FACTA UNIVERSITATIS
Series: **Physical Education and Sport** Vol. 1, N° 9, 2002, pp. 11 - 25

Scientific Paper

THE EFFECTS OF THE PLYOMETRIC SPORT TRAINING MODEL ON THE DEVELOPMENT OF THE VERTICAL JUMP OF VOLLEYBALL PLAYERS

UDC 796.325.015

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Abstract. *With the aim to investigate the plyometric training model used for the increase of explosive type strength (the vertical jump), an experimental research was carried out, drawing a sample of 33 volleyball players at the cadet level. Guided by the general principles of plyometric training, individual training plans were devised. In order to evaluate the effect of the sport training on the development of the vertical jump, three variables were applied. For the purposes of this research, two tests for the evaluation of the volleyball vertical jump were validated: the block jump and the spike jump. The experiment was carried out in the second part of the preliminary period, and it lasted for eight weeks, during which, two to three training sessions per week were held. The control group trained using technically tactical contents. The data was processed using univariate and multivariate analyses as well as a covariance analysis. Based on the findings of the research and the discussion, one could unfailingly conclude that the exercise model for the development of the vertical jump that had been used, as the fundamental factor of the experimental group, has contributed to the statistically relevant difference in the increase of the vertical jump in comparison to the control group, which had used technically-tactical contents to develop the vertical jump.*

Key words: *sport training, the vertical jump, experiment, volleyball players*

1. INTRODUCTION

With the changes made to the official rules of volleyball playing at the 28. FIVB congress, the roles of volleyball players during a match were altered as well (OSJ, 2001). The new offense and defence roles brought about a need for an intensive study of volleyball abilities, especially the ability of the leg muscles to produce explosive type strength,

Received March 20, 2004

which in volleyball terminology is referred to as the vertical jump. Due to the specific growth and development of young volleyball players, any vertical jump training must be approached with caution.

A volleyball match can be played for five sets, which means that the match can last about ninety minutes, during which time a player can perform 250-300 actions dominated by the explosive type strength of the leg muscles. Of the total number of actions, jumps take up around 50-60%, high speed movements and changes of direction in space about 30% and falls about 15%. The average height of a modern day volleyball player is greater compared to the one from earlier periods, and is between 195 and 200 centimeters. The average extent of a receiver's vertical jump in a spike, a spiker's and a middle blocker's is between 345 and 355 centimeters, and in a block from 320 to 335 centimeters (Ercolessi, 1999). The spike and block actions are dominated by the corresponding explosive type strength which is referred to as the player's vertical jump, which is usually the key to winning points.

Among the basic "model characteristics" of top volleyball players, apart from the anthropometric characteristics, abilities such as the standing linear jump and the long jump, as well as the high speed shift in space at short distances are also included (Trojačanec, 1992, 221). Considering the fact that the height of volleyball players can not be changed during the course of training, the height within reach during a spike or block (the vertical jump) can be increased by sport training. One of the fundamental goals of volleyball training is to "build" explosive type strength "into" not only the biochemical structure, but also many other structures of volleyball techniques (Kostić, 1995, 54).

When it comes to volleyball, explosive type strength is mainly manifested in jumps and in spiking. This explosive type strength is defined as the individual ability of the neuromuscular system to show signs of strain in the shortest time possible (Verhošanski, 1979, 65). The concept of explosive type strength is connected with the reactive abilities of the neuromuscular apparatus (Verhošanski, 1979, 71). In the definition of explosive type strength, Zaciorski introduced the concept of reversible strength, a strength which consists of two phases: the eccentric phase (the stretch) and the concentric phase (the shortening). The concentric phase is added to the previous muscle stretch in the shortest time interval possible (Zatsiorsky, 1995, 44).

In the theory of strength training, the specific training for the increase of explosive type strength is referred to as "plyometric training" and the training method is called the "plyometric method". "Plyometrics is a speed -strength training, a combination of strength and speed" (Marullo, 1999, 13).

The fundamental principle of the plyometric method lies in the speed of the shift from and to the eccentric and concentric muscle contractions. "The key to this lies in the time needed for one muscle to shift from a state of flexibility (the stretch) into a state of shortening (the return to its original position). This points to the fundamental principle of plyometric training: the measurement, the extent of the stretch (the degree), determines the use of the strength that allows flexibility and the transformation of chemical energy into energy used to move muscles" (Kostić, 1999, 109).

The muscle elasticity feature and the miotatic reflex (the stretch reflex) play an important role in the plyometric method. The reflex to stretch muscles includes the SSC (the stretch shortening cycle). In order for us to obtain a quality eccentric-concentric contraction, three important requirements need to be met:

- the timely activation of the musculature just prior to the eccentric contraction,
- the short duration of the eccentric contraction,
- the instantaneous shift between the stretching phase and the shortening phase (Komi & Gollhofer, 1997)

Based on the requirements as stated by Komi & Gollhofer (1997), we can come to the conclusion that the amortization phase during a depth jump has to be as short as possible. The duration of the amortization phase for top athletes is between 120 and 150 ms (Schmidtbleicher in Berger et al., 1984, 170).

By using the plyometric method, volleyball players may injure themselves, unless the requirements regarding the basic technique structures of the depth jump are met (the anatomic, dynamic, rhythmic, etc., as found in Kostić, 2000)

One of the major requirements for using the plyometric training method is a basic strength training. Young volleyball players do not require a high basic strength level. Once we have stabilized the basic strength, the next problem is the eccentric strength of the leg muscles. It is quite limiting, especially during any training consisting of high volume and increased force exercises. Without the adequate eccentric muscle strength, a high speed shift from the eccentric to the concentric mode proves to be ineefective. If the amortization phase lasts a long time, and if the movements are slow, the shift from eccentric to concentric muscle movement, the eccentric strength levels will not be adequate, and the training itself should be reduced in volume and intensity (Kostić, 1999).

The correct realization of the exercises needs to be monitored constantly during the shift, regardless of the level the athlete is at. When the plyometric method is being used with beginners, it is vital that they adopt the proper depth jump technique, which they will later improve with the intensity of the exercises. Jumps represent a constant exchange between the forces of production and reduction, leading to the merging of these forces by means of all three joints of the lower extremities (Kostić, 1999).

When it comes to individuals who have not been in sports training and children, the strength of their vertical jump musculature is inadequate for them to be able to manage their own body weight in the eccentric phase of the depth jump at greater heights (Weineck, 1990). Due to this fact, while practicing vertical jumping with children, depth jumps at a lesser height are recommended, as well as "reactive" exercises on the ground (Letzler & Letzler, 1990).

The maximal height of the depth jump is often cited as an important criterion for the proper jump technique, as cited in Schmidtbleicher & Gollhofer (1985, 280). It needs to correspond to the height at which one's heels do not touch the ground prior to takeoff during the depth jump. The concept of "border height" from which one jumps into "the depth" (Schmidtbleicher, 1984, 170) has been accepted as the logical depth jump height in the research of Bosco & Pitter (1982) and Letzler & Letzler (1990).

Apart from performing the correct motions during a depth jump, it is also vital that the body is optimally prepared before the reactive training, not only for the sake of preventing injury, but also because only the optimally innervated muscle can adapt to the effect of the "reactive" training. The preparations preceding the reactive training can be both general and specific (Weineck, 2000, 238). A volleyball "warm-up" has experimentally been proven to be adequate for reactive training (Baum et al., 1989).

In regards to the methods for increasing reactive strength, the duration of training based on this method has been researched. Training can last from 8 to 10 weeks (Verhošanski, 1970, 233); six weeks during the second preliminary phase, after increasing general strength, with at least two training sessions a week (Kistler, 2000; Hagl, 2003).

A better adaptation of the CNS and a greater growth increase in strength and vertical jumping during explosive type strength training has been proven by the research findings of many authors (Wilson, Newton, Murphy, & Humphreys, 1993; Harris, Stone, O'Bryan, Proulx, & Johnson, 1999).

There are different variations of plyometric training. First of all, there are impact plyometrics and non impact plyometrics. Within the abovementioned types one could also speak of maximal plyometrics, submaximal plyometrics and non-plyometrics. Maximal plyometrics can also be classical plyometrics, which in turn can be functional plyometrics and non-functional plyometrics. The submaximal type can also be supplementary plyometrics. Non-plyometrics can be preparatory/supplementary activities which consist of weight training and jump throws, etc (Siff, 2000, 271).

In both the theoretical and practical aspects of training volleyball players, there are several models for developing the explosive type strength of leg muscles, such as the Chu model (1991). The use of the plyometric method (the reversible method- Zaciorski), has emphasized the need to study the possibilities of its use in the training of cadets on one hand, and the effectiveness of a certain set of plyometric exercises in the development of vertical jumping, if used after the technically tactical training (TTT), on the other.

The fundamental goal of this experimental research was to investigate the effectiveness of the plyometric exercises model in the development of explosive type strength (vertical jumping) for cadets, or more precisely, to combine the TTT with the plyometric method. At the same time, the goal was also to determine the correctness of the metric characteristics of the two tests used for evaluating the spiking vertical jump and the blocking vertical jump.

In regards to the set aim, the assumption has been made that the experimental group, using the plyometric training method and the TTT, will achieve a statistically relevant growth increase in vertical jumping compared to the control group, which had not been using the plyometric exercises.

METHODS

The Sample of Examinees

The research sample numbered 33 examinees, and was drawn from the cadet age level. The basic criteria for selection: all the examinees were older than 16 (± 6 months); they were all members of a privately-owned volleyball club; they had all been training volleyball for a period of four to six years; they were all registered as competitors in the 2003/2004 season; they all had five training sessions a week during the preliminary period, and the sessions lasted from 90 to 120 minutes; they were all tested at the start and at the end of the experiment; all the volleyball players were physically healthy and the data on the injured players was not used in the statistical analyses.

By means of the random sample method, the examinees were divided into an experimental group (E), numbering 17 volleyball players, and a control group numbering 16 players (C).

The Variable Sample

The process of developing and of establishing the state of the vertical jumping at the initial and final measuring was carried out with the use of three measuring instruments which cover the area of explosive type strength. These instruments were labeled in the following manner:

- the block jump (BJ),
- the spike jump (SJ),
- the standing linear jump (SLJ).

The correctness of the first two tests was proven by measuring the calculable features by means of proceedings dealing with factors, proceedings proving any predictable capabilities, and which were administered by the authors of the research. In the SLJ test, the predictable capabilities were determined by Kurelić, et al. (1975, 30)

The Block Jump

The instruments: a wooden case used in gymnastic training, thin rubber carpeting of a rough surface, a board with a darkened background, fastened to the wall, magnesium, and a steel measuring tape.

The task: the examinee stands facing the wall and resting both outstretched arms on the board next to the fixed measuring tape, so that they are on the same level. After noting the height within reach for the block jump, the examinee takes off with both feet, and touches the board that is next to the steel measuring tape with the fingers of both hands, which have previously been coated with magnesium. The evaluator should be standing on the wooden case so that his head is at level with the height within reach of that jump, so as to increase the accuracy of the results. Three jumps are made. Any incorrectly performed jumps are repeated.

Marking: the height within reach for that jump is measured in centimeters, and then the height within reach is subtracted from it, and we get the height of that jump. Only the best attempts are actually used in the statistical analysis.

Notes: No double take off is allowed. The examinee can jump either barefoot or in his sneakers, but his fingers previously coated with magnesium.

The Table 1 shows the coefficients of the factor correctness and their statistical relevance, by which the good calculable features of this test at the cadet age level are confirmed.

Table 1. The factor correctness and predictability of the block jump test (BJ)

Item	Mean	Std.Dev.	Factor loading	Eigenvalue	% Total	Cronbach alpha	Standardized alpha	Average inter item corr.
I	43.27	5.50	0.97	2.77	92.26	0.957	0.959	0.888
II	43.80	5.42	0.97					
III	44.27	4.84	0.95					

The Spike Jump

The instruments: a wooden case used in gymnastic training, thin rubber carpeting of a rough surface, a board with a darkened background which has been fastened to the wall, magnesium, and a steel measuring tape.

The task: the examinee stands facing the wall and resting both outstretched arms on the board next to the fixed measuring tape, so that they are on the same level. After noting the height within reach for the spike jump, the examinee takes a step back, and with a running start of just one step, takes off with both feet, and touches the board that is next to the steel measuring tape with the fingers of both hands, which have previously been coated with magnesium. The evaluator should be standing on the wooden case so that his head is at level with the height within reach of that jump, so as to increase the accuracy of the results. Three jumps are made. Any incorrectly performed jumps are repeated.

Marking: the height within reach for that jump is measured in centimeters, and then the height within reach is subtracted from it, and we get the height of that jump. Only the best attempts are actually used in the statistical analysis.

Notes: No double take off is allowed. The examinee can jump either barefoot or in his sneakers, but his fingers should previously coated with magnesium.

The Table 2 shows the coefficients of the factor correctness and their statistical relevance by which the good calculable features of this test at the cadet age level are confirmed.

Table 2. The factor correctness and predictability of the spike jump test (SJ)

Item	Mean	Std.Dev.	Factor loading	Eigenvalue	% Total	Cronbach alpha	Standardized alpha	Average inter item corr.
I	52.80	7.51	0.98	2.89	96.47	0.981	0.982	0.948
II	53.73	7.11	0.99					
III	54.37	7.02	0.98					

Research Description

The preliminary period for the 2003/2004 season lasted for twelve weeks, staring with July 27, 2003. till the start of the season (October 19, 2003)

The first phase of the preliminary period lasted for three weeks. During each week five training sessions were held, lasting from 90 to 120 minutes. The basic goal during this period was to increase the basic abilities such as endurance and strength needed after takeoff. Within a week long micro-cycle, three training sessions were carried out with the aim of increasing endurance, and two sessions were used for exercising in a gym. After completing the first phase of the preliminary period, the initial measuring was carried out, and the final measuring took place three days after the completion of the experimental program, or more precisely, following the completion of the second phase of the preliminary period.

For eight weeks during the second part of the preliminary period, the experimental group had been using the plyometric sport training model for the purpose of developing the vertical jump. Nineteen training sessions were held. The set of the models for the development of the vertical jump consisted of five exercises, and the exercising took place at the beginning of each training session, following a thirty-minute volleyball "warm-up". The number of training sessions held, arranged by week, and beginning with the first week, was as follows: 2-2-3-2-2-3-3-2.

During the same period, the control group completed the technically-tactical training.

The Content of the Training Model for the Development of the Vertical Jump

For the purposes of this research, the set of the special model for the development of the vertical jump at the cadet age level consisted of five exercises which were to increase the explosive type strength by means of the plyometric (reversible-Zaciorski) method. In their choice of exercises, the authors were guided by the findings come by Chu (1991, 77).

Mutiple Box-to-Box Squat Jumps (Fig. 1)

Equiment: A row of boxes (all the same height, dependet on ability).
Start: Stand in a deep-squat position with feet shoulder-width apart at the end of the row of boxes.
Action: Jump to the first box, landin softly in a squat position. Maintaaining the squat position, jump off the box on the oder side and immediately onto and off of the followind boxes. Keep hands on the hips, or behind the head.

Fig. 1. Mutiple Box-to-Box Squat Jumps

Depth Jump (Fig. 2)

Equipment: A box (variety heights).
Start: Stand on the box, toes close to the front edge.
Action: Step from the box and drop to land on both feet. Try to anticipate the landing and spring up as quickly as you can. Keep the body from "settling" on the landing, and make the ground contact as short as possible.

Fig. 2. Depth Jump

30-60-90-Second Box Drill (Fig. 3)

Equipment: A box 30 cm high, 50 cm wide and 70 cm deep.
Start: Stand at the side of the box with feet shoulder-width apart.
Action: Jump onto the box, back to the ground on the other side, then back oto the box. Continue to jump across the top of the box for an allotted time, with each touch on top of the box counting as one. Use the following quidelines: 30 touches in 30 seconds- Start of training, 60 touches in 60 seconds- Middle of training and 90 touches in 90 seconds- End of training.

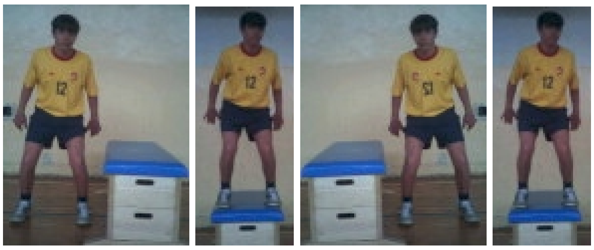

Fig. 3. 30-60-90-Second Box Drill

Split Squat Jump (Fig. 4)

Equipment: None.
Start: Spread the feet far apart, front to back, and bend the front leg 90 degrees at the hip and 90 degrees at the knee.
Action: Jump up; using arms to help lift, hold the split-squat position. Land in the same position and immediately repeat the jump.

Fig. 4. Split Squat Jump

Rim Jumps (Fig. 5)

Equipment: None.
Start: Spread the feet far apart, front to back, and bend the front leg 90 degrees at the hip and 90 degrees at the knee.
Action: Jump up; using arms to help lift, hold the split-squat position. Land in the same position and immediately repeat the jump.

Fig. 5. Rim Jumps

Determining the correct amount of strain to be put on each volleyball player was carried out on an individual basis. In designing individual programs, the principle used stated that the amount of strain during the first week should be 60% of the maximum, during the second 70%, the third 80%, the fourth 90%, the fifth 70%, the sixth 80%, the seventh 90% and during the eighth, 100%.

Example: cadet N.S. is 183.5cm tall, and at the initial measuring had a block jump of 53cm and a spike jump of 65cm. The maximum height of the box for the mutiple box-to-box squat jumps was 70cm. The maximum height of the box for the depth jump was 90cm. The maximum number of split squat jumps was 13, and the maximum number of rim jumps was 12.

Week 1. (17.8.2003- 23.8.2003), training one and two, intensity 60%

Mutiple Box-to-Box Squat Jumps	2 sets of 4 boxis, boxheight 40 cm
Depth Jump	2 sets of 8 repetitions; boxheight 50 cm
30-Second Box Drill	2 sets; boxheight 30 cm
Split Squat Jump	2 sets of 8 repetitions
Rim Jumps	2 sets of 7 repetitions

Week 2. (24.8.2003- 30.8.2003), training three and four, intensity 70%

Mutiple Box-to-Box Squat Jumps	2 sets of 4 boxis, boxheight 50 cm
Depth Jump	2 sets of 10 repetitions; boxheight 60 cm
30-Second Box Drill	2 sets; boxheight 40 cm
Split Squat Jump	2 sets of 9 repetitions
Rim Jumps	2 sets of 8 repetitions

Week 3. (31.8.2003- 6.9.2003), training five – six, intensity 80%

Mutiple Box-to-Box Squat Jumps	3 sets of 4 boxis, boxheight 50 cm
Depth Jump	3 sets of 10 repetitions; boxheight 70 cm
30-Second Box Drill	3 sets; boxheight 40 cm
Split Squat Jump	3 sets of 10 repetitions
Rim Jumps	3 sets of 9 repetitions

Week 4. (7.9.2003- 13.9.2003), training eight and nine, intensity 90%

Mutiple Box-to-Box Squat Jumps	4 sets of 4 boxis, boxheight 60 cm
Depth Jump	3 sets of 10 repetitions; boxheight 80 cm
60-Second Box Drill	3 sets; boxheight 30 cm
Split Squat Jump	3 sets of 12 repetitions
Rim Jumps	3 sets of 11 repetitions

Week 5. (14.9.2003- 20.9.2003), training 10 and 11, intensity 70%

Mutiple Box-to-Box Squat Jumps	3 sets of 4 boxis, boxheight 40 cm
Depth Jump	3 sets of 10 repetitions; boxheight 60 cm
60-Second Box Drill	3 sets; boxheight 40 cm
Split Squat Jump	3 sets of 9 repetitions
Rim Jumps	3 sets of 8 repetitions

Week 6. (21.9.2003- 27.9.2003), training 12 – 14, intensity 80%

Mutiple Box-to-Box Squat Jumps	3 sets of 4 boxis, boxheight 50 cm
Depth Jump	3 sets of 10 repetitions; boxheight 70 cm
30-Second Box Drill	3 sets; boxheight 50 cm
Split Squat Jump	3 sets of 10 repetitions
Rim Jumps	3 sets of 9 repetitions

Week 7. (28.9.2003- 4.10.2003), training 15 – 17, intensity 90%

Mutiple Box-to-Box Squat Jumps	3 sets of 4 boxis, boxheight 60 cm
Depth Jump	3 sets of 10 repetitions; boxheight 80 cm
90-Second Box Drill	3 sets; boxheight 40 cm
Split Squat Jump	3 sets of 11 repetitions
Rim Jumps	3 sets of 11 repetitions

Week 8. (5.10.2003- 11.10.2003), training 18 and 19, intensity 100%

Mutiple Box-to-Box Squat Jumps	4 sets of 4 boxis, boxheight 60 cm
Depth Jump	3 sets of 10 repetitions; boxheight 90 cm
90-Second Box Drill	3 sets; boxheight 50 cm
Split Squat Jump	3 sets of 13 repetitions
Rim Jumps	3 sets of 12 repetitions

The Methods of Data Processing

Due to the nature of the experiment, it was necessary that the data for the experimental and control group be gathered at both the initial and final measuring. For the purpose of analyzing the changes in the results for the dependent variables in the period between the initial and final measuring, the dependent sample test was used, and the relevance of the conclusions drawn was determined at the $p<0.05$ level. For the data collected at the final measuring, the covariance analysis was used.

The data was processed with the STATISTICA 6.0 statistics packet for Windows.

The following parameters were calculated:

Wilks' Lambda – value;
F – value;
Effect df; Error df – degree of freedom;
p – value;
Mean;
Std.dev. – standard deviation of Mean;
MS Effect;
MS Error;
Diff. – difference between two Means;
Growth % - % developement of Mean;
t – value;
df – degree of freedom;
Covariate means.

THE RESULTS OF THE RESEARCH AND THE DISCUSSION

At the initial measuring, it was necessary to determine any possible differences in the dependent variables between the experimental and the control group, because in the case of any differences, it would have been necessary to apply the covariance analysis at the final measuring, in order to divide into parts and neutralize the differences from the initial measuring. Only then would it have been possible to determine the true effects of the experimental factor (the use of the set of plyometric exercises). For this purpose, for the data collected at the initial measurement, the multivariate variance analysis was used-the measurements were taken again, and the coefficients of that analysis are shown in Table 3. By analyzing the obtained coefficients, it can be concluded that that there is a statistically relevant difference between the experimental and control group at a multivariate level regarding the studied variables. The value of Wilk's Lambda (0.473), Rao's approximation (F=9.64) and the degree of movement freedom of 3 and 26, point to the statistical relevance of the differences at the p=0.005 level.

Table 3. The multivariable analysis difference between the EG and the CG at the initial measurement

Test	Wilks' Lambda	F	Effect df	Error df	p
1	0.473	9.64	3	26	0.005

At the univariate level, we can determine that the statistically relevant differences at the spike and block test greatly contributed to the difference between the groups at the initial measuring, and whose F values were 22.84 and 24.90, which gives us a statistically relevant difference at the p=0.000 level. When it comes to the standing linear jump, no statistically relevant difference was noted, even though the experimental group had a jump which was almost nine centimeters longer (Table 4).

Table 4. The univariate analysis of the differences between the groups at the initial measurement

Test	Exsperimental group		Control group		ANOVA			
	Mean	Std.dev.	Mean	Std.dev.	MS Effect	MS Error	F(1,28)	p
BJ	48.33	3.85	41.60	3.87	340.03	14.89	22.84	0.000
SJ	57.87	4.93	49.67	4.03	504.30	20.25	24.90	0.000
SLJ	231.53	15.38	222.73	13.08	580.80	203.88	2.85	0.103

Table 5 shows the results of the analysis of the differences between the initial and final measuring of the experimental group. We can note that the players of the experimental group had greatly improved their results in the block and spike jumps, as well as in the long jump during the eight week period. The greatest growth increase of 9.52% was found in the block jump, then in the spike jump 7.72%, while the smallest in the sanding linear jump 3.77%. All the differences are statistically relevant at the p=0.000 level.

Table 5. The difference between the results of the initial and final measuring of the examinees of the experimental group

Test	Measuring	Mean	Std.dev.	N	Diff.	Growth %	t	df	p
BJ	Initial	48.33	3.85	15	4.60	9.52	28.17	14	0.000
	Final	52.93	4.25						
SJ	Initial	57.87	4.93	15	4.47	7.72	27.03	14	0.000
	Final	62.33	5.43						
SLJ	Initial	231.53	15.38	15	8.73	3.77	14.82	14	0.000
	Final	240.27	15.50						

Table 6. The differences between the results of the initial and final measuring of the examinees of the control group

Test	Measuring	Mean	Std.dev.	N	Diff.	Growth %	t	df	p
BJ	Initial Final	41.60 42.10	3.87 4.03	15	0.50	1.20	2.35	14	0.034
SJ	Initial Final	49.67 50.77	4.03 3.57	15	1.10	2.21	4.78	14	0.000
SLJ	Initial Final	222.73 226.47	13.08 12.84	15	3.73	1.67	12.43	14	0.000

The volleyball players of the control group (Table 6) at the final measuring also scored a numerically better set of results in all the tests, but these values were lower compared to the players of the experimental group. The greatest growth increase was found in the spike jump and it was 2.21%, then in the standing linear jump 1.67%, while the smallest was in the block jump 1.20%. The growth increase of the results is statistically relevant for the spike and standing linear jump at the p=0.000 level, and for the block jump at the p=0.034 level.

The growth increase of the numerical values for the height of the jumps is evident in both groups of examinees, but, it is necessary to determine whether there is a difference between the growth increase in the results of the experimental and control group, so that we could determine the effects of the experimental treatment. For this purpose, the covariance analysis was used, where the dependent variables were the results of the groups at the final measuring, and the covariates were the results of the initial measuring of both groups, in order to divide into parts and neutralize the differences between the groups at the initial measuring.

The results of the covariance analysis are shown in Table 7. They point to the conclusion that were the groups the same at the initial measuring, the difference between the groups would be statistically relevant. The value of Wilk's Lambda coefficient is 0.143, which with the F-approximation of 45.93 and the degree of movement freedom of 3 and 23 gives the statistically relevant difference between the experimental and control group at the p=0.000 level.

Table 7. Testing the relevance of the effects of the vertical jump program at the multivariate level-the MANCOVA model

Test	Wilks' Lambda	F	Effect df	Error df	p
1	0.143	45.93	3	23	0.000

The greatest contribution to the difference between the groups at the final measuring (Table 8), along with the neutralization of the differences at the initial measuring, lies in the block jump, whose value of F is 88.01, then the spike jump F=55.35, and the smallest is in the standing linear jump where F=29.61. The contribution to the difference between the groups is statistically relevant for all the dependent variables at the p=0.000 level, so that it can be assumed that it is the consequence of the experimental program consisting of the set of plyometric exercises which the experimental group used over an eight-week period.

Table 8. Testing the relevance of the effects of the vertical jump program at the univariate level-the ANCOVA model

Test	COVARIATE MEANS		ANCOVA			
	Experimental group	Control group	MS effect	MS error	F(1,25)	p
BJ	49.27*	45.77	43.50	0.49	88.01	0.000*
SJ	58.12*	54.98	35.11	0.63	55.35	0.000*
SLJ	236.11*	230.63	106.69	3.60	29.61	0.000*

It is emphasized in the statistical analysis discussion that by using the set of plyometric exercises on the experimental group and the TTT exercises on the control group, an increase in the explosive type strength of the leg muscles was brought about. The explosive type strength brought about an increase in the high jump as well as the long jump ability. Similar results were obtained in the Chu research (1991). A more considerable growth increase in the jumping ability was noted in the experimental group, so it is quite justified that these types of plyometric exercises be used in training at the cadet level. Many questions remain unanswered, and yet demanding answers. One such question has to do with determining which of the exercises have considerably contributed to the set differences between the experimental and control group. Another question refers to the part played by the speed component, which is to a considerable degree dependent on any innate potential.

The experimental group achieved an increase in the vertical jump of the spike and block which was in the 4.60 and 4.47 range. The achieved increase is numerically no different than the two to six centimeters which Hagl (2003) came up with in his research on a sample consisting of nine examinees.

Similar results in the research into the development of the vertical jump are to be found in the work of Blattner & Noble (1979), whose examinees increased their vertical jump by 5.2 cm over and eight-week period. With Polhemus & Burkherdt (1980) this increase was 8.12cm, and the highest values of the vertical jump (10.67) were published by the authors Adams, O'Shea, O'Shea, & Climstein (1992), who had used a combined plyometric training on a sample consisting of 48 to 103 examinees, after a seven-week long training period. The statistical analyses determined the relevance of the achieved coefficients in the development of the high jump.

There are general principles that apply to plyometric training regarding the muscular pattern of movement in the process of overcoming any strain, but each volleyball player requires an individual program. The vertical jump is an individual characteristic, and so one needs to select exercises and determine their intensity and extent accordingly. One of the significant conditions that come with using the plyometric method, are the characteristics determined by the age of each individual volleyball player.

CONCLUSION

Guided by the general principles of using a plyometric method in an experimental research on a sample consisting of cadets, individual plans for each volleyball player were made. It has been proven experimentally that an eight-week training model using the plyometric method can have an effect on the statistically relevant increase in the explosive type strength of the leg muscles, which in turn leads to an increase in the vertical jump of a block, spike and the long jump. In addition, it has been established that using the TTT program to a lesser extent in comparison to the experimental group, can have an effect on the development of explosive type strength. By means of the covariance analysis it has been established that the difference in the resulting vertical jump is beneficently relevant for the experimental group. Due to this, the individual use of the plyometric method is recommended as more effective in the development of the vertical jump at the cadet age level.

REFERENCES

1. Adams, K., O'Shea, J. P., O'Shea, K.L., & Climstein, M. (1992). The effect of six weeks of squat, plyometric and squat-plyometric training on power production. *Journal of Applied Sports Science Research,* 6(1), 36-41.
2. Baum, K., & Essfeld, D.(1989). Die maximal erreichbare Sprunghöhe nach unterschiedlichen Aufwärmelementen. In: Dannenmann F. (1989). *Volleyball analysieren, 15. Symposium des Deutschen Volleyballverbandes (*292-297).
3. Blattner, S., & Noble, L. (1979). Relative effects of isokinetic and plyometric training on vertical jumping performance. *Research Quarterly*, 50(4), 583-588.
4. Bosco, C., & Pittera, C. (1982). Zur trainingsirkung neuentwickelter Sprungübungen auf die Explosivkraft. *Leistungssport*, (1), 36-39.
5. Chu, D.A. (1991). *Jumping into plyometrics*. Champaign, IL: "Leisure Press".
6. Ercolessi, D. (1999). La caduta dal salto. *Super Volley*, (1), 79-82.
7. Hagl, S. (2003). Untersuchung verschiedener sprungkraftfördernder Übungen. Retreived April 3, 2004 from http://www.hausarbeiten.de/faecher/hausarbeit/spc/23805.html.
8. Hakkinen, K., & Komi. P.V. (1985). The effect of explosive type strength training on electromyographic and force production characteristics of leg extensor muscles during concentric and various stretch shortening cycle exercises. *Scandinavian Journal of Sports Science,* (7), 65-76.
9. Harris, G.R., Stone, M.H., O'Bryan, H., Proulx, C.M., & Johnson, R. (1999). Short term performance effects of high speed, high force and combined weight training. *Journal of Strength and Conditioning Research,* (13), 14-20.
10. Kistler, G. (2000). Verbesserung der Sprungkraft durch ein gezieltes Training. Retreived April 3, 2004 from http://www.hausarbeiten.de/faecher/hausarbeit/spc/15483.html.
11. Komi, P.W., Gollhofer, A. (1997). Stretch reflex can have an important role in force enhancement during SSC exercise. *Journal of Applied Biomechanics*, (13), 451-460.
12. Kostić, M.R. (1999). Fitness- teorija, metodika, praksa (Fitness-theory, methodology and practice). Niš: Samostalno izdanje autora.
13. Kostić, Z.R. (1995). Snaga u sportu na primeru odbojke (Strenght in Sport as Exemplified in Volleyball). Niš: Grafika "Galeb".
14. Kostić, Z.R. (2000). Teorija i metodika treninga sportske igre – odbojka (The Theory and Methodology of the Training for the Sports Game-Volleyball). Niš: Grafika "Galeb".
15. Kurelić, N., Momirović, K., Stojanović, M., Šturm, J., Radojević, Đ., et al. (1975). Struktura i razvoj morfoloških i motoričkih dimenzija omladine (The Structure and Development of the Morphological and Motor Dimensions of the Youth). Beograd: Institut za fizičku kulturu.
16. Letzler, H., & Letzler, M. (1990). *Krafttraining.* Reinbek.
17. Marullo, F. (1999). Plyometric training. *The Coach*, 4, 10-15.
18. OSJ (2001). Zvanična pravila odbojke 2001-2004 (The Official Volleyball Rulebook 2001-2004). Beograd: OSJ.
19. Polhemus, R. & Burkherdt, E. (1980). The effect of plyometric training drills on the physical strength gains of collegiate football players. *National Strength Coaches Association Journal,* 2(5), 14-17.
20. Berger, W., Dietz, V., Hufschmidt, A., Jung, R., Schmidtbleicher, D. et al. (1984). *Haltung und Bewegung beim Menschen. Physiologie, Pathophysiologie, Gangentwicklung und Sporttraining.* Berlin-Heidelberg: Springer.
21. Schmidtbleicher, D., & Gollhofer A. (1985). Einflußgrößen des reaktiven Bevegungs- verhaltens und deren Bedeutung für die Sportpraxis. In M. Bührle (Ur). *Grundlagen des Maximal- und Schnellkrafttrainings. Bericht über ein internationales Symposium vom 6. bis 8. Oktober 1983 in Freiburg* (pp. 271-281). Schorndorf: Bührle Martin.

22. Siff, M.C. (2000). *Supertraining*. Denver: Supertraining Institute.
23. Trojačanec, Z. (1992). *Osnovi na fiziologijata na sportot*. Skopje: „Medis-informatika".
24. Верхошанский, Ю. В. (1970). *Основы специальной силовой подготовки в спорте*. Москва: "Физкулътура и спорт".
25. Verhošanski, J.V. (1979). Razvoj snage u sportu (The Development of Strength in Sport (a translation from Russian)). Beograd: „Partizan".
26. Weineck, J. (1987). *Optimales training.* 5. überarbeitete und erweiterte Auflage. Erlangen: Spitta Verlag .
27. Weineck, J. (2000). *Optimales training*. 11. Auflage. Balingen: Spitta Verlag GmbH.
28. Wilson, G.J., Newton, R.U., Murphy, A.J. & Humphries, B.J. (1993). The optimal training load for the development of dynamic athletic performance. *Medicine and Science in Sport and Exercise*, 25(11), 1279-1286.
29. Zatsiorsky, V.M. (1995). *Science and practice of strength training*. Champaign, IL: "Human kinetics"..

EFEKTI PLIOMETRIJSKOG MODELA SPORTSKOG TRENINGA ZA RAZVOJ SKOČNOSTI ODBOJKAŠA

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Sa ciljem da se ispita pliometrijski model treninga za razvoj eksplozivne snage (skočnost) organizovano je eksperimentalno istraživanje na izorku od 33 odbojkaša kadetskog uzrasta. Rukovodeći se opštim principima za pliometrijski trening sačinjeni su individualni planovi treninga. Za procenu efekata sportskog treninga za razvoj skočnosti primenjene su tri varijable. Za potrebe ovog istraživanja validirana su dva testa za procenu odbojkaške skočnosti: skok u bloku i skok u smeču. Eksperiment je realizovan u drugom delu pripremnog perioda, a trajao je osam nedelja sa po dva do tri treninga. Kontrolna grupa je trenirala primenjujući tehničko taktičke sadržaje. Podaci su obrađeni univarijantnim i multivarijantnim analizama i analizom kovarijanse. Na osnovu rezultata istraživanja i diskusije može se pouzdano zaključiti da je primenjen model vežbi za razvoj skočnosti, kao osnovni faktor u eksperimentalnoj grupi, doprineo statistički značajnoj razlici u povećanju skočnosti u odnosu na kontrolnu grupu koja je za razvoj skočnosti koristila tehničko-taktičke sadržaje.

Ključne reči: *sportski trening, skočnost, eksperiment, odbojkaši*