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Reliability and Validity of the Digital Goniometry to Determining Active Shoulder Range of Motion in Occupational Therapy Contextual Learning Strategy Using Digital Technology

Muhammad Hidayat Sahid*
Occupational Therapy Departement
University of Indonesia
Depok, Indonesia
Email: m.hidayatsahid@gmail.com

Andriani Pratiwi
Occupational Therapy Departement
BrightFits Center
Depok, Indonesia
Email: andrianisukamto2509@gmail.com

Cacha Afradisa
Occupational Therapy Departement
University of Indonesia
Depok, Indonesia
Email: cachaafradisa2007@gmail.com

Fanza F. Ajjauza
Occupational Therapy Departement
University of Indonesia
Depok, Indonesia
Email: fanzafatina@gmail.com

*Corresponding Author

Abstract: Smartphones have become a very important thing in the digitaly year. Their function not only for communication tool but also as a lot of another function as their value add such as a healthcare tool to helping professional healthcare to measure range of motion of human body movement. G-Pro is one of digitaly goniometric application for helping healthcare professional to measure the range of motion of upper and lower extremity. Occupational therapy students in University of Indonesia using this technology to learning how to measure the range of motion of human body, but actually there is no research about validity and reliability of this tool in Indonesia. The purpose of this research is to analyze the reliability and validity of a G-Pro app as compared with traditional goniometry. 21 subjects of occupational therapy students in University of Indonesia, in 2018 had 4 measurements of their degree of shoulder extension for a randomly chosen shoulder position: 2 by universal goniometry (UG) and 2 by the Goniometer-Pro (G-Pro) application. A different evaluator made each measurement. The difference between mean intra-group values was 3,148º (±2,669º) and 2,476º (±2,638º) for G-Pro. The difference between the mean intra-group values was 5.45º. Inter-observer consistency for UG was 0,990 and 0,993 for G- Pro; As regards validity, the values obtained were 0,976 for UG and 0,992 for G-Pro. The Goniometer-Pro app seems to be a reliable and accurate tool for determining the values of shoulder extension. The values obtained are slightly more accurate than those of traditional goniometry. This study intend to promote the use of apps of systemic form in the health system, as a component integrated into the management of the health. This work not only compares the reliability of two methods of measurement, compare the reliability or validity with a gold standard, as it is the radiological measurement.

Keywords: Goniometry; smartphone app; shoulder flexion; shoulder; range of motion.

1. Introduction

Mobile phone and in particular mobile applications (apps), are the ones making the most profound impact on both patients and healthcare practitioners. These mobile applications (apps) has defined as “software applications intended for use in the diagnosis or cure, mitigation, treatment or prevention of diseases that may affect the structure or any function of the body of a man or other animals [1].

A report by the Institute for Healthcare Informatics (IMS) [3] states that over 40,000 health-based apps are available for download from Apple Store. In 2015, the number of smartphone users that had downloaded health-based apps, exceeded the 500 million mark [4].

Universal goniometry (UG) has long been regarded by both physicians and occupational therapists as the most objective tool for measuring articular range of motion (ROM), thus contributing to make accurate diagnoses and monitoring the efficiency of treatment [5,6,7,8]. Nonetheless, some factors exist that could negatively influence the reliability and accuracy of UG such as poor identification of anatomical landmarks, malpositioning of the arms of the goniometer and inconsistencies in limb positioning [9,10].

These apps may use the phone´s equipped sensors (accelerometer, inclinometer, etc.) to measure physiological parameters such as limb movement [1]. This technology is gaining increasing ground in clinical practice, as it constitutes a fast, accurate and easy-to-interpret tool [11,12,13,14,15]. Moreover, these applications can be used by patients themselves outside the clinical environment [16].

The purpose of this study is to analyze the reliability and concurrent validity of a health-related mobile phone app as compared with traditional UG for measuring shoulder range of motion.

2. Material & Methodology

A non-experimental double blind comparative and descriptive study was carried out by the occupational therapy students in University of Indonesia in 2018. The study was granted approval by the public health scientific and ethical committee of University of Indonesia.

The study was performed by an occupational therapists with over 10 years' experience in the field of musculoskeletal treatment plus a researcher responsible for statistical analysis and 2 occupational therapy students in University of Indonesia. Two of them were in charge of the measurements while the others was responsible for measuring the subject´s degree of the shoulder range of motion. Two of the evaluators used the Goniometer-Pro (G-Pro) health-based mobile phone app while the other two used UG. The first two had never used the G-Pro app, whereas the last two were in the habit of using UG. The method used to measure the degree of the shoulder range of motion with UG was as follows: The responden is sitting or prone. The arm is at the side, with the palm facing medially. The goniometer axis is placed at the lateral aspect of the center of the acro-mion process. The stationary arm is parallel to the lateral midline of the thrunk. The movable arm is parallel to the longitudinal axis of the humerus, pointing towards the lateral epicondyle of humerus [15]. As regards the G- Pro app, it bases its measurements in inclination with respect to horizontal, being that of the orientation of humerus.

The study sample comprised 21 subjects who were asked to sign an informed consent form. Subjects were placed in the prone position on an examination table in the occupational therapy laboratory room. Next, a occupational therapist placed the left shoulder at a randomly chosen degree of flexion. This flexion was stood still through a few cots and pillows to prevent any alteration in the positioning of the shoulder.

Subsequently, 4 measurements of the subjects' active of shoulder flexion were carried out: two measurements were made by UG and two with the G-Pro app, shown on Figure 1.

Each evaluator noted the value obtained on a specifically-designed template without disclosing any information to the others. Once all four goniometric measurements were performed, the values obtained by occupational therapists were e-mailed to the researcher, who was in charge of carrying out the statistical analysis without knowledge of what measurement group the each value belonged to.

Figure 1. Measurement using the G-Pro app.

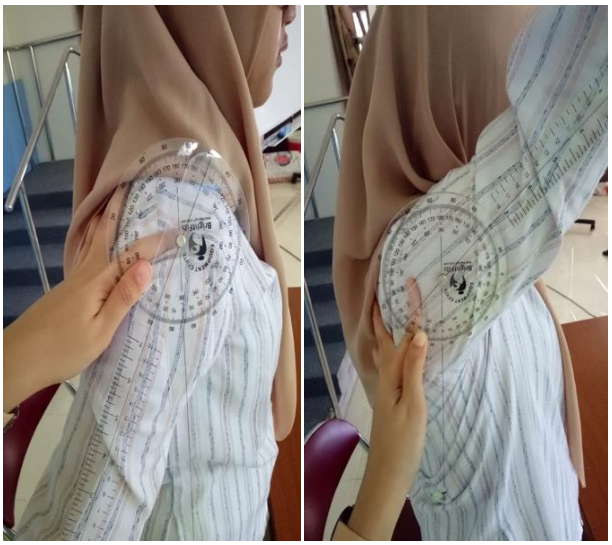

Figure 2. Measurement using the UG.

Analysis of the data was performed using SPSS 20® software for Macinthos. This analysis made it possible to obtain values for inter-observer consistency, using Cronbach's alpha. The intra-class correlation coefficient (ICC) was used for determining the accuracy of the two measurement tools, while the Pearson correlation coefficient was calculated to establish the average values obtained by the two measurement tools.

3. Result

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Descriptive data is shown on Table 1. The difference between the mean intra-group values was 3,157º (±2,669º) for UG and 2,468º (±2,638º) for G-Pro. The difference between the mean intra- group values was 5,53º.

Table 1: Data of measurements with Universal Goniometer (UG) and Goniometer-Pro (G-Pro) in active extension of shoulder.

No	UG			G-Pro		
	X_1(º)	X_2(º)	R(º)	X_1(º)	X_2(º)	R(º)
1	57	55	56	60	58	59
2	56	58	57	56	57	56,5
3	50	53	51,5	52	51	51,5
4	50	47	48,5	51	50	50,5
5	45	47	46	47	47	47
6	42	39	40,5	42	42	42
7	34	33	33,5	34	33	33,5
8	40	42	41	46	43	44,5
9	25	26	25,5	31	26	28,5
10	32	29	30,5	40	44	42
11	26	25	25,5	37	33	35
12	41	39	40	68	68	68
13	30	28	29	39	35	37
14	55	54	54,5	56	55	55,5
15	60	59	59,5	60	60	60
16	57	56	56,5	57	57	57
17	45	46	45,5	47	47	47
18	59	55	57	59	60	59,5
19	43	44	43,5	45	45	45
20	60	59	59,5	60	60	60
21	57	55	56	58	58	58

Note:
X_1 : First measurement
X_2 : Second measurement
R : Mean
UG : Universal Goniometer
G-Pro: Digital Goniometer

3.1 Reliability

The realiability score for UG, Cronbach's alpha was 0,983 and ICC was 0,990. And for G-Pro, Cronbach's alpha was 0,991 and ICC was 0,993. Its mean that both of them have high reliability but the digital tool have little bit a good score.

3.2 Validity

The accuracy of the different measurements was analyzed comparing the mean values obtained using each of the measurement techniques with the values obtained from the radiographs. The purpose was to determine which of the two techniques provided values that came closer to the real values as calculated from the radiographs. On this basis, the accuracy of the techniques was established at 0,976 for UG and 0,992 for G-Pro.

In addition, a graphic representation of the values measured by the two techniques under study (UG and G-Pro) was made in order to determine whether there was a strong correlation between them. For UG, the correlation coefficient between the mean values from both evaluators a was 0,977; the Pearson correlation coefficient was 0,988, in Figure 3. For G-Pro, the correlation coefficient between the mean values from both evaluators was 0,971; he Pearson correlation coefficient was 0,985, in Figure 3.

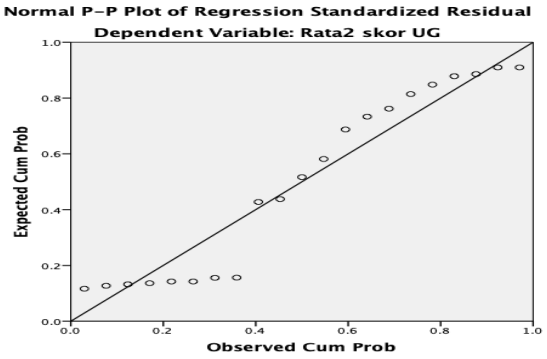

Figure 3. G-Pro and UG correlation.

4. Discussion

Mobile health is quickly becoming a mainstay of healthcare around the world, including developing countries [3]. As a technology that is available to "everyone, anywhere, anytime", it provides huge opportunities for innovation in healthcare. In this respect, applications conceived for measuring articular ROM are a straightforward and convenient tool that offers benefits to both patients and practitioners. As shown by this study, although both UG and G-Pro are highly reliable methods (0,983 and 0,993 respectively), Cronbach's alpha demonstrates a slight advantage in favor of the app. In terms of accuracy, both techniques are highly accurate but the mobile app G-Pro exhibited a slightly higher value (0,976 as compared with 0,992), with a quasi-perfect correlation (0,985).

Several studies have been published in the last few years comparing different mobile applications with the same purpose in mind. Milanese [12)] study the intra- and inter- observer consistency of three senior physiotherapy students and three experienced physicians in measuring passive range of motion in six right knees by means of a smartphone as compared with UG. Observers carried out the measurement using both UG and a smartphone app and reached similar conclusions to those of this study. Indeed, the measurement of the mobile application was slightly more accurate than that obtained from UG, with no statistically significant differences between the measurements made by the students and those of the experienced physicians (ICC > 0,96 in both cases). In a similar study, Jones [13] carry out a comparison between UG and an iPhone app for measuring the active flexion of the shoulder in a cohort of 36 subjects, no finding statistically significant differences between the two measurement tools (Pearson correlation coefficient 0,96 vs. 0,98), confirm that both systems are equally valid.

On the basis of a cohort of five subjects, Ockendon and Gilbert [11] compare the validity of a purpose-built mobile application to that of a traditional goniometer for measuring knee range of motion. This results show that the values obtained from both measurement instruments are closely correlated, albeit with slight differences in favor of the mobile app (inter-observer correlation: was 0,994 vs. 0,952 and intra- observer correlation: was 0,982 vs. 0,927); the mean difference between the two is only -0,4º. In this study, the difference was 5,45º. This value is not available in the work of Ockendon and Gilbert as the authors not

compare the results obtained from the measuring instruments with the real flexion value as measured by x-ray [21].

Other studies, such as the one by Ferretti [2], validate the clinical use of a smartphone application (SmartJoint) for measuring anterior tibial translation during Lachman's test in 35 knees with a deficient anterior cruciate ligament. In this study, two evaluators compared the values obtained from the app with those obtained from applying the KT-1000 arthrometer to both knees, one of them with a deficient ACL. The authors conclude that the performance of the new application is comparable and highly correlated with the measurements from the arthrometer (mean ICC for the knee with a deficient ACL was 0,987).

But the positive results obtained by mobile applications are in no way restricted only to the measurement of knee mobility. Several authors have found comparable results using similar apps for other joints such as wrist [4], fingers [8,9], shoulder [24,25], lumbar spine [5], or even to analyze range of motion in patients who have suffered a stroke [7].

The data presented so far provides ample evidence that mHealth and, specifically, health-based apps are likely to result in an improvement in quality of care and greater efficiency in the evaluations and examinations made by health care practitioners. However, further studies are required to determine the extent to which the new technologies conceived to measure range of motion may lead to cost savings in healthcare.

According to an analysis of the Kinsey Global Institute published in 2011 [8], health-based apps could save the European public health sector 250 billion euros and the United States' public health sector around 300 billion dollars. Moreover, as a result of the lower cost of mobile technologies and their widespread embrace, the use of apps is on the rise in places where traditional technology is virtually absent. In desolate and isolated regions of the world, mobile devices facilitate remote patient care, telemedicine and emergency intervention. A report by PricewaterhouseCoopers [9], published in 2012, claims that mobile applications could save over a million lives in Sub-Saharan Africa in the next five years and save the European Union up to 100 billion euros until 2017. In Spain, a recent study on the information society, published by the Telefonica Foundation [10], states that the use of mobile technologies may reduce the per capita healthcare bill in Europe by 18% in 2017. This reduction could be of up to 35% in the case of chronic patients.

Therefore mHealth can be considered a key factor in the progression to a more sustainable healthcare, resulting in improvements in efficacy and efficiency, reducing costs and meeting the most basic needs of our society at a time when aging and chronic diseases have emerged as a formidable challenge.

The study was several limitations; no symptomatic patients to compare the measurements with respect to the asymptomatic patients in the study, sample size was not high enough to draw conclusions from the outcomes.

5. Conclusions

In conclusion both the Goniometer-Pro app and the universal goniometer are reliable tools for accurately measuring the range of motion of a knee. The results presented of the mobile application were slightly more accurate than those of traditional goniometry, which seems to indicate that the G-Pro app is a useful tool to measure the arc of movement of the shoulder. In addition, the convenience and portability of a mobile application greatly simplifies ROM determination. Mobile Health Application is a groundbreaking technology that is bound to radically change the way medicine is practiced. But this should come as no surprise since it has long been known that almost 100% of medical knowledge is renewed every 20 years [16]. A day will probably come when physicians, pharmacists, physical therapists and other healthcare practitioners will prescribe, apart from the most appropriate treatments for each case, a

series of relevant, reliable and reputed online resources [16].

Future scope of this work will be the verification by other studies of the performance of Goniometer-Pro app and the universal goniometer in patients with knee injury and its comparison with symptomatic patients, checking whether the validity data shown in this study can be extrapolated into rehabilitation services.

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