. BMC Musculoskelet Disord 2010;11:39.

[24] Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. Stat Med 1998;17(1):101–110.

[25] Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull 1979;86(2):420–428.

[26] Cicchetti DV. Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. Psychol Assess 1994;6(4):284–290.

[27] Eliasziw M, Young SL, Woodbury MG, Fryday-Field K. Statistical methodology for the concurrent assessment of interrater and intrarater reliability: using goniometric measurements as an example. Phys Ther 1994;74(8):777–788.

[28] Lexell JE, Downham DY. How to assess the reliability of measurements in rehabilitation. Am J Phys Med Rehabil 2005;84(9):719–723.

[29] Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1(8476):307–310.

[30] Hey HWD, Teo AQA, Tan KA, Ng LWN, Lau LL, Liu KPG, et al. How the spine differs in standing and in sitting—important considerations for correction of spinal deformity. Spine J 2017;17(6):799–806.

[31] Hinman MR. Comparison of thoracic kyphosis and postural stiffness in younger and older women. Spine J 2004;4(4):413–417.

[32] McAlinden C, Khadka J, Pesudovs K. Statistical methods for conducting agreement (comparison of clinical tests) and precision (repeatability or reproducibility) studies in optometry and ophthalmology. Ophthalmic Physiol Opt 2011;31(4):330–338.

[33] Kolber MJ, Pizzini M, Robinson A, Yanez D, Hanney WJ. The reliability and concurrent validity of measurements used to quantify lumbar spine mobility: an analysis of an iphone® application and gravity based inclinometry. Int J Sports Phys Ther 2013;8(2):129–137.

How to cite this article: Şahinoglu E, Ergin G, Bakırhan S, Ünver B. Reliability, Concurrent Validity, and Minimal Detectable Change of a Smartphone Application for Measuring Thoracic Kyphosis. Clin Exp Health Sci 2023; 13: 511-516. DOI: 10.33808/clinexphealthsci.1038122