

Goniometria Digital Versus Goniometria Clássica na Avaliação da Mobilidade do Ombro: Um Estudo Piloto de Concordância

Digital Versus Classic Goniometry in Shoulder Motion Evaluation: An Agreement Pilot Study

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Resumo

Introdução: A avaliação do arco de movimento do ombro tem importância clínica e é igualmente relevante para monitorizar a resposta ao tratamento. Os *smartphones* incorporam acelerómetros que permitem medições fáceis de executar mas a sua fiabilidade quando comparada com a do goniómetro clássico ainda não foi comprovada. Os autores propõem-se a determinar a reprodutibilidade intraobservador entre a goniometria clássica e a goniometria digital baseada na utilização de um *smartphone* na avaliação da flexão anterior ativa e da rotação externa ativa nas posições de ortostatismo e decúbito dorsal.

Material e Métodos: Foi selecionada uma amostra por conveniência de 16 voluntários saudáveis. As medições foram efetuadas por um observador independente em dois momentos diferentes com intervalo de uma semana. A ordem dos participantes e da sequência das medições foi aleatorizada. O observador foi treinado de acordo com um protocolo pré-estabelecido e este foi cego para os resultados intermédios. Foi avaliada a concordância entre métodos utilizando o coeficiente de correlação intraclass, a inspeção visual dos *plots* de Bland-Altman e o cálculo dos limites de concordância.

Resultados: A reprodutibilidade intraobservador foi boa no que diz respeito à *external rotation-standing intraclass correlation coefficient* 0,87 (IC 95%: 0,66-0,95), *external rotation-supine intraclass correlation coefficient* 0,92 (IC 95%: 0,80-0,97) e a *active flexion standing intraclass correlation coefficient* 0,92 (IC 95%: 0,78-0,97). A pontuação foi mais baixa na *active flexion supine intraclass correlation coefficient* 0,81 (IC 95%: 0,55-0,93).

Conclusões: A reprodutibilidade intraobservador foi boa entre a goniometria clássica e digital na rotação externa (independentemente da posição) e na flexão anterior em ortostatismo. A goniometria digital pode ser uma ferramenta fácil de usar no exame físico de indivíduos saudáveis mas a sua precisão e aplicabilidade em ambiente clínico ainda necessitam de verificação adicional.

Palavras-chave: Amplitude de Movimento Articular; Artrometria Articular; Ombro; Posicionamento do Paciente.

Abstract

Introduction: Shoulder range of motion measurement is not only of diagnostic significance but is also relevant for monitoring response to therapeutic interventions. Smartphones incorporate accelerometers which enable easy multiaxial and multiangle measurements but their reliability compared to the classic goniometer remains to be established. The authors aim to ascertain the intra-rater reliability between manual and smartphone-based digital goniometry in measuring active flexion and external rotation in both standing and supine positions.

Methods: A convenience sample of 16 healthy volunteers was selected. Measures were taken by an independent rater at two different times, a week apart. We randomized both participant's order and measurement sequence. The rater was trained according to a predetermined measurement protocol and blinded to intermediate

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measurements. We evaluated agreement between methods using the intraclass correlation coefficient, visual inspection of Bland-Altman plots and calculation of the limits of agreement.

Results: The intra-rater correlation was good regarding the external rotation-standing intraclass correlation coefficient 0.87 (IC 95%: 0.66-0.95), the external rotation-supine intraclass correlation coefficient 0.92 (IC 95%: 0.80-0.97) and the active flexion standing intraclass correlation coefficient 0.92 (IC 95%: 0.78-0.97). The score was lower in the active flexion supine intraclass correlation coefficient 0.81 (IC 95%: 0.55-0.93).

Conclusion: There was a good intra-rater reliability between classic and digital goniometer in external rotation (regardless of positioning) and in standing active flexion. The smartphone based digital goniometer might be an easy tool to assist physical examination in healthy individuals, but its accuracy and applicability to clinical settings needs further evaluation.

Keywords: Arthrometry, Articular; Shoulder; Patient Positioning; Range of Motion, Articular

Introduction

Range of motion is a key component of the musculoskeletal physical examination,¹ since it is part of diagnostic workup and monitoring response to several interventions in the field of Physical Medicine and Rehabilitation.^{1,2}

In shoulder mobility measurement a number of instruments have been used, including visual estimation, classic goniometry, linear measures, and inclinometry. The chosen method varies among clinicians and institutions, influenced by factors such as time restraints, personal experience and available resources.^{2,3}

Classic goniometry has been widely used because of its portability and low cost. However, several limitations have been reported including lack of standardization in spatial orientation of goniometers' levers and body segment positioning during measurement, raising questions about reproducibility between individual raters and also between measurements overtime.³

Digital means of assessing range of motion have become available in the last few years, including accelerometers, inclinometers and photograph based techniques.⁴⁻⁶ The digital goniometer using smartphone-based apps has become widely available and might be useful in assisting physical examination but its reliability when compared to the classic goniometer remains to be established.⁷

These devices are easily accessible, portable, and require minimal training. However, a potential disadvantage of digital goniometry is that it requires the examiner to determine the zero point accurately and consistently prior to use in order to minimize the risk of measurement errors and to accompany the whole movement of the joint.⁸⁻¹¹

However, evidence showing the interchangeability of these two measurement methods is lacking and precludes a wider dissemination of these newer

technological-based options designed to assist the clinician on a more accurate, quantifiable physical examination.

Purpose

To ascertain the intra-rater reliability between manual and digital goniometry (through a smartphone app – GETMYROM 1.03) in shoulder motion evaluation of two classic positions, standing (St) and supine (Su), measuring active flexion (AF) and external rotation (ER).

Methods

Amongst workers in the Physical and Rehabilitation Medicine Department and non-musculoskeletal patients treated in the department, we recruited a convenience sample of thirty volunteers approached using a predefined questionnaire (Fig. 1). Demographic and anthropometric data was also collected at the same time. Selection criteria for inclusion were aged older than 18 years, able to cooperate and having no history of surgery, major trauma or pain for the last 6 months in the dominant shoulder. Of the thirty initially approached, only sixteen were included in the final sample.

Measures were taken by an independent rater at two different times, a week apart. The order of the participants and the measurement sequence were randomized. The rater was blinded to the results of intermediate measurements, which were subsequently analyzed and inserted in an individual database by a second independent researcher. The rater was previously trained according to a predefined measurement protocol including both classic and digital goniometers.

A classic goniometer with a 360 degrees scale was used. The digital goniometry was done using an iPhone 5® and the digital app GETMYROM version 1.0.3® commercially available through the appstore (Fig. 2).

QUESTIONÁRIO
Dados sócio demográficos

Data
Iniciais do Nome:
Data de nascimento:
Sexo
Profissão:
Altura
Peso
Membro dominante: Esquerdo ____ Direito ____

Participa?
Ombro

OMBRO

QUESTÕES	Sim	Não
Antecedentes de cirurgia ao ombro direito		
Fratura/luxação ou traumatismo maior prévio do ombro direito		
Omalgia no membro superior direito nos últimos 6 meses		

Figure 1 - The questionnaire that was used to select the study participants.



Figure 2 - Instruments used for the measurements. On the left the classic goniometer and on the right the smartphone (Iphone5®) with the app GETMYROM®.

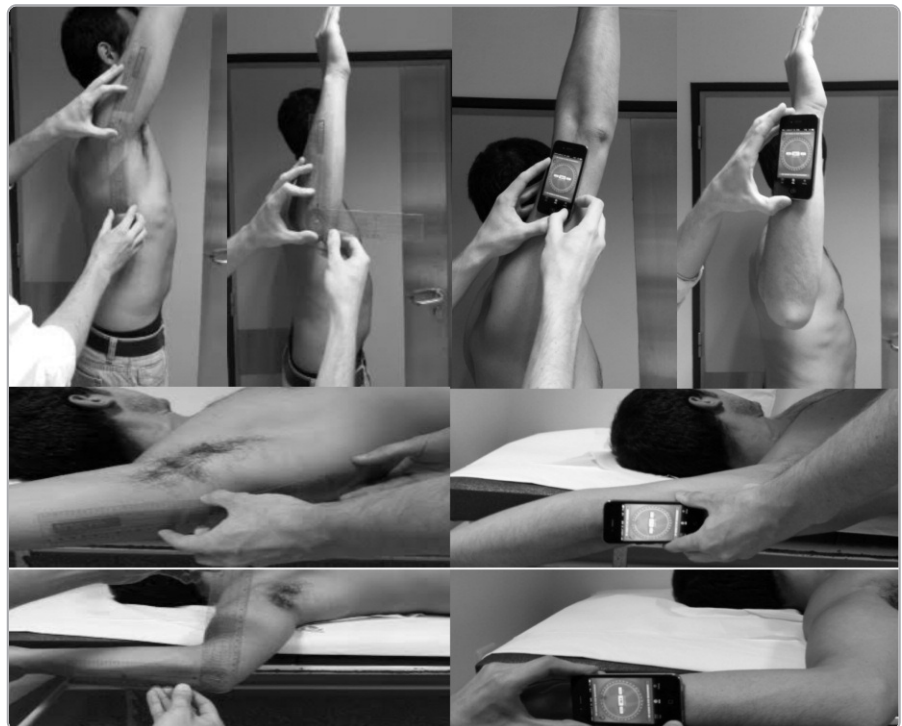


Figure 3 - Positioning of the patient and of the instruments during measuring: Classic goniometer on the left, digital goniometer on the right; Standing in the upper row, Supine in the lower rows.

Two measures were taken in each position (active anterior flexion (AR) and active external rotation (ER)) and the mean value was selected and registered. The procedure was done both in the standing (St) and supine (Su) positions (Fig. 3).

By convention and to simplify the protocol, the

dominant shoulder was measured (all patients were right-handed). Examination began with a simple explanation of the procedure and an active-assisted mobilization along the plane to be measured. Patients were instructed to achieve full painless range of motion in each direction.

Below, each measuring procedure is described in detail:

St AF: measurements were done with the participant's right shoulder standing at the side of the body (anatomic position at 0°) and then elevating the arm along the sagittal plane, thumb pointing up, until there was discomfort or end-capsular resistance feeling. The participant was instructed to keep the upper limb in that position until measurements were made. **Classic goniometry:** The goniometer's fulcrum was positioned laterally in the middle point of the glenohumeral joint with the fixed lever arm aligned vertically and the mobile lever arm parallel to the humerus long axis in the direction of the lateral epicondyle of the humerus. **Digital goniometry:** The smartphone was placed on the distal third of the lateral aspect of the arm and the shoulder motion was accompanied, keeping the smartphone parallel to the long axis of the humerus in the direction of the lateral epicondyle. The total range of motion was indirectly and automatically estimated by recording the initial and end-positions.

St ER measurements were done with the participant's right shoulder at 90° of abduction and neutral rotation, elbow flexed at 90°; the participant would then actively externally rotate the shoulder until there was pain or end-capsular resistance feeling. **Classic goniometry:** The goniometer's fulcrum would then be positioned at the olecranon with the fixed lever arm perpendicular to the middle axillary line and the mobile lever arm parallel to the long axis of the forearm in the direction of the ulnar styloid process. **Digital goniometry:** The smartphone was placed on the distal third of the forearm and the external rotation motion was accompanied, keeping the smartphone parallel to the long axis of the ulna in the direction of the ulnar styloid process.

Su AF was evaluated with the volunteer lying on his back, hip and knee partially flexed, both at 45° to stabilize the torso; The glenohumeral joint was positioned on the outer limit of the observation table, starting from the anatomical position and then actively anteriorly flexing the arm, until there was pain or end-capsular resistance feeling. **Classic goniometry:** The goniometer fulcrum was applied to the posterior axillary line on the projection of the gleno-humeral joint with the fixed arm lever parallel to the torso and the mobile lever arm parallel to the long axis of the humerus in the direction of the humerus lateral epicondyle. **Digital goniometry:** The smartphone was placed on the distal third of the posterior aspect of the arm and the shoulder motion was accompanied, keeping the smartphone parallel to the long axis of the humerus in the direction of the olecranon.

SU ER starting in the same supine position described above, but with the upper limb supported by the observation table, shoulder in 90° of abduction and

neutral rotation and elbow flexed at 90°; the participant would then externally rotate the shoulder. **Classic goniometry:** Goniometer's fulcrum placed at the olecranon with the fixed lever arm perpendicular to the middle axillary line and the mobile lever arm parallel to the long axis of the ulna in the direction of ulnar styloid process. **Digital goniometry:** The smartphone was placed on the distal third of the forearm and the external rotation motion was accompanied, keeping the smartphone parallel to the long axis of the ulna in the direction of the ulnar styloid process.

Statistical analysis was done using the SPSS (Statistical Package for the Social Sciences) version 22®. According to standard recommendations for intra and inter-rater reliability studies we used the intraclass correlation coefficient (ICC) and the Bland-Altman methods.^{12,13} Since our aim was to use the study information for general application in clinical practice the ICC (2.1) equation was chosen.¹³ ICC values range from 0 (no agreement) to 1 (total agreement) and values above 0.90 suggest excellent agreement, 0.75-0.89 moderate agreement and below 0.75 poor agreement.¹⁴ We used the Bland Altman method for plotting plots the difference against the mean of two measurements to allow visual judgment of any systematic error. Limits of agreement were calculated and presented as mean \pm 1.96 standard deviation of the difference between measurements.¹²

Results

The study sample consisted mainly of men (n = 14; 87.5%), age (mean(standard deviation)), 43.5(17.5) years old, ranging from 25 to 71 years old.

Regarding anthropometric features, mean height was 171.4 (7.7) cm (range: 155.0 – 183.0 cm), mean weight 74.9 (13.2) kg (range: 51.0 – 98.0 kg) and a mean body mass index of 25.4 (3.9) kg/m² (range: 20.7-34.1).

Mean values for each measurement method are shown in Table 1. Despite relatively small mean differences (ranging from 0.96 to 4.6) we found a somewhat high standard deviation reflecting considerable variation and possibly problems concerning sample size.

We found a good intra-rater correlation in both ER St_{ICC} 0.87 (IC 95%: 0.66-0.95), the ER Su_{ICC} 0.92 (IC 95%: 0.80-0.97) and AF St_{ICC} 0.92 (IC 95%: 0.78-0.97), and somewhat lower in the AF Su_{ICC} 0.81 (IC 95%: 0.55-0.93) (Table 2). These findings are similar to those reported in previous work concerning both digital and classic goniometry, and support the hypothesis that regardless of the measurement method, measuring technique (and its standardization) might be the most important factor affecting reproducibility.⁸⁻¹¹ Using the Bland-Altman method we calculated the 95%

Table 1 – Mean values for the different measurements.

	Classic	Digital
St AF	158.5 (14.9)	162.5 (14.6)
St ER	86.6 (13.7)	91.2 (13.6)
Su AF	167.1 (12.1)	168.1 (13.7)
Su ER	83.5 (16.2)	86.0 (16.1)

St AF- standing anterior flexion; St ER- standing external rotation; Su AF- supine anterior flexion; Su ER- supine external rotation.

limits of agreement and found the narrower range for St AF (-15.86; +7.8) and the wide for St ER (-19.61;10.41). What this range means is that 95% of measurement differences with the two methods will fall in the range between -7.8° and 15.86° (absolute variation 23.7°), for St AF, and -19.61° and 10.41° (absolute variation 30.1°), for St ER (Table 2). Visual inspection of the Bland-Altman plots showing difference against mean for measurements with digital and manual goniometry, show differences did not vary in any systematic way over the range of measurement, hence there is no systematic bias even for the most extreme observations (Fig. 4).

Table 2 – Measures of agreement between measurement methods for each motion.

	ICC	ICC-95%CI	Mean diff (d)	SDdiff (SD)	LOA $_{(d\pm 1,96*SD)}$
St AF	0.92	0.78-0.97	-4.03	6.04	-15.86; 7.8
Su AF	0.81	0.55-0.93	-0.96	7.86	-16.35; 14.45
St RE	0.87	0.66-0.95	-4.60	7.66	-19.61; 10.41
Su RE	0.92	0.80-0.97	-2.50	6.14	-14.53; 9.53

CI- confidence intervals; ICC- intraclass correlation coefficient; LOA- limits of agreement; Mean diff- mean difference; SD diff- standard deviation difference. St AF- standing anterior flexion; St ER- standing external rotation; Su AF- supine anterior flexion; Su ER- supine external rotation.

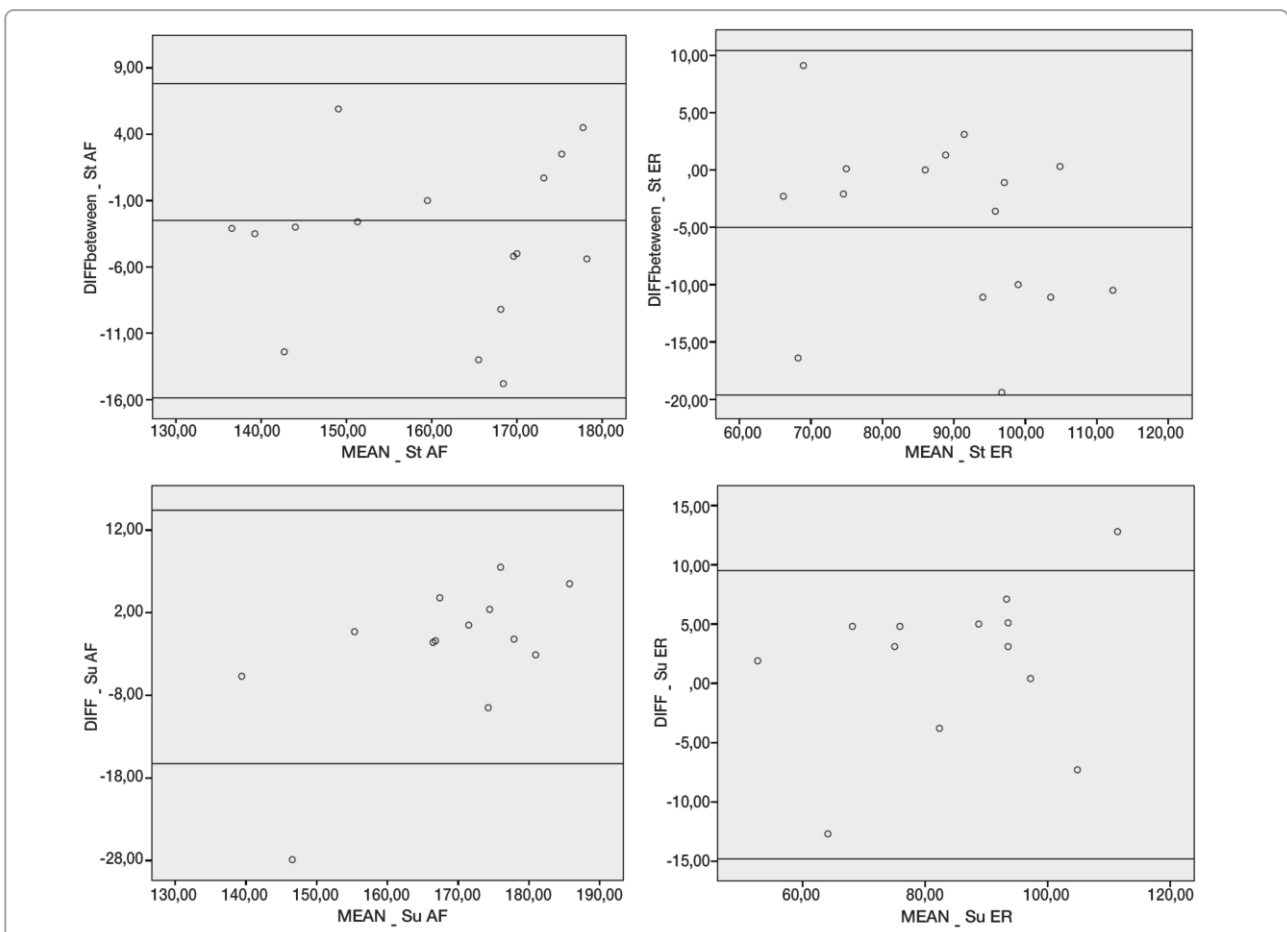


Figure 4 - Bland and Altman plots for difference between measures and mean measures. DIFF- difference; St AF- standing anterior flexion; St ER- standing external rotation; Su AF- supine anterior flexion; Su ER- supine external rotation.

Overall, we found digital goniometry to have slightly higher readings compared to manual goniometry, both in standing (St AF: +4.0°; St ER: +4.6°) and supine (Su AF: +1.0°; Su ER: +2.5°) (Table 2). This slight overestimation with digital measurements has been previously reported,⁴ and should be considered when choosing methods for follow-up studies, ideally using the same method and measurement protocol throughout the study.

The strengths of this study are the randomization of measurement sequence and order of participants, the rater's occultation for intermediate measurements and the sample heterogeneity regarding age and different clinical backgrounds. Nonetheless, we have to acknowledge some limitations: small sample size reflected in the wide confidence intervals of measurements, the low representation of females and the exclusion of patients having history of shoulder pain or trauma/surgery might affect both internal and external validity of results. Furthermore, clinicians should consider that the limits of agreement found when using these instruments suggest that clinically significant differences are likely to be present in some scenarios of the shoulder motion evaluation and so these measurements should be valued accordingly and clinical judgment should prevail.

Conclusions

In a healthy population, there was good intra-rater reliability between classic and digital goniometer in active external rotation (regardless of positioning). Correlation between the two techniques was also good in standing active anterior flexion and lower in the supine active anterior flexion. We have found that shoulder range of motion measurement depends mainly of the rater and intrinsic variability of the instruments, rather than the specific measurement method chosen.

Digital measures appear to have slightly higher values than manual goniometry, making it difficult for these methods to be used interchangeably in follow-up studies.

In conclusion, the smartphone based digital goniometer might be an easy to use tool to assist physical examination in healthy individuals. However its accuracy and applicability to clinical settings still need further evaluation.

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