

# Validity, Agreement and Accuracy of A Hand-Held Dynamometer for Shoulder Muscles Strength Assessment in Healthy Individuals

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## Research Article

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# Abstract

**Background:** The shoulder complex has a high prevalence of injuries. It is fundamental to quantify the muscle strength and identify muscular imbalances that predispose to lesions. The aim was to test concurrent validation of the muscle strength assessment with a hand held dynamometer (HHD) for shoulder joint muscles, and measure the accuracy and diagnostic agreement between instruments for assessing the strength of this joint with the hand held dynamometer and isokinetic dynamometer (ID) in a population of healthy individuals

**Methods:** healthy individuals aged between 18 and 40 years were included. The HHD was used to test the isometric contraction of the main shoulder movements. Isometric contraction was performed for 3 seconds. Assessments with HHD and DI were performed on the same day, with a minimum interval of 90 minutes between tests. The study was approved by the Ethics Committee by report No.1537948. Concurrent validation was calculated with Pearson's correlation, the accuracy obtained by the ROC curve and agreement by Kappa test.

**Results:** The HHD showed concurrent validation between 0.51 – 0.83, with sensitivity between 0.90 and 0.98 and specificity between 0.64 and 0.89 for shoulder movements. The HHD demonstrated moderately-strong to excellent concurrent validity.

**Conclusion:** These results are encouraging for the routine use of this portable and lower cost instrument in quantification of the pique torque of the shoulder muscles. Moreover, this instrument showed good accuracy and moderate to high agreement in comparison with diagnosis of the gold standard instrument.

## Introduction

Muscle strength is one of the most important health related physical fitness component. Muscle strength has a known relationship with several prognostic factors, such as general health status, risk of developing complications, as well as mortality<sup>1-5</sup>.

Currently, the Isokinetic dynamometer (ID) is considered the gold standard to determine muscle strength since it has shown to provide reliable and valid measures taking into consideration peculiarities of the muscle tension-length curve in diverse angles and execution speeds. However, such evaluation is limited to a small number of centers in the world mainly due to the high operational cost.<sup>6-9</sup>

Hand-held dynamometer (HHD) is a portable, low-cost, reliable and objective way to obtain strength measurements of several appendicular and axial muscles in our body. Its usefulness is very promising in patients unable to access ID, such as hospitalized, home care and skilled nursing facilities patients and less developed cities without a reference physical rehabilitation center<sup>10-13</sup>.

The shoulder complex is widely known for the high prevalence of injuries among amateur and professional athletes and is the main source of pain among sedentary elderly individuals due to

sarcopenia and muscle imbalance. According to studies<sup>7,9</sup> muscles play an important role to stabilize dynamically the shoulder girdle, enhance fundamental movements and therefore prevent injuries to the complex. Thus, it is essential to be available a low-cost, valid, reliable and objective instrument to quantify the muscle strength of this complex in order to provide precise information to a future rehabilitation plan.

The present study had a purpose to establish the concurrent validity, accuracy and diagnostic agreement between the hand-held dynamometer and the isokinetic dynamometer for the shoulder muscle strength assessment in a population of healthy individuals.

## **Methods**

This study was approved by the Institutional Ethics Committee of Health Sciences Institute of Federal University of Bahia (protocol no. 15379480), Brazil. Written informed consent was obtained from all the study participants

## **Study design**

This is a validation and accuracy study of a hand-held dynamometer (HHD) for shoulder muscles strength assessment and its diagnostic capacity to identify muscle imbalance in healthy individuals compared to the isokinetic dynamometer (ID). The study followed the Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) Checklist to assess reliability and validity using Classical Test Theory<sup>14</sup>

## **Study population**

The study included healthy volunteers from the academic community of the Federal University of Bahia, recruited through electronic invitation and printed posts. After initial contact with one of the researchers, individuals interested in participating in the study were evaluated in a proper and quiet place at a previously scheduled time.

## **Sample Size calculation**

Previously to the inclusion of volunteers a sample size calculation was carried out considering 80% of test sensitivity, with a confidence interval of 95% and test precision of 5%. Thus, a sample of 50 volunteers was required taking into account a 10% dropout rate.

## **Inclusion and exclusion criteria**

Healthy volunteers of both sexes, aged between 18 and 40 years, not diagnosed with chronic pulmonary, cardiovascular or neuromuscular diseases, not using of corticosteroids or muscle relaxants medication and consenting to participate in the research were included<sup>15</sup>. Volunteers with pain associated with movements, cramps and fatigue who interrupted the evaluation protocol were excluded.

# Procedures

## Anthropometric measures

A mechanical anthropometric scale (Filizola, São Paulo, Brazil) was used to measure height and weight with volunteers barefoot and wearing light and comfortable. Furthermore, body mass index (BMI) was calculated and demographic data such as age, sex, race and dominance were registred. The Physical Activity Readiness Questionnaire (PAR-Q)<sup>16</sup> and International physical activity questionnaire (IPAQ)<sup>17</sup> were applied to categorize cardiovascular risk and the level of physical activity of each volunteer, respectively.

Peak torque values were separately obtained with HHD and ID for each shoulder movement according to the evaluation protocol in order to determine concurrent validity as well as accuracy, agreement and deficit prevalence of muscle imbalance.

Muscle imbalance was established by comparing torques obtained on the right and left sides for the same volunteer. According to the literature<sup>16,18</sup>, a clinically significant muscle imbalance is considered when the muscle groups showed difference > 15% compared to the same contralateral muscle group.

## Muscle strength assessment protocol

Prior to measurements, the volunteer was guided and trained for each movement and peak torque (Nm) was evaluated for flexion, extension, abduction, adduction, internal rotation, external rotation of the shoulder bilaterally.

All instruments underwent calibration to minimize measurement bias and assessments were performed on the same day with a minimum interval of 90 minutes between the two tests. Further, a simple randomization was performed for test order (ID and HHD) to minimize bias in the peak torques obtained in the second evaluation.

## Hand-Held Dynamometry (HHD)

The assessment of isometric muscle strength was performed using a HHD, model 01165, Lafayette Instrument brand (Lafayette, Sagamore, USA) and a manual goniometer (ISP, Brazil) to determine the joint position in the test of each muscle group. Isometric contraction was performed for three seconds and an audible beep from the equipment itself signaled the beginning and end of the evaluation for each movement.

For each movement, the evaluator used verbal encouragement to stimulate the maximum effort during the movements. To guarantee the occurrence of maximum torque for each muscle group, the HHD was positioned with the hands in the evaluated segment, always with maximum resistance and with a movement vector contrary to the requested contraction. Among the evaluations of each muscle group, the

recovery time of not less than 90 seconds was respected. The positioning used in the evaluations was tested and described in a previous publication<sup>17,19</sup>.

## Isokinetic Dynamometry (ID)

The ID, model S4 Pro (Biodex, New York, USA), was used to assess the isokinetic muscle strength of the shoulder. To assess shoulder muscle groups performance, the participant was positioned in the machine chair according to the position oriented by the manufacturer, respecting the position of the articular center to the axis of rotation of the machine.

The evaluation was carried out bilaterally, with the same procedure, with one shoulder being evaluated after the other. Three series of ten concentric contractions were performed at an angular speed of 60°/s and a recovery time not less than 90 seconds was respected between muscle groups assessed.

The evaluation process was conducted by a properly trained evaluator. The peak torque of the flexor, extensor, abductor, adductor, internal and external rotator muscles of the shoulders was evaluated. The volunteer was evaluated seated, with 0° of orientation of the dynamometer and 5° of inclination, seat positioned at 0° of rotation, with inclination of 85°. The resistance was positioned in the palm of the hand and held with closed fingers.

## Statistical analysis

Statistical analysis were conducted with the *Statistical Package for the Social Sciences* (SPSS, IBM, Armonk, NY, USA), version 28.0. Qualitative data were presented as absolute and relative frequency whereas quantitative data were expressed as mean and standard deviation. A histogram was used to determine normality of data set.

Pearson's correlation test was calculated to determine concurrent validity considering peak torque assessed with HHD and ID for each movement of shoulder complex. The classification proposed by Domholdt<sup>20</sup> was adopted to establish correlation magnitude as such: high correlation ( $r \geq 0.70$ ), moderate correlation ( $0.70 > r \geq 0.40$ ) and low correlation  $< (0.40)$ .

Analysis of the receiver operating characteristic curve (ROC) and the area under the ROC curve (AUC) with 95% confidence interval (95% CI) was performed to establish accuracy between the assessment of muscle strength between HHD and ID. The sensitivity criterion demonstrates how sensitive a positive test is to detect muscle imbalance<sup>16</sup> whereas the specificity criterion demonstrates how specific a negative test is to detect muscle balance compared to ID, test considered as the gold standard. The prevalence of muscle imbalance among the sample of healthy volunteers was also measured through the ratio between the number of volunteers affected by muscle imbalance by the total number of volunteers evaluated.

The absolute and relative frequency of diagnostic agreement between the instruments was calculated using the Kappa test. The classification proposed by Stemler<sup>21</sup> to stratify the degree of agreement

between the instruments was adopted as such: excellent agreement > 0.75, moderate-strong agreement = 0.40 -0.75 and poor agreement <0.40.

## Results

A total of 66 volunteers applied to participate in the research, however, 16 volunteers were excluded as such: 07 due to recent respiratory infection; 05 for having chronic cardiovascular disease, 03 for having chronic lung disease and 01 diagnosed neuromuscular disease. Overall, data collection of 50 volunteers were considered to final analysis.

Table 1 displays sociodemographic and anthropometric characteristics of sample. Volunteers were young with an average of 28.8 years, mostly female (66%), black and brown (38% each), average BMI 24.3, with no cardiovascular risk according to the PAR-Q questionnaire and with level of physical activity predominant to irregularly active.

Table 1  
Socio-demographic and anthropometric characteristics of the sample (n=50).

<b>Characteristics</b>	<b>n(%)</b>	<b>Mean (SD)</b>
Age (years)		28.8 (12.6)
Gender (female)	33(66.0)	
Dominance (right-handed)	46 (92.0)	
Race: Black	19 (38.0)	
Brown	19 (38.0)	
White	12 (24.0)	
Height (cm)		1.7 (0.7)
Weight (kg)		69.0 (13.7)
BMI		24.3 (5.1)
PAR-Q, no cardiovascular risk	50 (100.0)	
IPAQ: Very Active	4 (8.0)	
Active	8 (16.0)	
Irregularly active A	14 (28.0)	
Irregularly active B	13 (26.0)	
Sedentary	4 (8.0)	

Table 2 shows the average peak torque of shoulder muscle strength assessment performed by HHD and ID according to each movement. As demonstrated, the concurrent validity between was considered to be high for the extension ( $r= 0.77$ ,  $p <0.001$ ) and abduction ( $r= 0.83$ ,  $p <0.001$ ) movements and moderate validity for all other shoulder movements.

Table 2  
Concurrent validation of the assessment of muscle strength between HHD and ID for shoulder movements.(n=50)

<b>Movement</b>	<b>HHD†</b>	<b>Isokinetic†</b>	<b>r</b>	<b>P value*</b>
	Mean (SD)	Mean (SD)		
Flexion	85.4 (22.1)	47.6 (17.5)	0.51	<0.001
Extension	93.5 (34.9)	57.7 (22.0)	0.77	<0.001
Abduction	78.8 (24.5)	43.2 (16.0)	0.83	<0.001
Adduction	80.3 (29.6)	50.1 (20.6)	0.54	<0.001
Internal rotation	85.0 (33.5)	44.1 (18.1)	0.64	<0.001
External rotation	91.9 (34.0)	31.9 (13.7)	0.66	<0.001
† peak torque, expressed in Nm.				
* P value <0.05 considered statistically significant.				

Figure 1 shows the ROC curves for all evaluated shoulder movements. As observed, a comparison between HHD and ID produced excellent AUC values for the following muscles assessed: flexors (0.89), extensors (0.77), abductors (0.92), adductors (0.81), internal rotators (0.93) and external rotators (0.89). The study of the diagnostic accuracy of HHD is complemented with data displayed on Table 3. As shown the sensitivity for identifying shoulder muscle imbalance was between 90% and 98%, while specificity ranged from 64–89%. Additionally, a muscle imbalance prevalence of 16% for the flexors muscles, 22% for extensors and external rotators muscles, 18% for abductors and internal rotators muscles and 20% for adductors muscles was noticed.

Table 3  
Accuracy for the diagnosis of muscular imbalance of HHD for shoulder movements, based on the ROC curve. (n=50)

<b>Movement</b>	<b>AUC</b>	<b>95%CI</b>	<b>Sensitivity</b>	<b>Specificity</b>
Flexion	0.89	[0.75 – 1.00]	0.91	0.88
Extension	0.77	[0.59 – 0.95]	0.90	0.64
Abduction	0.92	[0.79 -1.00]	0.95	0.89
Adduction	0.81	[0.64 – 0.99]	0.92	0.70
Internal rotation	0.93	[0.80 – 1.00]	0.98	0.89
External rotation	0.89	[0.75 – 1.00]	0.95	0.82

The diagnostic agreement between HHD and ID was analyzed for all shoulder movements, with excellent agreement for abduction and internal rotation of the shoulder and moderate to strong agreement for all other movements as shown in Table 4.

Table 4  
Agreement in diagnoses of muscle imbalance between HHD and ID for shoulder movements. (n=50)

<b>Movement</b>	<b>Agreement</b>	<b>Disagreement</b>	<b>Kappa</b>	<b>P value</b>
	n(%)	n(%)		
Flexion	45(90)	5(10)	0.68	<0.001
Extension	42(84)	8(16)	0.53	<0.001
Abduction	47(94)	3(6)	0.81	<0.001
Adduction	44(88)	6(12)	0.63	<0.001
Internal rotation	48(96)	2(4)	0.86	<0.001
External rotation	45(90)	5(10)	0.72	<0.001

## Discussion

In comparison with the gold standard instrument, the measurement of shoulder muscle strength with HHD in healthy volunteers demonstrated moderate to excellent concurrent validity and accuracy to diagnose muscle imbalances. Such results are encouraging and suggest the use of HDD as a simple and objective to quantify the peak torque of the muscles in clinical practice.

As observed, HHD showed adequate diagnostic accuracy compared to ID, provided excellent sensitivity to diagnose muscle imbalances between contralateral muscle groups and moderate to excellent specificity



to identify individuals without muscle deficit. The diagnosis agreement rate between the two strength assessment tools was considered to be moderate to excellent.

The prevalence of muscle imbalance observed in the sample investigated was relatively low, with a percentage lower than 25% for all movements of the assessed shoulder. Such prevalence has not been previously described in the literature. The number of studies that validated HHD using the ID is limited. When such validation is related to the upper limbs muscles, the evidence is even scarcer, being restricted to one plane movements<sup>21-24</sup>. Therefore, this is a pioneer study to investigate the concurrent validity for the main shoulder muscle groups in healthy individuals using the ID.

Magnusson et al<sup>24</sup> in a study with 9 healthy individuals with a mean age similar to the present study found concurrent validation to be excellent  $r=0.86$  for shoulder abductors, similar to the present results  $r=0.83$ . The difference between the measurement protocols is restricted to the fact that the study by Magnusson et al<sup>25</sup> the measurement of HHD was performed in a seated position, while in the present study all measurements were performed in the supine position. Karabay et al<sup>13</sup> in a study with 25 healthy individuals found concurrent validation of 0.76 for eccentric isotonic abduction of the shoulder with an angular velocity of 30°/s. Such value was lower than the validation found in the present study.

Johansson et al<sup>24</sup> developed a study with 25 healthy individuals where Pearson's correlation between ID with angular velocity 30°/s and HHD were investigated. As observed in the study, coefficients were respectively 0.70 and 0.78, considering that ID was performed for eccentric muscle contraction of external rotation of the shoulder. The presented values were higher than the concurrent validation of 0.66 noticed in the present study. This difference may be related to the fact that in this study the eccentric isometric and non-isotonic contraction were assessed with an angular velocity of 60 °/s.

Anthropometric data were similar between studies, with both having females as the majority of their sample. A study developed by Chamorro et al<sup>12</sup> with 24 healthy individuals, investigated the concurrent validity of an electromechanical pulley dynamometer, finding ICC of 0.93 with IC95 (0.82-0.97) for internal rotation and 0.84 with IC95 (0.60-0.93) for external rotation compared to the measurement with ID. In this study, the authors used a contraction time of 6 seconds of isometry, against 3 seconds in the current study and did not describe the angular speed at which the ID was assessed.

In a recent study with 14 athletes, Romero-Franco et al<sup>23</sup>. described a measurement protocol for movements of the upper limbs in a seated position using a digital dynamometer with a tension cell. Study findings showed a Pearson correlation  $> 0.90$  for the shoulder movements. Such values were also higher than the results found in the present study, however is important to highlight the study by Romero-Franco et al<sup>22</sup> assessed entirety physically active individuals, which suggest greater physical fitness in comparison to a sample of healthy but sedentary volunteers of the present study. Furthermore, other limitations such as the use of dynamometer with a force cell and absence of angular velocity description when performing ID assessment precluded any comparison between the studies and the protocols adopted.

The peak torque assessments obtained with HHD and ID showed considerable differences for all shoulder movements evaluated possibly due to different types of contractions produced as stated by Corvino et al<sup>26</sup> in a cross-sectional study with 14 healthy volunteers that noticed the rate of strength development was different according to the type and speed of contraction produced. The authors<sup>26</sup> demonstrated that the lower the velocity and amplitude of muscle contraction, the greater the torque generated. This statement is based on the greater recruitment of muscle motor units in isometric contractions and with smaller angular velocities attributed. Such physiological behavior is analogous to that observed in the present study, in which a higher mean torque peak was found during an HHD compared to an isokinetic evaluation. Such difference between the means does not reflect the relevant clinical difference, given the lack of specific reference values in the literature for each type of contraction evaluated.

The present study is a pioneer to establish the accuracy of HHD for shoulder movements in healthy individuals using a protocol suggested by Vasconcelos et al<sup>16</sup>. In this study, 40 individuals underwent reconstruction of the anterior cruciate ligament, was found that sensitivity was between 50 and 88% for the identification of the imbalance and specificity 63 to 100% for the identification of muscle balance. The intervals are similar to those found for the accuracy of HHD for diagnostic assessment of shoulder muscles for healthy individuals in the present study.

Moreover, this study is the first to investigate concurrent validation and establish the diagnostic accuracy of HHD compared to the gold standard for all shoulder movements in healthy individuals. Additionally, it has been shown that HHD may be considered a useful tool to evaluate muscle imbalance and enhance early identification and treatment of this muscle deficiency. The main limitations of the study were the different positions required in the assessments carried out (ID and HHD) and the mean age of sample included.

In conclusion, study findings suggested HHD is a useful tool for measuring muscle performance in healthy individuals given the considerable concurrent validity of the instrument compared to a gold standard method. Further, HDD also demonstrated acceptable accuracy to identifying muscle imbalance for the various shoulder movements and sufficient agreement rate. Results suggest the implementation of HDD as a low-cost, straightforward and valid resource to establish shoulder muscle performance in clinical practice.

## Abbreviations

HHD, hand held dynamometer; ID, Isokinetic dynamometer; PAR-Q, Physical Activity Readiness Questionnaire; IPAQ, International Physical Activity Questionnaire; SPSS, *Statistical Package for the Social Sciences*; ROC, *receiver operating characteristic curve*; AUC, *Area under the ROC curve*; 95% CI, 95% confidence interval.

# Declarations

## Acknowledgement:

The authors of this manuscript certify that they comply with the ethical guidelines for authorship and publishing in the Journal.

## Disclosure of Conflicts of Interest:

Balbino Nepomuceno declares that he has no conflict of interest. Ingara Schindler declares that he has no conflict of interest. Mariana Machado declares that he has no conflict of interest. Thiago de Melo declares that he has no conflict of interest. Manueto Gomes declares that he has no conflict of interest.

## Ethical Publication Statement:

The manuscript contains a statement to the effect that all human and animal studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments

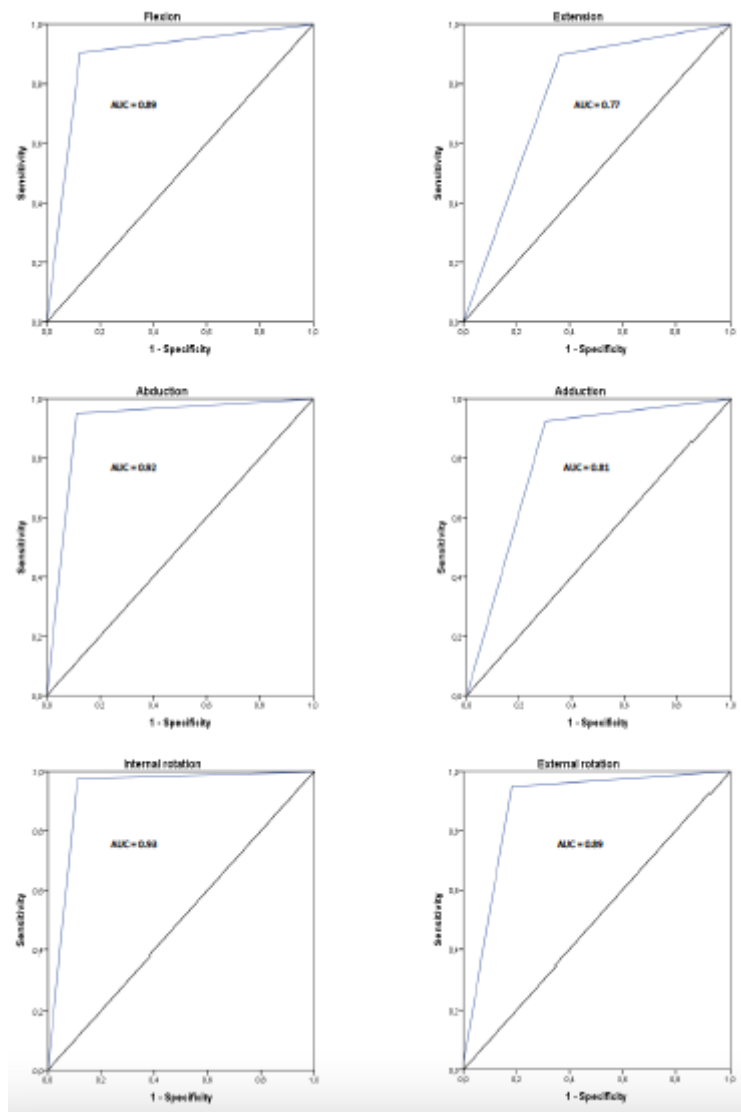
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## Figures



**Figure 1**

Accuracy of the diagnosis of muscle imbalance with HHD for shoulder movements in healthy individuals.