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# Concurrent Validity and Intra-Rater Reliability of Smartphone Application Angle Meter for Shoulder Range of Motion

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## ABSTRACT

**OBJECTIVE:** To evaluate concurrent validity and intra-rater reliability of smartphone application angle meter for shoulder range of motion.
**METHODS:** An observational cross-sectional study was performed using a non-probability convenient sampling technique to collect data. Data from 37 healthy volunteers was recruited from Riphah Rehabilitation Center Lahore in April-September 2022. Participants aged 18 to 35 years who could actively move the Shoulder's dominant side were included in the study. The active shoulder range of motion was measured with the universal goniometer, and the angle meter application flexion, abduction, internal rotation, and external rotation of the shoulder joint were performed on the dominant side. Each movement was performed three times and assessed one by one with a universal goniometer and angle meter application to limit exertion. There was a resting period of 1 day after each movement. Collected data was analyzed with a statistical package for social sciences (SPSS) version 20.0.
**RESULTS:** An angle meter app could be a feasible alternative to the goniometer instrument for healthcare practitioners to evaluate active shoulder range of motion. The Cronbach's alpha value was 0.933 for Shoulder Flexion, 0.986 for Shoulder Abduction, 0.994 for Shoulder Internal Rotation, and 0.980 for Shoulder External Rotation. Overall, Cronbach's alpha value portrayed excellent reliability for the Smartphone Angle Meter. Based on the results, it can be stated that the Smartphone Angle Meter app has a high strength to robust positive correlation for the Shoulder range value of <0.001, confirming the statistical significance of the positive relationship.
**CONCLUSION:** According to this study's findings, the Angle meter app was a valid and reliable alternative goniometer tool for assessing active shoulder range of motion in healthy adults.
**KEYWORDS:** Angle meter, Range of motion, Reliability, Concurrent validity, Shoulder joint, Smartphone, Universal goniometer

## INTRODUCTION

One of the essential skills in the musculoskeletal assessments that physiotherapists and some strength and conditioning coaches frequently undertake is measuring joint range of motion in both static and dynamic, passive and active human motions[1]. These measurements are critical for establishing a baseline, determining functional limitations, and tracking changes in joint mobility resulting from treatment. By taking a range of motion measurement, it is also possible to identify abnormalities and mobility limitations that can raise the risk of injury. The universal goniometer has long been regarded as the gold standard for clinical range of motion assessment because of its ease of use, low cost, reasonable reliability and validity proven in many studies[2].

Numerous studies have shown that the Universal Goniometer has excellent inter-rater and intra-rater reliability for assessing upper extremity range of motion. However, there are problems related to its use: The therapist must use two hands to control the Universal Goniometer, which has poor anatomical feature recognition, improper arm alignment, and changes in limb orientation; to read and place measurements, precise visual estimation is needed. These limitations might increase measurement error. And errors in reading measurement occur frequently. These restrictions might result in measurement errors[3].

Mobile technology started as a remarkable achievement in the world of technology but is now transforming into user comfort technology due to its diverse functionality. Specifically, mobile applications play a noteworthy role in making tasks easier in every field; if we talk about medical, mobile phone applications have a significant impact on patients and healthcare professionals[4]. These mobile applications (apps) are software applications that can be used to assess and treat disease and to prevent diseases that may affect the anatomy or any normal physiology of the human body. The new information and communication technologies have played a vital role in medicine. Around the world, even in developing countries, it is quickly becoming a mainstay of healthcare[5].

During the musculoskeletal evaluation of the patient, measuring the joint range of motion is essential. These measurements are used for diagnosis and to help monitor the effectiveness of a patient's treatment[6,7]. The range of motion of the joints can be measured using various applications designed for this purpose (8). With advances in smartphone technology and software applications combined with ubiquitous smartphone ownership, it is now possible to measure a shared range of motion on smartphones. Like universal goniometers, smartphones are easy to use, relatively inexpensive, and very affordable[9,10]. This study explores the efficacy of a smartphone application, an angle meter, designed to measure Shoulder joint range of motion. The App accurately gauges angles, slopes, and inclinations in horizontal and vertical planes, leveraging accelerometer and gyroscope functionalities. The recorded data can be conveniently stored in a database and visualized through records, charts, or gallery photographs. The primary focus of the investigation is to assess the correlation strength and reliability of this health-oriented smartphone app compared to the widely used Universal Goniometer. The latter is a traditional tool in clinical settings for measuring joint angles, specifically targeting shoulder flexion, abduction, internal rotation, and external rotation.

By establishing the association and reliability of the smartphone app in this context, the study aims to contribute valuable insights into its potential as a trustworthy alternative for shoulder joint range of motion assessment. The findings are anticipated to have implications for future research, particularly in comparing diverse measurement tools such as smartphone app-based goniometers, laser-guided digital goniometers, and the conventional universal goniometer. This research is essential for advancing musculoskeletal assessment practices and integrating modern technology into healthcare methodologies.

## METHODOLOGY

An observational cross-sectional study was performed using a non-probability convenient sampling technique to collect data. The data of 37 healthy volunteers was recruited from Riphah Rehabilitation Center Lahore in April-September 2022. The sample size calculated using Rao-soft was 37 using the following: the margin of error = 5%, Confidence interval= 95%, Population size= 40, so the computed sample size= 37 [11]. Participants 18 to 35 years of age and able to actively move the dominant side of the Shoulder were included in the study. Self-report of pain in the Shoulder, neck or upper back pain, previous history of pain in the upper extremity, which is referred and surgery at the Shoulder were excluded from the study.

The authors demonstrated the desired movement, and then the participant performed a single return demonstration of that movement as a warm-up. The warm-up motion serves two purposes: first, as a teaching tool for the participant to practice the range of motion and second, as a stretch to increase range[12]. The dominant side of the Shoulder's active movement was measured with the UG and the angle meter application for flexion, abduction, internal rotation, and external. Each movement was performed three times and assessed one by one with a universal goniometer and angle meter application to limit exertion. There was a resting period of 1 day after each movement. For each Shoulder, the movement was repeated with verbal instructions and demonstration[12].

Study tools included an Angle meter application, Universal Goniometer, and DASH Scale. There are three different sensing modalities to implement goniometric measurement with a smartphone, which discusses the smartphone application. These are classified into three categories: Accelerometer-based, Photographic-based, and Magnetometer-based. These apps may use the phone´s equipped sensors (accelerometer, inclinometer, etc.) to measure physiological parameters such as limb movement. It's an App that uses an internal smartphone inclinometer to measure ROM[12]. A universal goniometer is a device that is used to measure joint motion and is a benchmark to be used by the physical therapist in the clinical setup[13]. Disabilities of the Arm, Shoulder and Hand (DASH) is a self-report questionnaire to measure physical function and symptoms in patients with upper-extremity disorders. Active shoulder movement was assessed with the universal goniometer and the angle meter application flexion, abduction, internal rotation, and external Shoulder joint rotation. This procedure was performed on the dominant side of the contralateral Shoulder. Each movement was performed three times and assessed one by one with a universal goniometer and angle meter application to limit exertion. There was a resting period of 1 day after each movement. Each shoulder movement was repeated, and verbal instructions and demonstration were given[14].

**Figure I: Strobe flow diagram**

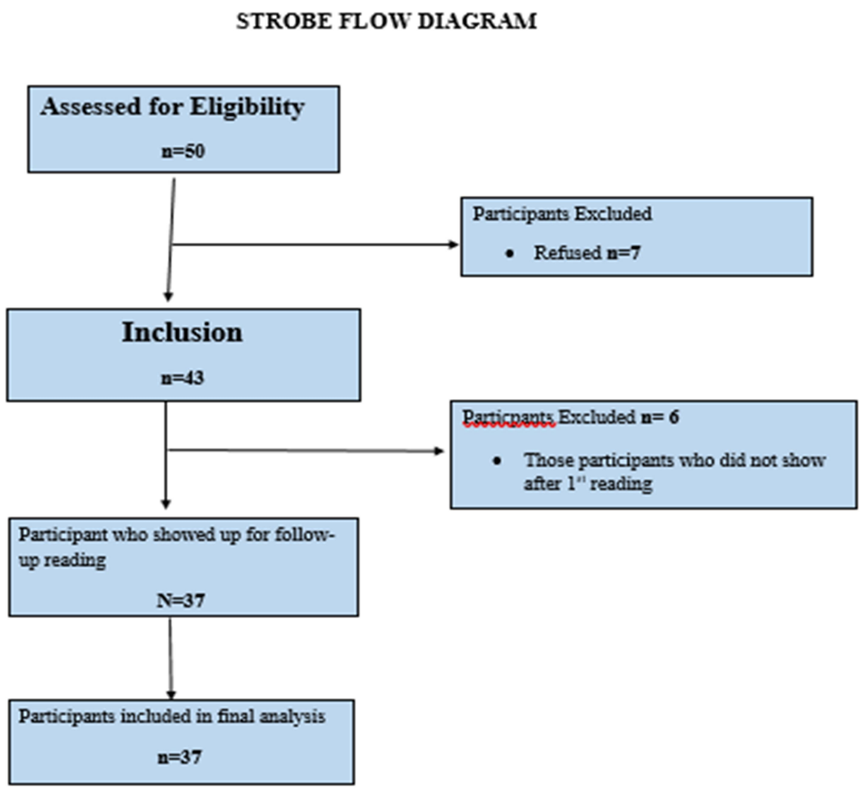


**Figure I:** Strobe flow diagram shows 50 participants were Assessed for Eligibility, out of which 7 Participants were Excluded because they refused to come, 6 participants did not show up after 1st reading Participant who showed up for follow-up reading were 37 and Participants included in the final analysis were 37.

**Statistical Analysis:** Analysis was done on SPSS version 25. Quantitative variables were presented as mean± SD and with frequency and percentage. Reliability was determined by Intra-rat reliability across repeated measures, internal consistency, and an inter-item correlation. Intra-Rater reliability was determined using an intra-class correlation coefficient (ICC) at 95% confidence intervals (CIs). Internal consistency was determined with Cronbach's alpha. Concurrent validity was measured by Pearson's correlation coefficient value (r). Construct validity was measured through Pearson correlation.

## RESULTS

This study gathered 37 healthy individuals with a mean age of 26.00 years and a standard deviation of 2.52. The mean height of the people was 1.69±0.07, whereas the mean height was 62.14±7.94. Before performing shoulder movements, the DASH Scale assessed all the participants' shoulders. The mean score was 2.67±0.93, and 51.5% of male and 48.6% of female healthy individuals participated in this study. Out of 37 participants, 91.9% had a healthy weight. The dominant side of the Shoulder was assessed with the DASH scale; 89% were on the right dominant side, and 11% were on the left as the dominant side. (**Table I**)

**Table I: Descriptive statistics of Baseline Characteristics of Participants (n=37)**

| Variables | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|
| **Age** | 26.00 | 2.52 | 21.00 | 32.00 |
| **Height** | 1.69 | 0.07 | 1.58 | 1.82 |
| **Weight** | 62.14 | 7.94 | 49.00 | 78.00 |
| **DASH score at the recruitment of Participants** | 2.67 | 0.93 | 0.80 | 4.20 |
| | **Construct** | **Frequency** | **Percentage** | |
| **Gender** | Male | 19 | 51.4% | |
| | Female | 18 | 48.6% | |
| **BMI** | Underweight | 1 | 2.7% | |
| | Healthy weight | 34 | 91.9% | |
| | Overweight | 2 | 5.4% | |
| **Dominant side of Shoulder** | Right | 33 | 89% | |
| | Left | 4 | 11% | |

In **Table II,** the shoulder range of motion measured by goniometer showed the mean shoulder flexion of 178º, mean abduction of 177.15º, mean internal rotation of 64.91º, and mean external rotation of 84.28º. On the other hand, the shoulder range of motion measured by smartphone angle meter showed mean flexion of 177.95º, mean abduction of 177.26º, mean internal rotation of 64.88 and mean external rotation of 84.30º.

**Table II: Descriptive statistics of shoulder range of motion with Universal Goniometer and Smartphone Angle meter**

| Measuring Meter | Shoulder Movement | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| **Shoulder Range of Motion by Goniometer** | Flexion | 178.00 | 1.99 | 173.00 | 182.00 |
| | Abduction | 177.15 | 2.29 | 168.00 | 181.00 |
| | Internal Rotation | 64.91 | 6.25 | 52.00 | 78.00 |
| | External Rotation | 84.28 | 3.09 | 75.00 | 89.00 |
| **Shoulder Range of Motion by Smartphone Angle meter** | Flexion | 177.95 | 1.64 | 174.00 | 181.00 |
| | Abduction | 177.26 | 2.31 | 167.00 | 180.00 |
| | Internal Rotation | 64.88 | 6.17 | 53.00 | 78.00 |
| | External Rotation | 84.30 | 3.02 | 75.00 | 89.00 |

Shoulder movements were recorded. Shoulder Flexion had a Cronbach's alpha value of 0.933, Shoulder Abduction of 0.986, Shoulder Internal Rotation of 0.994, and Shoulder External Rotation of 0.980 to test the accuracy of the smartphone angle meter. Cronbach's alpha value showed that the Smartphone Angle Meter had outstanding dependability. The inter-item correlation, intra-rater reliability, and internal consistency of the smartphone angle meter were robust to very strong positive for the shoulder flexion range. For the shoulder abduction range of motion, the smartphone angle meter demonstrated weak to robust positive inter-item correlation, excellent intra-rater reliability, and excellent internal consistency. The smartphone angle meter demonstrated robust positive inter-item correlation, excellent intra-rater reliability, and outstanding internal consistency for the shoulder internal rotation range. For shoulder external rotation, the smartphone angle meter demonstrated excellent intra-rater reliability, great internal consistency, and high to very high levels of positive inter-item correlation. Between the Smartphone Angle Meter and the Universal Goniometer for Shoulder Flexion, there was a modest to moderately high positive association at three separate time points, with Pearson correlation values ranging from 0.420 to 0.659. (**Table III**)

**Table III: Intra-rater reliability, Internal Consistency, and Inter-Item Correlation values for Shoulder Movements Measured from Smartphone Angle Meter at three different time intervals**

| Shoulder Flexion | | Shoulder Abduction | |
|---|---|---|---|
| 1st measurement | 177.95±1.64 | 1st measurement | 177.26±2.31 |
| 2nd measurement | 177.96± 1.82 | 2nd measurement | 177.16±2.35 |
| 3rd measurement | 177.97± 2.31 | 3rd measurement | 177.162±2.35 |
| Inter Item Correlation | 0.74 - 1.00 | Inter Item Correlation | 0.037 - 1.00 |
| Cronbach's alpha | 0.933 | Cronbach's alpha | 0.986 |
| ICC (95% CI) | 0.822 (0.752 – 0.877) | ICC (95% CI) | 0.958 (0.939-0.972) |
| **Shoulder Internal Rotation** | | **Shoulder External Rotation** | |
| 1st measurement | 177.26±2.31 | 1st measurement | 84.30±3.02 |
| 2nd measurement | 177.16±2.35 | 2nd measurement | 84.23±3.15 |
| 3rd measurement | 177.162±2.35 | 3rd measurement | 84.16±3.45 |
| Inter Item Correlation | 0.037 - 1.000 | Inter Item Correlation | 0.897 – 1.000 |
| Cronbach's alpha | 0.986 | Cronbach's alpha | 0.980 |
| ICC (95% CI) | 0.958 (0.939-0.972) | ICC (95% CI) | 0.943 (0918 - 0.962) |

For Concurrent validity, the Smartphone Angle Meter score was crossed with the gold standard scale of ROM "Universal Goniometer" score. **Table IV** presented a low to moderately strong positive relationship between the Smartphone Angle Meter and Universal Goniometer for Shoulder Flexion at three different time intervals with Pearson correlation values ranging from 0.420 to 0.659. Overall, it can be stated that the Smartphone Angle Meter app has a low to moderately strong positive relationship with shoulder flexibility. A p-value of <0.001 confirms the statistical significance of the positive relationship. It also revealed a strong positive relationship between the Smartphone Angle Meter and Universal Goniometer for Shoulder Abduction at three different time intervals with a Pearson correlation value near +1. All the values were above 0.78, which shows an excellent relationship. On the whole, it can be stated that the Smartphone Angle Meter app has a robust positive correlation with shoulder abduction. A p-value of <0.001 confirms the statistical significance of the positive relationship.

**Table IV: Pearson Correlation of Smartphone Angle Meter Score with Universal Goniometer Score for Shoulder Flexion**

| Variables | R | P-value |
|---|---|---|
| **Shoulder Flexion** | | |
| Smartphone Angle Meter Day 1 vs UG Day 1 | 0.659 | < 0.001 |
| Smartphone Angle Meter Day 1 vs UG Day 2 | 0.554 | < 0.001 |
| Smartphone Angle Meter Day 1 vs UG Day 3 | 0.481 | < 0.001 |
| Smartphone Angle Meter Day 2 vs UG Day 1 | 0.592 | < 0.001 |
| Smartphone Angle Meter Day 2 vs UG Day 2 | 0.562 | < 0.001 |
| Smartphone Angle Meter Day 2 vs UG Day 3 | 0.481 | < 0.001 |
| Smartphone Angle Meter Day 3 vs UG Day 1 | 0.468 | < 0.001 |
| Smartphone Angle Meter Day 3 vs UG Day 2 | 0.495 | < 0.001 |
| Smartphone Angle Meter Day 3 vs UG Day 3 | 0.420 | < 0.001 |
| **Shoulder Abduction** | | |
| Smartphone Angle Meter Day 1 vs UG Day 1 | 0.939 | < 0.001 |
| Smartphone Angle Meter Day 1 vs UG Day 2 | 0.882 | < 0.001 |
| Smartphone Angle Meter Day 1 vs UG Day 3 | 0.856 | < 0.001 |
| Smartphone Angle Meter Day 2 vs UG Day 1 | 0.889 | < 0.001 |
| Smartphone Angle Meter Day 2 vs UG Day 2 | 0.810 | < 0.001 |
| Smartphone Angle Meter Day 2 vs UG Day 3 | 0.799 | < 0.001 |
| Smartphone Angle Meter Day 3 vs UG Day 1 | 0.889 | < 0.001 |
| Smartphone Angle Meter Day 3 vs UG Day 2 | 0.810 | < 0.001 |
| Smartphone Angle Meter Day 3 vs UG Day 3 | 0.799 | < 0.001 |

## DISCUSSION

This study obtained 37 healthy participants with a mean age of 26±2.52 years. The study aimed to find the reliability and validity of the angle meter application contrasted with the universal goniometer. An ICC for dependability under 0.5 is viewed as frail, under 0.75 is viewed as moderate and more than 0.80 is viewed as solid. In this study, Cronbach's alpha value showed that the Smartphone Angle Meter had outstanding dependability overall.

Milanese Jones et al. examined the knee joint's range of motion using a universal goniometer. For repeated measurements of knee flexion angles, both the universal goniometer and the smartphone goniometric application were proven to be accurate with both veteran medical professionals and final-year physiotherapy students. (Average ICCs > 0.96). No statistically significant differences exist between the two measuring instruments. Both the universal goniometer and the smartphone app provided accurate readings of knee flexion degrees over time. Greater precision in evaluating knee range of motion in clinical settings might be necessary, and the smartphone goniometric app's measurement results might show reduced error. Similar to the current study, the study found that smartphone apps can be used as a valid tool to measure range of motion[15].

Findings from the current study in conjunction with T Lau and S Lin's studies (F=13.1, df=2, 74, P0.001; Tukey test p-value 0.05) The human-measured gold standard measurements were substantially more significant than values from the two devices. There was no discernible difference between the App and the goniometer (p>0.05). The degree of agreement between the App or goniometer and the human gold standard was moderate to good. The goniometers and the App were dependable and in good to excellent condition. The standard goniometer showed a smaller percent difference (15.0 percent vs. 20.8 percent) than the gold standard. The Rate Fast Goniometer was much more accurate than the regular goniometer, but not by much[16]. The current study is supported by research by Smith, Allison B, Smith et al. in which25 male volunteers, ages 18 to 23, underwent bilateral Shoulder internal and external rotation measurements by a skilled Certified Athletic Trainer using a hand-held goniometer and the "Clinometer" smartphone application. The application's validity and inter-rater reliability were evaluated using Pearson correlation coefficients. With values of 0.959 and 0.940, respectively, smartphone validation for Shoulder internal and external range of motion was statistically significant. Internal and external rotations with the application and external rotation with the goniometer showed statistically substantial intra-rater reliability (0.804, 0.800, and 0.838). According to the study's findings, there is no distinction between the "Clinometer" smartphone application and a hand-held goniometer for evaluating the Shoulder's internal and external range of motion[17].

It was tough to convince the participants to come to the setting for the second reading. It was not taken into account how rapidly shoulder fatigue would occur. The authors observed that the volunteer occasionally shifted out of position after being positioned during the first day of data collection. Compared to the planned degree, this drift may have increased the percent inaccuracy of both measurements. Instrumentation is yet another risk to the study's internal validity. The accuracy of the measurements the clinicians took with the smartphone app improved as they gained more experience. According to this reasoning, authors anticipate that data measurements will improve precision and dependability over time.

Furthermore, there are recommendations for future research; multiple raters should take readings to evaluate internal consistency and reduce errors caused by improper device placement and a lack of anatomical landmark recognition. A modification to the methodology in future studies to assess volunteers when they are lying flat will probably improve the study's accuracy and validity. This position is easier to maintain and will probably result in fewer data-gathering problems. For smartphone applications, thorough training is advised before data collection to standardize this for upcoming protocols.

## CONCLUSION

It was concluded that the "Angle Meter" smartphone-based application might be considered a reliable and valid tool for assessing shoulder ROM as it showed excellent internal consistency and intra-rater reliability for flexion, abduction, and Shoulder joint rotation among healthy adults. In addition, it showed a mild to moderately positive correlation for shoulder flexion, whereas there was a moderate to strong positive correlation for shoulder abduction with a universal goniometer. Hence, an angle meter is recommended in physiotherapy clinical settings to measure shoulder range of motion among healthy individuals.

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## AUTHOR CONTRIBUTION

| | |
|---|---|
| Iftikhar A: | Concept, design |
| Akram S: | Drafting of article, Final approval |
| Bakht W: | Collection and assembly of data |
| Ashraf HS: | Statistical analysis |
| Altaf A: | Critical revision of the article |
| Javed H: | Data collection |

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