HUMAN MOVEMENT
2009, vol. 10 (2), 149–152

CHANGES OF POWER–VELOCITY RELATIONSHIP IN VOLLEYBALL PLAYERS DURING AN ANNUAL TRAINING CYCLE

DOI: 10.2478/v10038-009-0006-2

Krzysztof Buśko
Department of Anthropology, The Józef Piłsudski University of Physical Education, Warsaw, Poland
Department of Biomechanics, Institute of Sport, Warsaw, Poland

ABSTRACT
Purpose. The aim of the study was to follow the changes of maximal power output and power–velocity relationship in male volleyball players during an annual training cycle. **Basic procedures.** The study was conducted on six first-league volleyball players: age 25.0 ± 5.3 years, body height 195.2 ± 7.2 cm and body mass 91.2 ± 14.7 kg. Force–velocity and power–velocity relations were determined from five maximal cycle ergometer exercise tests, 10 s each, with increasing external loads amounting to 2.5, 5.0, 7.5, 10.0 and 12.5% of body weight, respectively. There were 2-min breaks between the tests. Maximal power output was computed from power–velocity curves. Maximal power output and power–velocity relationships were determined before the preparatory period (I), after the first competitive season (II) and after the second competitive season (III). **Main findings.** Significant increases occurred in the maximal power output from 12.80 ± 0.79 (preparatory period) to 13.11 ± 0.94 (after the first competitive season) and 13.44 ± 0.62 W·kg^{-1} (after the second competitive season). The mean optimal velocity (v_o) increased non-significantly from 122.2 ± 16.1 rpm (I) to 129.2 ± 14.9 rpm (II), and decreased non-significantly during the second competitive season (119.5 ± 18.5 rpm). **Conclusions.** In the annual training cycle under study a statistically significant increase of the power output with the external load of 7.5% of body weight was noted. The relative maximal power output increased significantly after the second competitive season as compared with the measurement before the preparatory period. The optimal velocity changed insignificantly in the entire annual training cycle.

Key words: power–velocity relationship, maximal power output, volleyball

Introduction

Volleyball is a sport involving short and intensive physical efforts during training and competition [1, 2]. Volleyball players' fitness relies on their force, power output and jumping ability [3, 4]. Although the players' power output is measured on a cycloergometer, its value depends, however, on the amount of external loading [2]. Different authors have examined the force-velocity (*F–v*) and power–velocity (*P–v*) relationships, measured during cycloergometer exercises in different groups of athletes [5, 6] and discussed the effects of specific training exercises on the force–velocity relationship [7–9]. Their results suggest that sport training can influence the correlation mentioned [5–7]. With the exception of Häkkinen's work [10] discussing changes of force and jumping ability in female volleyball players during the competitive season, there have been no studies, however, examining changes in the force–velocity and power–velocity relationships in volleyball players during an annual training cycle. The aim of the present study was to follow changes of the maximal power output and power–velocity relationship in male volleyball players during an annual training cycle.

Material and methods

The study was granted approval of the Research Ethics Committee. The sample consisted of six male volleyball players from the Polish Volleyball League aged 25.0 ± 5.3 years, with body height of 195.2 ± 7.2 cm and body weight of 91.2 ± 14.7 kg. The measurements were performed before the preparatory period (I), after the first competitive season (II) and after the second competitive season (III).

The force–velocity (*F–v*) and power–velocity (*P–v*) relationships were determined on the basis of results of exercises performed on a Monark 874 E cycloergometer connected to a PC, using the MCE 4.0 software package. After adjusting the ergometer saddle and handlebars each subject performed the tests in a stationary position, without lifting off the saddle, with his feet strapped onto the pedals. Each player performed five 10-second maximal cycloergometer tests with increas-

Table 1. Absolute (P) and relative (P/mass) power outputs recorded for an external force–velocity relationship (mean values ± SD) in volleyball players during the competitive season

Load (% BW)		I	II	D (%)	III	D (%)
P (W)	2.5	421.5 ± 93.5	429.5 ± 61.6	**4.2**	442.8 ± 50.1	**7.9**
	5.0	796.5 ± 133.3	815.3 ± 119.8	**2.7**	811.7 ± 112.6	**2.4**
	7.5	1021.0 ± 153.4	1064.8 ± 143.4	**4.6**	1049.7 ± 110.9	**3.5**
	10.0	1144.2 ± 181.9	1183.5 ± 165.1	**3.8**	1170.2 ± 136.9	**2.9**
	12.5	1110.8 ± 113.1	1113.5 ± 170.5	**0.2**	1189.8 ± 160.4	**6.8**
P_{max} (W)		1162.7 ± 164.1	1191.2 ± 163.2	**2.6**	1202.0 ± 145.3	**3.7**
P/mass (W/kg)	2.5	4.60 ± 0.55	4.72 ± 0.28	**3.8**	4.95 ± 0.19	**9.2**
	5.0	8.74 ± 0.54	8.96 ± 0.70	**2.5**	9.06 ± 0.54[a]	**3.9[a]**
	7.5	11.24 ± 0.96	11.72 ± 0.84[a]	**4.4[a]**	11.75 ± 0.51[a]	**4.9[a]**
	10.0	12.59 ± 0.96	13.02 ± 0.98	**3.6**	13.11 ± 0.87	**4.3**
	12.5	12.29 ± 0.82	12.29 ± 1.47	**0**	13.28 ± 0.64	**8.5**
P_{max}/mass (W/kg)		12.80 ± 0.79	13.11 ± 0.94	**2.4**	13.44 ± 0.62[a]	**5.1[a]**

[a] mean values differ significantly ($p < 0.05$) between the I (before the preparatory period), II (after the first competitive season) and III (after the second competitive season) measurements; D – percent differences in relation to the values recorded before the preparatory period (I) and successive measurements during the first (II) and second (III) competitive seasons

ing external loads amounting to 2.5, 5.0, 7.5, 10.0 and 12.5% of body weight, respectively. There were 2-min breaks between the tests. The standard procedures of exercise performance were followed, and the subjects were verbally encouraged to achieve and maintain as quickly as possible the maximal pedaling velocity. With the use of MCE v. 4.0 the maximal power output at a given load (P_i; *i* – load value) and velocity (v_i) necessary to achieve P_i were determined [11].

On the basis of the results obtained the force–velocity and power–velocity relationships as well as individual maximal power output (P_{max}) and optimal pedaling velocity (v_o) were calculated for each subject [6]. The maximal power output and optimal pedaling velocity were computed from individual equations of the second degree polynomial describing the *P*–*v* relationship [5, 11]. The maximum of the curve (largest value of the function) was defined as maximal power (P_{max}), and the pedaling velocity necessary to achieve it as optimal velocity.

The results were statistically processed using analysis of variance (ANOVA) with repeated measures. The statistical significance of the mean values was analysed using post-hoc Fisher's least significant difference test (LSD). The level of statistical significance was set at $p < 0.05$. All statistical calculations were made with the use of Statistica (v. 8.0, StatSoft) software package.

Results

Table 1 presents the results obtained. The changes of the absolute values of maximal power and the highest velocity at a given load were statistically non-significant. In terms of relative values a significant increase of the maximal power output at the load of 7.5% of body weight was observed from 11.24 ± 0.96 W $\cdot kg^{-1}$ before the preparatory period (I) to 11.72 ± 0.84 W $\cdot kg^{-1}$ after the first competitive season (II) and 11.75 ± 0.51 W $\cdot kg^{-1}$ after the second competitive season (III). The relative maximal power output increased from 12.80 ± 0.79 W $\cdot kg^{-1}$ (I) to 13.44 ± 0.62 W $\cdot kg^{-1}$ (III). Furthermore, a non-significant increase of optimal velocity was noted from 122.2 ± 16.1 rpm (I) to 129.2 ± 14.9 rpm (II), and non-significant decrease after the second competitive season (III) (119.5 ± 18.5 rpm).

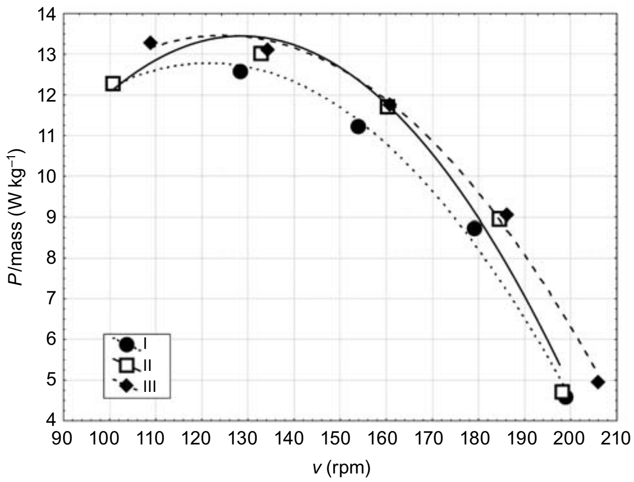

Figure 1. Changes of relative power–velocity curves in volleyball players during competitive season (I – the start of preparatory period, II – after the first competitive season, III – after the second competitive season)

Discussion

Volleyball is commonly classified as an “interval” sport, which uses both anaerobic and aerobic metabolism [3, 4, 12–14]; whereas volleyball players can be categorized as “power athletes” [15]. Thus volleyball training should develop the power of legs and improve players’ strength and/or velocity. The preparatory training period is usually devoted to the training of motor skills; while the competitive period focuses primarily on the improvement of volleyball technique and tactics [10].

A number of studies indicate that strength training consisting of exercises with high external loads and low velocity enhances the final course of the *F–v* curve (high power, low velocity), unlike the high velocity [8, 9, 16]. Training with low loads and high velocity improves the results in the entire course of the *F–v* curve [8, 16], or increases the force and power of movements performed with a high velocity [9, 16].

The present study showed that the volleyball training improved the players’ power–velocity relationship at a high force and low velocity between the preparatory period and the first competitive season. After the second competitive season a parallel shift of the power–velocity curve was noted (Fig. 1). During the entire season the values of relative maximal power increased. The changes in the *P*–v relationship and maximal power output were accompanied by a non-significant increase of the optimal velocity between the I and II measurements and a non-significant decrease after the second competitive season (III). Buśko [17] reported a significant training-related increase of the optimal velocity after the first competitive season as compared with the measurement results from before the preparatory period. The present study revealed non-significant changes of the optimal velocity. Considering the fact that volleyball training aimed at the improvement of players’ force also enhances their power and jumping ability [18, 19], the results obtained are satisfactory. It must, however, be kept in mind that a study of female volleyball players by Häkkine [10] revealed an increase in all measured parameters only until the completion of the first competitive period, after which a decrease was noted.

Conclusions

1. In the annual training cycle under study a statistically significant increase of the power output with the external load of 7.5% of body weight was noted.
2. The relative maximal power output increased significantly after the second competitive season as compared with the measurement before the preparatory period.
3. The optimal velocity changed non-significantly in the entire annual training cycle.

Acknowledgments

The study was partly supported by the Józef Piłsudski University of Physical Education in Warsaw under grant I.29 financed from the National Scientific Research Committee.

References

1. Chamari K., Ahmaidi S., Blum J.Y., Hue O., Temfemo A., Hertogh C., Mercier B., Préfaut C., Mercier J., Venous blood lactate increase after vertical jumping in volleyball athletes. *Eur J Appl Physiol*, 2001, 85 (1–2), 191–194. DOI: 10.1007/s004210100415.
2. Driss T., Vandewalle H., Monod H., Maximal power and force–velocity relationships during cycling and cranking exercises in volleyball players. Correlation with the vertical jump test. *J Sports Med Phys Fitness*, 1998, 38 (4), 286–293.
3. Smith D.J., Roberts D., Watson B., Physical, physiological and performance differences between Canadian national team and universiade volleyball players. *J Sports Sci*, 1992, 10 (2), 131–138. DOI: 10.1080/02640419208729915.
4. Viitasalo J.T., Rusko H., Pajala O., Rahkila P., Ahila M., Montonen H., Endurance requirements in volleyball. *Can J Appl Sports Sci*, 1987, 12, 194–201.
5. Buśko K., Wit B., Force–velocity curve and power in karate, rowing and volleyball athletes. *Acta Bioengin Biomech*, 2003, 5 (Suppl. 1), 67–72.
6. Vandewalle H., Peres G., Heller J., Panel J., Monod H., Force-velocity relationship and maximal power on a cycle-ergometer. *Eur J Appl Physiol*, 1987, 56 (6), 650–656. DOI: 10.1007/BF00424805.
7. Hamar D., Monitoring biomechanical parameters of movement during weightlifting exercises [in Polish]. *Sport Wyczynowy*, 1999, 1–2, 36–45.
8. Häkkinen K., Neuromuscular adaptation to strength training in men and women and strength athlete. In: Lee C.P. (ed.), Proceedings of 2nd International Conference on Weightlifting and Strength Training. Department of Education, Pro Muscle Exercise Centre, Ipoh, Malaysia 2000, 5–9.
9. Kanehisa H., Miyashita M., Specificity of velocity in strength training. *Eur J Appl Physiol*, 1983, 52 (1), 104–106. DOI: 10.1007/BF00429034.
10. Häkkinen K., Changes in physical fitness profile in female volleyball players during the competitive season. *J Sports Med Phys Fitness*, 1993, 33, 323–332.
11. Buśko K., Economical and optimal pedaling velocity characteristics during maximal and submaximal efforts on cycloergometer. *Biol Sport*, 2007, 24 (3), 209–226.
12. Conlee R.K., McGrown C.M., Dalsky G.P., Robinson K.C., Physiological effects of power volleyball. *The Physician and Sportsmedicine*, 1982, 10 (2), 93–97.
13. Gonzáles C., Ureña A., Llop F., Garcia J.M., Martin A., Navarro F., Physiological characteristics of libero and central volleyball players. *Biol Sport*, 2005, 22 (1), 13–27.

14. Küntslinger U., Ludwig H., Stegeman J., Metabolic changes during volleyball matches. *Int J Sports Med*, 1987, 8, 315–322.
15. Driss T., Vandewalle H., Quievre J., Miller C., Monod H., Effects of external loading on power output in a squat jump on a force platform, a comparison between strength and power athletes and sedentary individuals. *J Sports Sci*, 2001, 19 (2), 99–105.
16. Moss B.M., Refsnes P.E., Abildgaard A., Nicolaysen K., Jensen J., Effects of maximal effort strength training with different loads on dynamic strength, cross-sectional area, load–power and load-velocity relationships. *Eur J Appl Physiol*, 1997, 75, 193–199. DOI: 10.1007/s004210050147.
17. Buśko K., Changes of maximal power, force-velocity and power–velocity relationship of lower extremity muscles in volleyball players during training. *Acta Bioengin Biomech*, 2004, 6 (Suppl. 1), 246–249.
18. Clutch D., Wilton M., McGown C., Bryce G.R., The effect of depth jumps and weight training on leg strength and vertical jump. *Res Q Exerc Sport*, 1983, 54 (1), 5–10.
19. Young W.B., Wilson G.J., Byrne C.A., A comparison of drop jump training methods: effects on leg extensor strength qualities and jumping performance. *Int J Sports Med*, 1999, 20, 295–303. DOI: 10.1055/s-2007-971134.

Paper received by the Editors: June 3, 2008.
Paper accepted for publication: November 28, 2008.

Address for correspondence
Krzysztof Buśko
Zakład Biomechaniki
Instytut Sportu
ul. Trylogii 2/16
01-982 Warszawa, Poland
e-mail: krzysztof.busko@insp.waw.pl