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THE EFFECTS OF CONCENTRIC ISOKINETIC TRAINING ON JUMPING PERFORMANCE

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Abstract

The aim of this study was to determine the effects of lower extremity concentric isokinetic training on explosive strength in jumping performance, and compare results with those of conventional and unconventional methods. The sample was consisted of 30 healthy, physically active female students from the Faculty of Sport and Physical Education, age 19 to 25, and they conducted a 4-week (3 times a week) progressive leg strength training on isokinetic dynamometer. The reciprocal concentric knee flexor and extensor contractions were used, as well as plantar and dorsal flexion at different angular speeds. The results show statistically significant ($p<0,001$) improvement in the long jump performance of 13,6cm, or if represented in percentage 7,21%, and the improvement in the high jump by 3,82cm or 10,18%. We came to an overall conclusion that lower extremity concentric isokinetic training can result in the significant transformational effects on explosive strength in jumping performance, including both of its components, horizontal and vertical. Also, it points out that the effects are sometimes similar or even better than the other conventional and unconventional training methods intended for the explosive strength and jump performance development.

Introduction

As a type of motor ability, the explosive strength represents one of the determinants of success in all the activities which demand the use of great muscle force for the shortest time unit (Metikoš et al., 1989; Kreamer & Newton, 1994).

The most commonly used tests in evaluating the explosive strength in jumping performance are high jump and long jump. A number of books, manuals and other publications suggest the use of vertical jump tests when evaluating the muscle explosive strength (Astrand & Rodahl, 1986; Metikoš et al., 1989), present in the literature regarding kinesiology and in practice for more than 90 years. The first jump technique was defined at the beginning of the last century (Sargeant, 1921), whereas the high jump technique, used in this study for the purpose of evaluating the explosive strength of the lower extremities, represents a modified version (Seminick, 1990; Marković et al., 2004), which are proven to be reliable by the previous studies. (Carlock et al., 2004; de Salles et al., 2010; Ditroilo et al., 2011).

If we take into account that the vertical jump is defined as a multi-joint activity, we can conclude that if we want to improve the height of a jump we need to perform multi-joint activity which in the first place includes the use of knee and ankle joint during movement specific for jumping performance, i.e. plantar flexion and knee extension. In addition to high jump, as a measure of explosive strength in lower extremities, we included the long jump since it was confirmed to be in a positive correlation with the vertical jump and the strength of both lower and upper extremities (Castro-Piñero, 2010). What we have discovered so far is that these tests do not require much skill, but are greatly depended on muscle strength thus providing us with valid and trustworthy indicators of the lower extremities explosive strength (Morriss et al., 2001).

In achieving better results during strength and power training, the researches regularly try to improve and advance the training technology. Apart from conventional methods, as a part of scientific and professional literature, the specific methods of the development in strength and power are more commonly expressed, and these include vibration and isokinetic training. Numerous studies support that the training should be incorporated in the conditional training programme, specifically intended for the development of strength and power.

Thisle et al. (1967) have come to the conclusion that the isokinetic resistance holds several advantages over the other training methods. Its biggest advantage is the fact that a certain muscle group can be trained to its maximum potential using the entire range of movement amplitude. In addition, amplitude and speed are adjustable, which represents one more advantage.

The greatest advantage of isokinetic training lies in approaching each examinee individually. One of the basic principles of training is the individualisation principle related to the idea that every training must be conducted on an individual basis, according to the abilities, potential, characteristics and specificities of individual sport (Bompa, 1994). When applying isokinetic methods we need isokinetic trainers, which are usually shaped as to allow the performance of isolated isokinetic exercise, with an adjustable movement speed which is in no connection to the performance of strength which an athlete is employing in his attempt to overcome load while the speed remains constant. The advantage of this training method is reflected in the ability to perform isolated and combined muscle action.

Isokinetic muscle action consists of fixed movement speed and changeable resistance. Many authors, in their studies have indicated that the constant speed of the extremities movement performed at an angle is not followed by constant speed of muscle shortening. Hinson et al. (1979) have, in the early phases of research in the field of isokinetics, established that the term isokinetic can be reserved for the muscle type which follows a constant speed of the extremities movement under the angle, and not constant linear speed of muscle shortening (Perin, 1986).

The information on isokinetic training available to us, affirm that this type of muscle exercise has certain advantages in relation to the classical exercising methods. This justifies its use in a conditional training.

In relation to the above stated, the aim of this study is to determine the effects of lower extremities concentric isokinetic training on the explosive strength in jumping performance, with the use of conventional and unconventional methods when comparing their development.

Methods

Subjects

The sample represents a group of 30 healthy and physically active female students at the Faculty of Sport and Physical Education, age 19 to 25. Average height (BH) - 168.06±4.85; Average weight (BW) - 61.26±6.81.

Neither of the examinees had a history of lower extremity's injury in the last two years, therefore they have not been included in the systematic training of strength and power in lower extremities, for which reason they were already acquainted with the technique of jump performance used in this study's evaluation of explosive strength jump performance.

Variables

HJ – High Jump – the height of jump was calculated by extracting the height of standing reach from the height of jumping reach, indicating its value in cm. The jump performed was a countermovement jump aided with arms.

LJ – Long jump – The examinees were placed at a track for long jump (ELAN, Slovenia) and were instructed to jump as far as they can. The difference between the starting line and the place of contact was marked as a jump length, expressed in cm.

The protocol for both jumping tests was taken from Marković et al. (2004).

Experimental plan

The selection, or setting up isokinetic training protocol is of primary value for the success in training process and the overall effects of strength and power growth. In fact, during this stage based on the initial testing, the entire training process is planed and programmed, including all the resistance parameters. The overall training load during isokinetic training is defined by the scope of parameters (the number of series, the number of repetitions and/or the duration of exercise) and parameters of intensity expressed by the angle of movement per a second (°/s) and movement amplitude. When selecting isokinetic training protocol, the following factors should be taken into consideration, the duration and the speed of the exercise, the range of joint movement used in the exercise and the relation of muscle group tension length used for the exercise. It is necessary to point out that the protocols of isokinetic exercise need to be developed separately for each examinee/athlete, in line with the basic regulations in sport training.

The female examinees tested in this study spent 4 weeks (3 times a week) in leg strength progressive training on an isokinetic dynamometer. Reciprocal concentric extensor and flexor knee joint contractions were used, as well as the plantar and dorsal flexor at different speeds. The training of the knee joint was conducted at a speed of 60 and 180°/s and under the amplitude of 90°, while the training of the ankle joint was performed at a speed of 30 and 60°/s and at 45° amplitude. The examinees conducted 2 to 4 series in 5 to 8 repetitions per each joint. The number of repetitions and series was progressively increased week by week.

Statistical analysis

The results were analysed using the software package SPSS 20 for Windows. For all the dependant variables in all the conducted measurement, the standard descriptive parameters were calculated: Mean, Standard Deviation, Minimum and Maximum value, Skewness and Kurtosis, as well as KS test to determine the distribution normality. The changes in dependable variables occurring between initial and final measurement in every group were analysed by T-test for the dependable samples. The level of statistical significance was set at $p<0.05$.

Results

Table 1 demonstrates the descriptive and dispersion parameters, and the Kolmogor-Smirnov test values for the normal distribution evaluation.

Descriptive Statistics							
	KS	Min	Max	Mean	Std. Deviation	Skewness	Kurtosis
BH	.10	151	178	167.30	5.497	-.615	1.232
BW	.12	45.5	75.0	60.833	7.1587	-.193	-.211
LJI	.09	154	231	188.73	16.099	.145	.960
LJF	.13	174	241	202.33	13.461	.484	1.815
HJI	.15	30	52	37.59	5.074	1.179	-1.618
HJF	.09	33	53	41.41	5.096	.682	.260

Table 1. Mean, Standard Deviation, Minimum and Maximum Value, Skewness and Kurtosis of examinees for all the variables calculated in the initial and final measurement; BH- body height; BW-body weight; I-initial; F-final

Considering that a critical value of KS test (Max D) for the stated population is 0.242 (Dizdar, 2006), we come to a conclusion that all the variables are normally distributed.

Paired Samples Test									
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	LJF - LJI	13.600	7.384	1.348	10.843	16.357	10.088	29	.000
Pair 2	HJF - HJI	3.827	1.753	.325	3.160	4.495	11.752	29	.000

Table 2. T-test of initial and final status of dependable variable

The T-test of dependable sampling, represented in table 2, shows the difference between initial and final testing, related to Long Jump (LJ), which was recorded in this study at 13,6cm, indicating the difference, to be more accurate an improvement of 7,21% .

When considering the variable HJ (high jump), the recorded difference between the initial and final state equals to 3,82cm, or to be accurate there is 10,18 % of improvement.

Both differences, presented in table 2 are statistically significant ($p<0,001$).

Discussion

Considering that there is a limited number of studies which conducted the research on the effects of isokinetic training of the explosive strength in jumping performance, the results of this study will be generally compared with the studies which measured the training effects of the dimensional increase n the lower extremities strength by isokinetic dynamometer because isokinetic parameters of lower extremities strength and explosive strength are in unison. Furthermore, the achieved effects will be contrasted by conventional training methods, in this case the isotonic training with and without an external load, and plyometric training, and in the case of unconventional training methods we included were isometric training and whole body vibration training.

When dealing with isokinetic training, regardless whether it is concentric or eccentric, it is evident that the strength in the muscle-joint system can be increased. The increase in strength, by isokinetic dynamometer was measured in the previous studies between 2,5% (Ewing and co-authors., 1990) and 37% (Colliander & Tesch, 1990). In fact Ewing et al. (1990) have come to a conclusion in the final testing stages of a 10 week training for men, conducted at 60°/s, that the slower group (60°/s) has increased the final momentum by 8,5%, while in the fast group (240°/s) no significant difference was achieved. The strength increased for 13,6% in the slower group and 2,5% in the fast group, while at speed of 180°/s both groups increased the momentum and strength. During testing at the speed of 240°/s, the fast group increased the value of the force momentum for 19,7% and in the slower group there was no significant difference. Likewise, Nickols-Richardson et al. (2007) have established positive effects of concentric and eccentric unilateral isokinetic training in the duration of 5 months, in the case of women examinees. Their results indicate that the leg strength has increased by 18,6% in concentric training, while the increase in eccentric training was achieved by 28,9%.

The differences in power and strength effects in the conducted studies were most likely caused by great differences among the examinees and training protocol. However, it is quite clear that the isokinetic training has offered positive effects on the power and strength, and that their deviations in size can be regarded as a consequence of their specificity (Kovačević et al., 2012_a).

Considering that the connection between isokinetic power and explosive strength was confirmed in the jumping performance, we can assume that the studies which achieved positive effects on the power and strength with the help of isokinetic training, most probably (even without any direct measurements) increased the explosive strength in jumping performance.

Kovačević et al. (2012_b) claim that a multiple stepwise regression analyses has indicated a group of isokinetic parameters which is responsible for 68% of the overall accomplished work for standing high jump variance ($p<0.05$) and 72% of the overall accomplished work for standing long jump variance ($p<0.005$), therefore concluding that the isokinetic test performed on more joints and various speed angles can predict the lower extremities explosive strength, just in case when it is not possible to perform ballistic movement.

If we analyse the studies where the examinees completed isotonic training with and without external loading, the extent of the explosive strength increase in vertical jump performance ranges from 0,03% (Kleinöder et al., 2003) to 15,4% (Mester et al., 2006). Apart from such a wide scope of results, there are those which have not recorded any increase. For example, Delecluse et al. (2003), whose study exclusively analysed knee extension and flexion, but did not gain any statistically relevant differences between the final and initial testing, not even after 12 weeks of training. The reason for this might be, the examinees were performing under a load of 10 and 20% of 1RM, and also a fact that the force had not changed during the entire experimental programme. In addition the differences from 0,03 to 1,14% taken from the Kleinöder et al. study and which were likewise statistically insignificant, can be assigned to the inadequate observation. In fact, the examinees performed squats without any external load. Rønnestad (2004) has come to a conclusion that a 5 week training of lower extremities with an external load (10 RM) resulted in 4,2% increase of countermovement squat jump. If we analyse the results obtained from this study, considering isotonic training, the recorded increase is the most similar to the one obtained from Mester et al. (2006) where examinees exhibited increase between 9,3 and 15,4%.

If we analyse the studies with plyometric training, the best example was provided by Marković (2007), who included 26 studies in his Meta analysis, with 4 to 24 weeks duration period of experimental plyometric training program, and a number of training sets between 12 and 60. He stated that, when taking into account squat jump, the average increase, recorded in the previous studies had the value of 4,7%, with its value between 1,8% and 7,6%. Bigger changes were recorded in squat jump with counter movement aids from arms (CMJA- 7,5%; range from 4,2 to 10,8%), and counter movement jump (CMJ - 8,7%; range from 7 to 10,4%) (Marković et al., 2004).

Analysing the studies with conventional training methods, we can conclude that the results are consistent with some results obtained by isotonic training and most results obtained by plyometric training. Still, there are some differences which can be assigned to the coefficients of jump variations. The Variation coefficient of the sergeant jump (obtained from the test used to evaluate the explosive strength in jumping performance in this study) was 3%, while with the other two jumps its value was determined at 3,3% (squat jump) and 2,8% (counter movement jump).

Furthermore, the study results of unconventional training methods will be presented. There are a small number of studies which used procedures including isometric exercise with an aim to develop explosive strength in legs. On one hand, isometric training is rarely used for the purposes of developing explosive strength, but on the other hand whole body vibration training is currently the most popular unconventional training method of this motor quality, which makes it quite interesting when comparing the results of this study with the effects of the studies which used the above mentioned training methods.

In the study by Cochrane et al. (2004), the examinees were performing isometric exercises of the lower extremities during 9 consecutive days, which resulted in negative effects from -4% and -3.5%, in squat jump and counter movement squat jump. Furthermore, in Paradisis et al. (2007) study, the examinees performed 3 training sets including a set of isokinetic exercises for the lower extremities. They recorded an increase of 0,3%. The greatest positive increase in the jump height was recorded by Fagnani et al. (2006). Namely in this study, where the experimental procedure lasted for 8 weeks, and the examinees performed unilateral and bilateral isometric squat, the authors recorded the 3,3% increase in the height of squat jump with counter movement aids from arms height, which is by far the best recorded result.

All the study analyses of the whole body vibration training effects on the height of the squat jump have achieved positive effects in the range from <1% (Owen, 2004) to 16% (Roelants et al., 2004). This can be demonstrated in the study of Osawa and Oguma (2013), who have achieved the results after 13 weeks of training (2 times a week) performed by the examinees in unilateral and bilateral squat on the vibration platform. The results indicated that the height of the jump with counter movement has increased for 15%, while based on the analyses of the previous studies, Nordlund and Thorstensson (2007) indicated in their review article that the whole body vibration training can have positive effects on the explosive strength in jumping performance, i.e. in height increase of the vertical jump in the range from 4,5 to 16%. Apart from these studies, Fernandez-Rio et al., (2010) obtained the results of 2,6% improvement for the squat jump with counter movement and 3,4% for the squat jump, all after 14 weeks of training (2 times a week) including the set of isometric exercise performed on the vibration platform.

There are a limited number of studies which confirmed the training effects on the explosive strength of standing long jump, and it is therefore difficult to perform a quality comparison of the achieved training effects from the previously conducted studies. Some studies (Trajković et al., 2012) have obtained results which indicate that after 6 week skill-based conditioning in the volleyball training, using the sample of 16 volleyball players, there is no statistically significant difference between initial and final testing which signifies no difference in the standing long jump results. These findings could easily be explained by the character of the performed skill based conditioning whose initial purpose was not intended for the increase in the explosive strength of the jumping performance, especially long jump, because that is an unspecific structural movement for volleyball. In addition, we could not perform a quality comparison of the achieved effects, because there was no vertical jumping performance in this study. Considering that there is 0.50 correlation between long jump and squat jump, and 0.59 between long jump and squat jump with counter movement jump, we can assume that the studies, which have achieved positive effects on the height of the vertical jump (though there was no direct measuring) had the same effect on the ability of the long jump. This hypothesis is supported by the study results, which indicate a great similarity in the scope of achieved effects of the both explosive strength jumping performance components.

Conclusion

Based on the demonstrated results we can conclude that lower extremity concentric isokinetic training had significant transformational effects regarding the explosive strength in jumping performance. Standing long jump, as an applied variable of the explosive strength and a horizontal jump component, indicate that the applied isokinetic training did have statistically significant effects ($p<0,001$), i.e. the results improvement occurred between two points of measurement, calculated at 13,6cm, which is an improvement of 7,21%. Also, we can conclude that there are statistically significant differences ($p<0,001$) between initial and final measurement for the variable standing height jump reflected in the increase of 3,82cm in height or 10,18%. Considering that the tests of explosive strength in jumping performance have high correlation coefficients, the results of the height jump are greatly similar with the results of the long jump. Once we compare the obtained training effects of this study with the conventional and unconventional training methods we can conclude that the concentric isokinetic training produces similar effects in regard to the explosive strength of lower extremities such as plyometric training and whole body vibration training.

Generally speaking we can conclude that the concentric isokinetic training of the lower extremities produces significant transformational effects on the explosive strength in jumping performance, affecting both of its components, horizontal and vertical. These effects are very similar and very often have proven to be better than conventional and unconventional training methods intended for the development of the explosive jumping performance.

It should be noted, that this type of training at the time of modern sport cannot replace the basic conditional training in isotonic conditions, but it can serve as an additional training within the integral training programme.

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