DIFFERENCES IN THE ANAEROBIC POTENTIAL OF MALE AND FEMALE VOLLEYBALL PLAYERS

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ABSTRACT
Volleyball is an intermittent sport dominated by the ability of competitors to perform explosive movements of both the lower and upper limbs. We find many studies related to the sport in the methodological literature, but most of them consider only one aspect. From this perspective, the present study aims to determine the differences in the manifestation of anaerobic power potential in volleyball players. To achieve the study's goal, we solved the following tasks: 1) Determining the level of development of indicators characterizing anaerobic potential in male and female volleyball players. 2) Determining their correlations 3) Comparing their level of development. We used speedometry, chronometry, force plate tests, anthropometry, and statistical methods (descriptive statistics, correlation, and comparative analysis) to solve the research tasks. After the analysis, we obtained the following results. The average values for the individual tests for men and women show significant homogeneity. In all indicators, men have better indicators than women. The interrelationships among the studied indicators show that in women, there is a clear transfer of test results characterizing the anaerobic potential of the lower extremities, without this power being transferred to the upper extremities. Meanwhile, men tend to a complete transfer of anaerobic potential. Conclusions: Men and women demonstrate a good level of development of the explosive power abilities of the lower extremities and less of the speed abilities. These results indicate an incomplete deployment of upper-extremity explosive-power capabilities in women.

Keywords: *speed, speed endurance, explosive power, strength, and conditioning*

INTRODUCTION

Volleyball is one of the most popular sports in the world, played by thousands of people in all its forms. As such, it is of interest to sports professionals. Volleyball is an intermittent sport dominated by the ability of competitors to perform explosive movements of both the lower and upper limbs (Tillman et al., 2004). We find many studies related to the sport in the literature, but most of them consider only one aspect (Fry et al., 1991; Marques et al., 2009; Sheppard et al., 2008; Ziv & Lidor, 2010; Borràs et al., 2011; Nikolaidis et al., 2012; Sattler et al., 2012; Taware et al., 2013; Nikolaidis et al., 2015; Bun et al., 2020). Most studies on conditioning primarily focused on developing strength training and explosive power abilities with a view to the main game actions, namely rebounding. However, an integral part of a volleyball match is other actions, both technical and physical. These locomotions are determined by the game's two phases – attack and defense. According to some authors, between 65 and 135 different types of rebounds are performed during a match (Borràs et al., 2011). Moreover, during a game, each player performs at least 30 rebounds (Sánchez-Moreno et al., 2016). Although a basic action, the vertical rebound is as important in volleyball as any court movement. Due to the short duration of the games, all these actions are intense and occur at maximum speed, placing great demands on the conditioning and, in particular, the anaerobic potential of volleyball players.

From this perspective, the present study aims to determine the differences in the manifestation of anaerobic power potential in volleyball players that would be beneficial for optimizing the training process through a better understanding of the synergistic influence between motor abilities. To achieve the study's goal, we solved the following tasks: 1) Determining the level of development of indicators characterizing anaerobic potential in male and female volleyball players. 2) Determining their correlations 3) Comparing their level of development.

METHODOLOGY

The study group consisted of 49 men (195±8cm; 86±8kg) and 24 women (180±9cm; 73±5kg), all of them professional volleyball players in the Bulgarian Super League. Detailed position distribution is available in Table 1.

Table 1. *Distribution of volleyball players by gender and position*

Gender → Position ↓	Women	Men
Opposite hitter	2	4
Libero	4	9
Outside hitter	4	16
Setter	6	8
Middle blocker	8	12

To realize the overall research's purpose and the main tasks derived from it, we used the following methods: Anthropometry, Chronometry, Speedometry, Force plate test, and Statistical methods (Descriptive statistics, Normality test, Correlation, *T*-test). All of the research indicators are shown in Table 2.

Table 2. *Research indicator, tests, and measurement precision used in the research*

№	Test	Investigated parameter	Precision	Measure unit
1	Height	Physical development	0.01	cm
2	Weight	Physical development	0.10	kg
3	20 м running	Speed abilities	0.01	sec
4	4 x 20 shuttle run	Speed endurance	0.01	sec
5	Squat jump	Explosive power	0.1	cm
6	CMJ	Explosive power	0.1	cm
7	CMJA	Explosive power	0.1	cm
8	Serving speed	Explosive power upper limb	1.00	km/h

Before the tests, the athletes did a standard warm-up within 15 minutes, including light running, general development exercises, specific running exercises, acceleration and start drills, and stretching. A trained specialist performed height as part of anthropometric measurements. Height was measured while the athlete stood with legs together, arms at the sides, legs straight, shoulders relaxed, and head in a horizontal plane, with heels, buttocks, shoulder blades, and the back of the head resting against a vertical wall. These measurements were taken in centimeters using a SOEHNLE 5003 digital height meter (Soehnle Professional, GmbH Co., Backnang, Germany), which measures heights from 50 cm to 240 cm with an accuracy of 0.01 cm. Weight was recorded using the InBody 230. Competitors were measured barefoot to the nearest 0.1 kg.

We used the Witty timing system (Microgate, Bolzano, Italy) to measure the speed with an accuracy of 0.01 seconds. The system consists of wireless photocells and their reflectors. The cells are located at a height of 1 m and a distance of 2 m between the reflectors. The distance is measured in advance using a hand tape measure and marked with a coloured sticker. Competitors start on a pre-prepared colored line 30 cm from the first cell, at will, and run the distance with maximum effort. Scores are counted to 0,01 of a second by making two runs and taking the better score.

The exact route of the 20m sprint test is used to measure speed endurance. Moreover, the Witty timing system (Microgate, Bolzano, Italy) differs in that the competitor runs four 20-meter lengths without stopping, with three 180° turns at given markers. The results are counted every 0.01 seconds during one run.

The competitors‘ lower limbs‘ explosive power was measured by performing individual jumps on a geometric platform. The platform and software used to record, process, and analyze jump parameters are NORAXON USA and a MyoForce module. The jumps were performed according to the following protocols:

- Squat Jump (SJ): From the starting position, a squat is performed at an angle between the hip and lower leg of 90°, with feet planted on the ground at shoulder distance. The hands are placed on the waist. From this static position, a quick extension of the lower limbs and an upward bounce are performed to reach maximum

height. The lower limbs are in an extended position until the moment of landing.

- Counter Movement Jump (CMJ): This is performed from a standing starting position. Feet are shoulder-width apart, with feet planted on the ground and hands placed on hips. From this position, a quick squat (flexion) to 90° is performed, followed by an extension of the lower limbs and an upward bounce, in which the hands remain grasped at the player's hips. The lower limbs remain extended until landing.
- Counter Movement Jump with Arms Trust (CMJA): This is performed from a standing starting position. Feet are shoulder-width apart, with feet planted on the ground and arms raised overhead. From this position, a quick squat (flexion) to 90° is performed, in which the arms perform a quick downward and backward swing, followed by an extension of the lower limbs and an upward bounce, in which the arms perform a forward and upward swing and help lift the CM to reach maximum height. The lower limbs remain extended until landing.

To measure ball speed when serving, a Radar Handheld Electronic Gun model 10-1900 is used, which measures ball speed in the range of 16-322km/h (Bushnell, Kansas, USA). Competitors perform a standard serve behind the end line in any direction to achieve maximum ball speed. The measurer stands 18 meters in front of the service bounce. The ball is a standard all-age competition (Mikasa MVA, Mikasa Corporation, Hiroshima, Chūgoku). According to the manufacturer, the accuracy is up to 0.4 m/s.

The tests were performed in the following sequence, shown in Table 3.

Table 3. *The sequence of tests and rest intervals between them*

Sequence	Test	Trials	Rest (min)
1	20м running	2	2
2	CMJ	1	2
3	SJ	1	2
4	CMJA	1	2
5	4x20 shuttle run	1	3
6	Serving speed	2	1

Voluntary informed consent was obtained from all players before the study began. Permission from the club was received to record and analyze the data.

RESULTS

The results of the research are placed in Tables 4 and 5 for men and women, respectively. Men's volleyball players (3.2 seconds) are faster than women (3.5 seconds) in 20m running.

Table 4. *Variability of the research indicators for male volleyball players*

Indicator → Statistical indicator ↓	20 running (sec)	Serve speed (km/h)	4x20 shuttle running (sec)	CMJ (cm)	SJ (cm)	CMJA (cm)
Mean	3.2	86.8	15.6	43.6	43.7	53.9
SD	0.14	19.0	0.68	5.9	5.7	7.7
As	1.148	-0.098	0.462	-0.617	-0.022	-0.044
Ex	2.350	-1.055	0.093	0.575	-0.569	-0.885
R	0.74	66	2.90	28.1	23.2	28.6
Min	2.95	54	14.48	25.0	32.0	38.7
Max	3.69	120	17.38	53.1	55.2	67.3
V%	4.42	21.93	4.39	13.54	12.96	14.36

Men's 4x20m shuttle running test results are better than women's, with 1.7 seconds (15.6 to 17.3 seconds). Serve speed is higher for men (86.8 km/h) than for women (69.1 km/h). Men jumped in the three different modes accordingly, CMJ for 43.6 cm, SJ for 43.7 cm, and CMJA for 53.9 cm.

Table 5. *Variability of the research indicators for female volleyball players*

Indicator → / Statistical indicator ↓	20 running (sec)	Serve speed (km/h)	4x20 shuttle running (sec)	CMJ (cm)	SJ (cm)	CMJA (cm)
Mean	3.5	69.1	17.3	31.6	32.3	35.9
SD	0.15	5.51	0.99	3.7	3.0	3.6
As	1.456	-0.771	0.539	-0.129	0.555	-0.105
Ex	2.067	0.123	-0.320	-1.013	-0.667	-1.836
R	0.54	18	3.26	11.6	9.40	9.3
Min	3.34	58	15.94	25.4	28.8	31.1
Max	3.88	76	19.20	37.0	38.2	40.4
V%	4.56	7.99	5.75	11.61	9.28	10.09

The same fact is also visible for all the tests that characterized the explosive power of the lower limbs. Women jumped accordingly, CMJ for 31.6 cm, SJ for 32.2 cm, and CMJA for 35.9 cm. Those results are lower than men's.

Women's results were more homogenous than men's, which is visible from the coefficient of variation that varies between 4.6 and 11.6 percent. In contrast, men's results are between 4.4 and 22 percent. Regardless of these facts, all variables have a normal distribution, as indicated by the normality test ($p > .05$).

Table 6. *Correlation between the research indicators for male volleyball players*

Indicators	20 running	Serve speed	4x20 shuttle running	CMJ	SJ	CMJA
20 running	1	-.254	**.676****	**-.584****	**-.596****	**-.498****
Serve speed		1	-.320	**.500****	**.399***	**.430****
4x20 shuttle running			1	**-.572****	**-.514****	**-.534****
CMJ				1	**.823****	**.770****
SJ					1	**.858****
CMJA						1

Table 6 shows all correlations of the studied traits. They range from moderate to high correlation (r = .399 to r = .858), except for the correlation between running tests and serve speed, which was not significant.

Results for women are in Table 7. The situation is different for them than for men. The obtained correlation values are higher than those for men (r =- .768 to r = .906). Apart from this, serving speed shows no statistically significant correlation with any of the indicators studied (r =- .358 to .294).

Table 7. *Correlation between the research indicators for female volleyball players*

Indicators	20 running	Serve speed	4x20 shuttle running	CMJ	SJ	CMJA
20 running	1	-.465	**.906***	**-.655***	**-.544***	**-.692***
Serve speed		1	-.358	.258	.294	.125
4x20 shuttle running			1	**-.768***	**-.677***	**-.729***
CMJ				1	**.856***	**.704***
SJ					1	**.720***
CMJA						1

*All the interrelations between the researched indicators that are significant are marked with *.*

At the same time, the results of both men and women differed statistically significantly in all measured characteristics ($p < .05$).

DISCUSSION

In volleyball, a certain level of aerobic and anaerobic capacity is required to perform technical actions during the game (Gabbett & Georgieff, 2007). Due to the intermittent nature of the game, the plays are short and high-intensity, which determines the leading role of the anaerobic energy system. Hence, there is a need to know the specifics in the profiles of men's and women's volleyball, which will help optimize and intensify the training process. In this line of thought, aerobic capacity is required to a greater extent in the training pro-

cess and for more extended periods than in regular play. In contrast, anaerobic capacity is needed for specific actions during the game. In this line of thought, the term anaerobic capacity is related to the anaerobic potential because *Anaerobic potential is the ability to develop higher anaerobic capacity*. Anaerobic potential refers to the body's ability to produce energy without oxygen during short-duration, high-intensity activities. In our case, it relies on the ATP-PCr (Phosphagen) System, which provides immediate energy for explosive efforts (≤10 seconds) and utilizes stored ATP and phosphocreatine (PCr). Our previous research has proven the highly informative values of these tests for anaerobic potential (Gadev et al., 2022; Nurja et al., 2024). From the descriptive statistics, the significantly higher variability in the serve speed among men is striking. These results indicate greater differences in the explosive power abilities of the upper leg, on the one hand, and greater technical differences in their execution and the speed achieved by them. Based on the vertical jump results of Sattler et al (2015) for male and Nikolaidis et al. (2015) and Şimşek et al. (2016) for female volleyball players, there was a good level of development of the explosive power. Another notable finding from the statistical analysis is the higher value of the results in SJ compared to CMJ, which suggests an insufficient use of the elastic properties of the muscles. This fact is surprising, as rebounding is a fundamental action in the game and warrants further research (Bosco et al., 1982). At the same time, in CMJA, the difference should be between 10-20% in the use of the jump with a swing of the arms (Lees et al., 2004; Hara et al., 2006; Vaverka et al., 2016). In this indicator, specific differences are also observed between the two genders, with men (23,6%) using hand gestures better overall than women (11,4%).

The correlation between the individual tests characterizing the speed-strength abilities of the lower and upper limbs is moderate (r = .399 – .500). There is no correlation between speed abilities and speed-strength abilities of the upper limbs (r = -.254 – .320), but there is one for the lower limbs (r = -.498 – .596). These two correlations suggest that other unexplored factors, such as the execution technique, may also influence the ball's speed. At the same time, a regular moderate to high correlation between speed and explosive power is found, which is characteristic of all intermittent sports (Sheppard et al., 2011; Loturco et al., 2015; Peev, 2021; Krasteva et al., 2022; Peev & Gadev, 2022). The reasons for these results can be twofold: biomechanical and physiological. The biomechanical aspects include ankle, knee, and hip joint extension, as well as the efficiency of the stretch-shortening cycle (SSC). From a physiological point of view, elite athletes must have more fast muscle fibers through which they can generate greater power in both types of movement (Bobbert et al., 1988; Komi, 2000; Wagner et al., 2009; Sheppard et al., 2011; Balasas et al., 2022). All these relationships demonstrate that increasing anaerobic potential, particularly in speed abilities, leads to an improvement in speed-strength abilities of the lower extremities and speed endurance.

Regarding the results for women, there are no statistically significant correlations between ball speed and any other indicator (r = -.358 to .294). The primary reason for this lack is most likely rooted in the inability to fully utilize one's potential when performing a serve, which necessitates additional research on the issue. At the same time, higher values of correlations are noted for individual signs related to the explosive power of the lower limbs and speed abilities (r=-.692 - .906). All this determines the greater correlation of the previously mentioned regularity in men, namely that an increase in anaerobic capacity, and in particular speed abilities, leads to an increase in explosive power of the lower limbs and speed endurance.

From the variation analysis, the much higher variability in the speed of service execution among men makes a strong impression. That indicates the greater differences in the speed-strength abilities of the upper leg on the one hand, and the greater technical differences in its execution and the speed that is achieved in them. Another thing that makes a clear impression from the variation analysis is a higher value of the results in SJ than in CMJ, which indicates an insufficient use of the elastic properties of the muscles, which is strange because the rebound is a basic action in the game and needs further study (Bosco et al., 1982). At the same time, in CMJA, the difference should be between 10-20% in the use of the jump with the swing of the arms (Lees et al., 2004; Hara et al., 2006; Vaverka et al., 2016). In this indicator, specific differences are also observed between the two sexes, as men (23.6%) generally use the swing of the arms better than women (11.4%).

The correlations between the individual tests that characterize the speed-strength abilities of the lower and upper limbs are moderate (r = .390 – .500). There is no correlation between speed abilities and speed-strength abilities of the upper

extremities (r = -.254 – .320), but there is one for the lower extremities (r = -.498 – .596). These two correlations suggest that other unexplored factors, such as execution technique, influence the ball's speed. At the same time, a regular moderate to high correlation between speed and speed-strength abilities is found, which is characteristic of all intermittent sports (Sheppard et al., 2011; Loturco et al., 2015; Peev, 2021; Krasteva et al., 2022; Peev & Gadev, 2022). The reasons for these results can be twofold: biomechanical and physiological. Biomechanical factors include ankle, knee, and hip extension and the efficiency of the Stretch-Shortening Cycle (SSC). From a physiological point of view, elite athletes must have more fast-twitch muscle fibers through which they can generate greater power in both types of movement (Bobbert et al., 1988; Komi, 2000; Wagner et al., 2009; Sheppard et al., 2011; Balasas et al., 2022). These relationships demonstrate that increasing anaerobic potential, particularly in speed abilities, leads to enhanced speed-power capabilities in the lower extremities and improved speed endurance.

As for the women's results, there are no statistically significant relationships between ball speed and any other indicators (r = -.358 to .494). The primary reason for this lack is most likely rooted in the inability to fully utilize one's potential when performing a kick-off, which necessitates additional research on the issue. At the same time, higher values of correlations are noted for individual signs related to the speed-strength abilities of the lower limbs and speed abilities (r = -.692 – .906). All this indicates a greater correlation with the previously mentioned regularity in men, namely that an increase in anaerobic potential and, in particular, speed abilities leads to greater explosive power in the lower limbs and increased speed endurance.

To develop explosive power in men, greater external stimuli are required in terms of the number of repetitions and rebound height compared to women. Based on the results obtained and the synergetic effect in training sessions, work on anaerobic capabilities generally has a positive impact on speed, speed endurance, and explosive power.

In summary of the research, it is noted that the greatest differences in the realization of anaerobic potential are observed in tests with upper limb movements, namely the execution of a serve. Men manage to realize a greater part of their capabilities in this element than women, as evidenced by the higher correlation values. In both cases, there is a lack of correlation between the serve speed and the shuttle run, which we define as a law, considering that they characterize anaerobic alactate and anaerobic lactate energy supply. As for the running tests, a higher realization of speed abilities is seen in women than in men.

CONCLUSIONS

Based on the research and the generalizations resulting from it, we can conclude:

1. Volleyball players of both sexes have a similar anaerobic potential
2. Men have a higher level of anaerobic potential than women
3. The realized serve values in women are evidence of the insufficient use of this potential by them.

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