MAXIMUM ISOMETRIC MUSCLE STRENGTH AS A PREDICTOR OF ONE REPETITION MAXIMUM IN THE SQUAT TEST

MAKSIMALNA IZOMETRIJSKA MIŠIĆNA SILA KAO PREDIKTOR JEDINOG MAKSIMALNOG NAPRZANJU U TESTU ČUČANJ

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ABSTRACT

This study aims to determine whether maximum isometric muscle strength, exerted at a certain angle in the knee joint (80 °, 110 °, and 140 °), may be used as a predictor of 1RM in the squat movement task. A group of twenty-four male students (N = 24) took part in the research in 2 separate sessions and 7 days of rest between each. In the first session, the anthropometric measurements and assessment of muscle strength, that is 1RM, were measured by maximum repetition to failure method on the Smith machine. The maximum isometric force (Fmax) of the leg muscles was measured by the Alternating Consecutive Maximum Contraction Test in laboratory conditions on a Smith machine using a dynamometer probe and the Globus Ergo Tesys System 1000 software system. Analyzing the results based on linear regression, the authors conclude that, with an accuracy of 84.5%, we can estimate 1RM in the squat exercise measuring the maximum isometric force exerted at an angle in the knee joint of 140 °. The results obtained by this research can be used in practice when assessing 1 RM based on the measurement of the maximum isometric force for a given movement task.

Keywords: *muscle strength, prediction, 1RM, squat*

INTRODUCTION

The squat is a conventional exercise that improves muscle strength and the strength of the lower extremities. Also, it is used as an assessment tool when assessing the previously mentioned myogenic abilities. Muscle force testing provides significant kinematic parameters that are key for programming strength and power training, and based on the given parameters, the effects of a training model are assessed (Herman 1990, Hakinen 1994). However, one of the fundamental goals of muscle strength testing in sports is to estimate the maximum voluntary muscle force in static or 1 RM (maximum repetition) in dynamic conditions. Maximum voluntary muscle force, or muscle strength, is the maximum force that a muscle or group of muscles can generate when overcoming large external loads at low speeds of muscle contraction or in isometric conditions (Zaciorsky and Kreamer, 2009). Isometric conditions represent the manifestation of voluntary muscular (isometric) force, with a constant angle in the joint of the corresponding limb (Petrović, Kukrić, Dobraš, and Zlojutro, 2019). Furthermore, 1 RM represents the manifestation of maximum muscular force in dynamic conditions, that is the maximum load that can be overcome by the appropriate technique only through one repetition. 1 RM can be estimated directly or indirectly through a number of repetitions based on % 1RM with the submaximal load. Direct measurement requires lifting heavy loads and is therefore not recommended to be performed with less trained individuals due to the high risk of injury. Indirect assessment of 1 RM and the testing of maximal voluntary muscle contraction have emerged as a safer option for the health of the subjects. The reliability coefficient of the tests that assess muscle strength by the indirect method, ie by applying a specific test of repeated (repetitive) maxima (RM) is in the range from r = 0.92 to 0.98 (Sale, 1991; Carpinelli, 2011). Researches have shown that the isometric dynamometry method is also highly reliable. A number of researchers have obtained high test reliability when measuring maximum isometric squat muscle force (Kawamori et al., 2006; Beckham et al., 2012; Comfort, Jones, McMahon, & Newton, 2015; Haff, Ruben, Lider, Twine, & Cormie, 2015; Thomas, Comfort, Chiang, & Jones, 2015).

Thus, there appears to be a scientific basis that supports the use of testing methods, that is the estimation of maximal muscle force under isometric and dynamic conditions of 1RM. However, the question arises whether it is possible to predict the maximum muscle force in dynamic conditions based on the kinematic parameters obtained by the maximum voluntary muscle contraction in isometric conditions. The fact that justifies such assumptions is that the maximum muscle force achieved in slow motions does not differ significantly from the maximum muscle force of motion in isometric conditions (Smidtbleicher 1992; Zaciorski and Kreamer 2009; Lum et al., 2020). Furthermore, the results of several studies (Blazevich et al., 2002; Nuzzo et al., 2008; Demura et al., 2010; Caleb et al., 2015) showed a significantly high correlation between isometric squat and 1 RM in the squat test. Nevertheless, there are different scientific opinions when it comes to the angle in the knee joint when testing the maximum isometric force, ie the prediction of 1RM based on the maximum force exerted at a certain angle. Studies show that higher joint angles of 90 ° -160 ° are more suitable for estimating Fmax in the last squat (Marchetti et al., 2016). Sale (1991) proposes that isometric measurements be performed in the position in which the force is the greatest for a given range of motion.

This study aims to determine whether the manifestation of maximum isometric muscle force at a certain angle in the joint (80 °, 110 °, and 140 °) can be used as a predictor of 1RM in the squat exercise.

METHOD

The study sample consisted of twenty-four first-year male students from the Faculty of Physical Education and Sport at the University of Banja Luka. All examinees were male, healthy, physically active, and did not have any intense physical activities 72h prior to testing. In order to reduce errors in conducting the experimental procedure, selected examinees who were trained to lift weights and use weight machines. The tests

were performed at the Institute of Sports at the Faculty of Physical Education and Sports, at the University of Banja Luka.

All measurements were carried out in two separate sessions with seven days of rest between them. Familiarization with the experimental protocol, anthropometric measurements, and the assessment of 1RM in the squat exercise was done in the first session. The measurement of the maximum isometric force of leg muscles exerted in three different knee joint angles in the squat movement was executed in the second session.

After the familiarization with the experimental protocol, the respondents started with the anthropometric measurements. Anthropometer and body analyzer (TANITA BC - 418MA, Tokyo, Japan) were used for anthropometric measurements. The measurement of anthropometric variables was conducted according to the International Biological Program (IBP), and in this paper, these have been used: body height, body mass, muscle tissue percentage, fat tissue percentage, MFR-index (the ratio between muscle and fat tissue in the body). All measurements were performed according to the ACSM´s protocol.

The assessment of muscle force, that is 1RM, was carried out using the training-to-failure method on a Smith machine. The respondents were asked to lift a load of a given weight the maximum number of times, with the number of repetitions not exceeding 10. The approximate muscle force value was obtained based on the regression equation 1RM = weight / (1.0278 - (0.0278 * number of repetitions)) according to Brzycki (1993) and Carpinelli (2011). After a ten-minute warm-up, all the respondents did 2 sets with 5 repetitions of the additional warm-up session of squats, with the load of 70 and 90 kg. In the third set, the weight was progressively increased by 10% for the measurer to predict the optimal weight for the test. If the respondent, due to poor estimation of the meter, succeeded in lifting the given weight more than 10 times in the fourth series, the task would be interrupted only to be continued after a ten-minute break in the fifth series where additional load would be added.

The maximum isometric force of leg muscles was measured using the Alternating

Consecutive Maximum Contraction Test in laboratory conditions (Suzović, 2008 and Suzović et al., 2015) on the Smith machine using a dynamometer probe and the Globus Ergo Tesys System 1000 software system. The respondents performed two maximum voluntary contractions 3-5 seconds long with a one-minute break between the repetitions. The three angles of the knee joint of 80°, 110°, and 140° were measured using the Leica Vetronix - SG12F goniometer. The respondents were asked to perform every repetition from the same initial position. They were, also, asked to place their feet in the width of the hips and to perform the maximum possible muscular effort. The dynamometer was fixed to the ends of the machine used, with the fixers specifically designed for this test. The structure was designed to allow a change in the angle of the knee joint when other angles were tested. The maximum force value (Fmax) was obtained from the derivation of the signal using the Globus Ergo Tesys System 1000 software, registered by stretching the probe of the dynamometer.

The basic descriptive parameters were measured for all the variables, while stepwise multiple regression was used to obtain the regression model as a predictor of 1RM, with statistical significance set at $p<0.05$. The SPSS *(IBM SPSS Statistics 20. Chicago, IL, USA)* application program was used for mathematical processing of the original data, as well as their graphic illustration.

RESULTS

Table 1 shows the basic descriptive indicators of anthropometric variables. Considering the fat-to-muscle ratio (BMI) of the group, which is 4,14, it can be concluded that the examinees share a sport-specific morphology profile (Ugarković 1996).

Table 1. *Basic descriptive indicators of anthropometric and motor characteristics.*

Variable	N	Min.	Max.	AM	SD	CV
Height (cm)	24	168,00	190,30	179,63	5,96	0,03
Weight (kg)	24	57,10	95,00	73,89	8,85	0,11
Adipose tissue (%)	24	5,40	21,40	13,28	3,74	0,28
Muscle tissue (%)	24	45,30	52,40	49,69	1,67	0,03
BMI index(%)	24	2,22	9,25	4,14	1,63	0,39
Squat 80°	24	954	1957	1290,46	303,56	0,23
Squat 110°	24	1217	2714	1834,71	435,89	0,23
Squat 140°	24	1690	3198	2402,71	484,44	0,20
Aquat 1RM	24	115	191	150,41	21,56	0,20

Legend. **N** – the number of examinees, **Min**. – range minimum, **Max**. – range maximum, **AM** – arithmetic mean, **SD** – standard deviation, **CV** – the coefficient of variation

Table 1 shows that the highest average muscle force was achieved in the knee joint angle of 140 °, 2402 ± 484 N, then at an angle of 110 ° 1834 ± 435 N, and the lowest value was recorded at an angle of 80 ° 1290 ± 303 N.

Table 2 and Image 1 show that one model of multiple regression was singled out, which takes into account only the influence of the subtest **Squat 140** ° and tells us that the explanation of the criteria by the predictor R2 = 0.836, or 83.6%. Thus, the value of the isometric force achieved in the squat movement task at an angle in the knee joint of 140 ° is a good predictor (explanation of the criterion by the predictor 83.6%) compared to the values of the force achieved at one maximum effort in the squat movement task under dynamic conditions. The

standard measurement deviation was 9.1 kg, which is understandable due to the sample of respondents.

Table 2. *Regression model to predict 1RM on the basis of maximum isometric muscle force exerted in the leg press movement when at an angle in the knee joint of 140 °.*

MODEL 1		**SQUAT=a+b*SQUAT 140°**						
Equation parameters	Parameter value	Standard error	T(20)	P-level	R	R^2	Korig. R^2	St
a	**52,179**	9,196	5,674	0,000				
b	**0,0409**	0,004	10,889	0,000	0,918	0,843	0,836	8,72

Legend. **MODEL 1** predictor: Squat at 140º, Criteria: Squat

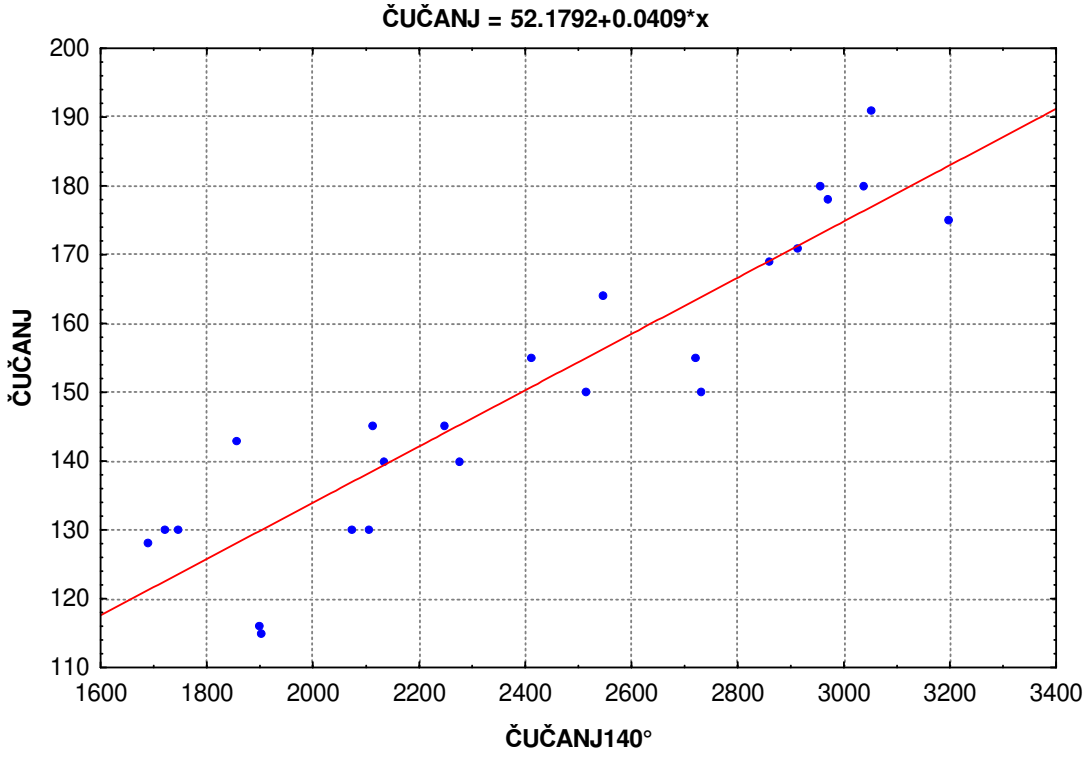

Image 1. *Prediction of 1RM based on the isometric force achieved in the squat test at an angle in the knee joint of 140º.*

Based on the analysis of the regression model, a unique formula for estimating one maximum repetition in the squat test 1RM = (52.1792 + 0.0409 * max isometric force at an angle of 140 °) with a reliability of 83.6% was selected.

DISCUSSION

The results of this study confirmed earlier findings (Smidtbleicher, 1992, Zaciorski and Kreamer 2009, June, 2010; Bazyler et al. 2015; Marchetti et al. 2016; Petrović et al. 2019) that muscle strength achieved in slow movements did not differ significantly from the maximum muscle force achieved under isometric conditions. Taking these findings into account it is important to emphasize that they refer to biomechanically similar movement patterns. The analysis of the results showed that body position, as well as a suitable angle in the knee joint, are very important when testing myogenic properties, which is confirmed by some previous research (Blazevich et al., 2002; Nuzzo et al., 2008; Demura et al., 2010; Caleb et al. 2015). The results of the study (Marchetti et al. 2016) on a sample of 50 well-trained individuals showed that the greatest force develops at an angle of 90 ° at the knee joint compared to angles of 40 ° and 160 °. According to research data (Bazyler et al. 2015), the highest correlation between 1 RM and the maximum muscle force of isometric squatting is at angles of 90 ° and 120 °. In the study with the students, the correlation of r = 0.77 was confirmed between 1 RM in the squat and Fmax at a joint angle of 90 ° in the isometric squat. These claims show that there is a result deviation obtained in this research compared to the previous studies. It should also be noted that the extent of the manifestation of strength and power depends on the training load program, time, and goals of the program. The respondents in this research paper were students who perform more exercises with larger joint angles in their training programs, which is one of the reasons why they exerted greater force at larger angles. The standard deviation of 9.1 kg can be attributed to the sample of subjects and, on the other hand, to the anthropometric characteristics. Thus, the patterns derived from this study relate to the sample of respondents used in this study. The patterns derived from this study relate to the sample of respondents used in this study.

CONCLUSION

The results obtained in this study show that from a methodological point of view, this approach to the study of myogenic properties is acceptable and that its principles can be used in future research. In order for the values of isometric force to be used as predictors for field tests, it is necessary to perform the test at a precisely defined body position, taking into account the angle in the joint at which the test is performed. Additional research should be conducted with professional athletes experienced in working with external loads by using more sophisticated equipment in the assessment of 1 RM in dynamic and isometric conditions. Kinematic parameters obtained using an isoinertial encoder and a tensiometric platform would reduce the measurement error.

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SAŽETAK

Cilj ovog istraživanja je bio da se utvrdi da li ispoljavanje maksimalne izometrijske mišićne sile pri određenom uglu u zglobu koljena (80°, 110° i 140°) može služiti kao prediktor 1 RM-a kod kretnog zadatka čučanj (squat). Istraživanje je sprovedeno na grupi od dvadeset i četiri studenta (N=24), muškog pola u okviru 2 odvojene sesije sa po 7 dana odmora između svake. Antropometrijska mjerenja i procjena mišićne sile, odnosno 1 RM-a izvršeno je metodom repetitivnih maksimuma do otkaza na Smit mašini u okviru prve sesije. Maksimalna izometrijska sila (Fmax) muskulature nogu mjerena je testom uzastopnih maksimalnih kontrakcija u laboratorijskim uslovima na smit mašini uz pomoć sonde dinamometra i softwerskog sistema Globus Ergo Tesys System 1000. Analizom rezultata dobijenih na osnovu linearne regresije, autori zaključuju da sa preciznošću od 84,5% možemo izvršiti procjenu 1RM-a u vježbi čučanj na osnovu maksimalne izometrijske sila ispoljene pri uglu u zglobu koljena od 140°**.** Rezutati dobijeni ovim isztraživanjem mogu poslužiti aplikativno u praksi prilikom procjene 1 RM-a na osnovu mjerenja maksimalne izometrijske sile za dati kretni zadatak.

Ključne riječi: *Mišićna sila, predikcija, 1 RM, čučanj*

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