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ORIGINAL ARTICLE

Smartphone Goniometric Application for the Assessment of Active Wrist Range of Motion: A Reliability and Validity Study on Asymptomatic Subjects

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ABSTRACT:

Joint motion measurements are important component of physical evaluation. To perform the active ROM, the patient willingly transfers the body part through the ROM without any help to execute successful ROM and to perform the passive ROM the body moves through the ROM by the therapist or some external force. For the assessment of ROM of joint the therapist must have the sound knowledge of anatomy. It includes the joint articulations, motions and limiting factors. **Methods:** This study was a cross sectional survey which enlisted 100 participants through non-probability convenient sampling. The data was collected from general population of Lahore including both male and female, age 18-65 years, while individuals with wrist deformities, pregnant females, amputed limb and fracture history of wrist were excluded. The ROM of wrist joint which includes flexion, extension, ulnar deviation and radial deviation of both hands was measured through universal goniometer and Smartphone goniometric application at three different occasions. **Results:** Results were analyzed by SPSS version 25. The mean age of participants was 30.32± 12.28. Out of 100 participants maximum were female 55.0 (55%) and male were 45.0 (45%). In this study the correlation of every movement was taken separately flexion r=0.65, extension r=0.68, ulnar deviation r=0.68 and radial deviation was r=0.80 whereas, p-value of all the movement was 0.00 which is considered significant. **Conclusion:** The Smartphone goniometric application was found to be a reliable and valid measurement method for active wrist range of motion in this investigation. **Key Words: Universal Goniometr, range of motion, Wrist joint, Goniometric application**

INTRODUCTION:

Joint motion measurements are important component of physical evaluation.(1) To perform the active ROM, the patient willingly transfers the body part through the ROM without any help to execute successful ROM and to perform the passive ROM the body moves through the ROM by the therapist or some external force.(2) For the assessment of ROM of joint the therapist must have the sound knowledge of anatomy. It includes the joint articulations, motions and limiting factors.(3) The upper extremity's hand and wrist are the most involved and active parts. Additionally, they are prone to harm, which can result in ROM faults and serious functional issues.(4) The wrist joint injury is a common issue and the most common fracture site is the distal radius. Regarding kinematics, different brace positions are performed manually in biomechanical tests with dead weights or with pneumatic cylinders.(5) The typical wrist range of motion will be severely restricted by a variety of pathologies, including soft tissue disorders, autoimmune diseases, degenerative joint diseases and neurological conditions. (4) The maximum range of joint mobility can be estimated in degrees by adjusting the universal Goniometer stationary and moving arms with different bony landmarks on other side of joint. (6) It is simple to use, non-invasive and provides data that have verified to be reliable measure of joint ROM. The reliability of the standard method varies from one joint to another.(7) The smartphone based goniometers were first recommended in 2011 in a peer-review of medical literature. Milani et al first time conducted their research of a mobile phone app for determining the location of the body during rehabilitation.(8) A variety of smartphone based goniometry applications are now available for each app using a different mechanism for measuring joint angles.(9) The goniometer-pro is one of a free application which is used for measuring the joint ROM and wrist movements were measured through an elastic band which was used to fix the phone in the hand for measuring the active wrist ROM.(10) The measurement of wrist range of motion during a physical examination is crucial for the assessment, diagnosis, treatment and prognosis of patients with various wrist diseases. For this goal, numerous tools have been introduced. The G-Pro software makes it easy and quick to use a goniometer.(11) Dr. Goniometer is one such software that tests the angles of the images captured using the built-in phone sensor. The app helps the user to position a virtual goniometer over a picture to calculate the angle of the joint. (12) The information gathered can be utilized in the patient's personal clinical record and can be utilized by the doctor for reference during follow-up appointments or for therapeutic purposes. The software is also useful because it can facilitate contact with the psychiatrist the client and other health providers.(13)

METHODS:

This cross-sectional study was conducted on the general population of Lahore. Hundred participants were selected through non-

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probability convenient sampling technique. The active ROM of the wrist joint was measured through the universal goniometer and goniometric application of iPhone. Version 25 of SPSS Statistics was used to analyse the data. The study's inclusion criteria included the following: age range of 18 to 65 years; absence of elbow, forearm or wrist fractures; absence of implants in upper limb; absence of any UL deformity; absence of any upper extremity pathology, such as neurological diseases, carpal tunnel syndrome, soft tissue disorder, rheumatoid arthritis.[14] whereas the exclusion criteria were Amputated limb, pregnant limbs, pathologies of wrist (carpal tunnel syndrome, arthritis, dupuytren's syndrome etc), any history of wrist, elbow and shoulder fracture, any surgical implant of the upper extremity. The goniometer used in the examination was dual arm goniometer with 360^0 set apart in 1^0 additions, and each arm was 18 cm long.[15] It contains three scales: 0º to 180º, 0º to 90º, and 180º to 360º to accommodate the various quantifying systems. [16]Additionally, the smartphone goniometer utilised was the G-pro goniometer, which measures angles precisely in two easy steps: setting the 00 to determine the relative 00, rotating the device to the appropriate angle and getting a reading, then resetting and beginning a fresh measurement. Depending on the device, the G-pro app's precision has been observed to be between 0.20 and 0.30 degrees. IPhone X was used to take the measurement. The patient was in sitting position with elbow flexed at 90 degree, the shoulder abducted at 90 degrees, forearm pronated while the wrist hanging over side of the table. The movable arm was parallel to the fifth metacarpal's longitudinal axis, while the fixed arm was parallel to the ulnar. The anticipated wrist flexion range is 0-75degree .[17] For measuring the extension of wrist joint the patient was seated with elbow flexed at 90 degrees, shoulder abducted at 90 degrees, pronated forearm while wrist adjusted over edge of the table. The goniometer axis was above the side of the triquetrial bone, and the movable arm was parallel to the longitudinal axis of the fifth metacarpal while the fixed arm was parallel to the ulnar. The expected range of wrist extension is $0–70^0$ [17]. The patient was seated with elbow flexed at 90 degrees, shoulder abducted at 90 degrees, pronated forearm while wrist adjusted over edge of the table.in order to measure the ulnar deviation of the wrist joint. The goniometer axis was above the capitate bone, the stationary arm was at the forearm's dorsal midline, and the moving arm was parallel to the third metacarpal's long axis. The anticipated radial deviation range is 0-20°. [18] For measuring the radial deviation of the wrist joint the patient was seated with elbow flexed 90^0 and wrist over the edge of the table with forearm pronated. The goniometer axis was at the capitate bone, the stationary arm was in the middle of the forearm's dorsum, and the moving arm was parallel to the third metacarpal's longitudinal axis.. The expected range of radial deviation is 0-20º. [19]

RESULTS:

SPSS version-25 was used for data analysis. All four wrist movements, which comprise the active ROM, were evaluated. Table 1 summarises the descriptive data that was reported as mean, standard deviation, and range for each movement.

Table-1: Descriptive Statistics of Universal Goniometer and Smartphone Goniometer

		Universal Goniometer		
Movement	**stats**	**R1**	**R2**	**R3**
Flexion	**Mean**	76.15	73.60	73.90
	Std.	4.80	6.10	6.10
	Range	60-85	60-85	60-85
Extension	**Mean**	69.00	71.70	71.57
	Std.	5.23	6.75	6.79
	Range	60-80	60-85	60-85
Ulnar Deviation	**Mean**	33.12	30.40	30.25
	Std.	3.41	4.73	4.47
	range	30-40	20-40	20-40
Radial Deviation	**Mean**	21.15	21.75	21.67
	Std.	3.84	4.53	4.49
	Range	15-30	15-35	15-35

Table 1 provides a summary of the intra-rater reliability for both devices (universal goniometer and smartphone goniometer), including intra-day and inter-day reliability. The interclass correlation coefficient (ICC) for the intra-rater analysis was used to find the test-retest reliability of all measurements. For calculating the Standard Error of Measurement (SEM), which was used to assess the instrument's precision, the following formula was utilised: SEm = s1-R_{xx}.[20] Whereas, minimum detectable change at 95% confidence level ($MDC_{95\%}$), which shows the magnitude of change was calculated through MDC% = (1 − 10-MDC) * 100. [21]

		Universal Goniometer		
Movement	**stats**	**R1**	**R2**	**R3**
Flexion	**Mean**	76.11	76.34	76.52
	Std.	4.63	4.77	4.77
	Range	60-85	60-85	60-85
Extension	**Mean**	69.34	69.31	69.31
	Std.	4.93	4.87	4.80
	Range	60-85	60-80	60-80
Ulnar Deviation	**Mean**	34.29	34.48	34.41
	Std.	3.32	3.25	3.27
	range	30-40	30-40	27-40
Radial Deviation	**Mean**	21.85	21.30	21.11
	Std.	4.49	3.84	3.78
	Range	15-35	15-30	15-30

The guidelines provided by the Bland and Altman for classifications of reliability values were used. According to which, the ICC value below 0.20 was considered as poor, 0.21-0.40 as fair, 0.41-0.60 considered as moderate, 0.61-0.80 as good and exceeding 0.81 as excellent. In current study the reliability of the smartphone and the universal goniometer was excellent. So, the goniometric application can be used in the clinical practice for measuring the active wrist ROM.[22]

Table-2: Intra-rater reliability of smartphone Goniometer and universal Goniometer

Movements	Reliability (Intra-rater)	Universal Goniometer		Smartphone Goniometer	
		Within-day	**Between-days**	**Within-day**	**Between-days**
Flexion	**ICC**	0.81	0.83	0.87	0.78

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		(0.71-0.85)	(0.71-0.85)	(0.83-0.970	(0.72-0.83)
	SEM	3.63	3.75	1.69	2.20
	2SEMs	7.26	7.5	3.38	4.4
	MDC	10.0	10.3	4.67	6.07
Extension	**ICC**	0.79 (0.65-0.85)	0.81 (-0.65-0.85)	0.99 (0.99-0.99)	0.94 (0.93-0.96)
	SEM	5.04	4.96	0.49	1.19
	2SEMs	10.08	9.92	0.98	2.38
	MDC	13.92	13.70	1.35	3.28
Ulnar Deviation	**ICC**	0.83 (0.75-0.85)	0.79 (0.75-0.85)	0.92 (0.90-0.94)	0.77 (0.71-0.82)
	SEM	3.56	3.43	0.92	1.57
	2SEMs	7.12	6.86	1.84	3.14
	MDC	9.83	9.84	2.54	4.33
Radial Deviation	**ICC**	0.73 (0.66-0.79)	0.71 (0.64-0.77)	0.83 (0.78-0.87)	0.73 (0.66-0.79)
	SEM	2.17	2.24	1.71	2.15
	2SEMs	4.34	4.48	3.42	4.3
	MDC	5.99	6.19	4.72	5.94

SEM= Standard Error Measurement, ICC= Intra class correlation, MDC= Minimum Detectable Change. The concurrent validity was determined by using the Pearson correlation coefficient (r) between universal goniometer and smartphone goniometer readings. The Pearson correlation varies between -1 and +1. There is no correlation between the two variables, as indicated by the 0 value. If the value is larger than 0, the correlation is positive, indicating a direct correlation between the two variables, meaning that if one measure rises, the other rises as well. A value less than 0 indicate the negative correlation which shows the inverse relationship between the two variables i.e. if one variable increases the other decreases. The correlation coefficient values classified according to (Chicco, 2022) guidelines were considered in this study which defines that values between 0.00–0.09, 0.10–0.29, 0.30–0.49, 0.50–0.69, 0.70–0.89, 0.90–0.99, 1.00 shows non-existent, small, medium, large, very large, nearly perfect, and perfect relationship, respectively. The Pearson correlation coefficient value (r) for all movements of wrist was between 0.65-0.80, showing large to very large relationship between universal and smartphone goniometer. This indicates that the concurrent validity of smartphone goniometer was good and it is a valid instrument for measuring wrist ROM.[23]

Table-3: Pearson's Correlation between Universal Goniometer and Smartphone

Wrist ROM	r	p-value
Flexion	0.65	0.00
Extension	0.68	0.00
Ulnar Deviation	0.68	0.00
Radial Deviation	0.80	0.00

DISCUSSION:

In this study, a total of hundred participants were recruited in order to observe the reliability of an iPhone goniometric application for measuring active ROM. The mean age of participents was 30.32± 12.28.[24] Out of 100 participants, 55 (55.0%) were females and 45 (45.0%) were males. However, there were 51 (51.0%0 students, 33 (33.0%) employed and 16 (16.0%) housewives. According to the current study the smartphone goniometer application is accurate in measuring active ROM of wrist joint. A tool called universal goniometer is used to assess range of motion (ROM) at wrist. The universal goniometer's dependability in the current investigation is consistent with that of earlier studies, which found good to exceptional ICC values..[25] According to a previous study, for the inter-rater analysis MDC_{95} ranged from 1.97° to 6.15° and for the intra-rater analysis MDC_{95} ranged from 1.66° to 5.35°. The concurrent validity was found to be high between the two instruments i.e. $r \geq 0.80$. These results are similar with our present study the reliability of the smartphone and the universal goniometer was excellent as their ICC values given in above table 2.[26] [27] A prior study found that utilising three distinct methodologies, passive wrist ROM could be measured with intra-rater reliability ranging from 0.80 to 0.92. The inter-rater reliability mean fell between the range of 0.80 and 0.93. The ICC values in our investigations vary from 0.72-0.85, which are good to exceptional. [28] This study's good to excellent reliability is probably attributable to the universal goniometer's precise and firm placement, which prevented it from slipping off the subjects' skin while they moved, three repetitions of each measurement, the ease with which the instrument was used, and the subjects' increased familiarity with the testing procedures.. [29, 30] The findings of this study lay the foundation for future research in this field because no published research has assessed the reliability (intra-rater) of smartphone goniometer (iPhone application) and universal goniometer for the measurement of active wrist range of motion.[31] Results from smartphone goniometers typically span a variety of joints, joint movements, populations, cellphones, and apps. These findings suggest that clinicians can measure joint ROM using a number of smartphones and apps. [32, 33] This study is supported by literature of previously conducted studies that the overall reliability remained excellent and the ICCs were also in the excellent range. Thus, repeated measurements of the wrist motion by the same therapist can be expected to be highly reliable under the clinical conditions.[34] Some variables related to subject such as anatomical changes due to any trauma or deformity and variations in application of external force were found to have no effect on reliability. [35]

CONCLUSION:

The study found that the G-Pro app has good concurrent validity and moderate to outstanding dependability. Smartphone goniometric applications are a useful option for both clinical and academic purposes for evaluating wrist ROM.

Author Contributions:

Conception and design: *Mahnoor*
Collection and assembly of data: *Muhammad Shazib Butt*
Analysis and interpretation of the data: *Mahnoor*
Drafting of the article: *Muhammad Shazib Butt*
Critical revision of article for intellectual content: *Mahnoor*
Statistical expertise: *Muhammad Shazib Butt*
Final approval and guarantor of the article: *Mahnoor*
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