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Research article

RELIABILITY OF TESTS FOR MEASURING ISOMETRIC FORCE OF THE MUSCLES WHILE SHOOTING IN BASKETBALL

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Abstract. *The aim of this research is to determine the isometric muscle force (IMF) of the dominant arm in the position directly before the basketball shooting, and to check test reliability. Fifteen male basketball players (age 17±1 years, body height 185.60±6.31 cm; body mass 78.07±8.56 kg) with at least 5 years of the basketball experience, were subjected to a muscle manual test (shoulder flexion, elbow extension and wrist flexion), using a hand-held dynamometry (HDD). High values of relative reliability are reported in each of the tests (0.79, 0.82, and 0.84, respectively). Cronbach's alpha coefficient indicated the values of reliability during shoulder flexion, elbow extension and wrist flexion range from 0.779, 0.807, 0.848 respectively, presenting the results of the reliability as high. The applied F test provides a statistically significant Intraclass Correlation Coefficient at the level of $p<0.001$ for each test. Absolute reliability is displayed through the coefficient of variation, and meets the criterion which ranged between 5.6 to 7.8%. HDD was determined to be reliable in terms of measuring IMF.*

Key words: *Manuel Muscle Test, Hand-Held Dynamometry, Biomechanics, Basketball Players*

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INTRODUCTION

The study of muscle force as a motor ability in sports has grown dramatically over the years. The phenomenon of isometric muscle force (IMF) can be estimated in different ways (Marković, Dopsaj, Koprivica, & Kasum, 2018). One of the ways is known in physiotherapy practice as a muscle manual test (MMT). This test qualitatively and directly assesses the magnitude of muscle force, depending on the movement and position of the patient (Bohannon, 2019). For many years, there have been procedures applied to standard movements, justified by plenty of studies and with confirmed metric characteristics. The development of technology enabled highly suitable dynamometers to be used in muscle force assessment in different positions, i.e., depending on which movement is being analyzed, the position of subject varies. Some of the studies have been completed on the basis of the reliability and validity of hand-held and hand grip dynamometers while measuring isometric force magnitude in patients by one or two experienced testers (Bohannon, 1986; Wadsworth, Krishnan, Sear, Harrold, & Nielsen, 1987; Wadsworth, Nielsen, Corcoran, Phillips, & Sannes, 1992; Bohannon, 1998; Awatani et al., 2016).

However, not many scientific papers have dealt with the hand-held dynamometry (HDD) and force assessment upon specific movements in a particular sport. Basketball is one of the most popular sports today. It would have been interesting to further analyse and compare isometric muscle force data obtained through hand held dynamometry testing with other motor abilities, e.g., precision. HDD testing should not be assumed and related to players' performance only, but to injury and time loss prevention. Although, muscle force is not a ruling characteristic while shooting, it is crucial to acknowledge the parameters of the normal function of the upper arm (Diesel, Dana, & Laver, 2020).

Despite the shooting style being specific to each basketball player, levers of the arms fulfill certain biomechanical laws related to the ideal arms position.

The aim of this research is to determine the IMF of the dominant arm in a position directly before the basketball shooting, and to check test reliability.

METHODS

Participants

The participants of the study were elite, adolescent basketball players aged 16 to 18 (17±1 years), with a body height of 185.60±6.31 cm and body mass of 78.07±8.56 kg (Mean±SD). Fifteen (n=15) male players, in good health, with basketball practice experience of at least five years were recruited from a single team. The testers were recruited from the graduates and teachers of the Faculty of Sport and Physical Education, University of Niš. Study procedures were approved by the Faculty of Sport and Physical Education Ethics Committee in accordance with the Helsinki Declaration. All of the participants provided informed consent prior to participation.

Design and procedures

In order to activate the muscles of the upper extremities, the participants completed warm-up exercises for a duration of 10 minutes prior to testing. The starting position of the IMF testing is sitting on a chair without a backrest in order to neutralize the retroactive force in the lower extremities. The participant assumes a shooting position, the one he finds

most suitable and most practiced throughout the years, and without a ball. The tester assumes a stable and comfortable standing position beside the chair in accordance to the established MMT procedure, with an HDD in his palm, and establishes contact with the provided region of the participant's dominant arm. The tester uses his other arm for the fixation (Figure 1). After the voice signal of the tester to start the test by imitating shooting, the participant gently pushes the dynamometer and the tester's arm until he overcomes the threshold defined at 5 kilograms, after which he is notified by the sound signal of the dynamometer to manifest the maximum force in the given time of 3 seconds.

The established interaction between tester and basketball player generates IMF results. Isometric muscle testing is based on a closed kinetic chain principle which implies that force is the same at any point of the chain.

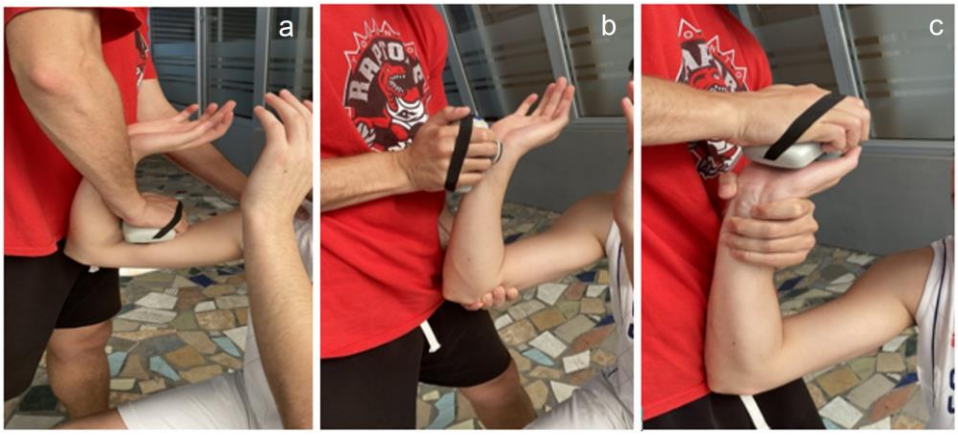

Fig. 1 Setting of the isometric muscle force testing of the shoulder flexors with a fixed proximal part of the upper arm (a); of the elbow extensors with a fixed proximal part of the lower arm (b); of the wrist flexors with a fixed proximal part of the palm (c); with the inclusion of a hand-held device

Both testers and participants performed a couple of pre-trials to become familiarized with the testing procedure. Subsequently, each set (testing of the shoulder flexors+the elbow extensors+the wrist flexors) of the IMF tests is performed three times with a fifteen-minute break between sets. The best score is used for analysis. The measurement procedure is repeated over three successive days, in order to obtain data for further processing and verification of the reliability of the measurement. Visual and verbal feedback on the force curve status is avoided. The dynamometer used in this study was a HDD (Lafayette Instrument Company).

Instruments

IMF was evaluated using a digital HDD, Lafayette Instrument Company, Sagamore, USA (Ribeiro, Cools, & Camargo, 2020).

Statistical analysis

For data processing, the test-retest method was used to determine the reliability of the proposed tests. Along with the basic descriptive statistics and intraclass correlations, the Analysis of variance was calculated to assess the statistical significance of each item. Finally, the Intraclass correlation coefficient, Confidence interval, Cronbach's alpha coefficient for determining the internal consistency of the test, the Coefficient of variation, Typical error, and the Smallest worthwhile change for assessing the usefulness of the test were calculated. SPSS 20 Statistical Package for the Social Sciences version 20.0 (IBM Corporation, New York, USA) was used to analyze the data.

RESULTS

After data acquisition, the best results were extracted for further reliability analysis. Thus, the variability was obtained: best A-B, where A represents the measurement 1-3, and B represents the test 1-3 (testing of the shoulder flexors, testing of the elbow extensors, and testing of the wrist flexors, respectively). Using the Shapiro-Wilk test determined that almost all the variables met the criteria and did not statistically significantly deviate from the normal distribution (Table 1).

Table 1 The Shapiro-Wilk test of the normality

A-B	Shapiro-Wilk		
	Statistic	df	Sig.
Best 1-1	0.906	15	0.116
Best 1-2	0.951	15	0.546
Best 1-3	0.895	15	0.081
Best 2-1	0.936	15	0.339
Best 2-2	0.905	15	0.114
Best 2-3	0.927	15	0.250
Best 3-1	0.969	15	0.848
Best 3-2	0.863	15	0.056
Best 3-3	0.943	15	0.425

Homogeneity of the variance was also tested using Levene statistics. Each of the variables displayed equal variance (the values of Leven statistics were not statistically significant at the level $p \geq 0.05$ (Table 2).

Table 2 Test of the homogeneity of variance

	Levene Statistic	df1	df2	Sig.
Flexion in the Shoulder Joint (kg)	2.980	2	42	.062
Extension in the Elbow Joint (kg)	2.539	2	42	.091
Flexion in the Wrist Joint (kg)	.319	2	42	.729
Angle in the shoulder joint (deg)	.541	2	40	.587
Angle at the elbow joint (deg)	.314	2	40	.733
Angle in the wrist (deg)	.744	2	40	.482

It is known that the manifestation of IMF directly depends on the lever system of the human body. The force produced depends on the angle in particular joints when taking a certain position. Therefore, it was necessary to check the consistency of the hand position when shooting, i.e., to check whether the angles in the actual joints change depending on the trial. For this purpose, hand positions were recorded during the first day of IMF testing, and the angles were calculated by the help of the Kinovea program, Copyright (C) 1989, 1991 Free Software Foundation, Inc. Based on Cronbach's α-coefficient, it can be concluded that the consistency of the shooting angles is evaluated as high (Table 3).

Table 3 Cronbach's Alpha Level of the Reliability

Test	Trial	Mean±SD	Cronbach (α)
Angle in the shoulder joint deg)	1	99.33 ± 8.10	0.904
	2	99.80 ± 8.05	
	3	99.30 ± 6.77	
Angle at the elbow joint (deg)	1	65.06 ± 10.42	0.961
	2	65.13 ± 9.11	
	3	63.07 ± 8.24	
Angle in the wrist joint (deg)	1	139.86 ± 8.70	0.938
	2	139.20 ± 7.69	
	3	141.92 ± 10.96	

Table 4 shows the descriptive and reliability statistics of the IMF testing. High values of relative reliability are reported in each of three tests (Flexion in the shoulder joint, Extension in the elbow joint, and Flexion in the Wrist joint, 0.79, 0.82, and 0.84, respectively). According to Hopkins, Marshall, Batterham, and Hanin (2009) Intraclass Correlation Coefficient (ICC) values ranging from 0.71 to 0.90 are considered high. Furthermore, Cronbach's alpha coefficient reported the magnitude of reliability of the items in each test. According to Darren and Mallery (2003) this coefficient ranges from unacceptable≤0.5; weak=0.51-0.60; suspicious=0.61-0.70; acceptable=0.71-0.80; good= 0.81-0.90; to excellent ≥0.91. It was noticed that the values of reliability in Flexion in the shoulder joint, Extension in the elbow joint, and Flexion in the Wrist joint range from 0.779, 0.807, and 0.848 respectively. Hence, the reliability of these tests is good. The applied F test provides statistically significant ICC at the level of $p<0.001$ for each test. Absolute reliability was displayed using the coefficient of variation (CV) and typical error (TE) (Atkinson & Neville, 1998). The coefficient of variation of 10% is taken as a criterion for accepting internal reliability. It is calculated as the ratio of standard deviation and arithmetic mean multiplied by 100. Table 4 shows that the coefficient of variation ranged from 5.6 to 7.8%, which satisfies the taken criterion. The test efficacy was determined by comparing the typical error (TE) with the least significant change. The Smallest Worthwhile Change (SWC) was determined by multiplying the standard deviation of each measurement by 0.2 (Hopkins, 2004). Since the value of the SWC is lower than the TE, it is concluded that the test score is “marginal”, i.e., insufficiently sensitive. However, it should be taken into account that according to Hopkins, the smallest effect of 0.2 is taken, while any other larger effect (e.g. 0.3) is graded as “good” (this research deals with adolescent athletes who are still in adopting shooting patterns of the motor skills).

Table 4 Descriptive and reliability statistics of the isometric muscle force testing

Test (kg)	Trial	Mean±SD (kg)	ICC (95% CI)	α	p	CV (%)	TE (kg)	SWC (kg)	Rating
Flexion in the Shoulder Joint	1	20.00±3.51	0.79 (0.49, 0.92)	0.779	4.515 p<0.001	7.8	0.59	0.44	Marginal
	2	20.00±2.33							
	3	19.93±2.22							
	In total	19.98±2.29							
Extension in the Elbow Joint	1	20.80±2.65	0.82 (0.56, 0.93)	0.807	5.189 p<0.001	7.3	0.64	0.50	Marginal
	2	20.80±3.47							
	3	21.00±2.62							
	In total	20.87±2.50							
Flexion in the Wrist Joint	1	21.60±2.06	0.84 (0.63, 0.94)	0.848	6.584 p<0.001	5.6	0.49	0.38	Marginal
	2	21.53±2.03							
	3	22.33±2.44							
	In total	21.82±1.91							

Legend: SD=Standard Deviation; ICC=Intraclass Correlation Coefficient; CI=Confidence Interval; α=Cronbach's alpha; p=F Value set at level <0.001; CV=Coefficient of Variation; TE=Typical Error; SWC=Smallest Worthwhile Change=0.2xSD.

DISCUSSION

What distinguishes this study from previous ones are the participants, i.e., the aim of the study. While in previous studies, the sample of participants consisted mainly of patients, and less of healthy athletes and non-athletes, we focused on elite adolescent basketball players and their isometric muscle force testing in the function of sport performance and the results to be achieved.

One of the first articles dealing with reliability of testing certain muscle groups in patients using the MMT and HDD was written by Beasley in 1956. The suggestion was that MMT without HDD in terms of reliability should be taken with consideration in some cases.

Indeed, the usage of the MMT without HDD can represent a potential source of error. Namely, a tester is not able to precisely evaluate the subtle variations in muscle strength (Wadsworth et al., 1987).

And although MMT measurements are quantitatively less precise than HDD measurements, muscle testing is generally dependent on the strength of the tester. Wikholm and Bohannon (1991) determined that tester strength above 120N represents a major determinant of the reliability upon HDD force measurements.

Bohannon and Andrews (1987) tested 6 muscle groups in patients, using the MMT and HDD. Good tohigh inter-rater reliability related to 6 muscle groups was determined, with the authors' note that due to differences in the testers' mean values related to two muscle groups, a further investigation of HDD is needed.

Estimating the muscle force and the reliability of tests using the HDD in healthy participants, Byl, Richards, & Asturias (1988) found intra-rater reliability coefficients to have acceptable values (ranging from 0.833 to 0.957), but interrater reliability coefficients proved to be more variable, ranging from low (0.518) to high (0.840).

Kim, Lim, & Cho (2016) confirmed high degree intra-rater (0.992) and inter-rater (0.949) reliability of the MMT, performed by one or two testers, using a HDD in healthy, non-athletes, who were Korean university students.

In addition, Tudini, Myers, & Bohannon (2019) determined high intra-rater and inter-rater reliability (ICC ranging from .885-.974) and the SWC ranging from 21.1 to 47.6 N in HDD testing of healthy subjects.

The fact that dinamometry measuring is reliable in terms of handgrip strength was proved by Gerodimos (2012) in his study of adult male basketball players.

Another study measuring hand dynamometry and field test performance worth mentioning is that of Gil and associates (2015), and it included wheelchair basketball players. Handgrip strength and the tests measuring ball throwing ability (pass and shooting) are determined to be positively related to the disability class of the participants.

Based on the results of the current study, the reliability of HDD to measure IMF appears to be in line with previous studies.

Hence, a common feature of previous and the current study is that, despite differences in the participant sample (patients, healthy athletes and non-athletes), and more or less sophisticated devices used, the reliability of the measurements could be evaluated as high.

CONCLUSION

A study was conducted on a sample of 15 elite, adolescent male basketball players aged 16 to 18, with the aim of assessing the IMF of the dominant arm in the position directly before the basketball shooting, and to check test reliability. The testing was conducted over three successive days, and the best, i.e., the highest value of the applied isometric muscle force among three trials within each test, was further statistically processed. The HDD presented to be reliable in terms of measuring muscle force.

The application of the MMT using an electronic dynamometer has been in practice for years and there are papers confirming its validity and reliability. However, studies are conducted mostly with patients in physiotherapy practice.

This paper attempts to open a new chapter in the study of muscle strength in situational conditions of sports performance. Further study of the differences (and influences) between the isometric muscle force obtained in the basketball shooting position through HDD testing and other motor abilities is needed.

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POUZDANOST TESTOVA ZA MERENJE IZOMETRIJSKE SILE MIŠIĆA TOKOM ŠUTA U KOŠARCI

Cilj ovog istraživanja je da se utvrdi izometrijska sila mišića (ISM) dominantne ruke u položaju neposredno pred šut u košarci i da se proveri pouzdanost testa. Petnaest košarkaša (starosti 17±1 godina, telesne visine 185.60±6.31 cm; telesne mase 78.07±8.56 kg) sa košarkaškim iskustvom ne kraćim od 5 godina, podvrgnuto je manuelnom mišićnom testu (Fleksija u zglobu ramena, Ekstenzija u zglobu lakta i Fleksija u zglobu ručja), primenom ručne dinamometrije. Visoke vrednosti relativne pouzdanosti zabeležene su u svakom od navedenih testova (0.79, 0.82, i 0.84, tim redosledom). Cronbach-ov alfa koeficijent ukazuje je na vrednosti pouzdanosti tokom fleksije u zglobu ramena, ekstenzije u zglobu lakta i fleksije u zglobu ručja u rasponu od 0.779, 0.807, i 0.848 (tim redosledom), predstavljajući rezultate pouzdanosti kao visoke. Primenjeni F test pruža statistički značajan koeficijent korelacije unutar klase na nivou p<0.001, za svaki od testova ponaosob. Apsolutna pouzdanost je predstavljena koeficijentom varijacije i zadovoljava kriterijum koji se kretao između 5.6 i 7.8%. Ručna dinamometrija predstavljena je kao pouzdana metoda u pogledu merenja ISM.

Ključne reči: *manuelni mišićni test, ručna dinamometrija, biomehanika, košarkaši.*