EFFECTS OF MAXIMUM ISOMETRIC CONTRACTION ON EXPLOSIVE POWER OF LOWER LIMBS (JUMP PERFORMANCE)

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Abstract
The aim of the research was to determine acute effects of maximal isometric contraction on explosive power of lower limbs (jump performance). Nine elite senior tennis players were taken as sample examinees for this research. Tennis players from this group had not had any severe injuries of trunk and lower limbs in the last six months. To assess explosive power, this research used variables for assessment of vertical and horizontal component of explosive power (high jump and long jump). Maximum isometric concentric contraction was used in a semi-squat exercise as an operator for stimulation of post-activation potentiation. There is a statistically significant difference with control variable of a vertical jump between a pre-activation and a post-activation attempt after time period of 60 and 90 seconds. With other control variable - horizontal jump - there is no statistically significant difference between a pre-activation and a post-activation jump.
Key words: *post-activation potentiation, contrast methods, tennis players*

INTRODUCTION

Scientists constantly search for new methods in sport which would improve training process and enable a sportsman to achieve a higher level of functioning and top results. Primary factor of success in many fields of sport is explosive strength. According to Marković (2008), explosive strength is defined as an ability to produce maximum muscle force in shortest possible period. Explosive strength is one of limiting factors in most mono-structural and complex sports. Therefore, we can conclude that it is very important to improve training technology which deals in improvement of explosive strength and exploiting of sportsmen's potential. New training technology should be oriented towards development of explosive strength and it should affect it as fastest and as effective as possible. It is known that explosive strength has a high coefficient of genetic determination, which underlines a need for a method or a set of methods which could contribute to application of existing potential and improve results in realization of speed – explosive activities. A contrast method and contrast training were established by Russian and Bulgarian coaches in the 60s in the previous century. In one training, small and large load are changing and large load precede small load (Ebben, 1998). Chu (1996) claims that strength increased through complex training load is up to three times more effective than application of traditional training methods. One of ways which could possibly contribute to improvement of training process is post-activation potentiation (PAP), which could be more integrated into the training process itself.

According to Verhoshanski (1974), the effect after various activities is changed depending on order and it can reflect the quality of obtained strength. One exercise with maximum muscle contraction before certain jumps has more influence on explosive power then in the inverted order of realization of the task. The reason of this phenomenon is post- activation potentiation (PAP), which means that muscle force is acutely increased after maximum muscle activity as well as explosive moves. Sale (2002) concluded that post-activation potentiation that appears in several seconds to several minutes improves muscle ability to generate maximum muscle force and to generate force in an explosive way. Post-activation potentiation can increase force gradient at high frequencies of activity of motor units, which can increase acceleration. Mechanisms that initiate PAP are still being researched. One common theory of PAP mechanism includes a concept of myosine light chain phosphorylation, where actin-myosine interaction is more sensitive on releasing of Ca2+ from sarco lasmatic reticulum - Sale (2002). Answers to this question can contribute to clarification of acute transformation issue. We can conclude that most researches are related to appearance of post-activation potentiation and they are realized with application of maximum contraction as pre-activation of explosive strength of lower limbs. This showed statistically significant values and that PAP effect was defined after maximum isometric or dynamic contraction in one treatment. The problem of functioning is contained in a question whether maximum isometric pre-activation has a positive influence on horizontal and vertical component of explosive power. Therefore, the aim of the research was to determine acute effects of maximal isometric contraction on explosive power of lower limbs (jump performance).

METHODS

Participants

In this research participants were nine elite senior tennis players. All of examines were timely informed about the nature of this research. Examinees who

participated in the research were completely healthy and they had not had any serious injuries of trunk and lower limbs in the last six months. All of the examinees had previous experience in strength training, plyometric jump training and testing of vertical and horizontal component of explosive power. Chronological age of examinees was 22,5 ± 2,4 years on average, while average number of years of experience in sport was 13,1 ± 2,8 years, at the level of the group. Morphologic variables show that average body weight at the level of the group was 80,8 ± 6,6 kilos, while average body height for the complete group was 181,6 ± 5,2 centimeters.

Instruments

Morphologic variables:

- Body height - BH
- Body weight - BW
- Body mass index - BMI
- Age - AGE
- Tennis experience - TE
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Note: selected variables from the field of morphologic status are taken to define certain morphologic characteristics of selected entities in a better way, as well as factors related to chronological age and (tennis experience) time spent in this sport activity (tennis) and give a precise and clear picture of characteristics of a selected sample.

Control variables:

Control variable - Squat jump

This is a vertical jump of concentric type and a test for an assessment of a vertical component of explosive power of lower limbs. We obtain jump height on a basis of a difference between reached height and height achieved after the squat jump.

VJ-I - vertical jump initially (conducted before maximal isometric contraction)
VJ-F1 - first vertical jump final (conducted 30seconds after maximal isometric contraction)
VJ-F2 - second vertical jump final (conducted 60 seconds after maximal isometric contraction)
VJ-F3 - third vertical jump final (conducted 90 seconds after maximal isometric contraction)

Control variable – Standing long jump

A test for an assessment of a horizontal component of explosive power of lower limbs. One measures a length of jump from standing position to landing position on a mattress marked with centimeters.
SBJ-I - first standing board jump initial (conducted before maximal isometric contraction)
SBJ-F1 - first standing board jump final (conducted 30seconds after maximal isometric contraction)
SBJ-F2 - second standing board jump final (conducted 60 seconds after maximal isometric contraction)
SBJ-F3 - third standing board jump final (conducted 90 seconds after maximal isometric contraction)

Testing procedure

A complete testing procedure happened in the period of three days (Table 1). In those three days the examinees realized testing according to a previously created protocol. Testing lasted for about 60 minutes daily. To examine influence one preformed maximum isometric contraction with a maximum semi-squat as an activator exercise, which, in authors' opinion should cause effects of post-activation potentiation.

Table 1 Testing procedure and protocol

1st day	Measuring anthropometric characteristics	Aerobic running	Dynamic stretching	Testing vertical and horizontal component of explosive power
Extensity	5 minutes	10 minutes	5 minutes	5 minutes
2nd day	Aerobic running	Dynamic stretching	Maximum isometric pre-activation	Testing vertical component of explosive power
Extensity	10 minutes	5 minutes	6 seconds	90 seconds
3rd day	Aerobic running	Dynamic stretching	Maximum isometric pre-activation	Testing horizontal component of explosive power
Extensity	10 minutes	5 minutes	6 seconds	90 seconds

Activation (maximum isometric contraction) in semi-squat

An examinee stands on a specially designed platform with adjustable chain length, taking a position of a semi-squat where lower and upper leg are positioned in the angle of 90°. This position, thank to adjustability of the length of the chain, is set individually for each of examinees. The examinee performs maximum static contraction against vertically set metal bar placed in the upper part of the back also performing maximum static contraction against immovable load, as illustrated in Picture 1. Maximum isometric contraction was performed for six seconds.

Picture 1 – Maximum isometric pre-activation in semi-squat

Data processing methods

Data were processed by the statistical software package SPSS 12.0 for Windows. Central and dispersive parameters were calculated for the both measurements. Univariate changes were tested by a series of t-tests for dependent samples.

RESULTS

Table 2 represents descriptive parameters (range, minimum, maximum, mean, standard deviation) of all tested variables, vertical and horizontal jumps before and after application of maximal isometric contraction. No significant variability can be observed with tested jumps.

Table 2 Descriptive parameters of all tested variables

Variables	N	Range	Min	Max	Mean	Std. Dev
VJ-I	9	16,7	36,0	52,7	48,578	5,0413
VJ-F1	9	14,0	40,5	54,5	49,233	4,8192
VJ-F2	9	14,5	41,5	56,0	50,756	4,9838
VJ-F3	9	17,3	40,0	57,3	51,400	5,0995
SBJ-I	9	228,0	206,0	434,0	278,311	86,5841
SBJ-F1	9	217,1	215,9	433,0	277,789	85,6236
SBJ-F2	9	217,5	214,5	432,0	278,978	84,6340
SBJ-F3	9	218,2	216,8	435,0	282,500	83,6193

Table 3 shows results after a t–test for small dependent samples for a variable of vertical jump (semi-squat jump) which clearly indicate related t values, static significance of differences among arithmetic mean of formed pairs of variables from initial (pre-activation) measuring, and results of final (post-activation) jumps with a time interval of performance of 30, 60 and 90 seconds after application of maximum isometric contraction in a semi-squat. On a basis of obtained data, it is possible to claim that expected differences at a statistically significant level took place on pairs of variables under number 2 and 3, which is visible from values of coefficients of statistical significance (pair2 0,04 and pair3 0,00).

Table 3 Results of t-test for variables of explosive power of vertical type

PAIRS	VARIABLES	Paired Differences 95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
		Lower	Upper			
Pair 1	VJ-I VJ-F1	-2,7715	1,4604	-,714	8	,495
Pair 2	VJ-I VJ-F2	-4,3069	-,0487	-2,359	8	**,046**
Pair 3	VJ-I VJ-F3	-4,4894	-1,1550	-3,904	8	**,005**

Table 4 shows results of t-test for small depending samples of variables of a long jump which show related values, statistical significance of differences of arithmetic mean of the initial (pre-activation) jump and final (post-activation) jumps with time intervals of 30,60 and 90 seconds after maximum isometric pre-activation. An insight in the table enables us to conclude that there are not any statistically significant differences in any of the pairs of selected variables between jumps of pre-activation and post-activation phase, in regard to values of coefficients of statistical significance of differences at the selected level of p=0,05. Simply saying, it is possible to be 95% sure and claim that there were not any statistical differences between selected jumps in the pre-activation and post-activation phase.

Table 4 – Results of t-test for variables of explosive power of horizontal type

PAIRS	VARIABLES	Paired Differences 95% Confidence Interval of the Difference		t	Df	Sig. (2-tailed)
		Lower	Upper			
Pair 1	SBJ-I SBJ-1	-6,9871	8,0316	,160	8	,877
Pair 2	SBJ-I SBJ-2	-4,4225	3,0892	-,409	8	,693
Pair 3	SBJ-I SBJ-3	-10,2428	1,8650	-1,596	8	,149

On a basis of obtained results one can conclude that maximum isometric contraction in the semi-squat exercise as an activator exercise caused a positive growth of effects visible through achievement of better results in post-activation jumps

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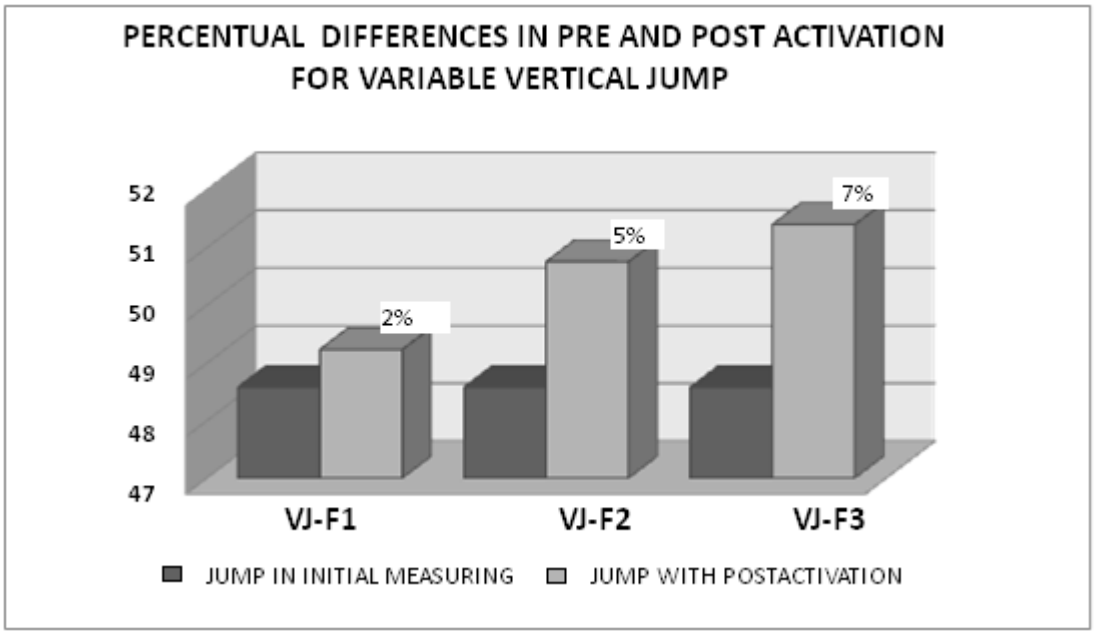


Graph 1 –Differences in pre and post activation for variables of standing high jump in percents

The graph shows differences in mean value of achieved height of jumps with and without maximum isometric pre-activation shown in percentage. Analyzing data one can conclude that there is a significant difference of 2,17cm or 5% on the second, and 7% or 2,8 cm on the third jump. This confirms that there is the effect of post-activation potentiation.

Similar results are found in a research by Verhosanski from 1974, who also used a maximum isometric semi-squat of 6 seconds as an activation exercise. There were statistically significant differences between pre-activation and post-activation jumps. Namely, this study researched the difference between maximum vertical pre-activation jump and the same post-activation jump after a break of 1 or 5 minutes. Obtained results show that post-activation jumps differ from pre-activation ones for 3 % after a break of 1 minute and 5% after a 5- minute break.

In a study that examines effects of post-activation potentiation on maximum willing isometric contraction on a basis of electromiographic measuring Baudry and Duchateau (2007) confirm existence of positive post-activation effects and increased electro muscle activity after maximum pre-activation. These observations suggest that PAP can be concerned as a mechanism that can influence our daily activities during contraction and can be used for improvement of muscle performance in explosive sports.

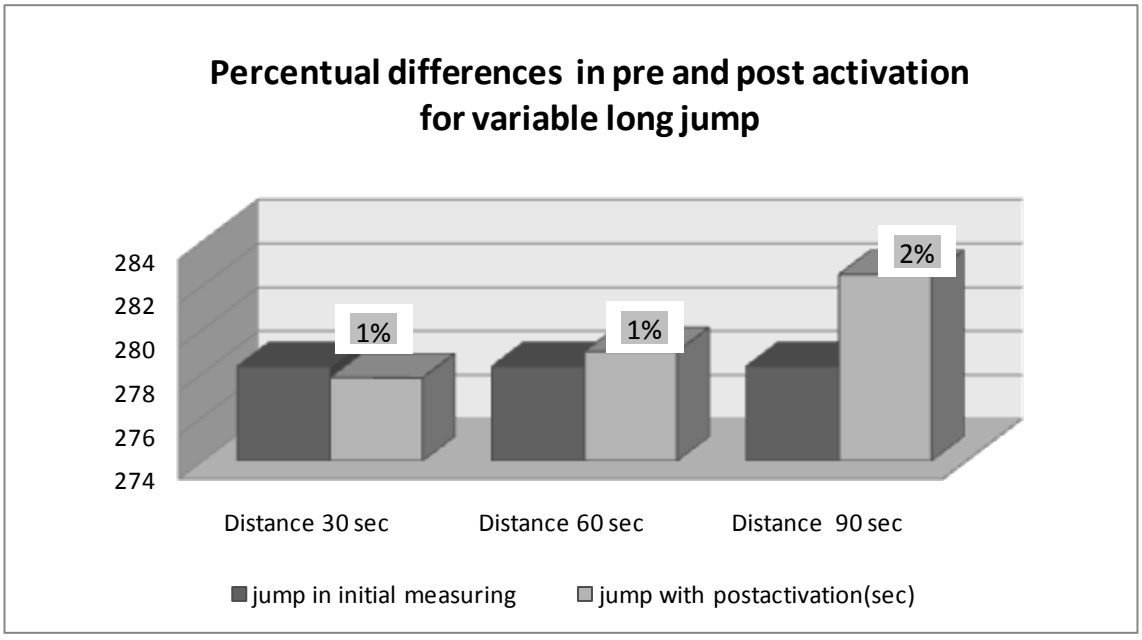
Various authors (Chui 2003, Duthie 2002, Hamada 2000) achieved various results in regard to existence and effects and size of effects of post-activation potentiation. Gregov et al. (2006) conclude that appearance of PAP is not questionable, but training conditions in which it arises are not fully known. Similar effects of post-activation potentiation but with different activation exercise that reflects in maximum dynamic regime of muscle contractions were achieved by: Young et al. (1998), Webber at al. (2008) and Babajić (2010).

Babajić's research (2010) which used maximum parallel back squat as an activating exercise showed similar result. It is noted that there were statistically significant differences between formed pairs of variables and jumps performed in pre-activation phase and post-activation phase of squat jump variable after the third and the fourth jump in the time period after 60 seconds and 90 seconds. A reply to absence of a statistically significant difference on pair 1 between variables (VJ-I/VJ-F1) can be searched in fatigue, as one of acute effects which existence was defined in numerous similar researches and which result from previous maximum load and maximum isometric muscle contraction in the activation exercise.

Weber et al. (1998) also noted a positive effect of post-activation jump after heavy sub-maximal parallel squat in regard to pre-activation jump. In this research there was a short-term improvement of vertical jump so that one can conclude that heavy load can cause acute improvement of jump performance.

In a research of Young et al. (1998) they examined effects of various protocols of warming up, and they also underlined improvement of vertical jump for 2,8% after submaximum load in regard to pre-activation jump. The conclusion is that warming up protocol which includes semi-squat with submaximum load and explosive performance can be used for a short-term improvement of vertical jump performance.

Results from the second control variable which concerned performance of long distance jump show that there were not any statically significant differences between jumps in pre-activation and post-activation phase but in all of the three post-activation jumps there was a better average result in post-activation phase in relation to the equivalent pair from pre-activation phase. An analysis of the results presented in table 2 shows that there is not any statistically significant difference in any of formed variable pairs. This is supported by values of coefficients related to statistically significant difference (pair1 0,87 / pair2 0,69 / pair3 0,14).



Graph 2 Quantitative differences in pre-activation and post-activation for variable long jump

Obtained results underline the fact that an operator or maximum isometric pre-activation in a semi-squat did not cause any statistically significant differences, according to author's presumptions. Graph 2 clearly shows differences in arithmetic mean expressed in centimeters and in percentage. Structure of performance of maximum isometric pre-activation which is realized in semi-squat differs in regard to the control variable of long jump. In this case, an examinee performs maximum isometric towards vertical direction which is different from the control variable which is realized in horizontal direction. This is one of possible explanations why there were not any statistically significant differences with control variable long jump. We find similar results in other researches where a pre activation exercise is structurally different from a control variable. In a research where a parallel back squat was a pre activation exercise there was not any significant effect on realization of sprint, but there were statistically significant differences in realization of a high jump. The author quotes that a parallel back squat with more or less factors is more similar to the structure of moving that appears during performance (of a semi-squat jump) as the second control variable where post-activation potentiation effect actually appeared (Babajić, 2010). If exercising on training is more concurrent with tasks of moving that should be realized within a frame of specific moving activity it is more likely that a positive transfer would happen (Sale, 1991). However, these are only presumptions and logical thinking resulting from obtained results which leave space for future researches.

CONCLUSION

Results obtained from this research indisputably confirm existing of post activation potentiation as a phenomenon that appears when an exercise of speed-explosive character is preceded by maximum load which is identical to performance of the main exercise by structure. However, this research confirms that effects of PAP differ in regard to structure of pre-activation exercise and control variable. Also, necessary time between pre-activation and appearance of PAP is still questionable. However, it is evident that effects appear in the interval from 60 to 90 seconds after pre-activation. According to the obtained results of the research we can conclude that there is a statistically significant difference with individual control variables. With control variable vertical semi-squat jump (vertical component of explosive power) there is a statistically significant difference in results after influence of an operator and maximum isometric pre-activation.

Examining effects of PAP in order to emphasise performance of strength and speed, one has to resolve two dilemas. First, an intensive and extended conditioning activity can activate PAP mechanism more, but it also produces more fatigue. The second dilema is that when recuperation between a conditioning activity and commence of performance is longer, then decaying of PAP mechanisam is huger. These two dilemas can be resolved only through attempts and mistakes. Potentiation, fatugue recuperation and super compenzation are mechanisms that have to be taken into consideration in an analysis of body reaction to load. It is noticeable in this research that with a control variable vertical jump 30 seconds after pre-activation there is no statistically significant difference, which most probably is a consequence of acute fatigue.

With the second control variable horizontal jump (horizontal component of explosive power) there was not any statistically significant difference. Since huge load in a similar move towards structure of performance of a certain exercise improves maximum strength and force of experienced sportsmen in a similar moving activity, one could assume that post-activation potentiation related to severe pre-load has a potential to increase additional performance of activities where similar moves are performed. According to the obtained results we can conclude that with implementation of maximum isometric pre-activation in a uniquely constructed warming up protocol based on a principle of a contrast training enables a possibility of an improved performance before a competition where there is expression of speed - power characteristics.

REFERENCES

1. Babajić, F., Pojskić, H., Kovačević, E., Pašalić, E. (2010). Aplikacija maksimalnog predopterećenja radi poboljšanja brzinsko eksplozivnih svojstava sportaša. [The application of maximal preload with purpose of improving speed and explosive power of athletes] Proceeding book of VIII annual international conference "Conditioning preparation of athletes" Zagreb, Croatia, (page. 450-463).
2. Baudry, S., Duchateau, J. (2007). Effect on the rate of torque development of tetanic and voluntary isometric contractions. Journal of Applied Physiology, 102: 1394–1401.
3. Chiu, L.Z.F., Fry, A.C., Weiss, L.W., Schilling, B.K., Brown, L.E., Smith, S.L. (2003). Postactivation potentiation response in athletic and recreationally trained individuals. Journal of Strength and Conditioning Research, 17: 671-677.
4. Ebben, W.P., & Watts, P.B. (1998). A review of combined weight training and plyometric training modes: Complex training. Journal of Strength and Conditioning Research, 20: 18-27.

5. Gregov, C., Jukić, I., Marković, G. (2005). Akutni efekti primjene eksplozivnih dinamičkih kontrakcija na manifestaciju eksplozivne snage tipa bacanja. [Acute effects of applied explosive dynamic contractions on throwing performance] Proceeding book of XV annual international conference "Summer school of Croatian Kinesiologists " Poreč, Croatia
6. Zbornik radova 15. Ljetna škola kineziologa Repubike Hravatske. Zagreb (str. 121 - 125).
7. Hamada T., Sale D.G., MacDougall J.D. (2000). Postactivation potentiation in endurence-trained male athletes. Medicine & Science in Sports & Exercise. 32:402-411.
8. Marković, G. (2008.). Jakost i snaga u sportu (Strength and Power in Sport): Proceeding book of VI annual international conference "Conditioning preparation of athletes" Zagreb, Croatia, (page. 19-22.)
9. Sale, D.G. (2002). Postactivation potentiation:role in humen performance. Exercise in sport science reviews, Vol. 30, Issue (3): 138-143.
10. Verhoshansky, J., Adem K. (1974). Grundlagen des speziellen Krafttrainins im Sport. Bartels und Wernitz, Berlin.
11. Weber, K.R., Brown, L.E., Coburn, J.W., Zinder, S.M. (2008). Acute effects of heavy-load squats on consecutive squat jump performence. Journal of Strength Conditioning Research, 22(3): 726-730.
12. Young, W.B., Jenner, A. & Griffiths, K. (1998). Acute enhancement of power performance from heavy load squats. Journal of Strength Conditioning Research, 12, 82-84.

EFEKTI MAKSIMALNE IZOMETRIČKE KONTRAKCIJE DONJIH EKSTREMITETA NA EKSPLOZIVNU SNAGU TIPA SKOKA

Originalni naučni rad

Sažetak
Cilj ovog istraživanja predstavlja utvrđivanje veličine razlika neposrednih efekata nakon aplikacije maksimalne izometrijske kontrakcije paralelnog na manifestaciju eksplozivne snage tipa skočnosti. Devet elitnih tenisera seniorske kategorije činili su uzorak ispitanika u ovom istraživanju. Teniseri koji pripadaju ovoj grupi u prethodnom periodu od šest mjeseci nisu imali ozbiljnije povrede trupa i donjih ekstremiteta. Za procjenu vertikalne i horizontalne komponente eksplozivne snage korišteni su skok u vis iz polučučnja i skok u dalj iz mjesta. Kao operator za stimulisanje postaktivacijske potencijacije korištena je maksimalna izometrička koncentrična kontrakcija u vježbi polučučnja. Postoji statistički značajna razlika kod kontrolne varijable vertikalnog skoka iz polučučnja između predaktivacijskog i postaktivacijskog pokušaja i to nakon vermenske distance od 60 i 90 sekundi. Kod druge kontrolne varijable, odnosno, horizontalnog skoka ne postoji statistički značajna razlika između predaktivacijskog i postaktivacijskog skoka.
Ključne riječi*: postaktivacijska potencijacija, kontrastna metoda, teniseri*

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