

THE RELIABILITY BETWEEN SMARTPHONE GONIOMETER APPLICATION AND TRADITIONAL GONIOMETER FOR MEASURING FIRST METATARSOPHALANGEAL JOINT DORSIFLEXION

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Abstract

Objective:

Accurate assessment of joint range of motion (ROM) is fundamental in musculoskeletal evaluation, diagnosis, and rehabilitation. With the increasing integration of smartphone technology into healthcare, mobile applications designed to measure joint angles have gained attention as potential alternatives to traditional tools. The objective of this study was to determine the reliability of a smartphone-based goniometer application compared with a traditional universal goniometer for measuring passive dorsiflexion of the first metatarsophalangeal joint (MTPJ).

Methods:

A descriptive cross-sectional study was conducted among healthy, physically active individuals aged 18–40 years recruited from COMSATS University Islamabad. Passive dorsiflexion of the first MTPJ was measured using both a traditional universal goniometer and a smartphone goniometer application (Goniometer Records). Measurements were performed by a single examiner following standardized procedures to minimize variability. Statistical analysis was conducted using SPSS version 25.0. Descriptive statistics were calculated, and reliability between the two measurement methods was assessed using Pearson's correlation coefficient and Cronbach's alpha.

Results:

Eighty participants (31 males and 49 females) were included in the analysis. The mean dorsiflexion angle measured using the universal goniometer was $59.21^\circ \pm 6.34^\circ$, whereas the smartphone application recorded a mean of $56.10^\circ \pm 5.86^\circ$. Reliability analysis demonstrated a strong positive correlation between the two measurement methods ($r = 0.887$). Internal consistency between the instruments was excellent, with a Cronbach's alpha value of 0.939.

Conclusion:

The findings indicate that the smartphone goniometer application is highly reliable when compared with the traditional universal goniometer for measuring first MTPJ dorsiflexion. Given its accessibility, ease of use, and reliable performance, smartphone-based goniometry may serve as a practical alternative for joint ROM assessment in clinical and rehabilitation settings.

INTRODUCTION

Assessment of joint range of motion (ROM) is a cornerstone of musculoskeletal evaluation and plays a critical role in determining physical function, diagnosing pathology, and monitoring the effectiveness of therapeutic interventions (1). Accurate measurement of joint movement is essential for clinical decision-making, rehabilitation planning, and outcome evaluation. Therapeutic exercise remains a fundamental component in the management of many musculoskeletal conditions; therefore, clinicians must monitor joint mobility precisely to ensure appropriate exercise prescription and progression (2). Although clinicians are trained to visually assess joint movement, reliance on visual estimation alone may result in inaccuracies, particularly when subtle movement deviations are present.

The goniometer is one of the most commonly used instruments for measuring joint angles in clinical practice, with measurements expressed in degrees. Goniometric assessment assists clinicians in identifying functional limitations, diagnosing musculoskeletal disorders, and evaluating treatment outcomes (3). The universal goniometer (UG) has long been regarded as the standard tool for ROM measurement due to its low cost, portability, and acceptable reliability across various joints (4). Despite these advantages, the universal goniometer presents several limitations. Accurate use requires proper alignment with anatomical landmarks and stabilization of the limb, often necessitating the use of both hands by the examiner. This can compromise limb stabilization and introduce measurement error, even when used by experienced clinicians (5).

Previous research has suggested that goniometric measurements may include errors ranging from 5° to 10°, raising concerns regarding the precision

and repeatability of ROM measurements in routine clinical settings (6). Variability in examiner technique, patient positioning, and anatomical landmark identification further contributes to measurement inconsistency. These limitations have prompted researchers and clinicians to explore alternative methods for assessing joint ROM that may enhance accuracy, efficiency, and clinical feasibility.

Advancements in smartphone technology have led to the development of accelerometer- and magnetometer-based applications capable of measuring joint angles. Smartphones offer several advantages, including widespread availability, ease of use, digital readouts, and the ability to store and share data. As smartphone usage has expanded globally, their integration into healthcare has increased, with numerous applications designed to assist in musculoskeletal assessment and rehabilitation monitoring (7,17). Smartphone goniometer applications have been proposed as practical alternatives to traditional tools, particularly in settings where access to standard equipment is limited.

Despite their growing popularity, evidence supporting the reliability and validity of smartphone goniometer applications remains limited, particularly for specific joints of the lower extremity (18). While several studies have demonstrated promising results for joints such as the knee, hip, shoulder, and elbow (1,3,6,22), fewer studies have focused on the first metatarsophalangeal joint (MTPJ), which plays a critical role in gait and lower-extremity biomechanics.

The first MTPJ is essential for normal walking mechanics, particularly during the terminal stance and push-off phases of gait. Adequate dorsiflexion of this joint facilitates forward progression of the body and contributes to efficient energy transfer

during ambulation (9). Restricted dorsiflexion of the first MTPJ has been associated with pathological conditions such as hallux limitus and hallux rigidus, which can lead to pain, altered gait patterns, and reduced functional capacity (10). Consequently, accurate assessment of first MTPJ dorsiflexion is a key component of lower-extremity biomechanical evaluation and clinical decision-making (11).

Reported values for first MTPJ dorsiflexion vary widely in the literature. Radiographic studies have documented dorsiflexion ranges between 40° and 100° (12), with mean values of approximately 82° reported by Buell et al. (13). Approximately 65° of dorsiflexion is generally considered necessary for normal gait, while values below 60° may indicate pathological involvement, according to the grading system proposed by Coughlin and Shurnas (14). However, in vivo studies have reported lower average dorsiflexion values, ranging from 42° to 51°, highlighting the importance of reliable and consistent clinical measurement techniques (15,16).

Although the universal goniometer remains the most widely used tool for ROM assessment, its practical limitations have driven interest in alternative measurement methods. Smartphone goniometer applications may offer a feasible solution due to their simplicity, reduced examiner handling requirements, and ease of integration into clinical workflows. However, limited evidence exists regarding their reliability for measuring first MTPJ dorsiflexion, particularly in young, healthy populations.

Significance of the Study

The significance of this study lies in evaluating whether a smartphone-based goniometer application provides measurements comparable to those obtained using a traditional universal goniometer. Establishing reliability between these tools may support the use of smartphone applications as practical alternatives for joint ROM assessment in clinical practice, academic environments, and rehabilitation settings. This is particularly relevant in resource-limited settings, tele-rehabilitation programs, and situations requiring rapid or repeated assessments.

Furthermore, validating smartphone-based goniometry may enhance patient engagement and self-monitoring during rehabilitation.

The present study focuses on healthy, physically active individuals aged 18–40 years to minimize the influence of growth-related changes and age-related degenerative processes on joint mobility. While this controlled approach enhances measurement consistency, it may limit generalizability to older adults, pediatric populations, and individuals with musculoskeletal pathology. Nonetheless, establishing reliability in a healthy population represents an essential step toward broader clinical application.

METHODS

Study Design and Ethical Approval

A descriptive cross-sectional study was conducted following approval from the Ethical Review Committee of the University of Lahore. The study adhered to ethical principles for research involving human participants.

Participants

Participants were recruited from COMSATS University Islamabad using convenient and random sampling methods. Healthy, physically active males and females aged between 18 and 40 years were included in the study. Individuals younger than 18 years were excluded due to ongoing skeletal growth, while those older than 40 years were excluded because of the potential influence of degenerative changes on joint mobility.

Participants with a history of foot pathology, lower-limb surgery, or lower-extremity treatment within the previous year were excluded. Prior to data collection, all participants were informed about the study purpose and procedures, and verbal consent was obtained.

Measurement Instruments

Passive dorsiflexion of the first metatarsophalangeal joint was measured using two instruments:

1. A traditional universal goniometer
2. A smartphone goniometer application (Goniometer Records), installed on an Android device

Measurement Procedure

Participants were seated comfortably in a chair with the foot positioned in a relaxed manner. The examiner, a qualified physiotherapist, was seated at foot level to ensure accurate alignment and stabilization. Either the right or left foot was assessed, with no restriction imposed.

Anatomical landmarks were palpated prior to measurement. The axis of the goniometer was aligned with the first MTPJ, with the stationary arm aligned along the midline of the first metatarsal and the moving arm aligned with the proximal phalanx of the hallux (24,25). Passive dorsiflexion was performed by the examiner until the end of the available ROM, and the position was maintained while measurements were recorded. The same standardized procedure was used for both instruments to minimize measurement error. All measurements were performed by the same examiner.

Statistical Analysis

Data were entered and analyzed using SPSS version 25.0. Descriptive statistics were calculated for participant characteristics and ROM

measurements. Reliability between the universal goniometer and smartphone application was assessed using Pearson’s correlation coefficient. Internal consistency between the two instruments was evaluated using Cronbach’s alpha.

RESULTS

A total of 80 healthy, physically active individuals participated in the study, including 31 males (38.8%) and 49 females (61.3%). Participants ranged in age from 18 to 40 years.

The mean dorsiflexion angle of the first MTPJ measured using the universal goniometer was $59.21^{\circ} \pm 6.34^{\circ}$, with values ranging from 45° to 75° . The smartphone goniometer application recorded a mean dorsiflexion angle of $56.10^{\circ} \pm 5.86^{\circ}$, with values ranging from 44° to 71° .

Reliability analysis demonstrated a strong positive correlation between the universal goniometer and the smartphone application ($r = 0.887$), indicating good agreement between the two measurement methods. Internal consistency between the instruments was excellent, with a Cronbach’s alpha value of 0.939.

Table 1. Participant Characteristics (n = 80)

Variable	Category	Frequency	Percentage (%)
Gender	Male	31	38.8
	Female	49	61.3
Age (years)	Range	18-40	–

Table 2. Descriptive Statistics of First Metatarsophalangeal Joint Dorsiflexion (Degrees)

Measurement Tool	Mean	Std. Deviation	Minimum	Maximum
Universal Goniometer	59.21	6.34	45.00	75.00
Smartphone Application	56.10	5.86	44.00	71.00

Table 3. Reliability Analysis Between Measurement Instruments

Reliability Measure	Value
Pearson’s Correlation Coefficient (r)	0.887
Cronbach’s Alpha	0.939
Number of Instruments	2

DISCUSSION

The present study investigated the reliability of a smartphone goniometer application compared with a traditional universal goniometer for measuring passive dorsiflexion of the first metatarsophalangeal joint. The findings demonstrate a strong positive correlation and excellent internal consistency between the two measurement tools, supporting the reliability of smartphone-based goniometry in this context.

These results are consistent with previous studies that have reported high reliability of smartphone goniometer applications for measuring joint ROM. Sarac et al. (6) demonstrated excellent intra- and inter-rater reliability of a smartphone goniometer application for assessing hip ROM in patients with hip osteoarthritis. Similarly, Resende et al. (22) reported reproducible measurements between smartphone applications and universal goniometers during elbow ROM assessment.

However, not all studies have reported consistent findings. Norris et al. (20) identified variability and measurement bias in smartphone-based hip ROM measurements. Differences in joint type, application design, examiner experience, and measurement protocols may account for these discrepancies. In the present study, the use of a single examiner and standardized measurement procedures likely contributed to the high reliability observed.

The clinical implications of these findings are noteworthy. Smartphone goniometer applications offer advantages such as portability, digital display, ease of use, and potential integration into tele-rehabilitation programs. Their use may reduce examiner burden and facilitate repeated measurements in both clinical and non-clinical environments.

CONCLUSION

The smartphone goniometer application demonstrated high reliability when compared with the traditional universal goniometer for measuring passive dorsiflexion of the first metatarsophalangeal joint. These findings support the use of smartphone-based goniometry as a practical, accessible, and reliable alternative for joint ROM assessment in clinical practice and

rehabilitation settings. Further research is recommended to evaluate its validity in pathological populations and across different age groups.

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