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CONFIABILIDADE DA MEDIDA DE MOVIMENTO DE ROTAÇÃO DO OMBRO MENSURADA PELO APLICATIVO CLINÔMETRO PARA SMARTPHONE

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Resumo:. A goniometria é muito usada para medir a amplitude de movimento (ADM), mas requer habilidade e treinamento. Nesse sentido, os aplicativos para smartphones aparecem como uma alternativa. O objetivo foi avaliar a confiabilidade e a validade das medidas de rotação do ombro usando um aplicativo clinômetro de smartphone. Este estudo foi provado pelo Comitê de Ética da Universidade de Pernambuco. Participaram do estudo trinta e seis (36) adolescentes e adultos jovens, saudáveis e fisicamente ativos. Na intervenção, cada voluntário realizou rotação externa (RE) e interna (RI) do ombro nas posições em supino e decúbito lateral. A ADM de rotação do ombro foi medida por um goniômetro e um aplicativo. RE e RI foram medidas em dois dias por dois avaliadores. A confiabilidade foi determinada usando coeficiente de correlação intraclasse (CCI), erro padrão de medição (EPM) e mudança mínima detectável (MMD). A validade foi avaliada usando os coeficientes de correlação de Pearson. Ambos os dispositivos apresentaram excelentes níveis de confiabilidade intra e interexaminadores na maioria das avaliações. No entanto, o goniômetro apresentou confiabilidade interexaminadores moderada na medição da rotação interna realizada na posição deitada (ICC 0,61 a 0,67). O aplicativo mostrou confiabilidade interexaminadores variando de ruim a moderada para as mesmas medidas (ICC 0,35 a 0,61). Diferenças significativas foram observadas entre os valores registrados pelos dois instrumentos para todas as medidas realizadas (p <0,001). Uma forte correlação foi observada entre as medidas nas posições supina e deitada de lado com o goniômetro e o aplicativo clinômetro para smartphone (r> 0,85). O aplicativo apresentou excelentes níveis de confiabilidade, bem como demonstrou uma alta correlação com o goniômetro. No entanto, a avaliação da RI na posição deitada deve ser evitada.

Palavras-chave: Amplitude de movimento; Ombro; Goniômetro

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Reliability of shoulder rotation movement measured by the smartphone clinometer application

Abstract: Goniometry is widely used to measure range of motion (ROM), but requires skill and training. In this sense, smartphone apps appear as an alternative. The objective was to assess the reliability and validity of shoulder rotation measurements using a smartphone clinometer app. This study approved by Ethical and Research Committee of the University of Pernambuco. Thirty six (36) healthy and physically active adolescents and young adults participated in the study. In the measurement each volunteer performed external (ER) and internal (IR) rotation of the shoulder in the supine and side lying positions. The shoulder rotation ROM was measured by a goniometer and an application. ER and IR were measured in two days by two evaluators. Reliability was determined using intraclass correlation coefficient (ICC), standard error of measurement (SEM) and minimum detectable change (MDC). Validity was assessed using Pearson's correlation coefficients. Both devices had excellent intra- and inter-examiner reliability levels in most evaluations. However, the goniometer showed moderate inter-examiner reliability in measuring the internal rotation performed in the lying position (ICC 0.61 to 0.67). The app showed inter-examiner reliability ranging from fair to moderate for the same measurements (ICC 0.35 to 0.61). Significant differences were observed between the values recorded by the two instruments for all measurements performed ($p < 0.001$). A strong correlation was observed between measurements in the supine and side lying positions with the goniometer and a smartphone clinometer app ($r > 0.85$). The application presented excellent reliability levels as well as demonstrated a high correlation with the goniometer. However, the assessment of IR lying down position should be avoided.
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Key words: Range of motion; Shoulder; Goniometer.

Introduction

The range of motion of shoulder movements is widely studied and presented in different activities and age groups. Overloads and presence of shoulder joint pain may affect range of motion (ROM), manifesting in changes in internal and external rotations, including larger deficits in internal glenohumeral rotation (GIRD), which could lead to injuries[1,2]. About the average range of motion of the shoulder rotations in young, healthy and physically active individuals, Vairo et al.[3] presented an average of 58.91 ° for the passive movement for internal rotation in the dominant arm, with shoulder at 90 ° of abduction, and average 104.64° of passive external rotation with shoulder in 90 ° of abduction, also dominant arm. In this context, accurate ROM measurements are required for diagnosis and/or follow-up, which requires the use of reliable and valid tools.

The goniometer is a widely used tool for ROM measurements because it is a portable, easily accessible and inexpensive device which has good reliability and validity for movement measurements [4]. The inclinometer is an alternative method for assessing ROM which has an advantage over handling and measurement, but the equipment is expensive [5].

In this sense, different low-cost technologies have been developed for clinical use. The clinometer app is the free smartphone application that presents excellent reliability for assessing ROM [6]. However, it is essential to note that the device must have acceptable levels of reliability and validity for its clinical use. Specifically for shoulder rotation movements, it is possible to observe different body positions for performing the ROM assessment.

Therefore, it is important to evaluate the performance of the tool in different evaluation settings and to define the best choice. Thus, the goal of this study was to evaluate the reliability and validity of shoulder rotation measurements using the smartphone clinometer application in healthy adolescents and young adults in different positions.

Methods

This is a reliability study approved by Ethical and Research Committee of the University of Pernambuco. The sample consisted of both female (n=18) and male (n=18), physically active, healthy adolescents and young adults (mean age, 19.5 ± 1.1 years;

weight 65.72 ± 13.90 kg; height 1.66 ± 0.09 m). Volunteers who did not attend the session on the pre-established deadlines or who were unable to perform the procedure were excluded.

The measurements were performed on two days, with a minimum interval of 48 hours. Personal data and anthropometric records were initially collected. Then, the order of positions (supine and side-lying position), movements (internal and external rotation) and tools was randomized by a random draw. Three consecutive measures were done for both limbs using the goniometer (GO) and the Clinometer™ app, Plaincode, Munich, Germany (https://www.plaincode.com/products/clinometer/), then registering their mean. Prior to data collection, two evaluators were trained to perform the measurements.

The goniometer position during the evaluation followed Kolber & Hanney [7] recommendations, in which the axis was positioned on the olecranon and the mobile side stood parallel to the forearm and the fixed side perpendicular to the floor. The smartphone was positioned on the ventral side of the forearm during external rotation assessment and dorsal side of the forearm for internal rotation. For both measures, the elbow was positioned in a flexion of 90°.

Statistical Analysis

Statistical analyses were performed using the SPSS software package version 20.0. The normal distribution of data was initially confirmed by the Shapiro-Wilk test. The t-test and Pearson correlation were used to compare and correlate the measurements obtained by the two instruments, respectively. The 5% significance level was considered in all analyzes.

Inter-observer reliability was evaluated by the ICC (2,3), a two-way random effects model with an average of three measures and absolute agreement for each movement. Intra-observer reliability for each observer was assessed in terms of the ICC (3, 3), a two-way fixed effects model with an average of three measures and absolute agreement for each movement. An ICC was calculated for each ROM measurement and expressed as ICC with 95% confidence interval. The interpretation of each ICC was as follows: 0.00 to 0.20, slight correlation; 0.21 to 0.40, fair correlation; 0.41 to 0.60, moderate correlation; 0.61 to 0.80, substantial correlation; and 0.81 to 1.00, almost strong correlation [8].

The standard error of measurement (SEM) was calculated for each measurement as an additional measure of absolute reliability. Also, the minimal detectable change (MDC) at the 95% confidence level was employed to analyze the clinically meaningful degree of difference. The calculation used was $SEM_{95\%} = SD\ .\ \sqrt{(1 - ICC_{test-retest})}$, and SD is the standard deviation from the mean of the first assessment, and $MDC = 1{,}96\ .\ SEM_{95\%}\ .\sqrt{2}$, at constant 1.96 it represents the z score associated with 95% confidence level.

Results

The sample was composed of 36 volunteers, 18 men and 18 women The ROM values obtained by both evaluators by means of the GO and SCA in different days are described in Table 1.

Table 1. Mean and standard deviation values of ROM of the right and left shoulders in the different proposed positions.

		EVALUATOR 1			EVALUATOR 2		
		FIRST DAY	**SECOND DAY**	SEM EV 1	**FIRST DAY**	**SECOND DAY**	SEM EV 2
RIGHT SHOULDER	**GONIOMETER**						
	IRSP	77.94 ± 11.39	81.53 ± 12.53	4.74	81.67 ± 13.65	84.75 ± 14.46	2,63
	IRSLP	63.44 ± 13.19	63.75 ± 12.31	4.26	67.53 ± 9.83	68.89 ± 9.65	3,80
	ERSP	112.19 ± 13.72	112.44 ± 13.83	2.88	107.56 ± 14.92	108.11 ± 14.02	1,80
	ERSLP	108.14 ± 13.15	109.31 ± 11.83	2.24	104.56 ± 13.28	104.31 ± 12.80	1,67
	CLINOMETER APP						
	IRSP	90.39 ± 15.32	93.78 ± 16.33	4.20	92.65 ± 13.06	94.06 ± 14.07	3,91
	IRSLP	72.90 ± 17.32	74.63 ± 15.38	7.06	75.72 ± 9.51	77.82 ± 10.73	6,02
	ERSP	120.04 ± 17.19	120.22 ± 15.76	3.48	123.82 ± 16.61	124.88 ± 17.73	2,28
	ERSLP	116.36 ± 14.28	116.69 ± 13.12	2.59	117.97 ± 14.03	118.56 ± 13.50	1,71
LEFT SHOULDER	**GONIOMETER**						
	IRSP	85.67 ± 13.84	89.08 ± 13.84	3.87	84.03 ± 13.78	85.58 ± 13.48	2,23
	IRSLP	65.42 ± 12.62	66.08 ± 12.21	3.97	68.83 ± 11.34	69.28 ± 11.51	2,65
	ERSP	111.03 ± 13.76	110.39 ± 12.76	2.65	111.69 ± 15.94	113.39 ± 16.10	1,85
	ERSLP	105.53 ± 10.87	107.25 ± 10.31	2.31	107.33 ± 13.117	107.78 ± 12.213	1,26
	CLINOMETER APP						
	IRSP	101.53 ± 17.98	103.68 ± 16.90	3.36	96.49 ± 12.42	97.58 ± 12.03	3,82
	IRSLP	80.08 ± 15.09	80.68 ± 15.98	3.85	79.85 ± 10.27	81.86 ± 10.07	4,98
	ERSP	118.08 ± 17.33	117.28 ± 15.10	3.68	124.17 ± 17.98	125.69 ± 17.93	2,70
	ERSLP	113.17 ± 13.59	114.69 ± 12.25	2.92	117.37 ± 12.96	117.25 ± 12.64	1,64

IRSP = Internal rotation in supine position; IRSLP = Internal rotation in side-lying position; ERSP = External rotation in supine position; ERSLP = External rotation in side-lying position; SEM = Standard error of measurement; EV1 = evaluator 1; EV2 = evaluator 2

Both devices presented excellent intra-examiner reliability (ICC > 0.82) for all measures. However, the results showed that the measurement of internal rotation performed in the supine presented lower absolute error (SEM ≅ 5 and MDC ≅ 11), while external rotation data showed less error when evaluating the volunteer in the side-lying position (SEM ≅ 3 and MDC ≅ 8) (Table 2).

The SCA showed excellent levels of inter-examiner reliability in most of the performed evaluations. However, the GO presented moderate inter-examiner reliability in measuring the internal rotation performed in the side-lying position (ICC 0.61 to 0.67). The SCA showed inter-examiner reliability ranging from poor to moderate for the same measures (ICC 0.35 to 0.61) (Table 2). Significant differences were observed between the values recorded by the GO and SCA in all performed measurements ($p<0.001$). However, a strong correlation was observed between the measurements ($r>0.85$) (Table 3).

Table 2. Intraclass Correlation Coefficient, Confidence Interval, Standard Error Measurement and Minimum Detectable Change values for ROM measurements in the different positions.

		INTER- EXAMINER		INTRA- EXAMINER		
		ICC (CI95%)	**SEM**	**ICC (CI95%)**	**SEM**	**MDC**
RIGHT SHOULDER	**GONIOMETER**					
	IRSP	.839 (.666 - .920)	5.21	.827 (.646 - .914)	4.74	13.14
	IRSLP	.672 (.365 - .832)	3.71	.896 (.797 - .947)	4.26	11.80
	ERSP	.902 (.727 - .957)	3.01	.956 (.914 - .978)	2.88	7.98
	ERSLP	.923 (.798 - .966)	2.25	.971 (.942 - .985)	2.24	6.21
	CLINOMETER APP					
	IRSP	.917 (.837 - .958)	3.89	.925 (.838 - .964)	4.20	11.63
	IRSLP	.350 (-.271 - .668)	5.47	.834 (.676 - .915)	7.06	19.57
	ERSP	.921 (.827 - .962)	3.42	.959 (.919 - .979)	3.48	9.65
	ERSLP	.918 (.840 - .958)	2.57	.967 (.936 - .983)	2.59	7.19
LEFT SHOULDER	**GONIOMETER APP**					
	IRSP	.951 (.903 - .975)	3.86	.922 (.816 - .963)	3.87	10.72
	IRSLP	.794 (.592 - .895)	3.77	.901 (.806 - .949)	3.97	11.01
	ERSP	.932 (.867 - .965)	2.86	.963 (.929 - .981)	2.65	7.34
	ERSLP	.900 (.805 - .949)	2.54	.955 (.903 - .978)	2.31	6.40
	CLINOMETER APP					
	IRSP	.899 (.723 - .956)	2.84	.965 (.928 - .982)	3.36	9.33
	IRSLP	.607 (.221 - .801)	3.23	.935 (.872 - .967)	3.85	10.67
	ERSP	.909 (.698 - .963)	3.75	.955 (.911 - .977)	3.68	10.19
	ERSLP	.909 (.739 - .961)	2.85	.954 (.909 - .977)	2.92	8.08

IRSP = Internal rotation in supine position; IRSLP = Internal rotation in side-lying position; ERSP = External rotation in supine position; ERSLP = External rotation in side-lying position; ICC = Intraclass Correlation Coefficient; SEM = Standard error of measurement; MDC = Minimum Detectable Change

Table 3. Pearson Correlation Coefficient values between the Goniometer and Clinometer App in different positions.

		GONIOMETER (x±sd)	CLINOMETER APP (x ± sd)	p (t-test)	Correlation	p (Correlation)
RIGHT SHOULDER	**EVALUATOR 1**					
	IRSP	77.94 ± 11.399	90.39 ± 15.320	< 0.001	.893	< 0.001
	IRSLP	63.44 ± 13.196	72.90 ± 17.326	< 0.001	.863	< 0.001
	ERSP	112.19 ± 13.726	120.04 ± 17.190	< 0.001	.971	< 0.001
	ERSLP	108.14 ± 13.157	116.36 ± 14.283	< 0.001	.904	< 0.001
	EVALUATOR 2					
	IRSP	85.67 ± 13.848	101.53 ± 17.984	< 0.001	.947	< 0.001
	IRSLP	65.42 ± 12.623	80.08 ± 15.095	< 0.001	.878	< 0.001
	ERSP	111.03 ± 13.762	118.08 ± 17.338	< 0.001	.957	< 0.001
	ERSLP	105.53 ± 10.877	113.17 ± 13.592	< 0.001	.926	< 0.001
LEFT SHOULDER	**EVALUATOR 1**					
	IRSP	81.67 ± 13.655	92.65 ± 13.061	< 0.001	.920	< 0.001
	IRSLP	67.53 ± 9.834	75.72 ± 9.517	< 0.001	.854	< 0.001
	ERSP	107.56 ± 14.929	123.82 ± 16.615	< 0.001	.953	< 0.001
	ERSLP	104.56 ± 13.289	117.97 ± 14.038	< 0.001	.946	< 0.001
	EVALUATOR 2					
	IRSP	84.03 ± 13.781	96.49 ± 12.428	< 0.001	.922	< 0.001
	IRSLP	68.83 ± 11.345	79.85 ± 10.274	< 0.001	.888	< 0.001
	ERSP	111.69 ± 15.948	124.17 ± 17.987	< 0.001	.970	< 0.001
	ERSLP	107.33 ± 13.117	117.37 ± 12.962	< 0.001	.961	< 0.001

IRSP = Internal rotation in supine position; IRSLP = Internal rotation in side-lying position; ERSP = External rotation in supine position; ERSLP = External rotation in side-lying position

Discussion

Both devices presented excellent intra and inter-examiner reliability. However, the internal rotation measurement obtained in the side-lying position presented moderate reliability for the goniometer and poor reliability for the SCA. Thus, it is important to highlight that any unwanted movement during the goniometer handling, as well as an error of a few millimeters in determining the anatomical point may compromise the obtained angular values [9,10].

A similar study conducted by Shin et al. (2012), in which a digital goniometer and inclinometer were used to measure shoulder movements, showed excellent inter and intra-rater reliability, except for the internal rotation movement which showed moderate reliability on both instruments. The authors point out that variability in the degree of elbow flexion during the measurement may influence the measurements, and further suggest that the goniometer and clinometer are consistent with each other; therefore, the new smartphone's inclinometric measurements may be as useful as the goniometric measurements for measuring ROM. Furthermore, considering ours and previous study results, this position should be avoided for internal rotation measurement, whether made by either of the equipment.

Still considering the reliability, a study also carried out with a goniometer and the clinometer application, found inter-examiner reliability considered excellent. The goniometer showed ICC of 0.83 for external rotation with 90 ° abduction and 0.64 for internal rotation with 90 ° abduction. The application clinometer presented ICC of 0.86 for external rotation with 90 ° abduction and 0.81 for internal rotation with 90 ° abduction [11]. Another study conducted only with patients with some shoulder injury, also evaluated the reliability of applications for measuring range of motion. The authors found excellent inter-rater reliability values for the inclinometer application, with an ICC of 0.98 for passive internal rotation and 0.99 for passive external rotation [12].

In relation to clinical practice, our SEM results demonstrate the information that changes of about 3°-4° can be interpreted as an error. Furthermore, only changes larger than 8°-12° must be considered clinically relevant. These findings corroborate the previous study that demonstrated SEM values close to 6 degrees for the records obtained by the SCA[11].

Other important data concerns the difference between the absolute values of degrees measured with the two instruments; however, there is a high correlation between them. This finding indicates that both instruments are reliable for shoulder ROM measurement and are strongly correlated; however, instruments need to be standardized during clinical evaluation.

The study has some limitations, including the possibility that the reproducibility of the measures may have been affected, in part, by the ability of the evaluators or even by the condition in which the volunteers were on the day of the evaluation. In addition, this study proposed to evaluate the reliability of the goniometer and inclinometer only in the movements of the shoulder joint, not being able to generalize the findings for the use of the instruments in other joints.

Conclusion

The universal goniometer and digital inclinometer feature excellent inter-examiner reliability in measuring ROM of shoulder joint movements, except for internal rotation movement. Although there was a significant difference between the values obtained by the instruments, a high correlation between the measurements was observed, indicating that despite being reliable instruments for measuring ROM, there is a need for standardization of instruments in the clinical evaluation.

Future studies should be carried out in order to assess the reliability of the instruments in other joins and populations, since the present study evaluated only healthy individuals.

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