

A Study on The Reliability and Validity of Measuring The Range of Motion of The Knee Joint Using A Universal Goniometer and A Smartphone Application-Based Goniometer

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Received: September 30 2024 / Revised: October 4 2024 / Accepted: October 30 2024
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| Abstract |

PURPOSE: Range of motion (ROM) can help accurately interpret the patient's condition. With the increasing number of applications that can turn mobile phones into medical devices, measuring ROM has become possible. Therefore, the purpose of this study is to investigate the reliability and validity of knee joint range of motion measurements in healthy adults, utilizing both a smartphone application-based goniometer and a goniometer.

METHODS: After recruiting 20 healthy adult subjects, the purpose of the study and the experimental procedures were explained. Two raters used two devices (goniometer and smartphone application-based goniometer) to measure active full knee flexion, active full knee extension, and active 90 degrees of flexion for all subjects. It was divided into the first and second measurements, and each measurer took turns performing the measurements. The normal distribution of the

collected measurements was confirmed using the Kolmogorov-Smirnov test.

RESULTS: Intra-rater reliability and inter-rater reliability showed very high reliability ($ICC > .80$) for all measures, and the normal distribution of each measure was confirmed through a normality test with a statistically significant difference. Validity between the two devices showed a strong positive linear relationship ($r = .96$) and statistically significant differences ($p < .000$).

CONCLUSION: The app-linked digital therapeutic device used in this study showed high reliability and validity when compared to the goniometer used in clinical practice. Therefore, when measuring knee joint range of motion in clinical practice, the app-linked digital therapy device used in this study can be considered.

Key Words: Knee joint, Range of motion, Reliability, Smartphone application-based goniometer, Universal goniometer, Validity

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I. Introduction

One of the main evaluation criteria for evaluating the

outcome of musculoskeletal treatment is joint mobility, and range of motion (ROM) is one of the factors that determines the function of the musculoskeletal system [1]. The measurement of ROM is essential for musculoskeletal assessment as it aids in accurately interpreting the patient's condition and serves as an objective outcome measure [2-3]. In addition, ROM, which can easily identify and directly measure joint conditions, is a major component of the joint-specific scoring system, and clinical measurement of joint range of motion is a basic evaluation widely applied in physical therapy [4-5]. ROM measurement is a routine part of a physical therapist's duties, helping patients fully restore their ROM, mobility, strength, and function following an injury [6].

Physical therapists utilize some or all of the following tools to make assessments: visual estimation, a universal goniometer, an inclinometer, or a measuring tape [7]. Among them, the universal goniometer is the most commonly used clinical tool to measure ROM [8]. The full range of joint mobility can be measured in degrees by aligning the fixed and movable arms of the goniometer to specific bony landmarks on either side of the joint, and a universal goniometer is used to measure joint range of motion (ROM) [9]. However, one study has shown that the location of goniometer placement can affect measurements [10]. Nevertheless, many clinicians rely on visual estimation of joint angles without the use of a goniometer, as visual evaluation can be performed quickly without equipment [11]. Despite the possibility of such error, many papers have found that goniometer are highly intra-rater reliability [12]. Boone's study determined the intra-rater variability and reliability of goniometric measurements taken by four physical therapists on upper and lower extremity motions of normal male subjects. As a result, the intratester variation for all measurements was less than intertester variation [13]. Rothstein's study evaluated the reliability of angle measurements on passive elbow and knee positions in healthy subjects. The results

showed that intratester reliability for flexion and extension of the knee and the elbow joints was high [14].

It is estimated that over 40,000 health, fitness, and medical apps are currently available on the market. As the number of applications capable of turning smartphones into medical devices increases, healthcare professionals are increasingly using smartphones for medical and rehabilitation purposes [15,16]. Advances in digital technology have provided alternative methods for measuring ROM using a variety of digital devices or smartphone applications [17]. Recently, research on joint ranges using smartphones is actively being conducted targeting various joints such as shoulder joints, knee joints, neck, and lumbar, and is showing a high level of reliability and validity overall [18].

The smartphone application-based goniometer utilized in this study is a distinctive device compared to the equipment used in other studies, such as those with displays attached to the center of plastic rulers or conventional digital inclinometers[19-20]. Therefore, the purpose of this study is to investigate the reliability and validity of knee joint range of motion measurements in healthy adults, utilizing both a smartphone application-based goniometer and a goniometer. The findings of this research will provide valuable information for future studies comparing the reliability and validity of smartphone application-based goniometer and goniometer.

II. Methods

1. Study Design

This study was conducted to determine the reliability and validity of knee joint angle measurement using a goniometer used by physical therapists for conventional ROM measurement and a smartphone application-based goniometer. This reliability-validity study was conducted in accordance with the Guidelines for Reporting Reliability and Consistency Studies (GRRAS) [21].

2. Participants

A reliability study requires a minimum sample size of 15 to 20[22]. Therefore, 20 subjects were recruited for this study, and their general characteristics were as follows (Table 1). Participants were selected as adults aged 20 or older who voluntarily agreed to participate in the study. In relation to musculoskeletal diseases, those who had no surgery, trauma, or problems with proprioception, those with no neurological symptoms or movement limitations, and those without mental illness or cognitive impairment were selected. Before starting the experiment, the researcher explained the purpose and procedures of the experiment to the subjects.

3. Measurer

Two first-year graduate students in physical therapy conducted the experiment. Both examiners received training from senior faculty members on the proper use of the smartphone application-based goniometer and traditional goniometer for measuring knee joint range of motion. The measurement protocol involved the first examiner taking the angle measurements while the second examiner recorded the results. Subsequently, the roles were reversed, with the second examiner measuring and the first examiner recording.

4. Measurement Process

Two evaluators measured active knee full flexion, active knee full extension, and active 90 degrees of flexion in all subjects using two devices (a goniometer and a smartphone application-based goniometer). Each measurer

is divided into a primary measurer and a secondary measurer, and they take turns measuring. Before starting the experiment, the measurer has the subject wear the smartphone application-based goniometer, turns it on, and starts the experiment. The first is for the first measurer to verbally instruct the subject to full flexion the knee. After the subject stops moving, the angle is measured using a goniometer, and at the same time, the angle is collected from a smartphone application-based goniometer. Once measurements and angle collection are complete, the subject is verbally instructed to full extension the knee. After the subject stops moving, the angle is measured using a goniometer, and at the same time, the angle is collected from a smartphone application-based goniometer. Once measurements and angle collection are complete, the subject is verbally instructed to flexion the knee to 90 degrees. After the subject stops moving, the angle is measured using a goniometer, and at the same time, the angle is collected from a smartphone application-based goniometer. After that, the second measurer proceeds with the measurement in the same way, and after the first measurer completes the measurement, the second measurer also proceeds with the measurement.

1) Goniometer Measurement

Goniometer measurements were made using a portable

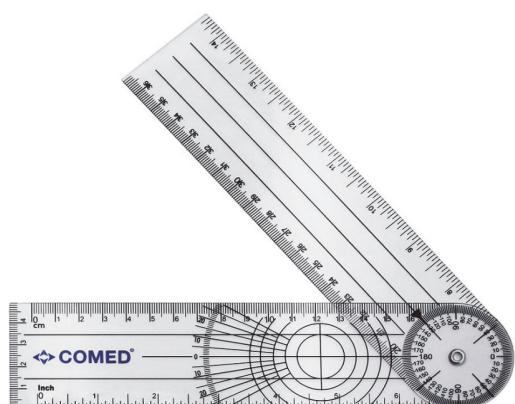


Fig. 1. Goniometer.

Table 1. General characteristics of participants (n = 20)

Variable	Mean \pm SD
Gender (Male/Female)	11/9
Age (year)	23.68 \pm 3.19
Height (cm)	168.11 \pm 9.38
Weight (kg)	69.50 \pm 15.36

*Values indicate mean \pm standard deviation.

two-arm goniometer marked at 2-degree intervals (Fig. 1). Measurements are made with the central axis of the goniometer positioned slightly below the lateral epicondyle of the femur. One arm of the goniometer is placed parallel to the greater trochanter of the femur, and the other arm is placed parallel to an imaginary axis aligned with the lateral malleolus. The measurement is read parallel to the mark on the goniometer, and the angle is measured and recorded in 2-degree increments [23].

2) Goniometer Based on Smartphone Application Measurement

In previous studies, digital goniometers typically featured a display attached to the center of a plastic ruler or utilized the Baseline® Digital Inclinometer brand [19-20]. In contrast, the smartphone application-based goniometer used in this study is detachable and has an electronic goniometer built in (Fig. 2). Both arms and axis are constructed of rigid steel, with both arms, excluding the axis, encased in cuffs. The sensor is affixed to the one arm, and angle measurement is only possible when the sensor is powered on and synchronized with the mobile application. The sensor power switch is button-type and located in the middle of the left edge. Wrap the cuff around the leg where you want to measure the angle of the knee joint and attach a smartphone app-based goniometer so that the axis is on the side of the patella. Afterwards, attach the arm with the sensor toward the greater trochanter of the femur, and the other arm toward the lateral malleolus. The smartphone application-based goniometer is synchronized

with the mobile application, real-time angle measurements can be observed on the application interface.

5. Data Analysis

Statistical analysis of the data collected in this study was conducted using 'IBM SPSS 22.0 statistical software.' The general characteristics of the subjects were calculated using descriptive statistics, and the mean and standard deviation of each variable were calculated. The normal distribution of the collected measurements was confirmed using the Kolmogorov-Smirnov test. Intra- and inter-rater reliability was analyzed using the intraclass correlation coefficient, ICC(2,1). An ICC of .9 or indicates excellent reliability, .9 to .75 indicates good reliability, .75 to .5 indicates moderate reliability, and less than .5 indicates poor reliability [24]. Validity was analyzed using Pearson correlation (r). r measures the strength of the linear relationship between two variables, with 1 indicating a positive linear relationship, -1 indicating a negative linear relationship, and 0 indicating no or very weak linear relationship. Values between 1 and .7 indicate a strong linear relationship, .7 and .3 indicate a moderate linear relationship, and .3 and 0 indicate a weak linear relationship [25]. All statistical significance levels were set at $\alpha = .05$.

III. Results

The normal distribution of each measurement was confirmed through a normality test. Both intra- and



Fig. 2. (a) goniometer based on smartphone application; (b) wearable goniometer based on smartphone application.

Table 2. Intra- and Inter- rater reliability and validity

		DTx			Goniometer		
		ICC (2,1)	95% CI	p	ICC (2,1)	95% CI	p
Intra-rater Reliability	Measurer 1	.87	.41-.95	.000	.83	.32-.94	.000
	Measurer 2	.86	.58-.94	.000	.84	.48-.94	.000
Inter-rater Reliability	1 st measurement	.91	.79-.96	.000	.89	.73-.95	.000
	2 nd measurement	.97	.92-.98	.000	.93	.83-.97	.000
	All	.93	.86-.97	.000	.92	.83-.96	.000
Validity			r			p	
			.96			.000	

inter-rater reliability demonstrated very high reliability across all measurements (ICC > .80). There was a statistically significant difference ($p < .000$). The validity between the two tools showed a strong positive linear relationship ($r = .96$) and a statistically significant difference ($p < .000$) (Table 2).

IV. Discussion

This study aimed to determine the intra- and inter-measurement reliability of the digital therapy device's angle measurement, and its validity compared to conventional goniometers used for angle measurement. According to the experimental results, the digital therapeutics showed very high reliability in both intra- rater and inter- rater reliability and showed high validity between the two devices. Range of motion(ROM) measurements are used to detect limitations in joint range of motion and to evaluate the patient's current condition or for rehabilitation purposes [26-27]. For physical therapists to accurately evaluate patients, ROM measurements must be accurate in terms of reliability and validity [28].

The most common tool for measuring ROM is a universal goniometer (UG). UG has the advantage of being easy to use and inexpensive but have the disadvantage of requiring two hands to measure angles, making it difficult

to stabilize other parts of the patient's body [29]. The digital therapeutic device linked to the app developed in this study recognizes the angle through the app after wearing the device with the attached goniometer, so your hands are free to measure the angle, and you can easily measure the angle by checking the angle through the app after wearing the device.

A study comparing the two devices showed very high reliability in both intra- and inter- rater reliability (ICC > .80), with statistically significant differences ($p < .000$). In both intra- and inter- rater reliability, the DTx showed higher reliability than the goniometer. That is, when comparing the two devices, the DTx is more accurate than the goniometer, even when measured by different measurers or over multiple measurements. Additionally, the high validity between the two devices (.96) suggests that DTx is effective for angle measurement.

A limitation of the study is that since the study was conducted on healthy young adults, data from all age groups and those with diseases cannot be predicted. In addition, in order to measure angles at the same time in the same posture, the angle may be measured with Universal goniometer while wearing application-based goniometer equipment, so there may be an error in the axis position. It is believed that further research should be conducted in the future to supplement the limitations of this study and prove validity and reliability to a wide range of subjects.

V. Conclusion

This study was conducted to confirm the intra- and inter-rater reliability of application-based goniometer and its validity with a Universal goniometer. The app-linked digital therapeutic device used in this study showed high reliability and validity when compared to the goniometer used in clinical practice. The application-based goniometer allows measurement with the therapist's two hands free and is easy to measure, so the application-based goniometer used in this study can be considered for measuring the range of motion of the knee joint in clinical practice.

Acknowledgements

Acknowledgments: The authors are grateful for the National Research Foundation of Korea (NRF), grant-funded by the Korean government (MSIT) (No. 2022R1C1C2007812).

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