

**Original empirical article**

## **INVESTIGATION OF THE RELATIONSHIP BETWEEN DIFFERENT MUSCLE STRENGTH ASSESSMENTS IN BENCH PRESS ACTION**

*UDC 796.015.865.1:894*

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**Abstract.** *The aim of this study was to determine the relationship between isometric tests and dynamic performance in bench press action. The subjects in this study were 22 male students from the Faculty of Sport and Physical Education in Niš. The testing of isometric muscle force provided the values of maximum voluntary force ( $F_{max}$ ), and four other indices of explosive force production of the muscle being tested ( $RFD$ ,  $T_{30-70}$ ,  $T_{30-80}$ , and  $T_{30-90}$ ). Subjects were tested in the isometric bench press machine in two different positions. All of the subjects were also tested in the classical bench press action. The performance measure of dynamic performance was 1RM in classical bench press action. The relationship between isometric and dynamic strength test was assessed by Pearson's correlation coefficients. The correlation between the  $F_{max}$  in isometric testing and the 1 RM in bench press in our study in initial position was  $r=0.16$ , and in final position  $r=0.33$ . The results of our study confirmed the results of the previously mentioned studies that failed to demonstrate a high correlation between the isometric testing and the performance task.*

**Key words:** *Isometric tests, dynamic performance, relationship, muscle force*

### INTRODUCTION

Muscular force is the maximum amount of force that a muscle or a muscle group can exert. Muscle contraction can be either dynamic or static. Static contractions do not involve movement and are termed isometric strength. Isometric strength is the maximum force that a muscle group can exert without movement. Tests of isometric strength are easy to perform as they require only a single maximal contraction. Isometric tests are

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Received December 4, 2008 / Accepted April 10, 2009

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very popular tests of muscle function and have been among the most widely used methods of strength assessment over the last 50 years. There are several reasons:

- They are easily standardized and hence reproducible. Indeed, a number of studies have reported high levels of reliability with the use of isometric procedures (Bemben, Massey, Boileau, & Misner, 1992; Hortobagyi & Lambert 1992).
- They are simple tests that require very little technique or skill and hence can be used with untrained and trained subjects.
- They are straightforward to administer and safe for subjects to perform.
- They use relatively inexpensive equipment.

Isometric tests are generally performed to quantify the maximal force (or torque) and/or the maximal rate of force development (RFD). The RFD presents the rate of rise in contractile force at the onset of contraction within the early phase of rising muscle force (Hakkinen & Komi, 1986), and it has been one of the most frequently applied tests for Explosive Force Production (Mirkov, Nedeljković, Milanović, & Jarić, 2004). In isolated muscle preparations, contractile RFD is obtained from the slope of the force time curve (force/time), whereas, for intact joint actions, RFD is calculated as the slope of the joint moment-time curve (moment/time). The maximal RFD is typically quantified as the greatest slope of the force time curve over some time interval (Wilson, Newton, Murphy, & Humphries, 1993; Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002; Rajić, Dopsaj, & Abella, 2004). Other methods include determining the time needed to reach a certain level of absolute force, or the time needed to achieve a relative force level such as 30% (Hakkinen, Alen, & Komi, 1985). Another important strength parameter is the total contractile impulse that can be produced within a given contraction time (Baker, Wilson, & Carlyon, 1994), or alternatively, the time interval between two relative force levels (Bobbert, & Van Zandwijk, 1999; Gorostiaga, Izquierdo, Iturralde, Ruesta, & Ibanez, 1999; Mirkov, & Nedeljković, 2002; Mirkov, Nedeljković, Milanović, & Jarić, 2004).

Dynamic contraction involves movement, either concentric, in which the muscle shortens, or eccentric, in which the muscle lengthens. For the assessment of dynamic strength, the repetition maximum (RM) is widely used. The RM is the maximum number of repetitions per set that can be performed with proper lifting technique, using the given resistance. Thus, a set of a certain RM implies that that the set is performed to momentary voluntary fatigue. The heaviest resistance that can be used for one complete repetition of an exercise is 1 RM. A lighter resistance that allows completion of 10 but not 11 repetitions with proper exercise technique is 10 RM.

Some researchers have extrapolated dynamic strength from isometric strength (Sale, & Norman, 1982; Young & Bulby 1993). In addition, questions about the relationship between isometric strength and dynamic strength have been raised. Can isometric strength predict dynamic strength? The researchers who studied this issue have found conflicting results. While some say yes, a number of researchers have reported that these tests show a relatively poor relationship.

The main aims of this study were to examine the relationship between the muscle strength tests of muscles involved in bench press action in isometric and dynamic conditions. In addition, we tried to determine the relationship between the different explosive force production tests.

## METHOD

### Participants

The subjects of this study were 22 second year students from the Faculty of Sport and Physical Education in Niš. All of the subjects were males. Their average age given in years =  $21.5 \pm 1.75$ ; weight given in kg =  $67.4 \pm 6.70$ . All of the subjects gave their informed consent to the procedures of the study after they received a complete explanation of the purpose and the procedures of the study. None of the subjects had previously participated in organized resistance training or reported either neurological disorders or recent injuries.

### Instruments

The testing procedure took place in the laboratory of biomechanics and sport diagnostics at the Faculty of Sport and Physical Education in Niš. The measurement of maximal muscle strength and RFD was carried out under isometric conditions on specially designed isometric equipment in the laboratory of biomechanics.

The subjects were tested in the bench press machine while the bar with a dynamometer was placed in two different positions. In the first position, the bar was fixed at a 2-5cm distance from the chest and in the second position the bar was fixed at a 30-50 cm distance from the chest, depending on the position where the elbow joint angle was  $135^\circ$  (180 full extensions). These two positions represent critical spots during the bench press.



Picture 1. Picture of the second position

After a 10-minute warm up, it was explained to the subjects what each particular test was, and after that they made their practice attempts. After a five-minute break, measurements in the two different positions were taken. Every subject performed three trials with a 60-second rest in between. The best attempt was chosen for the analysis. The subjects were carefully instructed to contract "as fast and forcefully as possible."

The testing was carried out by the software system 'Digidy' Co TCR, Novi Sad, Serbia. The signal was recorded and stored on the computer disk. The curve provided the maximum voluntary force ( $F_{max}$ ), and other indices of explosive force production of the

muscle being tested. The  $F_{\max}$  was assessed as the highest force level recorded during each contraction. The indices of explosive force development included the elapsed time interval between achieving 30% and 70% of  $F_{\max}$  ( $T_{30-70}$ ), the elapsed time interval between achieving 30% and 80% of  $F_{\max}$  ( $T_{30-80}$ ), and the elapsed time interval between achieving 30% and 90% of  $F_{\max}$  ( $T_{30-90}$ ). In order to estimate the RFD we used the ratio  $F_{\max}/T_{\max}$ , where  $T_{\max}$  is the time to peak force.

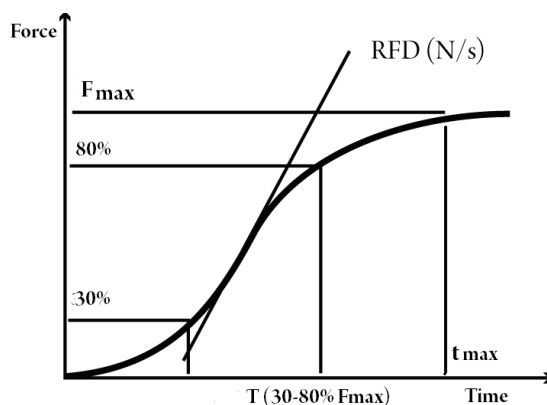


Fig. 1. The indices of explosive force development

Some researchers (Mirkov & Nedeljković, 2002) use the elapsed time interval between reaching 30% and 70% of  $F_{\max}$  to assess explosive force production. Some suggest (Jarić, 2006) the time interval between 20% and 80% of  $F_{\max}$ , and others suggest (Bellew, 2002) the time interval between 30% and 90% of  $F_{\max}$ .

All of the subjects were also tested in the classical bench press action. For estimation of the subjects 1RM we used a regression equation from (Brzycki, 1993). The formula permits one to "assess muscular strength in a safe, efficient manner, without requiring subjects to attempt maximum lifts. Brzycki's equation predicts the 1RM from persons "n RM".

$$1 \text{ RM} = \text{weight lifted during } n \text{ RM} / (1.0278 - .0278(n))$$

### Procedure

Statistical analyses were carried out with SPSS statistical package, ver. 12 (Chicago, IL, USA). Means and standard deviations (SD) were calculated for all three tests of explosive force production ( $T_{30-70}$ ;  $T_{30-80}$ ;  $T_{30-90}$ ) and for maximal voluntary force in both positions. The relationship between isometric and dynamic strength tests was assessed by Pearson's correlation coefficients. Hopkins (Hopkins, 2004) has ranked the meaningfulness of correlations as  $r$  = trivial (0.0), small (0.1), moderate (0.3), strong (0.5), very strong (0.7), nearly perfect (0.9), and perfect (1.0). The criterion for statistical significance of the correlations was set at  $P < 0.05$ .

## RESULTS

Table 1 shows the correlation coefficients for all six muscle strength tests obtained in the first position. All three tests of explosive force production ( $T_{30-70}$ ;  $T_{30-80}$ ;  $T_{30-90}$ ) correlate significantly with one another, while the relationship between these tests and the  $F_{max}$ , RFD and the 1RM bench press test was insignificant. In addition, both the  $F_{max}$  and the RFD do not correlate significantly with the 1RM bench press test.

Table. 1. The relationship among different muscle strength tests (first position)

		T 30-70	T 30-80	T 30-90	Fmax	RFD	1RM Bench press
T 30-70	Pearson Correlation	1	,721**	,605**	,225	-,321	,119
	Sig. (2-tailed)	.	,000	,003	,313	,145	,597
T 30-80	Pearson Correlation		1	,913**	,301	-,378	,124
	Sig. (2-tailed)		.	,000	,173	,083	,583
T 30-90	Pearson Correlation			1	,354	-,287	,125
	Sig. (2-tailed)			.	,106	,195	,579
Fmax	Pearson Correlation				1	,385	,157
	Sig. (2-tailed)				.	,077	,485
RFD	Pearson Correlation					1	,248
	Sig. (2-tailed)					.	,266
1RM Bench	Pearson Correlation						1
	Sig. (2-tailed)						.

\*\* Correlation is significant at the 0.01 level (2-tailed).

Table. 2. The relationship among different muscle strength tests (second position)

		T 30-70	T 30-80	T 30-90	Fmax	RFD	1RM Bench press
T 30-70	Pearson Correlation	1	,805**	,674**	,012	-,419	,335
	Sig. (2-tailed)	.	,000	,001	,959	,052	,127
T 30-80	Pearson Correlation		1	,942**	,014	-,532*	,357
	Sig. (2-tailed)		.	,000	,950	,011	,103
T 30-90	Pearson Correlation			1	,044	-,559**	,367
	Sig. (2-tailed)			.	,846	,007	,093
Fmax	Pearson Correlation				1	,458*	,325
	Sig. (2-tailed)				.	,032	,140
RFD	Pearson Correlation					1	-,084
	Sig. (2-tailed)					.	,709
1RM Bench	Pearson Correlation						1
	Sig. (2-tailed)						.

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

Table 2 shows the correlation coefficients among all six muscle strength tests obtained in the second position. All three tests of explosive force production ( $T_{30-70}$ ;  $T_{30-80}$ ;

$T_{30-90}$ ) correlate significantly with one another and the correlation coefficients are even higher in the second position. Both  $F_{\max}$  and  $T_{30-80}$  correlated significantly with the RFD at the 0.05 level, while the same relationship for  $T_{30-90}$  was significant at the 0.01 level. The correlation coefficient between the performance test (1RM bench press test) and the  $F_{\max}$  was strong but not statistically significant ( $r=0.32$ ).

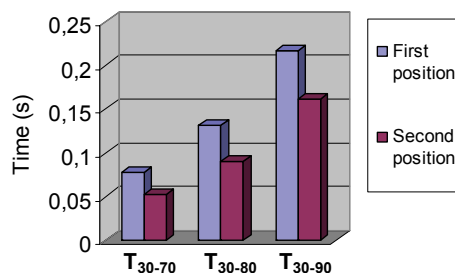


Fig. 2. The mean values of all three tests of explosive force production ( $T_{30-70}$ ;  $T_{30-80}$ ;  $T_{30-90}$ ) in both positions.

In the first position, the mean average (SD) for the test of explosive force production  $T_{30-70}$  was 0.07 (0.03) and in the second position it was 0.05 (0.02) seconds. For the test of explosive force production  $T_{30-80}$  in the first position it was 0.13 (0.05) and in the second position it was 0.09 (0.04) seconds. In addition, for the test of explosive force production  $T_{30-90}$  in the first position it was 0.22 (0.07) and for the second position, 0.16 (0.06) seconds (Figure 2). The mean value of  $F_{\max}$  in the first position is 582.76 (132.14) N and in the second position is 924.49 (189.17) N.

#### DISCUSSION/CONCLUSION

Even though it is much easier and safer to measure isometric strength than dynamic strength, and the correlations between the isometric and isotonic test in some studies were very high (Laughlin, 1998), the majority of studies that have directly compared isometric tests and performance have presented findings that demonstrate a poor relationship to dynamic performance.

In the study (Murphy, Wilson, & Pryor, 1994) on trained athletes, isometric and isoinertial strength testing in a bench press were compared against a variety of dynamic upper body performances, including a seated shot put throw (SSPT) and a maximum bench press lift. The isoinertial and not the isometric test showed the highest correlation with the performance test. They found a correlation between the  $F_{\max}$  and RFD in a bench press with an SSPT of  $r=0.22-0.38$ , and the correlation between the  $F_{\max}$  and RFD in a bench press and the 1RM bench press was  $r=0.47-0.78$ . In a similar study (Pryor, Wilson, & Murphy, 1994) on strength trained males, the RFD was compared with the same performance test. The correlation was  $r=0.42$ .

The correlation between the  $F_{\max}$  in isometric testing and the 1 RM in the bench press in our study in the first position was  $r=0.16$ , and in the second position, it was  $r=0.33$ . The results of our study confirmed the results of the previously mentioned studies that failed to demonstrate a high correlation between isometric testing and the performance task.

Many studies have examined the relationship between the isometric muscle strength of the lower body and the vertical jump performance, and most of them have found small or moderate correlation. The study (Jarić, Ristanović, & Coroc, 1989) that compared  $F_{\max}$  and RFD in a variety of lower body actions and the vertical jump performance on active male physical education students found a correlation for  $F_{\max}$   $r=0.22-0.42$ , and for RFD  $R=0.35-0.46$ . Similar studies (Viitasalo, Hakkinen, & Komi, 1981; Hakkinen, Komi, & Kauhanen, 1986) that examined the relationship between the RFD in a leg press and the vertical jump performance found a correlation of around 0.5. One study (Young and Bulby, 1993) found a small correlation between the RFD in squats and the vertical jump performance  $r=0.07$ . The subjects of this study were untrained males, same as in this study, so this may be one of the reasons for the small correlation between the isometric test and performance task.

The insignificant correlation between the  $F_{\max}$  and the EFP tests in bout positions could explain with general consideration that these tests reflect two independent functional abilities of the tested muscles, and a different relationship with various functional movements (Paasuke, Ereline, Gapeyeva, Sirkel, & Sander, 2000; Ugarković, Matavulj, Kukolj, & Jarić, 2002; Wilson & Murphy 1996; Mirkov, Nedeljković, Milanović, & Jarić, 2004).

The isometric measures of the muscle function and dynamic performance could best be described as poor. Many of the relationships were non-significant; and of those which were significant, the correlation coefficients were typically in order of  $r=-0.5$ , indicating that only approximately 25% of the variance was common.

A poor relationship between the isometric muscle test and the performance task could be explained with neural and mechanical differences between isometric and dynamic contractions. Differences in motor unit recruitment have been shown to occur within isometric tasks with changes in the direction of force application (Ter Haar Romeny, Denier van der Gon, & Gielen, 1982) or the performance of different tasks by the same muscle (Ter Haar Romeny, Denier van der Gon, & Gielen, 1994). Significant differences (Murphy & Wilson, 1996) were also reported in both the activity and firing characteristics of the musculature between isometric tests and dynamic performance. Distinct differences in activation patterns between isometric and dynamic contractions for the same joint angle influence the tests as well (Nakazawa, Kawakami, Fukanaga, Yano, & Miyashita, 1993).

In addition, there is a difference in isometric muscle strength in different positions. We can clearly see from the results that a subject needs less time to achieve better results in the second position. The differences in the results between the two positions are the result of muscle biomechanics. It means that while lifting a weight, strength tends to be greatest during the middle portion of the movement because of the amount of cross-sectional fibers in the muscle belly. In relation to the bench press, this means that the muscles are weakest at the beginning of the press (when the bar is near the chest) and get stronger with every inch until about the midpoint of the exercise (when the bar is halfway between your chest and full lockout). The number of muscles involved and different muscle angles also affects the result in different positions of the selected task.

One of the reasons for the poor relationship between the isometric muscle strength test and movement performance test could be a difference in the level of skills while performing the performance test or a high number of body segments and muscles involved in the task execution. This may be one of the reasons why the studies which were performed on untrained or novice subjects found the lowest correlations between the isometric tests and performance tasks.

Therefore, it would appear that for athletic assessment, dynamic tests of muscular function should be used because they can provide a more valid assessment of the functional capacity of the musculature in dynamic movements than the isometric tests.

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## ISTRAŽIVANJE ODNOSA IZMEĐU RAZLIČITIH PROCENA MIŠIĆNE SNAGE U AKCIJI POTISKA SA KLUPE

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*Sa ciljem utvrđivanja povezanosti izometrijskog i dinamičkog testa mišićne snage u potisku sa klupe (bench press), organizovano je testiranje 22 studenata Fakulteta sporta i fizičkog vaspitanja u Nišu. Iz izometrijskog testiranja dobijena je vrednost maksimalne izometrijske sile (Fmax), i vrednosti četiri testa za procenu brzine razvoja sile u izometrijskim uslovima (RFD, T<sub>30-70</sub>, T<sub>30-80</sub>, T<sub>30-90</sub>). Testiranje je sprovedeno u dve različite pozicije na aparaturi za izometrijsko merenje sile prilikom potiska sa klupe. Za procenu maksimalne dinamičke sile korišćen je 1RM prilikom izbačaja sa klupe (Bench press). Relacija između izometrijskog i dinamičkog testa snage je procenjena Pirsonovim koeficientom korelacije. Korelacija između maksimalne izometrijske sile i 1RM u prvoj poziciji je r=0.16, dok je u drugoj poziciji r=0.33. Ovi rezultati potvrđuju rezultate brojnih studija koje nisu pronašle značajnu povezanost rezultata na izometrijskom testu i dinamičkog zadatka.*

**Ključne reči:** *izometrijski testovi, dinamički zadatak, povezanost, mišićna sila*