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A Study on the Reliability and Validity of Measuring the Range of Motion of the Elbow Joint Using a Smartphone Application

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Abstract

The purpose of this study was to assess the intra-tester and inter-tester reliability and validity of elbow flexion range of motion using a smart phone used by the general public. Thirty-one general people participated in this study. The range of motion in active elbow flexion was measured with a goniometer and smart phone over two times by two observers. The intra-taster and inter-tester reliability were evaluated using the intraclass correlation coefficient(ICC). The validity was measured by Pearson's correlation coefficient. The intra-observer reliability was good in all measured items ICC>0.900. The inter-observer reliability was high with ICC>0.806. All correlation coefficients of android app and goniometer were greater than 0.868 and showed a significant positive correlation (p<0.01). The range of motion measurement with a smart phone showed acceptable reliability. Therefore, using a smartphone to measure the range of motion of the elbow joint could provide convenience and economic benefits.

Keywords: *Goniometer, Range of motion, Reliability and Validity, Android app, Elbow joint*

1. Introduction

A goniometer is an economic and portable instrument to measure range of motion, and it is most widely used in clinical settings. [1, 2]
The status of the joints can be examined at the initial stage of treatment using a goniometer in a more objective and accurate way. By repeating measurement and comparing the measured data, the progress of a treatment program can be evaluated, and the direction of follow-up treatment programs can be determined based on the data. In addition, the final value can be compared with those that have been measured or normal values. By doing so, the level of disability can be assessed, and, at the same time, the goals of treatment can be set. It is also important as a psychological factor that can increase the motivation of patients. [3]
Measuring the range of motion is also important as a manual muscle testing indicator. [4] Considerations in measuring the range of motion include determining selective starting positions, recording selective starting positions, sufficient orientation for patients, proper instructions for the use of a goniometer, necessity of

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comparing the passive and active range of motion, and necessity of bilateral comparison. The range of motion should be measured and recorded in a certain manner according to standardized instructions, and the date (month, day) of measurement and the signature of a recorder should be written. At the same time, it should be measured after fully understanding the accurate zero angular position based on anatomical positions. [5]

It is also necessary to record all the factors that can be observed while measuring the range of motion, such as edema, pain, retraction, contracture level, macroscopic shapes of joints, etc. and these factors can provide an important key to analyzing limiting factors of the range of motion. [6] In addition, the conditions and reactions of patients recorded during the measurement can be used to treat them and develop programs later, and, if possible, it should be ensured that the range of motion of a patient is measured each time by the same therapist who initially measured his or her range of motion because of differences in ways to measure it between individual therapists. [5]

A goniometer can be used to measure the range of motion in a convenient and instant manner, but there are also some disadvantages such as visually guessing starting positions, the central axis of rotation, and parallel positions, and difficulty in maintaining the position of the reference arm during the motion (1). To overcome such inconveniences, studies have been conducted on the measurement of the range of motion using various digital inclinometers. [7, 8, 9, 10]

A smartphone is one of the most widely used electronic devices in modern society, and its functionality has been recognized in various fields. Smartphones are equipped with a gyro sensor system, and used in various fields to measure inclination and gradient. Recently, studies have been actively conducted to utilize smartphones in measuring the range of motion of various joints, and they, in general, show a high level of reliability and validity. [11, 12]

However, there have been almost no studies on the elbow joint, and thus this study aimed to measure the range of motion of the elbow joint, to examine whether smartphones can be used as an instrument to measure the range of motion in clinical settings, and to analyze their reliability and validity.

2. Methods

1. Subjects

This study was conducted among 30 students of Masan University (aged 24 years on average), and they were selected from those who are right-handed normal persons.

Those who had undergone elbow joint surgeries, or who have felt pain in their elbow joints continuously, and those whose carry angle of the elbow joint is over 15 degrees were excluded in selecting the subjects of this study.

Sufficient explanations for the purposes and methods of this study were provided for participants in advance, and their voluntary consent for participation in this research was obtained. The general characteristics of participants were shown in the table below(Table 1).

Table 1. General charcsteristics of subject

	male(n=10)	female(n=21)
	mean±SD	mean±SD
Age(yrs)	23.6±2.60	21.52±2.08

Height(cm)	172.9±5.08	161.04±5.24
Weight(kg)	68.4±5.98	56.47±10.38
BMI	23.01±2.29	21.64±4.29

3. Methods

1) Measurement tools

A goniometer and android smartphones were used to measure the range of motion.

A semicircular goniometer (total length: 30cm) was used in this study, and it was graduated every 2.5 degrees. No limit was set on the size and model of smartphones. Goniometer Pro (ver.2.5), an Android application, was used, and two straps were used to firmly fix their position as shown in Fig. 1 and Fig. 2.

Figure 1. Goniometer and Smartphones (Note 3, G Pro 2)

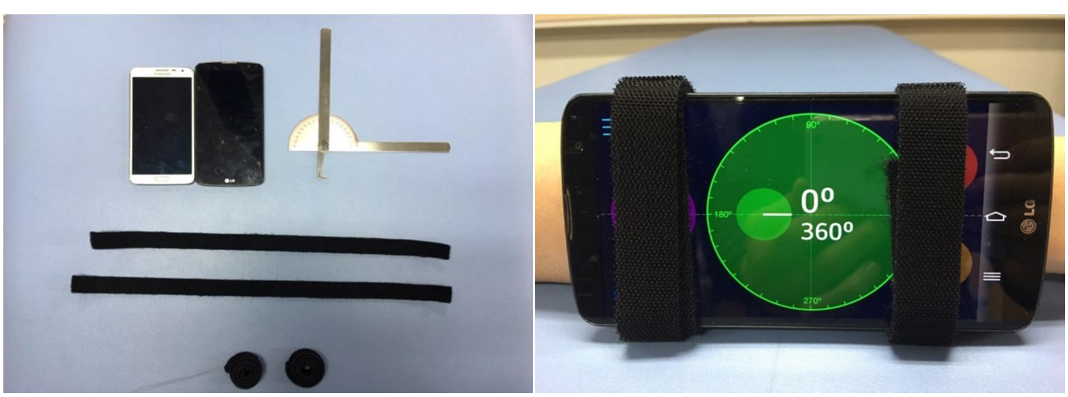

Figure 2. Straps used to fix smartphones

2) Measurement methods

To measure the active range of motion of the right elbow joint of participants, they were instructed to sit in front of a bed. To minimize errors caused by the thickness of their clothes, they wore a short-sleeve shirt, and their armpit was placed against the surface of the bed.

The range of motion was measured by 3 observers who were fully informed of the instructions of the Android application and the goniometer used in this study, and one measured it with the goniometer, and the other two, with the Android application.

First, one observer measured the range of motion of the elbow joint using the goniometer shown above twice, and there was a 15-minute break between the two measurements. The range of motion was measured by setting the axis of the goniometer on the lateral epicondyle; the stationary arm, on the humerus midline; and the moving arm, on the forearm midline. For more precise measurement, a sticker was attached on the lateral epicondyle of the humerus.

Using the same method, the other two observers measured the range of motion using the Android application mentioned above. The smartphone was placed on the flat area of the forearm, and the straps were wrapped around the smartphone at the position where 0° was displayed on the screen of the phone. After that, the active range of motion was measured.

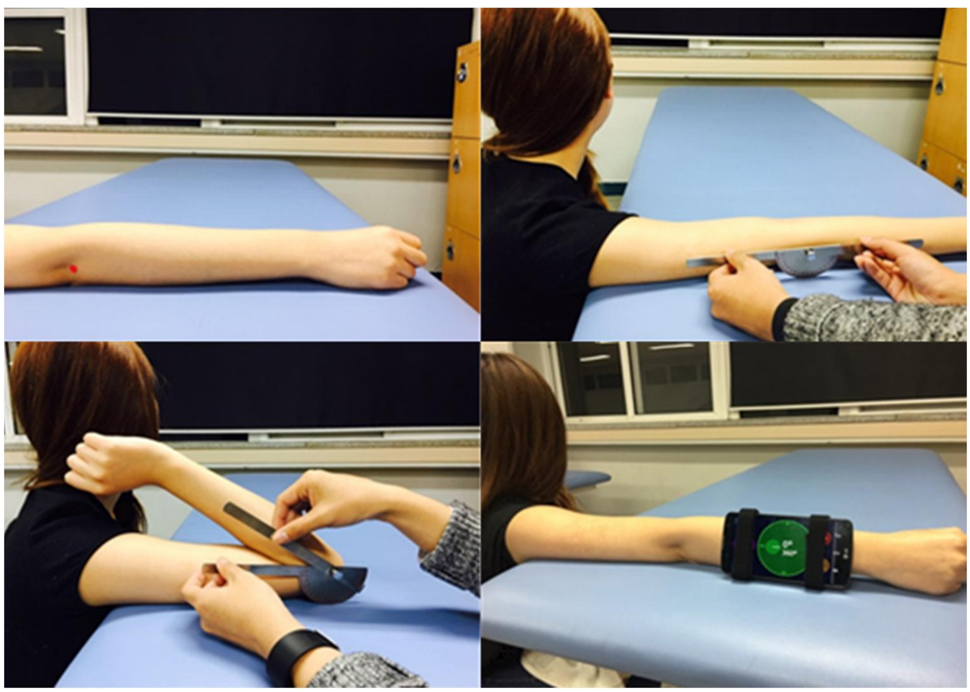

Figure 3. Methods of measuring with the goniometer and the Android application

3) Data analysis

Statistical analysis was conducted using SPSS for windows 18.0. Intra-class correlation coefficients (ICC(2,1)) were used to analyze the intra-rater and inter-rater reliability of the measurement tools.

To evaluate the concurrent validity of the measurement tools, the Pearson correlation coefficient (PCC) was used, and the level of significance was α=0.05. 3

4. Results

1. Intra-rater reliability

Two and one fully-informed observers measured the range of motion using the Android application and the goniometer respectively. The observers measured the range of motion once, and, after a 10-minute break, they measured it again. A different recording sheet was used for each observer to ensure they could not see the values measured by the others.

The intra-rater reliability of the active range of motion of the elbow joint measured twice by both Observers

A and B using the smartphones was statistically significant (α=0.05); Observer A (ICC=0.911), and Observer B (ICC=0.900) (Table 2).

Table 2. Intra-rater reliability of elbow angle measured on smartphone (n=31)

Modality	Movement	Examine A		Examine B	
		ICC	95% CI	ICC	95% CI
Smartphone	Flexion	0.911	0.82-0.96	0.900	0.80-0.95

ICC: Intra-class correlation coefficients
CI: Confidence interval

2. Inter-rater reliability

To examine the inter-rater reliability, one observer measured the range of motion of a participant using both the goniometer and the android application once, and the other two observers measured the same participant's range of motion using the same method.

The inter-rater reliability of the active range of motion of the elbow joint measured twice by Observers A and B using the smartphones was statistically significant (α=0.05): the first measurement reliability (ICC=0.806), and the second measurement reliability (ICC=0.817) (Table 3).

Table 3. Inter-rater reliability of elbow angle measured on smartphone (n=31)

Modality	Movement	Observer 1		Observer 2	
		ICC	95% CI	ICC	95% CI
Smartphone	Flexion	0.806	0.64-0.90	0.817	0.65-0.91

ICC: Intra-class correlation coefficients
CI: Confidence interval

3. Validity of measurement tools

The Pearson correlation coefficient (PCC) between the goniometer and the smartphones used to measure the range of motion of the elbow joint was statistically significantly high (r=0.922, r=0.868) ($p<0.05$) (Table 4).

Table 4. Pearson correlation of mean elbow angle between smartphone and goniometer (n=31)

	goniometer	Observer A	Observer B
goniometer	1	0.922**	0.868**

Observer A	1	0.806**
Observer B		1

**p<0.01

5. Discussion

A variety of smartphone applications that can be used in various health-related fields have been developed. [13] Such smartphone applications can be used in medical environments to measure the range of motion and their advantages such as their accessibility and convenience can be exploited, but the reliability and validity of smartphones used for patients in clinical settings have not been proved sufficiently. [14]

In an earlier study that measured the passive and active flexion, abduction and lateral rotation of the hip joint after surgery using smartphones and goniometers [15], the intra-rater reliability was over 0.78 (95% CI, 0.50~0.90), and the inter-rater reliability was over 0.90 (95% CI, 0.50~0.96).

In this study, the active flexion of the elbow joint was measured. The intra-rater reliability was over 0.9, and the inter-rater reliability was over 0.8. The study by Park et al. [15] measured the range of motion of the hip joint, while this study measured that of the elbow joint. Considering that both the two studies obtained reliable results, it can be concluded that the measurement of the range of motion using smartphones can replace a goniometer.

The range of motion of the elbow joint of normal persons that was measured using smartphones showed a higher inter-rater reliability than the intra-rater reliability.

Validity is an assessment of the extent to which the instrument measures what it is intended to measure. [11] Correlation is represented, depending on the values of correlation coefficient, by terms such as excellent (≥0.90), good (0.90~0.71), moderate (0.70~0.50), fair (0.50~0.30), and little or none (≤0.30) . [16] Earlier studies found that smartphones are a valid tool to measure the range of motion. [11, 17, 18]

In addition, the results measured using smartphones in this study showed a high intra-rater reliability, which is attributable to the fact that the smartphones used in this study were firmly fixed using two straps.

Meanwhile, it was difficult to set the starting point (0°) on the smartphone application (Goniometer Pro Preview) used in this study. However, since the angle is displayed in figures, it is easy to read and measure an angle just by touching the screen only one time. If it is possible to reliably measure the range of motion using widely distributed smartphones, therapists in clinics no longer need to bring a goniometer all the time, but instead they can measure it with the application on their own smartphone conveniently.

Still, it is necessary to conduct follow-up studies among patients targeting other types of joints to increase the reliability of smartphones as measurement tools. [19, 20, 21] If the application used in this study is improved to conveniently set the starting point (0°), it will be possible to measure the range of motion more accurately.

6. Conclusions

This study was conducted among 30 normal persons to examine the intra-rater and inter-rater reliability and validity of the flexion of the elbow joint measured using smartphones. The inter-rater reliability of the results was 0.806, and the intra-rater reliability was very high (ICC>0.90). The results of validity analysis showed a significantly high correlation (over 0.868 of correlation coefficient). Smartphones can be usefully utilized to measure the range of motion of patients by exploiting their various advantages such as convenience, portability, and their high distribution rate—most therapists carry smartphones. Therefore, it is believed that smartphones can be reasonably considered as a tool to measure the range of motion of the elbow joint.

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