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The predictive value of isokinetic assessment on the explosive strength of the lower extremities

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Abstract

The aim of this study was to determine the connection between the performance of vertical and horizontal jumps and isokinetic force parameters of the knee extensors and ankle joint (plantar flexion) of physically active female students (n = 40). The jump height, and Total work (jump height x body mass) were used as indicators of the vertical jump, while the length of the jump, and Total work (the jump length x body mass) were used as indicators of the horizontal jump. The knee and ankle joint were evaluated on the isokinetic dynamometer at speeds of 60 and 180º/s (knee), 30 and 60º/s (ankle joint). The results indicated that there was no significant correlation ($p<0.05$) between the isokinetic parameters and the length and height of the jump, while a medium to strong correlation exists between the isokinetic and Total work parameters. Multiple regression analysis showed that the isokinetic set of isokinetic parameters accounts for 68% of variance HJTW ($p<0.05$) and 72% of variance LJTW ($p<0.005$). Isokinetic tests on multiple joints and angular velocities can predict the explosive strength of lower extremities when it is impossible to perform a ballistic movement.

Key words: **Isokinetic, explosive strength**

Introduction

Explosive strength, as a motor skill, is one of the determinants of success in all activities that require high expression of muscular force in the shortest amount of time possible (Metikoš et al., 1989; Kreamer and Newton, 1994). The muscle force generated during the explosive activity is not always possible to measure, and also, the manifestations of explosive movements are often limited, e.g. injuries. For these reasons the testing of muscle strength is often conducted in controlled laboratory conditions. As regards to force, isokinetic dynamometers belong to a group of the finest indicators of the real state of the muscles. They are used to obtain objective, easily measurable and comparable results. The advantage over other methods is reflected in the possibility of assessing the dynamic performances of the muscle group responsible for the movement in a particular joint. Peak torque is one of the parameters of muscle activity which is most often analyzed for clinical and research purposes. It represents the greatest muscle force generated at any time during the repetitions (Kovačević, 2009). Isokinetic dynamometer «Biodex3 system» (Biodex Corp, Shirley, NY) whose validity has been confirmed in many studies (Drouin et al., 2004; Holmbäck et al., 1999; Pincivero et al., 1997), was used to assess the ability of muscles, in this case the dynamic stabilizers of the knee and ankle joint. Taking into account the fact that the variability of results is greater in concentric isokinetic testing at higher angular velocities, it is more reliable to use lower angular velocities in order to test strength (Iga et al., 2006; Jianzhong et al., 2000), this was taken into account in this study. Evaluating the amount of the demonstrated force is important, however, due to lack of equipment and the inability to organize laboratory testing, many turn to the usage of functional field tests. The tests most often mentioned as the tests used for assessing explosive strength are primarily the long jump and the high jump. Numerous textbooks, manuals and other publications propose the application of vertical jumping tests to assess explosive muscle strength (Astrand and Rodahl, 1986; Metikoš et al., 1989). Their use has been present in the kinesiology literature, and practice for approximately 90 years. The original description of the high jump technique was described at the beginning of the last century (Sargeant, 1921), while the high jump, that was used to assess the lower extremities explosive strength in this study, was a modified version (Seminick, 1990). The reliability of this test has been proven in previous studies (Carlock et al., 2004; Salles et al., 2010; Ditroilo et al., 2011). Taking into account that the vertical jump is a multiple joint activity and that a close connection can be made between the isokinetic parameters of the participants' joints in the vertical jump, a conclusion can be made that it is necessary to test multiple joints, primarily the knee joint and the ankle joint, in the specific movements needed for the execution of the jump. These are the extension of the knee and plantar flexion at the ankle joint. Besides the high jump, as a means of measuring the explosive strength of lower extremities, the long jump, which was also used, proved to be positively correlated with the vertical jump, the strength of the lower and also the upper extremities (Castro-Piñero, 2010). Based on current findings, these tests do not require much skill, they are highly dependent on muscle strength and provide valid and reliable indicators of the explosive strength of lower extremities (Morriss et al., 2001). The purpose of this study was to verify the relationship between isokinetic strength parameters and functional tests of explosive strength such as a jump. The results of previous studies are inconsistent, according to (DeStaso et al., 1997) the height of a vertical jump can be predicted with a set of isokinetic parameters, however, on the other hand Atabek et al. (2009) and Anderson et al. (1991) belong to a group of researchers according to whom a set of isokinetic parameters cannot predict the height of the vertical jump.

The relationship between functional tests and strength parameters and the results of isokinetic testing was the subject of studies of many authors who have come to different conclusions (Table 1). The variability of results in previous studies could be explained by the fact that the maximal isokinetic torque changes with sex and age (Neder et al., 1999).
They are:

Methods

The subjects

Subjects for this study were 40 healthy, physically active females, students of the Faculty of Sport and Physical Education, aged 19-25 years. The average height - 168.06 ± 4.85; average weight - 61.26 ± 6.81

None of the selected subjects had any history of lower extremity injuries in the last two years.

Sample of variables

KEPT60R - Knee extensions - Peak Torque - 60°/s - Right
KEPT60L - Knee extensions - Peak Torque - 60°/s - Left
KEPT180R - Knee extensions - Peak Torque - 180°/s - Right
KEPT180L - Knee extensions - Peak Torque - 180°/s - Left
PFPT30R - Plantar Flexion - Peak Torque - 30°/s - Right
PFPT30L - Plantar Flexion - Peak Torque - 30°/s - Left

Author	The subjects	Peak Torque of the knee and the vertical jump	Peak Torque of the ankle joint and the vertical jump	Peak Torque of the knee and the horizontal jump
Bosco et al.	12 male athletes	0.71**		
Binet et al.	22 years old and older fit football players	0.64**		
Almuzaini and Fleck	38 physical education students, volunteers	0.363*		0.503**
Tsiokanos et al.	29 male students	JH – 0.49** JW – 0.739**	JH – 0.468* JW – 0.375*	
Gerodimos et al.	180 12-17 years old basketball players	0.61**	0.61**	
Wilson, Murphy	30 active healthy subjects	0.5-0.73		
Saliba, Hrysomallis	19 subelite AF players	0.55 – 0.69*		
Maly et al.	14 male soccer players	0.12		
Blackburn & Morrissey	20 uninjured female subjects	0.097		0.070
Atabek et al.	21 healthy young male	Vertical jump height was not significantly correlated with the isokinetic parameters		
Anderson et al.	39 male athletes	Multiple regression - no combinations that predict vertical jump		

** - Significance at p<0.05; ** - Significance at p<0.01*
(JH – The height of the jump; JW – Jump „Total work")
Table 1.

PFPT60R - Plantar Flexion - Peak Torque - 60º/s - Right
PFPT60L - Plantar Flexion - Peak Torque - 60º/s - Left
LJ - Long Jump
LJTW - Long Jump - Total Work - according to the formula: TW = Long jump (m) * Body mass (N) (English et al., 2006)
HJ - High Jump
HJTW - High Jump - Total Work - according to the formula: TW = High jump (m) * Body mass (N) (Tsiokanos et al., 2002)

Functional testing

First, the subjects' height of reach was measured. After applying chalk on the fingertips, each subject had 3 attempts at a maximum vertical jump. Between the jumps they each had a one minute break. The highest fingerprint was taken into account (Almuzaini and Fleck, 2008). The height of reach was subtracted from that result providing an accurate jump height, expressed in centimeters (Anderson et al., 1991). They were instructed to jump vertically so as to land in the same position and at the same place from takeoff to avoid lateral or horizontal displacement (Yamauchi and Ishii, 2007).

The subjects were given standardized instructions on the long jump from a standing position, they were allowed to jump up from the position with bent knees, and that they can swing their arms. The distance between the starting line of the foot prints on the mat that is closest to the takeoff place, expressed in centimeters, represents the length of the jump. Each subject had 3 attempts, the best one was taken into account (Almuzaini and Fleck, 2008).

Isokinetic testing

1. Musculoskeletal screening
2. General body stretching and warm
3. Setting the optimal stabilization of the subjects
4. Aligning the joint and the axis of the dynamometer rotation
5. Verbal introduction to the isokinetic concept of exercises
6. Correction of gravitation (knee)
7. Warm-up (3 submaximal, 1 maximal repetition)
8. The maximum test at a test speed; knee - 60 and 180º/s; ankle - 30 and 60°/s (3 repetitions)
9. Testing of the contralateral extremity

Statistical analysis

Based on the previous authors who have dealt with this issue, this study used the Pierson correlation coefficient (Iossifidou et al., 2005; English et al., 2006), and also the standard multiple regression (Anderson et al., 1991; DeStaso et al., 1997).

Results

Table 2 presents the descriptive characteristics for the set of variables of isokinetic and functional testing.

Table 3, in which the correlation between functional tests and isokinetic parameters of the lower extremities is shown, it is evident that none of the isokinetic indicators of strength have any statistically significant correlation with the height and length of the jump (cm), while, in the case of Total Work indicators, explained in section "Sample of variables", there is a medium to strong positive correlation with the peak torque during the knee extension and the plantar flexion of both legs.

Table 2. Descriptive characteristics for the set of variables of isokinetic and functional testing

Descriptive Statistics							
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
BH (cm)	40	158.5	176.5	167.488	4.6278	-.102	-.901
BW (kg)	40	46.5	75.0	60.313	6.6010	.119	-.563
HJ (cm)	40	28	49	39.20	4.724	-.162	-.286
LJ (cm)	40	170	227	196.68	13.201	-.139	-.497
HJTW (Nm)	40	181.8	309.0	230.862	30.6313	.288	-.276
LJTW (Nm)	40	889.5	1500.9	1161.683	134.0290	.450	.149
KE60R (Nm)	40	105.1	197.6	148.568	20.6261	.272	.251
KE60L (Nm)	40	104.2	205.0	147.313	26.1600	.540	-.314
KE180R (Nm)	40	67.7	135.4	104.450	15.1570	-.239	.133
KE180L (Nm)	40	61.8	138.1	105.792	16.9789	-.379	.044
PF30R (Nm)	40	56.6	148.3	107.008	24.4011	-.267	-.607
PF30L (Nm)	40	45.9	155.6	102.575	27.0621	-.232	-.383
PF60R (Nm)	40	40.8	133.6	93.857	23.6388	-.316	-.607
PF60L (Nm)	40	48.5	134.8	93.028	19.4431	-.075	.354

Table 3. Correlation betwaeen functional tests and isokinetic parameters of the lower extremities

Correlations											
	LJ	HJTW	LJTW	KE60R	KE60L	KE180R	KE180L	PF30R	PF30L	PF60R	PF60L
HJ	.592**	.617**	.015	.011	.083	.090	.195	.182	.064	.269	.041
LJ		.361*	.362*	.204	.266	.168	.287	.276	.128	.208	.141
HJTW			.711**	.361*	.514**	.358*	.452**	.504**	.467**	.542**	.374*
LJTW				.520**	.659**	.436**	.490**	.522**	.524**	.437**	.372*
KE60R					.849**	.772**	.681**	.374*	.501**	.277	.314*
KE60L						.771**	.803**	.447**	.556**	.331*	.281
KE180R							.885**	.332*	.502**	.251	.329*
KE180L								.381*	.567**	.307	.340*
PF30R									.811**	.900**	.615**
PF30L										.780**	.748**
PF60R											.718**
** Correlation is significant at the 0.01 level (2-tailed).											
* Correlation is significant at the 0.05 level (2-tailed).											

Isokinetic parameters, included in the standard multiple regression, were not predictive for the height of the vertical and the length of the horizontal jump at a satisfactory level of significance ($p<0.05$). Namely, when it comes to high jump, the connection with a set of isokinetic parameters has shown a level of significance far greater than the set one ($p = 0.113$), while for the long jump it could be said that the it is on the limit of significance ($p = 0.054$). The display of multiple standard regression for variables HJ and LJ will be presented in table 3 (a and b).

As opposed to that, when it comes to the work that was done in the vertical (HJTW) and horizontal (LJTW) jump, standard multiple regression analysis showed that the isokinetic set of variables, that included the values of peak torque exerted at a speed of 60 and 180°/s for the knee and 30 and 60°/s for the ankle joint, explained 68% of variance HJTW ($p<0.05$) and 72% of variance LJTW ($p<0.005$). Regression analysis of HJTW and LJTW are shown in Table 4 (c and d).

a)

Model Summary							
Model		R	R Square	Adjusted R Square	Std. Error of the Estimate	F	Sig.
dimension0	1	.564[a]	.318	.143	4.375	1.810	.113[a]
a. Predictors: (Constant), PF60L, KE60L, PF30D, KE180D, KE60D, PF30L, KE180L, PF60D							
b. Dependent Variable: HJ							

b)

Model Summary							
Model		R	R Square	Adjusted R Square	Std. Error of the Estimate	F	Sig.
dimension0	1	.603[a]	.364	.200	11.810	2.216	.054[a]
a. Predictors: (Constant), PF60L, KE60L, PF30R, KE180R, KE60R, PF30L, KE180L, PF60R							
b. Dependent Variable: LJ							

c)

Model Summary							
Model		R	R Square	Adjusted R Square	Std. Error of the Estimate	F	Sig.
dimension0	1	.681[a]	.464	.326	25.1468	3.358	.007[a]
a. Predictors: (Constant), PF60L, KE60L, PF30R, KE180R, KE60R, PF30L, KE180L, PF60R							
b. Dependent Variable: HJTW							

d)

Model Summary							
Model		R	R Square	Adjusted R Square	Std. Error of the Estimate	F	Sig.
dimension0	1	.724[a]	.524	.401	103.7643	4.258	.002[a]
a. Predictors: (Constant), PF60L, KE60L, PF30R, KE180R, KE60R, PF30L, KE180L, PF60R							
b. Dependent Variable: LJTW							

Table 4

Discussion

The results of this study show that there is no correlation ($p<0.05$) between peak torque of the knee and ankle joint muscle force and absolute measures of the vertical jump height, Pierson correlation coefficient values ranging .01 - .27, and the length of the horizontal jump, Pierson correlation coefficient values ranging .13 - .29. Similar results were obtained by previous researchers (Atabek et al., 2009; Anderson et al., 1991) who found insignificant ($p<0.05$) correlation coefficients between the height of the vertical jump and peak torque extension of the knee, at the angular velocity of 60º/s. These results also confirm the results obtained by Genuario Dolgener (1980), Blackburn and Morrissey (1998), and Maly et al. (2011), however, they are opposite to the results obtained by Bosco et al. (1983) and Petschnig et al. (1998).

Maly et al. (2011), for example, have come up with results that show that the correlation between the height of the vertical jump and peak torque extension of the knee of the dominant leg, at a speed of 60º/s, was .12, which largely concurs with our findings that these values are .08 for the left and .01 for the right leg.

When it comes to the ankle joint, the findings do not deviate from some previous studies. The Pierson correlation coefficient in this study, when it comes to the set of isokinetic variables and HJ, are ranging from .04 - .27, and .13 - .28, when it comes to LJ, statistically insignificant ($p<0.05$), are very similar to the results obtained by Genuario and Dolgener, according to which Pierson's correlation coefficient between peak torque of plantar flexion and vertical jump height has a value of .17 - .42. However, in contrast to these results, Tsiokanos et al. (2002) obtained, although small, statistically significant correlation between the vertical jump height and plantar flexion. In their study, these results had a value of .46 ($p<0.05$).

Taking into consideration the correlation strength, Tsiokanos et al. (2002), concluded that there is a very small importance of individual isokinetic strength testing when one wishes to estimate the height of the vertical jump. This thesis was confirmed by our results.

However, using the formulas of previous researchers that provide Total Work, the coefficient of correlation between isokinetic and jump parameters is increased. As for the normalized values, as it can be seen in Table 3, between them and all of the 8 peak moments of force there are, on two levels, statistically significant ($p<0.05$, $p<0.01$), medium to strong correlations. Thus, between the peak moments of force of the knee muscle and ankle joint and the normalized values of the vertical jump, the correlation coefficient was in the range of .36 - .54, and the normalized values of the horizontal jump, where the range of values of the correlation coefficient was .37 - .66.

Of course, it is necessary to mention that the research carried out by Tsiokanos et al. (2002) the jump height (cm), was in a stronger positive correlation with the plantar flexion (.459, $p<0.05$) than the Total Work (.375, $p<0.05$), expressed in kpm (1 kpm č 9.81 Nm).

The values that we obtained through multiple regression analysis are not different from the previous ones. As in our study, Anderson et al. (1991) did not get statistically significant predictors of the height and length of the jump. Namely, our results, according to which a set of isokinetic variables predicts 56% of the variance for the HJ variable and 60% for the LJ variable, were not statistically significant (<0.05).

However, with the product of height and jump length and body mass, that is Total Work, higher regression coefficients were obtained for both the high jump (HJTW) and long jump (LJTW). The set of isokinetic variables predicts 68% of the variance for the variable HJTW ($p<0.05$) and 72% for variable LJTW ($p<0.01$). These results are much higher than in some previous studies. For example DeStaso et al. (1997) using Stepwise linear regression came to an equation that predicts 44% of the variance ($p<0.01$) of countermovement jump. Still, nevertheless, they perfectly match the results that were obtained by Tsiokanos et al., where the regression coefficients range from 65% to 75%. This finding provides confirmation that the work carried out during a jump can be used as an indicator for the possibility of a jump when the jump itself is being predicted through maximal isokinetic force.

Since this increase of the correlation coefficient was obtained by the inclusion of the body mass in the equation, a conclusion can be made that this formula is a better indicator of the explosive strength of the lower extremities. Assuming that the two subjects have the same jump height, the one who has a higher load, that is, a higher body mass has greater explosive force.

Regression analysis has shown that there exists a strong multiple correlation between the normalized values of the vertical and horizontal jump, presented in the previous studies as Total Work, and the linear combinations of peak moments of the torque generated in the knee joint and ankle joint.

However, for this formula to be valid, it is important to note that the isokinetic tests have to be carried out on more joints and more angular velocities.

According to Hoffman's division of the correlation coefficients (2006) it can be concluded that the isokinetic parameters, measured individually on the right and left leg, have a moderately strong correlation, when it comes to the dynamic knee stabilizers, and no correlation to a weak one, when it comes to dynamic stabilizers of the ankle joint in vertical jumps. It can also be concluded that the correlation of the isokinetic parameters of the dynamic knee stabilizer is stronger in horizontal jumps, so it is moderate to strong, while the peak torque of the ankle joint, although at the same level, has slightly lower correlation coefficient than the one in vertical jumps.

Medium to strong correlation and regression coefficients indicate that there is a close connection between the maximum torque of the knee and ankle joint and jumps.

Conclusion

Based on the presented results it can be concluded that isokinetic testing has its purpose in predicting the explosive strength of lower extremities, provided that relative-normalized values are taken into consideration. Namely, not a single separate isokinetic parameter has significant correlation coefficient with the manifestations of explosive strength such as a jump expressed in absolute units of measurement. Taking into consideration that the enormous advantage of the isokinetic test over all other forms of testing lies in the fact that with this type of resistance there is no load on the active joint (Desnica-Bakrač, 1999), and that the isokinetic dynamometer is the only safe way to dynamically load the muscle to its maximum potential through the whole amplitude of movements, these results can be useful in the early stages of rehabilitation, especially when the patient is unable to perform a maximum jump. The predictive strength of the model used in this testing is stronger than in the former ones (Van Oteghen 1975; Bosco et al., 1983; DeStaso et al., 1997), indicating that this method can be used to predict the possibility of vertical and horizontal jumps, with relatively reliable results, of physically active women. In addition to this, it is important to note that, since the maximal isokinetic torque changes with sex and age (Neder et al., 1999) and so there may be deviations from this method when it comes to a different sample of subjects.

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