Changes of Power-Velocity Relationship in Female Volleyball Players during an Annual Training Cycle

K. Busko

***Abstract*—**The aim of the study was to follow changes of power-velocity relationship in female volleyball players during an annual training cycle. The study was conducted on eleven female volleyball players: age 21.6±1.7 years, body height 177.9±4.7 cm, body mass 71.3±6.6 kg and training experience 8.6±3.3 years. Power–velocity relationship was determined from five maximal 10-second cycloergometer efforts with external loads equal: 2.5, 5.0, 7.5, 10.0 and 12.5% of body weight (BW) before (I) and after (II) the preparatory period, after the first (III) and second (IV) competitive season. The maximal power output increased from 9.30±0.85 W•kg^{-1} (I) to 9.50±0.96 W•kg^{-1} (II), 9.77±0.96 W•kg^{-1} (III) and 9.95±1.13 W•kg^{-1} (IV, p<0,05). The power output at the load of 2.5, 5.0, 7.5, 10.0% BW were statistically significant increased after the first and second competitive season. Power output at load of 12.5% BW was insignificant increased.

***Keywords*—**Female, Force-velocity relationship, Power output, Volleyball

I. Introduction

THE dependence between produced power and the pace shortening on contractile elements is a fundamental characteristic of muscle [1]. In the in vitro research conducted during exercises involving muscles of group of joints [2], [3] the force-relationship (F-v) relationship course was in accordance with Hill's equation (hyperbolic) or linear [2]-[6].

Volleyball is an intermittent sport that requires players to compete in frequent short bouts of high- intensity exercise, followed by periods of low- intensity activity [7]-[9]. In addition to technical and tactical skills, it has been argued that muscular strength and power are the most important factors that give a clear advantage for successful participation during competitions [5], [10], [11]. The players' power output is often measured on a cycloergometer [5], [6] . Its value depends on the amount of external loading [4], [8]. Many authors have described the effect of specific training on force-velocity relationship [5], [12], [13]. In the works of Buśko [5], [14] F-v characteristics were determined on the cycle ergometer for male volleyball players. But in the literature, there is no publication for changes on the force-velocity and power-velocity relationship in female volleyball players. There is also a paucity of research on performance characteristics of female volleyball players during an entire in-season [10], [15]. The aim of the study was to follow changes of power-velocity relationship in female volleyball players during an annual training cycle.

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II. Material and Method

The Scientific Research Board of Ethics accepted this research. Judoists were informed about the study goal and methodology. They also acknowledged the possibility of resignation at every stage of the experiment. Subjects accepted the above conditions in writing. The study was conducted on eleven second-league female volleyball players: age 21.6±1.7 years, body height 177.9±4.7 cm, body mass 71.3±6.6 kg (I), 72.3±6.2 kg (II), 72.0±6.9 kg (III), 71.2±6.7 kg (IV), and training experience 8.6±3.3 years. 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 (Sweden) connected to a PC, using the MCE 4.0 software package („JBA" Zb. Staniak, Poland). 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 increasing external loads amounting to 2.5, 5.0, 7.5, 10.0 and 12.5% of body weight (BW), 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 software the maximal power output at a given load (P_i; i – external load value) and velocity (v_i) necessary to achieve P_i were determined [4]. 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 [4]. The maximal power output and optimal pedaling velocity were computed from individual equations of the second degree polynomial describing the *P*–*v* relationship [4], [5]. 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 measurements were performed before the preparatory period (I), after the preparatory period (II), after the first (III) and second (IV) competitive season.

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 Tukeya test. The level of statistical significance was set at p<0.05. All statistical calculations were conducted using a Statistica^{TM} software package (v. 8.0, StatSoft 2007).

III. Results

The obtained results are presented in Table I. The absolute and relative power output at the load of 2.5, 5.0, 7.5 and 10.0% of body weight were statistically significant increase after the first and second competitive season (Fig. 1). The power output at the load of 12.5% BW insignificantly increased after the preparatory period. The velocity necessary to achieve the power output at external loads equal 2.5, 5.0, 7.5, 10% BW significant increased, too. Fig. 2 presents percentage differences of relative power output calculated according to measurements conducted before the preparatory period (I). The relative maximal power output increased from 9.30±0.85 W·kg^{-1} (I) to 9.50±0.96 W·kg^{-1} (II), 9.77±0.96 W·kg^{-1} (III) and 9.95±1.13 W·kg^{-1} (IV, p<0,05). Furthermore, a significant decrease of optimal velocity was noted from 115.2±12.7 rpm (I) to 97.5±10.114.9 rpm (II), and significant increase after the first competitive season (III) (104.0±18.8 rpm), and non-significant increase after the second competitive season (IV) (110.4 ± 12.5 rpm).

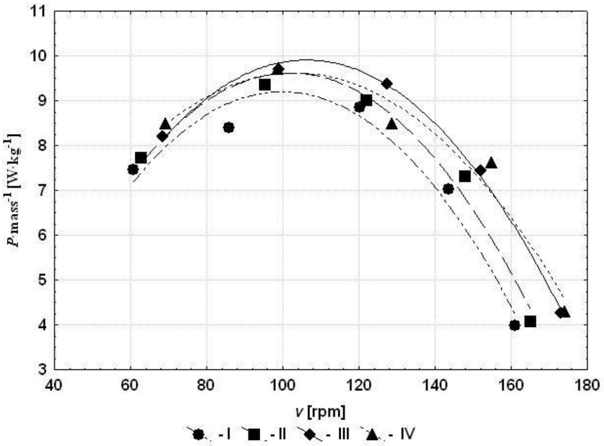

Fig. 1 Changes of relative power-velocity curves in female volleyball players during an annual training cycle (I – before the preparatory period, II - after the preparatory period, III - after the first competitive season, IV - after the second competitive season)

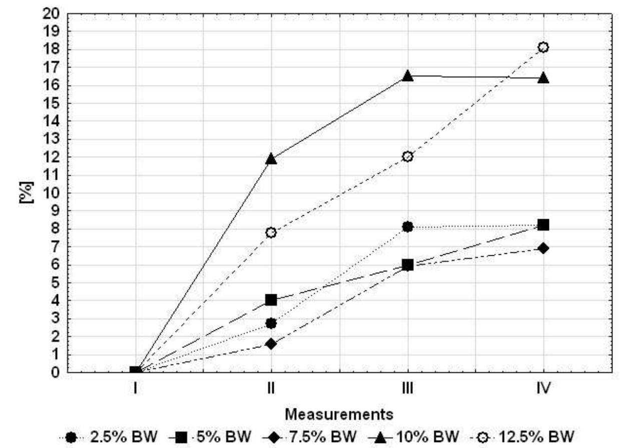

Fig. 2 Mean values [%] of the relative power output changes produced in the F-v relationship calculated according to the measurement taken before the preparatory period (I) and subsequently: II – after the preparatory period, III – after the first competitive season, IV - after the second competitive season

IV. Discussion

Volleyball is commonly classified as an "interval" sport, which uses both anaerobic and aerobic metabolism [11], [16]-[18]; whereas volleyball players can be categorized as "power athletes" [19]. Thus volleyball training should develop the power of legs and improve players' strength and/or velocity. Training of motor skills in volleyball players has its principal place during the preparatory period. In the competitive period the main emphasis is on improving the technique and tactics, and training of motor skills are reduced [20]. Thus the training of volleyball players should develop the power of legs and improve the strength and/or velocity. The present study revealed significantly increased the maximal power and non-significant changes of the optimal velocity. A number of studies have investigated the effects of different training methods at preseason [21], [22] or during the competitive season in volleyball [5], [15], [22], [23]. In the competitive season strength increased significantly by 15% and height in CMJ was significantly improved by 3.8% [15]. Height in squat jump (SJ) and CMJ were significantly increase by 7.6% and 4.6%, respectively and the strength of 6.01% in the second competitive season [24]. The results showed by Stanganell et al. [23] that the training-induced adaptations on the SJ (3.9%) and CMJ (2.3%) were not statistically significant during second competitive season while the attack height and block height presented significant differences during an annual training cycle (3.0% and 3.5%, respectively). Buśko [14] 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. In this paper, volleyball training improved the power output at a load of 5 and 10% BW during the preparatory period and at load of 2.5%, 5.0%, 7.5% and 10.0% BW after first and second competitive season. Change of power output accompanied by a significant increase in velocity of only 10% BW load during preparatory period and at load of 2.5%, 5.0%, 7.5% and 10.0% BW after first and second competitive season. There were no changes of power output and velocity under the first phase of the competition between the III and IV measurements, while at article Hakkinen [20] all measured values were reduced. Busko [5] described similar changes of the power-velocity relationship in male volleyball players under the influence of training after the first competitive season, compared with the values from before the start of the preparatory period. Considering the fact that volleyball training aimed at the improvement of players' force also enhances their power and jumping ability [15], [24], [25], the obtained results are satisfactory.

TABLE I
Absolute (P) and relative ($P \cdot mass^{-1}$) power outputs and velocity (v) recorded for an external force-velocity relationship (mean values ±SD) in female volleyball players during an annual training cycle

Variable	Load [% BW]	I	II	III	IV
P [W]	2.5	283.6±38.3	293.0±28.0	306.3±21.3[ab]	307.3±29.8[ab]
P [W]	5.0	501.6±55.9	527.1±46.3 [a]	533.9±38.9 [a]	538.3±38.9 [a]
P [W]	7.5	629.7±54.4	639.4±52.7	670.7±47.3[ab]	668.4±35.2[ab]

P [W]	10.0	596.3±81.0	670.6±69.9 [a]	682.6±56.3 [a]	682.8±54.1 [a]
P [W]	12.5	528.0±133.2	554.3±90.2	585.0±128.0	593.67±105.8
$P\cdot mass^{-1}$ [$W\cdot kg^{-1}$]	2.5	3.97±0.30	4.06±0.18	4.27±0.22 [ab]	4.28±0.21 [ab]
$P\cdot mass^{-1}$ [$W\cdot kg^{-1}$]	5.0	7.03±0.35	7.31±0.22 [a]	7.44±0.38 [a]	7.60±0.49 [ab]
$P\cdot mass^{-1}$ [$W\cdot kg^{-1}$]	7.5	8.85±0.48	8.99±0.68	9.38±0.87 [a]	9.47±0.86 [ab]
$P\cdot mass^{-1}$ [$W\cdot kg^{-1}$]	10.0	8.40±1.13	9.35±1.18 [a]	9.69±1.00 [a]	9.70±1.27 [a]
$P\cdot mass^{-1}$ [$W\cdot kg^{-1}$]	12.5	7.45±1.78	7.71±1.25	8.19±1.89	8.48±1.88
v [rpm]	2.5	161.1±11.1	165.2±6.7	173.0±8.3 [ab]	174.2±7.8 [ab]
v [rpm]	5.0	143.5±6.8	147.9±5.3	152.0±7.6 [ab]	154.8±9.1 [ab]
v [rpm]	7.5	120.3±6.5	122.1±9.6	127.5±11.8 [a]	128.8±11.7[ab]
v [rpm]	10.0	85.8±11.6	95.3±12.2 [a]	98.9±10.2 [a]	98.8±12.9 [a]
v [rpm]	12.5	60.7±14.5	62.9±10.1	68.4±17.4	69.2±15.4

I - measurements before the preparatory period, II - measurements during after the preparatory period, III - measurements during after the first competitive seasons, IV - measurements during after the second competitive seasons; a – mean values significantly different from the I measurement (p<0.05); b - mean values significantly different (p<0.05) from II measurement

V. Conclusion

In the studied training cycle a statistically significant increase of the power output with the external load of 2.5, 5.0, 7.5% and 10.0% of body weight and the velocity necessary to achieve the power output was noted. The relative maximal power output increased significantly after the second competitive season as compared with the measurement before the preparatory period.

Acknowledgments

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