

Reliability and Validity of Smartphone Goniometer Application for Measurement of Knee Flexion Range of Motion

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ABSTRACT

Background: The most widely used tool for assessment of range of motion is the Universal Goniometer. An accurate Goniometer reading depends on the accurate placement of the fulcrum over the centre of rotation of the joint and the correct alignment of the arms to proximal and distal bony landmarks. Differences in educational and experiential background have been implicated as measurement factors in goniometric accuracy. Since smartphones are becoming more accessible and portable, clinicians are exploring their use as a clinical tool including several applications specifically designed for ROM measurements.

Method: 100 young adults in the age group of 19-35 were evaluated for range of motion of knee flexion by the tester using a Universal goniometer followed by the smartphone application and the readings were recorded. After an hour the same procedure was followed by the inter rater with both instruments.

Results: Reliability and Validity of the smartphone application and universal goniometer was analyzed using ICC and Pearson's correlation. For the UG, ICC at 95% CI for intra rater reliability is 0.997 and for inter rater reliability is 0.991. For the smartphone application, ICC at 95% CI for intra rater reliability is 0.999 and for inter rater reliability is 0.999. Intra rater reliability of UG vs smartphone application with ICC at 95% CI is 0.997. There was a strong positive correlation to confirm concurrent validity between the smartphone goniometer application and the Universal Goniometer ($r=0.9931$; $p<0.0001$) in this study.

Conclusion: The results of the study suggest that the smartphone app has a good intra and inter-rater reliability and concurrent validity with the UG.

Keywords

Goniometer, smartphone, knee range of motion, reliability, validity

INTRODUCTION

The assessment of physiological range of motion (ROM) is a fundamental part of the physical examination of the musculoskeletal system. It is one of the key measures clinicians use to determine functional limitations, develop diagnosis, guide the treatment plan, and monitor progress throughout the course of treatment.⁽¹⁾ The technical measurement of ROM at the knee varies between the clinic or research setting and a user's familiarity of equipment. Common techniques include: visual estimation, inclinometer and goniometer.⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾ Less common methods including radiographs, cinematography, still photography, 3D gyroscopes and human motion capture analysis methods are either not practical or too expensive to use in a normal clinic setting and are reserved for research projects or large motion analysis laboratories.⁽⁶⁾⁽⁷⁾⁽⁸⁾ The most widely used tool in the clinic for ROM assessment for large joints such as shoulder, hip or knee is the Universal Goniometer (UG).⁽⁹⁾ The two main potential sources of error in joint angle evaluation are measurement error and instrument error. An accurate goniometer reading is reliant on the placement of the fulcrum over the center of rotation of the knee joint and the correct alignment of the arms to proximal and distal bony landmarks.⁽¹⁰⁾⁽¹¹⁾ Differences in educational and experiential backgrounds have been implicated as measurement factors in goniometric accuracy.⁽⁶⁾

Since smartphones are becoming more ubiquitous and portable, clinicians are exploring their use as an easily accessible clinical tool, including several applications specifically designed for ROM measurements.⁽¹²⁻²⁰⁾ Contemporary smartphones have numerous built-in sensors such as magnetometer, accelerometer and gyroscope that make the phone capable of detecting position in space to help gather ROM measurements. Having this application available on the clinician's smartphone allows for easy access and creates the potential to offer features that the standard goniometer cannot, including: instant recording and logging of

multiple points of data, and the possibility of transmitting data directly to the patient's electronic medical records. Another possible benefit when using the smartphone is the ability for instant recording with the touch of a button, allowing for ROM to be captured more accurately, thus decreasing transcription errors and eliminating inaccurate reading of numbers on the device.

However, prior to using these applications in the clinic, it is important to evaluate whether they are valid and reliable for use with research or patient care. (12-20)

MATERIALS AND METHODS

Departmental review was taken before the study was started. The research was conducted at the research lab of K.J. Somaiya College of Physiotherapy. Asymptomatic young adults in the age group of 19-35 years were selected as subjects. Individuals with any injury, musculoskeletal pathology or neurological disorder affecting the lower limb were excluded from the study. A written informed consent was taken from all the subjects. Knee flexion range was measured using a universal goniometer and the smartphone application 'Goniometer Records' by the main tester. A second reading was taken by the tester after half an hour using both instruments. After one hour, the same procedure was followed by the inter-rater, having the same educational and experiential background as the tester, with the smartphone and the universal goniometer, and the readings were noted. Thus, 100 subjects with 50 males and 50 females were assessed.

RESULT

The data of 100 participants (N=100) with 50 males (n=50) and 50 females (n=50) in the age group of 19 to 35 years of age (mean=22.24 years) was collected. The data obtained was analyzed using Statistical Package for the Statistical Sciences (SPSS) Software version 24. The data was represented on Bland-Altman Plot using Graph Pad Prism version 7. Intra Class Correlation (ICC) was done to analyze reliability and Pearson's test was done to analyze validity.

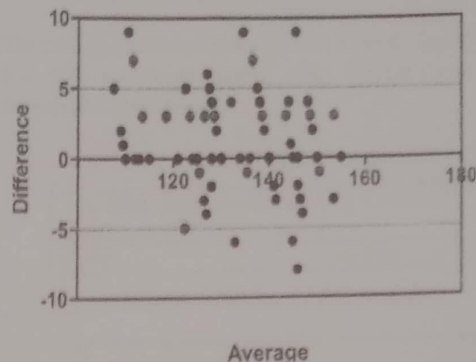
Intra Rater Reliability

The table given below represents Intra Rater Reliability by ICC 95% confidence interval using Cronbach's α for universal Goniometer.

Table 1

The Intra class correlation coefficient, ICC	p Value
0.997	<0.0001

Bland-Altman of GS and GS'



Graph 1

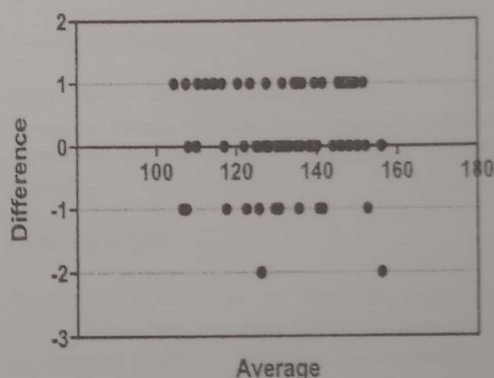
Therefore, Intra-rater reliability of Universal Goniometer for measuring knee flexion ROM is good.

The table given below represents Intra Rater Reliability by ICC 95% confidence interval using Cronbach's α for Smartphone application.

Table 2

The Intra class correlation coefficient, ICC	p Value
0.999	<0.0001

Bland-Altman of AS and AS'



Graph 2

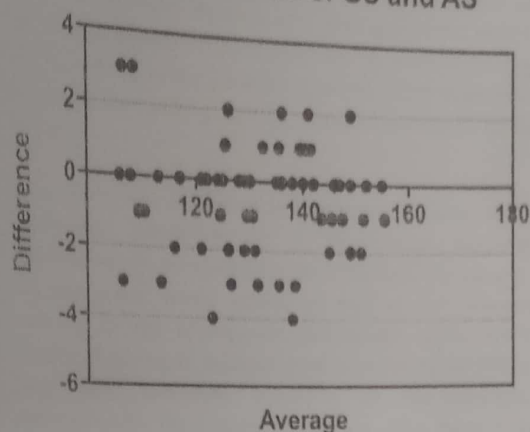
Therefore, Intra-rater reliability of smartphone application, Goniometer Records, for measuring knee flexion ROM is good.

The table given below represents Intra Rater Reliability by ICC 95% confidence interval using Cronbach's α for Universal Goniometer vs Smartphone application.

Table 3

The Intra class correlation coefficient, ICC	p Value
0.997	<0.0001

Bland-Altman of GS and AS



Graph 3

Therefore, Intra Rater Reliability of Universal Goniometer vs Smartphone application, Goniometer Records, for measuring knee flexion ROM is good.

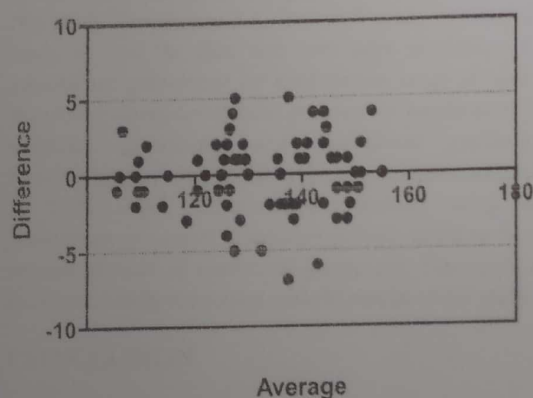
Inter Rater Reliability

The table given below represents Inter Rater Reliability by ICC 95% confidence interval using Cronbach's α for Universal Goniometer

Table 4

The Intra class correlation coefficient, ICC	p Value
0.991	<0.0001

Bland-Altman of GS and GK



Graph 4

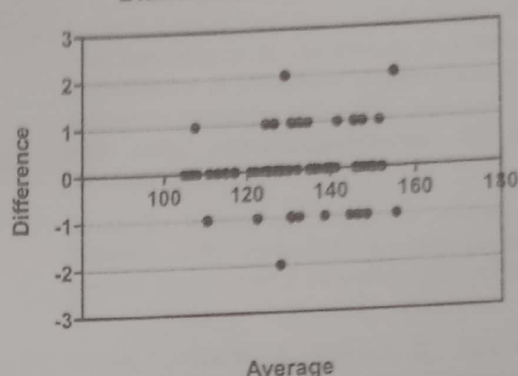
Therefore, Inter-rater reliability of Universal Goniometer for measuring knee flexion ROM is good.

The table given below represents Inter Rater Reliability by ICC 95% confidence interval using Cronbach's α for Smartphone application.

Table 5

The Intra class correlation coefficient, ICC	p Value
0.999	<0.0001

Bland-Altman of AS and AK



Graph 5

Therefore, Inter-rater reliability of smartphone application, Goniometer Records, for measuring knee flexion ROM is good.

Concurrent Validity

There was a strong positive correlation to confirm concurrent validity between the smartphone goniometer application and the Universal Goniometer ($r=0.9931$; $p<0.0001$).

DISCUSSION

Reliability is the extent to which an experiment, test, or measuring procedure yields the same results on repeated trials. ^[21] Concurrent validity refers to the extent to which the results of a particular test, or measurement, correspond to those of a previously established measurement for the same construct. ^[22]

The Universal Goniometer is an instrument which measures range of motion of the joints in the body. ^[23] It is a plastic or metal tool with a central disc marked with 1 degree increments and has two arms, one moveable and one fixed, which are usually not longer than 12-inches. The fixed or proximal arm extends from the central disc

and is the part of the goniometer that does not move during joint range of motion measurement. The movable arm, also called the distal arm, rotates on the central disc during joint range of motion measurement.^[24]

The smartphone goniometer application used in this study is the Goniometer Records app. This application works on the accelerometer of the smartphone to measure the degree of movement in the joint being tested. After measurement of ROM the readings can be recorded and saved for each patient.

This study was conducted to determine the intra rater and inter-rater reliability of a smartphone goniometer application as compared to the Universal goniometer in asymptomatic young adults, as well as the concurrent validity of the smartphone goniometer application. The results of the study indicate good intra rater ($r=0.998$) and inter rater ($r=0.998$) reliability of the smartphone application for the selected population. Also, there is good intra rater and inter rater ($r=0.983$) reliability of the universal goniometer. However, there is no significant difference between the inter rater and intra rater reliability of the smartphone application and the universal goniometer. There was a strong positive correlation to confirm concurrent validity between the smartphone goniometer application and the Universal Goniometer ($r=0.9931$; $p<0.0001$) this study.

Pourahmadi MR, Ebrahimi Takanyani I et al., in their study on active wrist ROM using a universal goniometer and an iPhone goniometer application found good to excellent intra-rater and inter-rater reliability for the universal goniometer with ICC values of ≥ 0.82 and ≥ 0.73 and the iPhone® app with ICC values of ≥ 0.83 and ≥ 0.79 , respectively. The concurrent validity between the two instruments was high, with r values of ≥ 0.80 . The results of the current study are in agreement with the results of this study. Dos Santos RA, Derhon Vet al., conducted a study to find the inter and intra rater reliability of a smartphone goniometer for knee flexion range of motion and found strong correlations between the measures of the universal goniometer and smartphone application (Pearson's correlation and interclass correlation coefficient > 0.93). Also, measurements obtained using the smartphone goniometric application were found to be as reliable as those of a universal goniometer. The results of the current study too concur with the results of this study.

CONCLUSION

The results of the study suggest that the smartphone goniometer application has a good intra and inter-rater

reliability and concurrent validity with the Universal Goniometer. Therefore, it can be used as a tool for measurement of range of motion clinically.

REFERENCES

- [1] Green S, Forbes A, Buchbinder R, Bellamy N. A standardized protocol for measurement of range of movement of the shoulder using the Plurimeter-V inclinometer and assessment of its intra-rater and inter-rater reliability. *Arthritis Rheum.* 1998;11(1):43-52.
- [2] Linda B. Johnson, Sean Sumner, Tina Duong, Posu Yan, Ruzena Bajcsy, R. Ted Abresch, et al. Validity and reliability of smartphone magnetometer-based goniometer evaluation of shoulder abduction – A pilot study. *Mskscienceandpractice*; 2015,dec; vol.20 (6).
- [3] Hayes, K., Walton, A., Zoltan, L., Murrell, G. Reliability of five methods for assessing shoulder range of motion. *Aust J Physiother.* 2001;46:289-294.
- [4] Terwee, C., Winter, A., Scholten, R., Jans, M., Deville, W., Schaarrdenburg, D. et al, Interobserver reproducibility of visual estimation of range of motion of the shoulder. *Arch Phys Med Rehabil.* 2005;86:1356-1361.
- [5] Van De Pol, R., Van Trijffel, E., Lucas, C. Inter-rater reliability for measurement of passive physiological range of motion of upper extremity joints is better if instruments are used: a systematic review. *J Physiother.* 2010;56:7-17.
- [6] Gajdosik, R., Bohannon, R. Clinical measurement of range of motion: review of goniometry emphasizing reliability and validity. *Phys Ther.* 1987;67:1867-1872.
- [7] McClure, P., Michener, L., Karduna, A. Shoulder function and 3-dimensional scapular kinematics in people with and without shoulder impingement syndrome. *Phys Ther.* 2006;86:1075-1090.
- [8] El-Zayat, B., Efe, T., Heindrich, A., Anetsmann, R., Timmesfeld, N., Fuchs-Winkelmann, S. et al, Objective assessment, repeatability, and agreement of shoulder range of motion with a 3d gyroscope. *BMC MusculoskeletDisord.* 2013;14.
- [9] Norkin, C., White, D. Measurement of joint motion: a guide to goniometry. FA Davis, Philadelphia (PA); 2003.

- [10] Clefken B, van Breukelen G, Brink P, van Mameren H, OldeDamink S. Digital goniometric measurement of knee joint motion. Evaluation of usefulness for research settings and clinical practice. *Knee*. 2007;14(5):385-9. doi: 10.1016/j.knee.2007.07.004.
- [11] Behnam Behnoush,1 Nasim Tavakoli,2 Elham Bazmi,3 Fariborz Nateghi Fard,3 Mohammad Hossein Pourgharib Shahi,4 Arash Okazi, et al. Smartphone and Universal Goniometer for Measurement of Elbow Joint Motions: A Comparative Study. *ASJSM*. 2016 Jun 11; vol. 7(2). doi: 10.5812/asjrm.30668
- [12] Ferriero G, Verecelli S, Sartorio F, Munoz Lasa S, Ilieva E, Brigatti E, et al. Reliability of a smartphone-based goniometer for knee joint goniometry. *Int J Rehabil Res*. 2013;36(2):146-51. doi: 10.1097/MRR.0b013e32835b8269.
- [13] Kolber MJ, Hanney WJ. The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical report. *Int J Sports Phys Ther*. 2012;7(3):306-13.
- [14] Shin SH, Ro du H, Lee OS, Oh JH, Kim SH. Within-day reliability of shoulder range of motion measurement with a smartphone. *Man Ther*. 2012;17(4):298-304. doi: 10.1016/j.math.2012.02.010.
- [15] Mitchell K, Gutierrez SB, Sutton S, Morton S, Morgenthaler A. Reliability and validity of goniometric iPhone applications for the assessment of active shoulder external rotation. *Physiother Theory Pract*. 2014;30(7):521-5. doi: 10.3109/09593985.2014.900593.
- [16] Anderson, D., English, E., Varea, K., Diaz, D., Lowe, D. Reliability and validity of an iPhone inclinometer as compared to a universal goniometer as a tool for measuring joint motion of the shoulder in apparently healthy subjects. *OTPT*. 2012;25:34-38.
- [17] Milanese, S., Gordan, S., Buettner, P., Flavell, C., Ruston, S., Coe, D. et al. Reliability and concurrent validity of knee angle measurement: smart phone app vs universal goniometer used by experienced and novice clinicians. *Man Ther*. 2014 Dec;19:569-574.
- [18] Milani, P., Coccetta, C.A., Alessia, R., Sciarra, T., Giuseppe, M., Ferriero, G. Mobile smartphone applications for body position measurement in rehabilitation: a review of goniometric tools. *PM R*. 2014;1-6.
- [19] Werner, B., Kuenze, C., Griffen, J., Lyons, M., Hart, J., Brockmeier, S. Shoulder range of motion: validation of an innovative measurement method using a smartphone. *Orthop J Sports Med*. 2013;1.
- [20] Yan, P., Kurillo, G., Bajcsy, R., Abresch, R., Nicorici, A., Johnson, L. et al. mHealth application for upper extremity range of motion and reachable workspace. *Stud Health Technol Inform*. 2013;184:478-480.
- [21] Merriam Webster. Reliability| Definition of Reliability. Available from: <https://www.merriam-webster.com/dictionary/reliability>
- [22] Study.com. Concurrent Validity: Definition & Examples. Available from: <https://study.com/academy/lesson/concurrent-validity-definition-examples.html>
- [23] Wikipedia. Goniometer-Wikipedia. Available from: <https://en.wikipedia.org/wiki/Goniometer>
- [24] physicaltherapynotes.com. Parts of the Goniometer| Physical Therapy(PT) Notes. Available from: <http://www.physicaltherapynotes.com/2011/02/parts-of-goniometer.html>

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