Reliability of a standing isokinetic shoulder rotators strength test using a functional electromechanical dynamometer: Effects of velocity

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Background. The evaluation of the force in internal rotation (IR) and external rotation (ER) of the shoulder is commonly used to diagnose possible pathologies or disorders in the glenohumeral joint and to assess patient's status and progression over time. Currently, there is new technology of multiple joint isokinetic dynamometry that allows to evaluate the strength in the human being. The main purpose of this study was to determine the absolute and relative reliability of concentric and eccentric internal and external shoulder rotators with a functional electromechanical dynamometer (FEMD).

Methods. Thirty-two male individuals (21.46 ± 2.1 years) were examined of concentric and eccentric strength of shoulder internal and external rotation with a FEMD at velocities of 0.3 m·s-1 and 0.6 m·s-1. Relative reliability was determined by intraclass correlation coefficients (ICC). Absolute reliability was quantified by standard error of measurement (SEM) and coefficient of variation (CV). Systematic differences across velocities testing circumstances, were analyzed with dependent t tests or repeated-measures analysis of variance in case of 2 or more than 2 conditions, respectively.

Results. Reliability was high to excellent for IR and ER on concentric and eccentric strength measurements, regardless of velocity used (ICC: 0.81-0.98, CV:5.12-8.27% SEM: 4.06-15.04N). Concentric outcomes were more reliable than eccentric due to the possible familiarization of the population with the different stimuli.

Conclusion. All procedures examined showed high to excellent reliability for clinical use. However, a velocity of 0.60 m·s-1 should be recommended for asymptomatic male patients because it demands less time for evaluation and patients find it more comfortable.

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Abstract

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Conclusion. All procedures examined showed high to excellent reliability for clinical use. However, a velocity of 0.60 m·s-1 should be recommended for asymptomatic male patients because it demands less time for evaluation and patients find it more comfortable.

Keywords. isokinetic, shoulder, strength, reproducibility, position, velocity.

Introduction

Clinicians and researchers periodically assess to monitor changes in the status of their patients (McLaine et al., 2016). The evaluation of the strength in internal rotation (IR) and external rotation (ER) of the shoulder is commonly used to (I) diagnose possible pathologies or disorders in the glenohumeral joint (II) evaluate the effectiveness and progression of the proposed treatment (III) as well as to quantify the change in muscle quality and the development of strength over time (Edouard et al., 2011; Cools et al., 2014). In addition, objective measurements of this variable have proved to be essential for the identification of a patient at risk of injury, especially in athletes, against subjective measurements or the self-report outcome score (Cools et al., 2015). Clinicians and researchers should have accurate and reliable protocol tests which objectively assess changes in strength over time that reflects real gain or loss due to the protocol measurement (Edouard et al., 2011; Johansson et al., 2015).

The reliability measures in test-retest concern the repeatability of the data observed in a population in repeated measures (Hopkins, 2000). In medicine, it is a requirement to have relative reliability data (ICCs) and absolute reliability (SEM or CV) (Hopkins, Schabort & Hawley, 2001). The relative reliability indicates how well the rank order of the participants in the test are similar to the retest. The main problem with relative reliability is that it depends on the variability of the sample (Hopkins, 2000; Hopkins, Schabort & Hawley, 2001). However, the absolute reliability is related to the consistency of individual scores (Hopkins, Schabort & Hawley, 2001; Weir, 2005).

Multiple tests have been created for the evaluation of shoulder strength with a wide variety of tools, including manual muscle testing (MMT) (Li et al., 2006; Lu et al., 2007), handheld dynamometers (HHD) (Cools et al., 2014; Holt et al., 2016; Chamorro et al., 2017) or isokinetic devices (Stickley et al., 2008; Andrade et al., 2010; Radaelli et al., 2010). Within these isokinetic devices are considered as the gold standard since they allow you to evaluate the maximum dynamic force (FMD) throughout the range of motion (ROM) (Caruso, Brown & Tufano, 2012). Due to the biomechanics of the shoulder joint and its wide mobility, the reliability of the measurements in isokinetic devices are influenced by many factors (mechanical aspects, subjects, joints, and testing protocols), the assessment position, including the position of the shoulder (shoulder posture and joint-axis alignment) and the position of the body (sitting, supine, or standing and stabilization)(Broztman & Wilk, 2005; Edouard et al., 2011). Also, there are discrepancies in the literature regarding the most reliable velocities for testing. Additionally,

most previous studies investigated the reproducibility of shoulder measurements between 60º/s and 240º/s (Nugent, Snodgrass & Callister, 2015). Higher velocities seems to be important when power assessment is necessary (the ability to produce moment rapidly) but less reliable. Some authors report faster velocities to be more reliable while others report that low speeds are more reliable for measuring shoulder rotators strength (Edouard et al., 2011; Nugent, Snodgrass & Callister, 2015).

Currently, there is new technology that allows to evaluate the strength in the human being as is the functional electromechanical dynamometry (FEMD) (Dvir & Müller, 2019). The isometric strength of the shoulder rotators 4 and hip abductor strength 3 has been studied with this technology, however, shoulder maximal dynamic strength has been not studied yet (Chamorro et al., 2018).

Therefore, the main purpose of this study was (I) to determine the absolute and relative reliability of concentric and eccentric internal and external shoulder rotators in standing position with a functional electromechanical dynamometer (Dynasystem, Symotech, Granada, España) in the evaluation of the isokinetic strength to determine the most reliable assessment condition. (II) To compare the absolute and relative reliability of different velocities for the assessment of isokinetic test. We hypothesized that (I) this new test will be a reliable method for the assessment of concentric and eccentric strength in shoulder rotators low speed would be more reliable than high speeds Additionally, we also hypothesized that (II) low speed would be more reliable than high speeds. The results are expected to provide new information regarding the dynamic shoulder strength evaluation protocols with functional electromechanical dynamometer (FEMD).

Materials & Methods

Participants

Thirty-two asymptomatic volunteers' men were recruited from local university (age 21.46 ± 2.1 years, body mass 69.22 ± 6.85 kg, height 1.73.5 ± 0.07 m, SPADI 15.2 ± 3.8 and BMI 22.98 ± 1.607 kg/m2) without any experience in isokinetic or dynamometers devices participated in this study. Participants were eligible for the study if they were: i) free of shoulder pain, with a maximum of 20% Shoulder Pain and Disability Index (SPADI); ii) free of musculoskeletal injury; iii) not practice specific training of upper body strength; and iv) a maximum of body mass index (BMI) of 25kg/m2. All participants were informed regarding the nature, aims and risks associated with the experimental procedure before they gave their written consent to participate. The study protocol was approved by the Biomedical Committee of the University (nº 350/CEIH/2017) and was conducted in accordance with the Helsinki Declaration.

Study design

A repeated-measurement design was used to evaluate the shoulder rotators strength with different protocols. After two familiarization session, participants attended to the laboratory on four separate days (at least 48 hours apart) during a 2-week period. On each testing day participants completed two sessions of familiarization and two protocols sessions with 0.3 $m \cdot s^{-1}$

or 0.6 $m \cdot s^{-1}$. Participants were asked to maintain their physical activity level during the 2 weeks of the study. All evaluations were conducted at the same time of the day (± 1 h) for each participant and under similar environmental conditions (~21ºC and ~60% humidity). The order of velocities was randomly established.

Instrument

Isokinetic strength was evaluated with a Functional Dynamometer (Dynasystem, Model Research, Granada, España), with a precision 3mm for displacement, 0.1 kg for a sensed load and a range of velocities between 0.05 m·s-1 to 2.80 m·s-1, couple with a pulley system and a subjection system of own manufacture.

Range of movement

Subjects were positioned standing or sitting next to an adjustable support where they supported the dominant upper limb. The humerus was fixed with a cinch at 2/3 of the distance between the lateral epicondyle and the acromion. Both the position and the range of movement of the same was determined with a baseline goniometer (Gymna hoofdzetel, Bilzen, Belgium). The position consisted of a 90º adduction of the glenohumeral joint and a 90º flexion of the humero-ulnar joint. For the glenohumeral joint the fulcrum was positioned in the acromion with the vertical arm stable and the arm movable along the humerus with the lateral epicondyle as a point of reference. For the humero-ulnar articulation the fulcrum was positioned in the lateral epicondyle with the arm stable in horizontal and the arm movable along the forearm with the processus styloideus ulnae as a reference point. The range of movement was measured during the two familiarization sessions. The fulcrum is positioned in the olecranon with the stable arm in vertical (IR) or horizontal (ER) position and the mobile arm along the forearm with the processus styloideus ulnae as a reference until the goniometer is at an angle of 90º registering this distance to keep it stable throughout the different measurements.

Familiarization Protocol

Participants first attend to 90 minutes familiarization sessions with the FEMD and to testing the procedures. The familiarization consisted of a general warm up for both test session consisted on 5 min of jogging (beats per minute < 130; measurement with a Polar M400), 5 min of joint mobility and 1 set of 5 repetitions of shoulder flexion-extension, 5 repetitions abduction and shoulder adduction, and 5 repetitions of IR and ER in the position of the test that was to be performed. After which, the same evaluation protocols that were going to be carried out in the evaluations were carried out

Test Protocol

Participants arrived in a well-rested condition at the start of each testing session. After the same warm-up of familiarization protocol, participants rested for 5 min before the initiation. The test consisted of two series of 5 maximum consecutive repetitions, of shoulder rotators at a velocity of 0.60 $m \cdot s^{-1}$ and 0.30 $m \cdot s^{-1}$ and with the range of movement previously established. The rest

between sets was a 3-minute. The three highest repetitions of the mean force for the concentric contraction and for the eccentric contraction were taken to calculate the dynamic force.

Statistical Analysis

The descriptive data are presented as mean ± SD. The distribution of the data was verified for the first time by the Shapiro-Wilk normality test. Reliability was assessed by t-tests of paired samples with the effect size (ES), the coefficient of variation (CV) and the intraclass correlation coefficient (ICC), with 95% confidence intervals. The scale used for interpreting the magnitude of the ES was specific to training research: negligible (<0.2), small (0.2–0.5), moderate (0.5–0.8), and large (≥0.8) (Cohen, 1988). The reliability observed in each evaluation condition was reported in the functional electromechanical dynamometer. For the relation between test and re-test a Pearson correlation coefficient was calculated with a 95% confidence interval. Following Hopkins et al., (2009) classify through a qualitative scale the magnitude of the values of the intraclass correlation coefficient, being the values close to 0.1 low reliability, 0.3 moderate, 0.5 high, 0.7 very high and those close to 0.9 extremely high. Sensitivity was estimated by the smallest detectable change (SDC) derived from the SEM (Courel-Ibáñez et al., 2019). The level of agreement between paired velocity outcomes from two devices was also assessed using Bland–Altman plots and the calculation of systematic bias and its 95% limits of agreement (LoA = bias ± 1.96 SD). Maximum errors (Max Error) at the 95% confidence interval were calculated from the Bland–Altman bias (Max Error) for the different condition outcomes analyzed (Paalanne et al., 2009). Reliability analyzes were performed using a customized spreadsheet (Hopkins et al., 2009) while JASP software package (version 0.9.1.0, http://www.jasp-stats.org) was used for all other analyses. Figures were designed using GraphPad Prism 6.0 (GraphPad Software Inc., California, USA).

Results

Table 1 presents the mean ± SD in Newtons (N), ICC, CV and SEM of the dominant arm strength obtained for two evaluation sessions. Analysis of systematic biases by paired student t-tests found no significant difference except for external rotation in concentric contraction at 0.3 $m \cdot s^{-1}$ and eccentric contraction at 0.6 $m \cdot s^{-1}$. ICC values were high or excellent in all conditions (0.81–0.98). Absolute reliability for concentric contractions ranged from 6.26% to 8.27% and 4.06 N to 6.8 N for CV and SEM, respectively. And for eccentric contractions ranged from 5.12% to 7.38% and 10.16 N to 15.04 N.

Table 1 near here

Discussion

The main purpose of this study was to determine the absolute and relative reliability of concentric and eccentric internal and external shoulder rotators in standing position with a FEMD. To our knowledge, this was the first study to asses reliability for dynamic shoulder strength test performed on an FEMD (Cerda Vega et al., 2018; Chamorro et al., 2018). The

present investigation shows high to excellent reliability with ICC and CV values ranging from 0.81 to 0.93 and 6.31 – 8.27% for IR and from 0.89 to 0.98 and 5.12-6.91% for ER.

Figure 1 here

Patients' position in the evaluations of shoulder strength is extremely relevant for the reliability of the tests, due to the complex structure of the glenohumeral joint (Edouard et al., 2011; Forthomme et al., 2011). There is no scientific consensus about which is the most reliable position to assess strength in the shoulder. The three positions most used by clinicians are supine (Forthomme et al., 2011; Andersen et al., 2017; Chamorro et al., 2018), sitting (Byram et al., 2010; Radaelli et al., 2010; Edouard et al., 2013) and standing (Greenfield et al., 1990; Frisiello et al., 1994). The sitting position has been the most widely studied due to the clinical nature of the studies and to an easier stabilization of the patient when evaluating (Edouard et al., 2011). Whether they are asymptomatic patients, athletes, or patients with chronic pain, the daily movements where the glenohumeral joint is used are usually not in this position (Beneka et al., 2002; Rodríguez-Rosell et al., 2017). Therefore, in this study we propose the creation of a standing test, closer to the actual position of patients in the movements that encompass the shoulder. The results of this study show that standing tests can be performed reliably for asymptomatic patients with minimal fixation tools. This study has obtained similar or better relative and absolute reliability data (ICC: 0.81 to 0.98, CV: 5.12 to 8.27) than most studies with this evaluation position Greenfield et al. (1990) (ICC: 0.81 – 0.95) and Frisiello et al. (1994) (ICC: 0.77 - 0.86) and similar data to articles with a sitting position for the same type of population: Mayer et al., 1994 (ICC: 0.09 - 0.89; SEM: 2.8 – 9.2), Kramer & Ng, 1996 (ICC: 0.83 – 0.96; SEM: 2 – 7) or Malerba et al., 1993 (ICC: 0.44 – 0.90).

Figure 2 here

Other aim of the study was to compare the absolute and relative reliability of different velocities for the assessment of isokinetic test. Velocity in isokinetic tests has been a widely studied variable in the literature (Andrade et al., 2010; Zanca et al., 2011; Hadzic et al., 2012). Although, most studies agree that speeds below 60º/s are usually the most reliable to perform strength assessments in most joints (Nugent, Snodgrass & Callister, 2015). There is no widely accepted consensus on which of these speeds is best suited for the shoulder joint (Edouard et al., 2011). In our study, we compared two speeds, one slow and one very slow to see if, as the velocity are lower, the reliability of the isokinetic test increased or, on the contrary, controlled slow speeds, but closer to the reality of the daily gestures of the patients produced a more reproducible application of force in these tests. Our results agree with this second idea as previously noted in (Hadzic et al., 2012; Castro et al., 2017). While both velocities are reliable, the slow speed presents better results compared to the very slow one, as we can see in the Bland-Altman plots (Figure 1 and 2), given that their bias are closer to 0 and most points are within the limits of agreement (LoA).

However, our analysis revealed large differences between the concentric and eccentric phases of both IR and ER. One possible explanation is that eccentric isokinetic tests require greater

familiarization in IR while it was more reliable in the ER (Hadzic et al., 2012). This may be due to the daily movements that the population performs, such as throwing where the ER phase is predominantly eccentric while the IR contraction is essentially concentric (Wagner et al., 2012). Clinicians and trainers should take these results into account in order to individualize the evaluation protocols according to the type of population and problem, whether they are overhead athletes or populations at risk of chronic pain in the shoulder.

Some limitations of this study should be noted to take them into account when evaluating our results. It was not possible to perform an inter-rater reliability analysis, so we can not know how this variable affects evaluations. We recommend both clinicians and coaches to always have the same evaluator with the same patient. In addition, the study was performed with asymptomatic active patients, which means that the results can not be extrapolated to other types of population such as the sedentary population, or patients with chronic pain in the shoulder. Further study of these variables would be necessary in order to standardize the results to any type of population.

The purpose of this study was to determine the absolute and relative reliability of concentric and eccentric internal and external shoulder rotators in standing position with a functional electromechanical dynamometer. The study results show high to excellent reliability values for all procedures performed. Clinicians should consider their choice based on the comfortability of the patient to achieve velocity required. In general, measurements in a standing position at 0.6 $m \cdot s^{-1}$ are recommended because of practical applicability and body stabilization in asymptomatic patients. Clinicians are recommended to use more than 1 procedure to allow functional measurements based on the patient's abilities at the moment of evaluation.

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401 **Table 1.** Reliability of the shoulder strength obtained during the isokinetic test on Dynasystem
402 dynamometer
403
404 **Figure 1**. Show the Bland-Altman plots of test-retest for internal and external rotation at 0,3 $m \cdot s^{-1}$
405 and 0,6 $m \cdot s^{-1}$. 0,6 $m \cdot s^{-1}$ showed the highest agreement and the most regular variation but
406 exhibited more variation in eccentric contractions.
407
408 **Figure 2.** Show the Bland-Altman plots of test-retest for internal and external rotation at 0,3 $m \cdot s^{-1}$
409 and 0,6 $m \cdot s^{-1}$. 0,6 $m \cdot s^{-1}$ showed the highest agreement and the most regular variation but
410 exhibited more variation in eccentric contractions.
411

Table 1(on next page)

Reliability of the shoulder strength obtained during the isokinetic test on Dynasystem dynamometer

SD: Standard Deviation, ES: Effect Size, ICC: Intraclass Correlation Coefficient, CI: Confidence Intervals, CV: Coefficient of Variation, SEM: Standard Error of Measurement

Table 1. Reliability of the shoulder strength obtained during the isokinetic test on Dynasystem dynamometer

Parameters			Mean ± SD		ES	ICC	95% CI lower-upper	CV (%)	SEM (%)
			Session 1	Session 2					
Internal Rotation	0,3 m·s^{-1}	Concentric	83,10 ± 17.6	81,40 ± 16,1	-0,10	0,85	0,71 - 0,92	8,27	6,8
		Eccentric	206,50 ± 34,9	201,20 ± 31,8	-0,16	0,81	0,64 - 0,90	7,38	15,04
	0,6 m·s^{-1}	Concentric	88,80 ± 20,6	88,10 ± 19,6	-0,03	0,93	0,86 - 0,96	6,31	5,58
		Eccentric	218,00 ± 39,3	218,20 ± 41,6	0,00	0,87	0,75 - 0,93	6,87	14,98
External Rotation	0,3 m·s^{-1}	Concentric	64,00 ± 13,2	67,00 ± 11,9	0,24	0,90	0,80 - 0,95	6,39	4,19
		Eccentric	198,90 ± 89	196,00 ± 89,9	-0,03	0,98	0,96 - 0,99	6,91	13,64
	0,6 m·s^{-1}	Concentric	64,40 ± 11,5	65,50 ± 12,1	0,10	0,89	0,78 - 0,94	6,26	4,06
		Eccentric	201,70 ± 32,6	194,90 ± 38,1	-0,19	0,92	0,85 - 0,96	5,12	10,16

Figure 1

Bland-Altman plots for the measurement of mean force (N) in Internal Rotation between test and re-test. Each plot depicts the averaged difference and 95% limits of agreement (dashed lines).

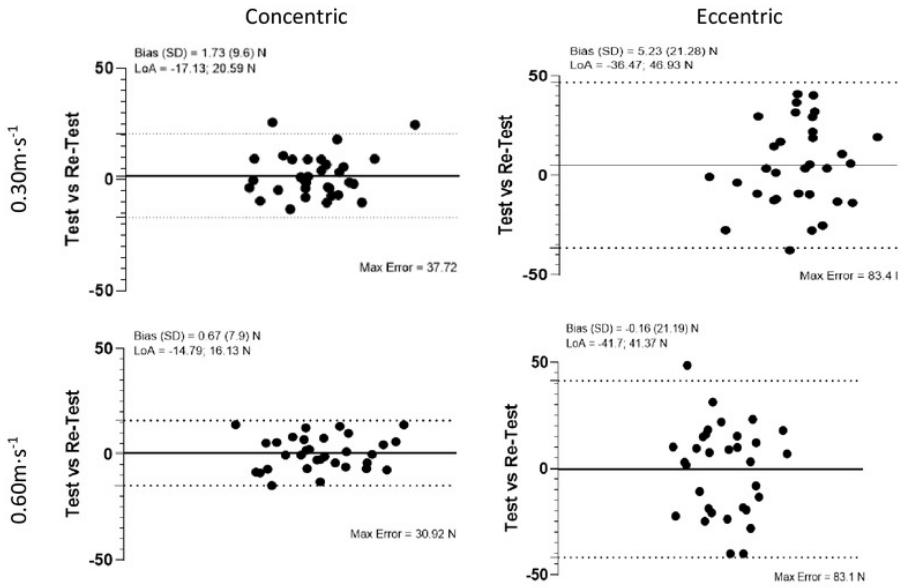

Figure 1. Bland-Altman plots for the measurement of mean force (N) in Internal Rotation between test and re-test. Each plot depicts the averaged difference and 95% limits of agreement (dashed lines).

Figure 2

Bland-Altman plots for the measurement of mean force (N) in External Rotation between test and re-test. Each plot depicts the averaged difference and 95% limits of agreement (dashed lines).

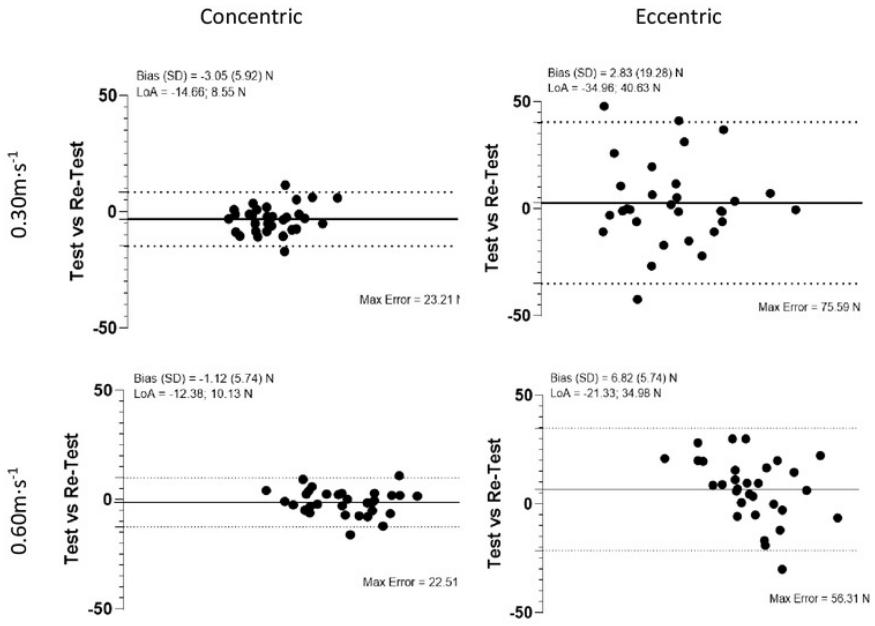

Figure 2. Bland-Altman plots for the measurement of mean force (N) in External Rotation between test and re-test. Each plot depicts the averaged difference and 95% limits of agreement (dashed lines).