CHANGES IN SPEED AND STRENGTH IN FEMALE VOLLEYBALL PLAYERS DURING AND AFTER A PLYOMETRIC TRAINING PROGRAM

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The goal of this article was the validation of a plyometric training program and the evaluation of the changes in monitored speed and explosive power predispositions during and after the end of the training program. The program was applied to a group of female youth volleyball players (n = 11) twice a week during an eight week period. Their actual level of explosive power and locomotor speed was evaluated before, during and after the intervention was completed. The levels were determined with the following tests: the standing vertical jump, the vertical jump with an approach and the shuttle run for 6 × 6 m. There were positive changes in the average values of test scores during the period of testing, but the dynamics of the changes in the explosive power and the speed were different. Other increases in all the characteristics were noticeable when the final measurements were made six weeks after the completion of the training program. Examination of the differences in the test scores by the follow up group, before the beginning and six weeks after finishing the intervention, was centred on objectively and statistically important changes in the volleyball players' motor predispositions ($p < .05$). The results of the program support the opinion that plyometric exercises are effective tools in the development of explosive power and speed in young athletes.

Keywords: Explosive power, speed, youth, training.

INTRODUCTION

Muscle strength is very important for most sport games at the present time. In volleyball, the achieved level of explosive power is fundamental. This explosive power is the most essential part of most player skills and enables players' activities during the game to be not only at the required height and with the necessary power but also at the right moment. A volleyball player's use of explosive power in vertical, horizontal and side movements is critical. The relationship between explosive power and the technical and tactical level of the player is especially evident when observing the player's activities at the net, attack from the field and spike serve.

The use of strength during the play is determined by the fact that the usage of maximum strength lasts from 0.5 to 0.7 seconds; however, most of the explosive movements take substantially less time. For this reason the optimal usage and transformation of the gained maximum muscle strength into the "explosivity" of the main muscle groups of the lower limbs, which take part in the takeoff, require special power training. This power training should be, according to Vechoshanskij (1995), clearly aimed and oriented and should activate the adaptation mechanism of the athlete's organism corresponding with the needs of the concrete sport activity. For the above reasons, an appropriate choice of training methods, exercises and individual intensity and volume of training load belongs among the key aspects in the preparation of the player's strength and power training program.

The plyometric method is ranked among the most frequently used methods for conditioning in volleyball. It leads to the development of explosive power and reactive speed of the muscle systems based on the improvement of the CNS reactivity and the power, which is needed for absorbing the stress when landing. The method is based on the reflex muscle fibre contraction, which gives a response to the quick stretch caused mostly by kinetic energy during the deceleration movement phase. In addition to contractile and elastic muscle attributes, we can see the improvement of the muscle proprioception and toleration for the stretching (stretching is producing elastic energy and with its release the energy of muscle contraction is growing). The method can influence muscle activity even with a well trained athlete and can evoke not only an adaptation of the neuromuscular functions, but also metabolic functions. The advantage of the plyometric method is that it increases functional power and enables the muscles to reach a higher power level than the maximum volitional power. The plyometric method also decreases muscle reflex inhibition, increases the sensitivity of the Golgi tendon organs, improves the sensitivity of the muscle spindles, increases

muscle tension and at the same time can decrease the risk of injuries (Bompa & Carrera, 2005; Boyle, 2004; Chu, 1998; Gambetta, 1999; Potach & Chu, 2000; Zatsiorsky & Kraemer, 2006).

The topic of using the plyometric method in athletes' preparation, volleyball players included, has been the centre of attention for many authors (Beal & Elder, 1988; Bosco, 1985; Brittenham, 1999; Johnson & Halling, 1990; Miller et al., 2006; Sandler, 2005; Schmidtbleicher & Gollhofer, 1982; Schneider, Mielke, & Mester, 1998). A plyometric training program should consider the goal of the training for a particular period, should respect basic training principles, first of all the principle of individualisation, a progressively increasing load (from low intensity to high intensity exercises over a period of several years and also during the annual training cycle), the principle of specificity (advanced athletes with plyometric method experiences should prefer specific exercises). It is also very important to have in mind their participation in the training cycles based on their actual health condition, competitions, jump load and possible combination with other training exercises (Beachle & Earle, 2000; Bourne, 1994; Faigeubaum & Westcott, 2000; Fergenbaum & Wayne, 2001; Gambetta, 1998; Chu, 1998; Komi, 1992; Marullo, 1999; Radcliffe & Farentinos, 1999; Reddin & Johnson, 1999; Scates & Linn, 2003).

We share the view of those experts who say that the plyometric method can be used both by adults and, to an adequate extent and intensity, also by youth players. The choice of exercises corresponding to the demands of exercises, acquired technique and good muscle strength belong among the basic conditions. In the preparation for plyometric training for the lower limbs, coaches have to focus on structural adaptation with an emphasis on the development of muscles, which create the "core" of the body and, after that, on the lower limb muscles with an emphasis on the area of the hip, knee and ankle joint.

The goal of this article is to verify a training program for female junior volleyball players consisting of plyometric exercises aimed at the lower limbs and, at the same time, to evaluate the dynamics of changes in monitored motor predispositions during and after the training program. We would like to find an answer for the following research questions:

1) What will be the dynamics of the changes in the explosive power and the speed evaluated by means of motor tests during and after ending an eight week plyometric training program?
2) What changes in the explosive power and the speed evaluated by means of locomotor tests will come after an eight week plyometric training program?

METHODOLOGY

The plyometric training program was applied during an 8 week period to a group of female youth volleyball players (n = 11; average age 14.8 ± 0.9; height 169 ± 6 cm; weight = 58 ± 9 kg). The players had completed a three-month preparatory training program focused on general strength development before starting our program. The players were informed about the principles of the plyometric exercises and they became familiar with the techniques of exercises. The exercises were practised twice a week (Monday and Wednesday) after warming up and the resting period between exercises series was two minutes. The jumping load while training with the ball was reduced during the time of the training program. The training program was divided into three cycles. The first cycle lasted two weeks and included the following exercises:

TYPE OF EXERCISE	JUMPS/SET
Alternating push off (one foot on a 30 cm box)	10 (L, R separately)
Two foot ankle hop (using only ankles for momentum)	10
Front barrier hops (eight 30 cm boxes set up in a row)	8
Spike jump at the net	10*

* *After four repetitions a short rest followed.*

The group of players had 2 series of the exercise in the first week and three in the second week of the first cycle.

The second cycle lasted 4 weeks and consisted of:

TYPE OF EXERCISE	JUMPS/SET
Zigzag double leg jump over the line	10
Tuck jump with knees up	10
Lateral box jump (landing on two feet on the 30 cm box and on one foot on the floor)	10
Single foot side to side ankle hop over medicine ball	10

The group of players had 2 series of the exercise in the first week and three series from the second to fourth week of the second cycle.

The third cycle lasted two weeks and consisted of:

TYPE OF EXERCISE	JUMPS/SET
Lateral medicine ball hops with a 180 degree turn (five medicine balls lined up three feet apart)	10
Front barrier hops back and forth (five 30 cm boxes set up in a row)	10
Block jumps at the net	8*
Alternate bounding with single arm action	8

* *After four repetitions a short rest followed.*

The group of players went through 3 series of the exercises in the first week and through 4 series in the second week of cycle three.

Testing of the motor predispositions took place on the same day after the standard warm up exercises and was accomplished by a semi skilled person with the assistance of the coach. None of the players mentioned any health problems when asked. Actual level of the takeoff power and locomotor speed was evaluated by these motor tests:

- standing vertical jump (height of the jump in cm),
- vertical jump with approach (height of the jump in cm),
- shuttle run for 6 × 6m (s) (Ejem, 1998; Kouba, 1998).

We determined the logical significance of the average values differences in the test scores as follows:

- standing vertical jump 3 cm,
- vertical jump with approach 4 cm,
- shuttle run for 6 × 6 m 0.4 s.

Part of the testing was the measurement of the person's height and the height of the one hand touch in the standing position. We did not note any significant changes in these characteristics (not mentioned in the text). To diagnose changes in the chosen parameters during the monitored period players were tested:

1. Before the start of the program.
2. After four weeks of the program.
3. The first week after completion of the program.
4. The third week after completion of the program.
5. The sixth week after completion of the program.

Friedman's ANOVA and Sign test were used to assess the statistical significance of the differences in average values of the tests scores.

RESULTS AND DISCUSSION

Dynamics of motor tests scores

TABLE 1
Basic statistical characteristics of the observed indicators in individual measurements – standing vertical jump (n = 11)

Parameter	M	Med	Min	Max	SD
SVJ1	29.50	29.50	23.00	37.00	3.89
SVJ2	30.45	31.00	23.00	37.00	3.53
SVJ3	32.09	32.00	24.00	39.00	4.08
SVJ4	31.18	33.00	18.00	36.00	5.03
SVJ5	33.54	34.00	24.00	39.00	4.08

Legend:
SVJ1–5 – standing vertical jump in measurements 1–5 (height in cm)
M – average
Med – median
Min – minimum
Max – maximum
SD – standard deviation

TABLE 2
Basic statistical characteristics of the observed indicators in individual measurements – vertical jump with an approach (n = 11)

Parameter	M	Med	Min	Max	SD
VJA1	38.33	39.50	30.00	46.00	5.46
VJA2	39.63	42.00	25.00	47.00	6.56
VJA3	42.63	43.00	27.00	51.00	6.28
VJA4	41.63	42.00	25.00	48.00	6.21
VJA5	43.27	45.00	28.00	50.00	5.98

Legend:
VJA1–5 – vertical jump with approach in measurements 1–5 (height in cm)
M – average
Med – median
Min – minimum
Max – maximum
SD – standard deviation

TABLE 3
Basic statistical characteristics of observed indicators in individual measurements – shuttle run for 6 × 6 m (n = 11)

Parameter	M	Med	Min	Max	SD
SR1	11.08	10.90	10.40	12.00	0.55
SR2	10.77	10.30	9.90	12.70	1.03
SR3	10.70	10.40	10.00	12.20	0.68
SR4	10.59	10.40	9.90	11.80	0.61
SR5	10.38	10.20	9.50	11.40	0.58

Legend:
SR1–5 – shuttle run for 6 × 6 m in measurements 1–5 (time in seconds)
M – average
Med – median
Min – minimum
Max – maximum
SD – standard deviation

Although plyometric training is a strongly individual matter and its realization is influenced by the current level of sport performance, the adaptability of the organism and its momentary state, experience with the particular training load, etc., we intend to orientationally assess the dynamic of changes in the explosive power and the locomotor speed evaluated by means of motor tests during and after ending the training program in the whole group of players (basic statistical characteristics of observed indicators are mentioned in TABLE 1–3).

TABLE 4
Statistical significance of test scores in performed measurements

Parameter	χ^2	p
Standing vertical jump	15.91	**.003**
One hand touch in the standing vertical jump	18.52	**.000**
Vertical jump with an approach	23.184	**.000**
One hand touch in the vertical jump with an approach	22.018	**.000**
Shuttle run for 6 × 6 m	15.514	**.003**

Legend:
χ^2– value of the test criterion (Friedman's ANOVA)
Statistically significant values ($p < .05$) are in bold characters.

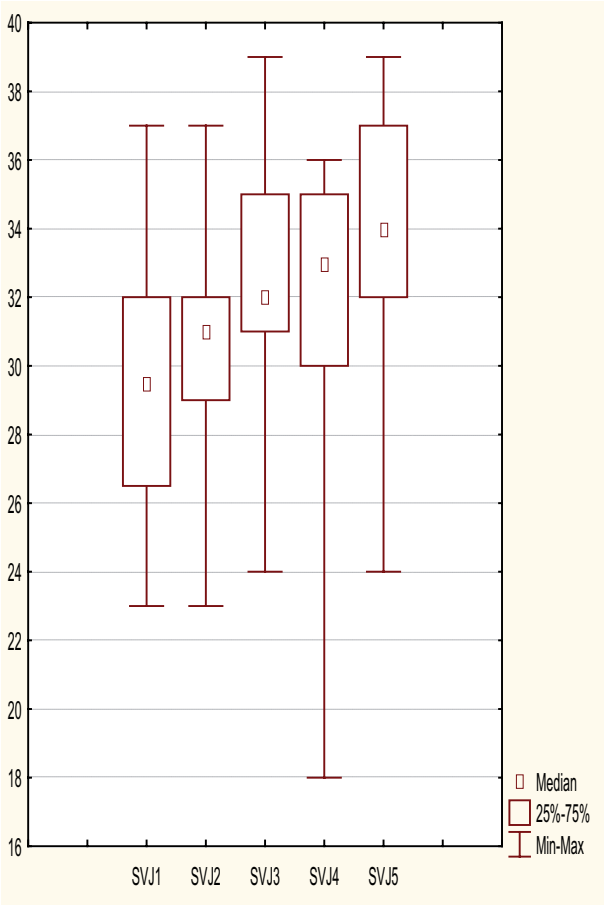
The results of the Friedman's ANOVA (TABLE 4) pointed to the relevance of the testing scores' differences for all monitored parameters (with respect to the specificity of game performance in volleyball, we also mentioned the significance of the testing scores' differences in the height of the one hand touch in the jump tests).

Furthermore we did a detailed comparison of the motor tests results, which were accomplished during and after completing the training program.

THE STANDING VERTICAL JUMP AND VERTICAL JUMP WITH AN APPROACH

The dynamics of the test scores' changes is similar and points to the sequential, even irregular, growth of the observed predispositions (Fig. 1, 2). There was a moderate increase in the average test score values (0.6 cm respectively 0.7 cm) between the first and the second measurement (before starting and five weeks after finishing the training program). According to Potach and Chu (2000) we can see bigger changes in the height of the vertical jump as early as after four weeks of plyometric training. Our results did not confirm this. We can suppose that a minor improvement can be associated with the lower intensity of the exercises, which were put on the first part of the program. We noticed other, statistically significant, improvements of over 1.64 cm ($p = 0.04$) respectively of over 3 cm ($p = 0.01$). These changes were noticed between the second and third measurements, respectively the fifth week of the training program and the first week after finishing the training program. We attribute these changes to a continuous adaptation to the specific training load. Between the third and the forth measurement (1st and 3rd week of the training program) there was a moderate lowering of the test scores. The reason for this fact is, in our opinion, the fatigue after the training program (0.91 cm, respectively 1 cm). Between the forth and fifth measurement (3rd and 6th week of the training program) there was another statistically significant increase in the average testing score values over 2.36 cm, respectively 1.7 cm ($p = 0.04$), and the values of the monitored indicators culminated. We suppose that the final improvement, which was noticed in the couple of weeks of distance measurements, is caused by usage of the, so called postponed (delayed) training effect. This effect can be cleared up by the fact that the human organism needs a longer time period for adaptation and relaxation after completing the training program (Zatsiorsky, 1995).

Fig. 1
Height of the jump in the test of the standing vertical jump in individual measurements (cm)



SHUTTLE RUN

The dynamics of changes in the test scores is typical of the continuous improvements made (Fig. 3). We noted the strongest reduction of the average time reached (0.31 s) at the beginning of the training program application (1st and 2nd measurement). This improvement is very surprising according to the time period of the adaptation. The possible explanation for the above can be the fact, that the type of the movement was repeated

Fig. 2
Height of the jump in the test of the vertical jump with an approach in individual measurements (cm)

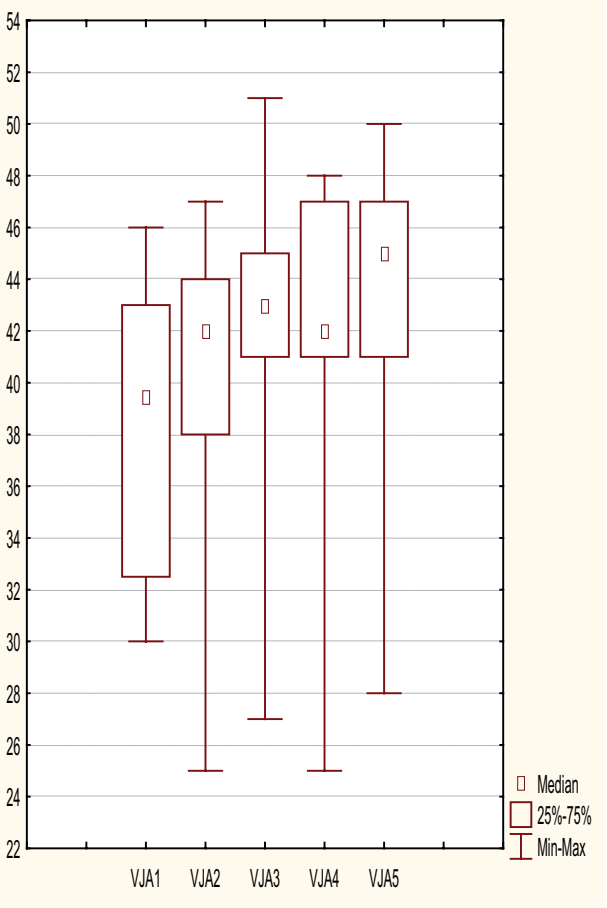
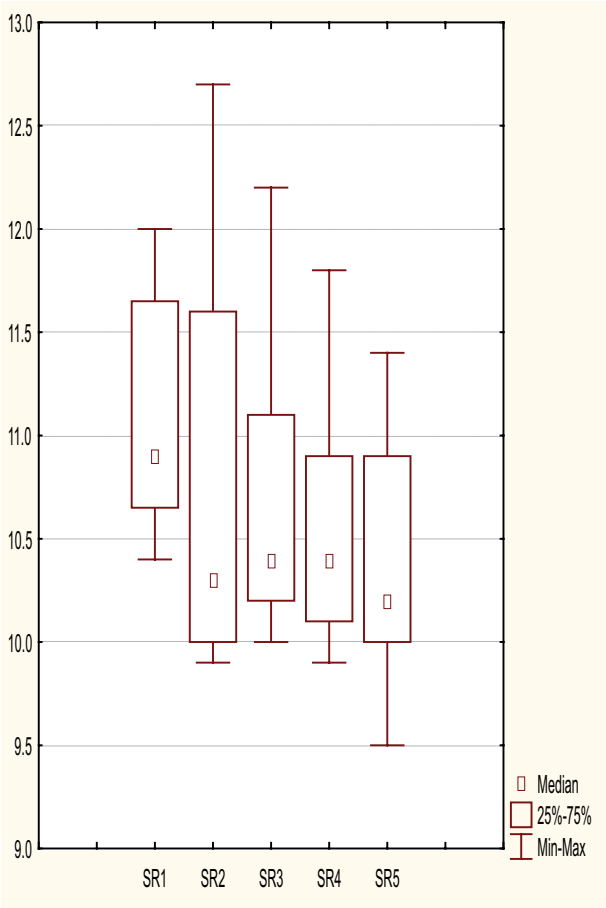


Fig. 3
Time in the test shuttle run for 6 × 6 m in individual measurements (s)



acceleration, respectively, deceleration and at the same time there are a lot of requirements for movement coordination.

We suppose that all these characteristics were strongly influenced by the exercises included in the programme. Differences between the results of the second and third measurement (approx. 0.06 s) show that the improvement in the second half of the plyometric training program was minimal, contrary to the results of the vertical jump testing. We noticed the very same trend (0.11 s) in the next period (between the 3rd and 4th measurement). The next increase in speed performance (0.21 s) can be seen between the 4th and 5th measurement (three and six weeks after finishing the training program). We suppose that the tiredness after the hard training program was already gone and the players could benefit from the training program. None of the above mentioned differences proved to be statistically significant.

We can summarize by saying that, according to the dynamic changes in the monitored speed and power characteristics, we noticed a positive, but, to some extent, different trend.

CHANGES IN MOTOR PREDISPOSITIONS – ENTRANCE AND OUTPUT MEASUREMENTS

The main criterion in the evaluation of the training program's efficiency is the difference in the sport performance. Examination in sport games is not, however, easy. So we set out from the basically acceptable presumption that the level of the speed and power demonstrated in the game skills connected with jumps and in locomotor movements is considered to be an important factor for game performance in volleyball. Taking into account the current literature (Zatsiorsky, 1995) and our experiences, we consider as decisive for the assessment of motor predisposition changes after the eight week training program the comparison of test results from the entrance measurement and the results from the output measurement (the 6th week after the end of the program). The comparison of the test results shows that the players were better in both the test of the standing vertical jump (the average improvement in height was about 4 cm) and in the test of the vertical jump with an approach (the improvement in the height was about 4.9

cm). Both results are statistically significant (TABLE 5). The greater improvement in the vertical jump with an approach could be caused by the higher similarity of the plyometric movement exercises and plyometric tests.

The results of the monitoring are similar to our previous study, which was made by volleyball players in the same age category (Lehnert, Šedá, & Zháněl, 2005). We can see an average improvement by this testing group after the plyometric training program in the test of the standing vertical jump (2.6 cm) and in the vertical jump with an approach (4.4 cm). The reasons for the greater improvement by the monitored group can be different. We consider that the positive factor could be the three month strength preparation, which was done before the plyometric program. Also, the logically and statistically significant improvements in average values in the test shuttle run for 6 × 6 m by 0.7 s coincide with the knowledge that plyometric exercises can stimulate athletes' speed. We didn't expect so strong an improvement. The similar progress in the dynamic speed changes during the ontogenetic improvement is typical for the longer time period (Zháněl & Lehnert, 2004; Zapletalová, 2002). The possible explanation for this efficiency improvement was presented in the previous text. In the face of the limits in the implemented study there is no objective chance to give a precise explanation of the relationship between the plyometric training program and monitored motor predispositions. Considering the age of the players it is important to keep in mind that it can be some impact of the training load also outside of the plyometric program and take into account biological development, which is still ongoing.

TABLE 5
The statistical significance of test scores – entrance and output measurements

Parameter	M	Med	d	Z
SVJ1	29.50	29.50	4.04	**2.41**
SVJ5	33.54	34.00		
VJA1	38.33	39.50	4.96	**2.41**
VJA5	43.27	45.00		
SR1	11.08	10.90	0.30	**3.01**
SR5	10.38	10.20		

Legend:
SVJ – standing vertical jump (cm)
VJA – vertical jump with an approach (cm)
SR1 – shuttle run for 6 × 6 m (s)
M – average
Med – median
d – difference
Z – value of statistical criterion (Sign test)
Statistically significant values ($p < .05$) are in bold characters.

CONCLUSION

1. The dynamics of changes in the monitored motor predispositions in female volleyball players showed a positive trend with differences between explosive power and speed values during the training program. We can see another increase of the test scores at time of the final measurement six weeks after finishing the training program.
2. We found logically and statistically significant improvements of explosive power tested by tests of the standing vertical jump and the vertical jump with an approach after eight week training period.
3. The results of the study support the opinion that plyometric exercises can be an effective tool for the improvement of the explosive power and speed predispositions of youth athletes.

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ZMĚNY RYCHLOSTNĚ-SILOVÝCH PŘEDPOKLADŮ VOLEJBALISTEK V PRŮBĚHU A PO ABSOLVOVÁNÍ PLYOMETRICKÉHO TRÉNINKOVÉHO PROGRAMU

(Souhrn anglického textu)

Cílem studie bylo ověřit v tréninkové praxi program sestávající z vybraných plyometrických cvičení a zhodnotit změny sledovaných rychlostně-silových předpokladů v průběhu a po jeho absolvování. Program byl aplikován u volejbalistek kadetské kategorie (n = 11) 2× týdně po dobu 8 týdnů. Aktuální úroveň výbušné síly a lokomoční rychlosti byla hodnocena před, v průběhu a po skončení intervence testy dosah jednoruč po výskoku z místa, dosah jednoruč výskokem po smečařském rozběhu a rychlostní člunkový běh na 6 × 6 m. V období realizace programu docházelo k pozitivním změnám průměrných hodnot testových skóre, avšak dynamika změn ukazatelů odrazové síly a rychlosti byla odlišná. Další nárůst výkonnosti u všech sledovaných ukazatelů byl zaznamenán při výstupním měření (šest týdnů po absolvování tréninkového programu). Posouzení rozdílů testových skóre sledovaného souboru před intervencí a šest týdnů po jejím skončení ukázalo na věcně i statisticky významné změny ve výkonnosti hráček ($p < .05$) Výsledky studie podporují názor, že plyometrická cvičení jsou efektivním prostředkem rozvoje výbušné odrazové síly a rychlosti sportující mládeže.

Klíčová slova: výbušná síla, rychlost, mládež, trénink.

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