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AN ASSESSMENT ON THE AEROBIC AND ANAEROBIC CAPACITIES OF A TENNIS PLAYER

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ABSTRACT
Purpose. The purpose of this research was to determine the relationship between a tennis players' technical abilities and their capacity evaluated in both a laboratory and on the tennis court. **Basic procedures.** Twelve tennis players participated in the study. The anaerobic capacity test (Wingate) and the progressive test were performed on a Monark E 895 cycloergometer. The aerobic and anaerobic capacities were evaluated in the laboratory. The Weber capacity test was performed on a tennis court. **Main findings.** The research did not reveal any significant correlation between the Wingate's mechanical parameters and the physiological parameters of the Weber test. A correlation of the maximal oxygen uptake with stroke precision on a tennis court can be observed. The research found that the maximal power output (P_{max}) and total work (W_{tot}) found in the laboratory is related to the stroke precision on a tennis court. **Conclusions.** The results may suggest that both tests can be applied in the assessment of capacity and the effects of training. From the results of the laboratory and on-court tests, it is possible to specify a player's semi-specific endurance.

Key words: laboratory and on-court tests, tennis, anaerobic capacity, aerobic capacity

Introduction

In literature the characteristics of tennis as a sport have already been described in detail. It includes a precise match analysis on tactics, biomechanics (technique) as well as the behaviour of top level players' organisms and their physiological reaction they have during a match.

According to Groppel and Roeter [1], from a physiological point of view, a player should be characterised by high aerobic and anaerobic capacity, as well as having a suitable level of motor skills and high mental resistance. Other authors share this opinion. Kovacs [2] reports that an elite tennis player should be trained in four important facets: the technical, tactical, physical and mental. Ziemann [3] writes that tennis belongs as an acyclic and open sport which is characterised by changeable intensity and a variable match duration. The factors which determine the achievement of top performance, according to the author, are as follows: motor preparation as well as technical, tactical and mental ones. Ładyga [4] claims that such qualities as mental resistance, speed, strength, power and nerve-and-muscle coordination are particularly desirable in tennis players.

Kovacs [2] believes tennis has a few exceptional aspects which do not occur in other sports. They include primarily the kind of movement on a tennis court, the duration of stroke exchanges and the duration of intervals. Another aspect, as Ziemann underlines [3], is the difficulty in foreseeing how many matches the athlete will play in a given tournament, how long each match will last, and how heavy the loads (the cost of physiological effort) will be. Kovacs [5] implies that the duration of a tennis match also depends on such factors as: court surface, playing style adopted by the athlete, environment, skill level, stroke speed and motivation. Laurentowska et al. [6] claim that the factor which determines a player's movement on a court is the length of stretches they cover. Ferrauti [7] reports that 80% of all strokes are executed at a distance of 2.5 m from the player, 10% at a distance that ranges from 2.5 to 4.5 m from the player. The remaining strokes are executed at a distance longer than 4.5 m. A player hits the ball 2.5–3 times during a stroke exchange, which depends on the style, kind of stroke, court surface and strategy; in addition, one changes the direction of movement on the court on average four times [5, 8]. Numerous studies have also analysed the time of stroke exchanges and time of rest during matches in elite tennis players. In the analysed matches, the ratio between work and rest oscillated from 1:2 to 1:5, where the mean time of stroke exchange between players ranged from 3 s (on fast courts – grass, carpet, and hard surfaces as defined in the International Tennis Federation ITF regulations as courts of categories 2 and 3) to 15 s on a slow surface, i.e. clay courts (category 1 according to the ITF regulations from 2006) [5]. Research done by Ferrauti et al. [9] indicate that the

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effective length of playing time expressed as a percentage share of the entire match amounts to 20% – 30% for clay courts and 10% – 15% for fast surfaces. An explanation to these findings is provided by Parson and Jones' research [10]. They sustain that each court surface requires a different game strategy. It is related to the speed of a stroke and its rotation, which, in consequence, determine the duration of matches.

The above data which characterises tennis points to the importance of various physiological parameters, such as heart rate (HR), maximal oxygen uptake ($\dot{V}O_{2max}$) and lactate concentration in the blood (LA), which can have a significant influence on an athlete's succes. In the available literature, heart rate (HR) is usually given in mean values [5, 8, 11], however some authors [2–4] say that such values do not reflect the interruptive character of the game. Novas et al. [12] proved that oxygen uptake ($\dot{V}O_2$) regenerates faster than HR. Bergeron et al. [13] report that measuring HR during a game can be imprecise due to dehydration, thermal stress or climatic conditions. The data obtained by various researchers [9, 14–16] indicate the importance of high $\dot{V}O_2$ in this sport. Kovacs [2], after Bernardi, recognised that athletes whose playing style is aggressive have a lower current HR and $\dot{V}O_{2max}$ than those playing defensively behind the baseline. The same author states that the mean values of maximal oxygen uptake $\dot{V}O_{2max}$ obtained from tennis players oscillate between 50–55 ml · min^{-1} · kg^{-1}.

The energy during a stroke exchange in a match is generated mainly through a consumption of adenosine triphosphate stored in muscles and its resynthesis by means of creatine phosphate (CP) [9, 17]. The time needed to regenerate CP is about 15 s in resynthesising 50% of its capacity, whereas in the case of full resynthesis, the time needed amounts to 1–5 min [18]. All the regenerating intervals during a match are fixed by ITF regulations which exactly define their maximum length. Currently, these times are: 20 s between scoring points in a game, 90 s between games and 120 s between sets [8]. In this process, the role of oxygen metabolism plays an important role as it helps resynthesise adenosine triphosphate during intervals [18–20]. It can be one of the causes of a high maximal oxygen uptake ($\dot{V}O_{2max}$) in athletes at the highest performance levels [17, 21, 22].

Kovacs [2] claims that having a very high $\dot{V}O_{2max}$ (above 65 ml · min^{-1} · kg^{-1}) does not necessarily improve one's game more than an oxygen uptake around 55 ml · min^{-1} · kg^{-1}. Therefore, he suggests devoting more time in tennis players' training to perfect other elements: the physiological, technical, tactical and mental. In some researchers' studies [1, 5, 9, 23] no difference

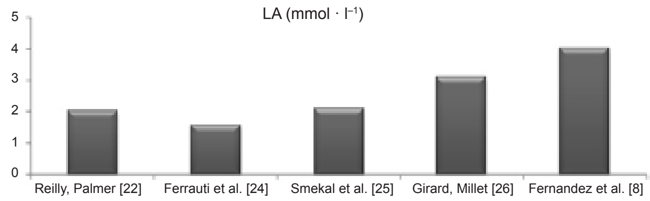

Figure 1. LA concentrations registered during playing in the studies done by the above mentioned authors

has been found among professional tennis players. The studies indicate lower values of $\dot{V}O_2$ (in comparison to $\dot{V}O_{2max}$) registered on a court in men than in women. This could have been caused by the duration of stroke exchange, which is statistically shorter in the case of men than women.

In the available literature, the results in lactate concentration (LA) (2–4,5 mmol · l^{-1}) registered during playing indicate that an overwhelming amount of energy comes from anaerobic, non lactic acid energy sources (Fig. 1).

However, one should not forget that during long and intensive tennis duels, LA can increase even to 8 mmol · l^{-1} which can imply that simultaneously other glycolytic sources of energy are engaged. McCarthy-Davery [27] reports that on LA concentration amounting to 7–8 mmol · l^{-1} of plasma disturbs the technical and tactical skills of the player. According to Christmass et al. [21] fatigue worsens a player's technical skills, movement coordination and concentration by over 80%.

The above data indicate that aerobic and anaerobic non lactic acid sources of energy play a fundamental role when playing tennis. However, during long and closely fought matches, LA concentration considerably increases and the concentration intensity can influence the result of the match.

The aim of this study was to determine the relationships between an athlete's technical playing skills and their capacity assessed in the laboratory and on the court during the Weber test. An analysis of the changes in the physiological parameters was to show which of the parameters examined can have a significant influence on the results obtained. Another aim of the study was to select the most effective assessment method of a tennis player's aerobic and anaerobic capacity.

Material and methods

Subjects

The study comprised of 12 professional tennis players. Their selected anthropometric and morphological data

Table 1. Anthropometric and morphological characteristics of the examined group

Anthropometric characteristics	Mean value $\bar{x}$	SD
Age (years)	21.83	3.88
Height (cm)	183.75	3.41
Weight (kg)	77.60	6.74
BMI (kg/m^2)	23.04	1.80
Body fat (%)	11.98	3.35
Water (%)	63.68	4.25
Water (l)	49.98	3.54

Table 2. Position in the PZT ranking

Tennis player	Position in ranking	Years of training
1.	537**	14
2.	157** (doules ranking)	16
3.	6	6
4.	45	7
5.	53	7
6.	6*	6
7.	8*	6
8.	97*	7
9.	1DV	12
10.	1DV	12
11.	NC	9
12.	NC	7

* Position in the PZT ranking – Juniors
** ATP – world ranking
1DV – first division (USA)
NC – non-classified

are shown in Table 1. Their ranking in the PZT (Polish Tennis Association) are shown in Table 2 [28].

The study was carried out in two stages. The first stage included an examination in the Sport Endurance Testing laboratory (which presently has a PN-EN ISO 9001-2001 quality certificate). A week later, the second stage was held, i.e. an examination on indoor tennis courts with the use of a breath analyser and a ball throwing machine.

The subjects had on average 9-years experience in playing tennis, which ranged from 6 to 16 years. One of the subjects was the Polish Indoor Champion in the senior category (Tab. 2).

Methods

Endurance test of anaerobic capacity (Wingate test)

In the laboratory test, athletes exercised for 30-seconds on a cycloergometer (Wingate test). The aim of the test was to determine their anaerobic capacity. It was conducted according to the methods proposed by Bar-Or [29]. The subjects underwent a 30-second Wingate test on a cycloergometer Monark E 895, with an individually selected load following the principle of 75 g on 1 kg of body mass. During the trial, the following parameters were measured by means of the computer program MCE v. 2.3:

– maximal power output (P_{max}) achieved at the moment of the highest pedalling rate,
– total work done during the 30-second effort (W_{tot}),
– time needed to reach (t_{rmp}) maximal power and its duration (t_{dur}),
– drop in power output (DP).

While undergoing the Wingate test, athletes were connected to a K4b^2 analyser by Cosmed (Italy), which measured cardio-respiratory parameters during the effort and restitution. The measured parameters were: oxygen uptake ($\dot{V}O_2$ ml · min^{-1} · kg^{-1}) and heart rate (HR) per minute.

Before the exercise and three minutes into the exercise a blood sample was taken from the finger tip in order to determine the lactate concentration (LA). The LA was measured by Dr. Lange's enzymatic method, the LKM 140 test.

Progressive test on the cycloergometer

In the second stage of the study, athletes underwent a progressive test on a Monark E 895 cycloergometer whose aim was to measure their aerobic capacity. The test started with a load of 50 W and was increased every 3 minutes by an additional 50 W. It continued until the maximal heart rate was reached. The cycloergometer was controlled by a computer which registered moment power, work time, and rotation; on these results the program calculated the total work done during the test. Maximal oxygen uptake ($\dot{V}O_{2max}$) as well as other cardio-respiratory parameters were measured by the Quark analyser (Cosmed).

Before the exercise and three minutes into the exercise blood was taken from the finger tip in order to determine the lactate concentration (LA). The LA was measured in the same way as above.

Weber method

The test performed on the tennis court based on Weber's method [30], was to assess an individual's endurance by simulating playing tennis.

According to Weber [30], an exact reconstruction of a tennis player's playing effort is possible only with the use of a ball throwing machine. In the test described here, a Miha 2002 training machine was used. It threw balls at a constant speed and frequency as well as at constant angles of delivery and bounce, alternatively for a forehand and backhand swing. The balls used were new Penny Championship, which provided equal ball compression and bounce.

In the trial, athletes had to perform four successive strokes (Fig. 2):

- forehand – cross, i.e. directing the ball from the right side diagonally to the opposite side of the court onto the marked zone (in the figure – zone B),
- backhand – cross, i.e. directing the ball from the left side diagonally to the opposite side of the court onto the marked zone (in the figure – zone B),
- forehand – down the line, i.e. directing the ball from the right side along the line to the opposite side of the court onto the marked zone (zone B),
- backhand – down the line, i.e. directing the ball from the left side along the line to the opposite side of the court onto the marked zone (zone B).

The subjects were asked to hit both forehand and backhand strokes from the "forehand corner" and "backhand corner" for the ball to hit the marked zone. During the test, oxygen uptake ($\dot{V}O_2$) expressed in ml · min^{-1} · kg, heart rate (telemetria – K4b^2 by Cosmed) and lactate concentration (LA) in the blood were measured by the way as described above.

In addition, the number of balls which hit the marked zone on the opposite side of the court were counted, i.e. both zones for the forehand and backhand swings were marked 1.7 m from the singles lateral line by special markers so that the athletes could see the destination zone (zone B) better. Anaerobic capacity was measured by the Weber test [30]. The test was proceeded by a 5-minute warm-up on the machine delivering balls at a constant speed (15–16 balls per minute). A relatively low starting load appears to be indispensible as a continuation of the "warm-up phase", which is especially useful for getting used to load conditions unusual for the subjects (running in different directions, shot combinations, blood sample taking) [30]. As a rule, the loads were gradually increased. An increase in loading was obtained by changing the lob rate. The initial load was 15 balls · min^{-1} (trial A), then 18 balls · min^{-1} (trial B), in each successive trial the number of balls were increased by 3 per minute in comparison to the preceding one. The test finished when the subject was not able to hit the balls in time or when the rate reached 30 balls · min^{-1} (maximal trial – E).

At the beginning of the third minute interval a blood sample was taken from a finger tip. A telemetric gas analyzer K4b^2, worn by athletes during the trial (effort and interval), made it possible to conduct tests with laboratory precision, yet in a natural environment, i.e. on the court. The device was attached by special straps worn by the player; its weight was 600 g and it did not disturb the athlete in playing tennis. The data obtained were transmitted by radio to a computer, which allows real time observation of the subject's reaction to their physical effort (the rate of the balls hit in the marked zone).

The results from both the laboratory and tennis court were worked out and presented in tables and figures. The arithmetic mean ($\bar{x}$) and standard deviation (SD) of selected mechanical parameters for the whole group were calculated. A comparative correlation between the mechanical parameters from the Wingate test and the physiological parameters from the Weber test, as well as a correlation between the physiological parameters and accuracy, were calculated by means of Spearman's rank-order in Statistica 8.0. The statistically significant level was set at $p < 0.05$.

The succession of strokes onto the marked out zone (B) in the test:
1. Forehand cross (grey colour)
2. Backhand cross (grey colour)
3. Forehand down the line (white colour)
4. Backhand down the line (white colour)

Figure 2. Tennis endurance test – the Weber test

Results

Table 3 shows the values of the mechanical parameters measured during the 30-minute Wingate test.

Athletes needed from 4.61s to 8.42 s to reach maximal power at the level $\bar{x}$ = 10.29 ± 0.84 [W · kg^{-1}] and they maintained it from 2.39 s to 5.80 s. Mean value of total work was $\bar{x}$ = 19.65 ± 2.35 [kJ]. While comparing

Table 3. Mechanical parameters obtained in the Wingate test of anaerobic capacity

Tennis players	Maximal power (P_{max}) ($W \cdot kg^{-1}$)	Time to reach max power T_{rmp} (s)	Time of duration T_{dur} (s)	Work done (W_{tot}) (kJ)	Drop in power Index (DP) (%)
$\bar{x}$	**10.29**	**5.57**	**4.38**	**19.65**	**19.25**
SD	**0.84**	**1.06**	**1.01**	**2.35**	**3.86**

Table 4. Correlation of mechanical parameters in the Wingate test and physiological parameters in the Weber test with the accuracy in each trial of the Weber test

Correlation	Accuracy (%)				
	P_{max}	W_{tot}	HR	LA	$\dot{V}O_2$
Weber test	Spearman's *r*				
A	**0.69**	**0.73**	**–0.78**	–0.13	–0.40
B	**0.61**	**0.79**	–0.49	–0.12	–0.19
C	0.46	0.41	–0.40	0.01	0.01
D	**0.70**	**0.64**	–0.14	**0.63**	–0.08
E	0.11	–0.19	**–0.87**	–0.32	0.26

Statistically significant correlations are in bold type.
P_{max} – maximal power output W_{tot} – total work
T_{rmp} – time to reach maximal power T_{dur} – time of its duration
LA – lactate concentration
$\dot{V}O_2$ – oxygen uptake

Table 5. Correlation between $\dot{V}O_{2max}$ and the accuracy achieved in the Weber test

	Accuracy (%)				
	Trial A	Trial B	Trial C	Trial D	Trial E
$\dot{V}O_{2max}$	**0.93**	0.26	**0.71**	**0.58**	**0.87**

Statistically significant correlations are in bold type.

the results of the mechanical parameters in the Wingate test with the physiological parameters in the Weber test, some significant single correlations were identified which prevented the calculation of the direction of adaptation (Tab. 4). Results obtained by comparing maximal power (P_{max}) expressed in Watt and the work done on the cycloergometer (W_{tot}) with the accuracy in the Weber test indicated that these factors significantly correlate with each other in trials A, B and D. No significant correlation was observed in trial C (21 balls thrown per minute). In the maximal trial (E) most athletes started losing their game rhythm half way through the exercise. Therefore, the trial was often suspended, which probably influenced the results. Correlation between lactate concentration (LA) in plasma and the accuracy (%) in the Weber test was observed only in trial D (Tab. 4). The results of $\dot{V}O_2$, compared to the accuracy obtained in the Weber test, did not show significant correlations (Tab. 4).

Maximal oxygen uptake ($\dot{V}O_{2max}$) measured during the progressive test on the cycloergometer and in four trials correlate significantly with the accuracy (Tab. 5).

Table 6 shows the accuracy achieved by athletes in each trial of the test of playing on a court. In this study, the percentage of accuracy was assumed as a measure of technical skills. In order to show the differences, a graphic comparison between the athlete with the highest score of accuracy (74.29%), ranked as the 537th in the world (ATP – Association of Tennis Professionals), and the athlete with the poorest accuracy (35.51%), 97th in the Polish junior ranking (PZT – Polish Tennis Association).

A comparison of selected mechanical and physiological parameters of the athlete with the best accuracy and the one with the worst is shown in Figure 3.

Table 6. Accuracy of tennis players in each trial of the Weber test as a percentage (%)

Trial – accuracy (%)	Tennis players											
	1	2	3	4	5	6	7	8	9	10	11	12
Trial A	46.67	46.67	53.33	73.33	80	60	33.33	33.33	80	80	60	73.34
Trial B	33.33	27.78	61.11	66.67	61.11	61.11	58.89	50	61.11	88	66.67	77.28
Trial C	66.67	28.57	47.62	52.38	76.20	52.38	42.86	33.33	71.34	66.67	47.61	80.95
Trial D	37.50	37.50	37.50	62.50	62.50	62.50	41.67	37.50	62.5	62.5	29.17	66.67
Trial E	60	37.03	51.85	60	33.33	40.74	18.52	37.03	59.26	–	–	59.26
$\bar{x}$	49.38	35.51	50.28	62.98	62.63	55.35	39.05	38.24	66.84	74.29	50.86	71.50
SD	**16.44**	**7.73**	**8.65**	**7.78**	**18.35**	**9.06**	**14.74**	**6.87**	**8.70**	**11.80**	**16.48**	**8.65**
PZT Ranking [28]	6*	97*	53	8*	1DV	1DV	NC	NC	6	537**	45	157***

* Position on PZT ranking – Juniors, ** ATP – world ranking, *** ATP – world doubles ranking
1DV – first division (USA), NC – non-classified players

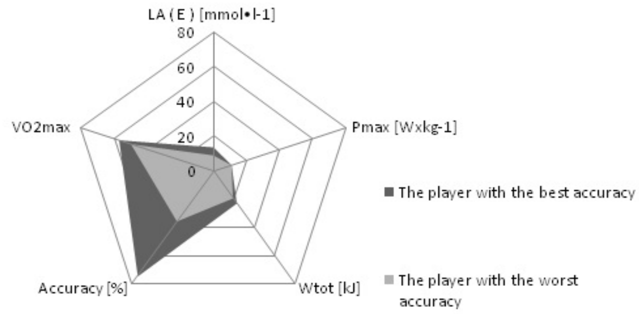

Figure 3. Comparison of the parameters achieved by two selected tennis players

Discussion

Kovacs [2] claims that the aim of basic anthropological and physiological measurements is to help coaches, athletes, researchers indentify talented athletes, monitor their progress as well as motivate them to hard work, i.e. training.

Ziemann [3] reports that the Wingate test is useful for assessing a tennis players' anaerobic capacity. It provides information on the efficiency of the phosphagen and glycolytic systems which provide the muscle with energy when playing, which according to literature amounts to 80% of the energy demand in tennis players during a match [31]. The results obtained in the Wingate test showed that maximal power reached, at $\bar{x} = 10.29 \pm 0.84$ [W · kg^{-1}] was close to the maximal power obtained by Laurentowska et al. [6] in their research conducted on nine Polish tennis players (P_{max} $\bar{x} = 10.31$ [W · kg^{-1}]).

Comparison of P_{max} and total work (W_{tot}) with the accuracy as performed in the Weber test showed correlation in 3 trials (A, B, D). Trial E (maximal) was not always completed by the tennis players. Hence, the lack of correlation and negative values are justified. This correlation indicates that level P_{max} and W_{tot} obtained in the Wingate test does have association with the accuracy in the test performed on the court. Maximal power indicates phosphagen capacities which can provide 70% of the energy demands in tennis players according to the ITF sources [31]. Total work in the test indicates glycolytic capacities of athletes which amount, according to ITF sources, 10% of the energy demands [31]. However, it is good to keep in mind that the usage of energy sources depends on the duration of stroke exchanges, the intervals between them which, in consequence, contribute to the duration of the whole match. Comparison between the mechanical parameters obtained in the Wingate test and the physiological parameters of the Weber test showed significant single correlations which did not allow for the calculation of the direction of adaptation.

The physical effort performed by professional tennis players has increased in the last several years [19]. In reference to the results obtained in the Weber test, one can notice that the heart contraction rate did not correlate with the accuracy in the test. The lack of such correlations of HR measurements during tennis play can be caused by the interruptive character of the game [2–4]. Other authors [9, 14–16] point to the considerable significance of high $\dot{V}O_2$ in this sport. With the use of modern equipment measuring the composition of exhaled gas, it is possible to control the player's oxygen uptake during a match. In studies carried out by Fernandez et al. [8], oxygen uptake ranged from 23 to 29 ml · min^{-1} · kg^{-1}. It amounted to 46% – 56% of athletes' $\dot{V}O_{2max}$ and differ from the values reported by König et al. (60–70% $\dot{V}O_{2max}$) [32]. Although tennis can be classified mainly as an anaerobic activity, a high efficiency of cardio-respiratory reaction can prevent fatigue and help regenerate the organism between game intervals, matches and tournaments, which in turn favour good performances [33] (Fig. 4).

Having a high aerobic capacity is important when playing and in-between-tournaments periods [2, 5, 33, 34]. A tennis player is recommended to try to reach a value of maximal oxygen uptake which exceeds 50 ml · min^{-1} · kg^{-1} [2, 8]. The results of maximal oxygen uptake in the subjects obtained in the laboratory ranged from 42 to 59 ml · min^{-1} · kg^{-1}. Oxygen uptake during the Wingate and Weber tests did not show any significant correlations with the on-court accuracy. Maximal oxygen uptake ($\dot{V}O_{2max}$) measured in the lab in the progressive test correlated with the accuracy achieved in the Weber test. As it was highlighted before, $\dot{V}O_{2max}$ can play an important role during a tennis competition, but

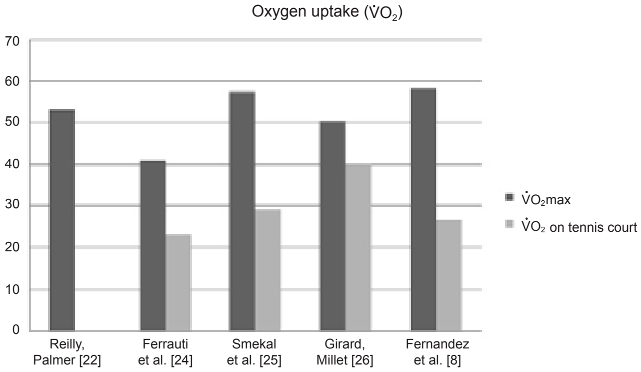

Figure 4. Mean values of $\dot{V}O_{2max}$ obtained in the studies done by the above mentioned authors and oxygen uptake ($\dot{V}O_2$) during a match (light grey)

(particularly) during training. The aerobic system helps resynthesize adenosine triphosphate during intervals [18–20]. The correlation obtained confirms the implications as described in the literature.

According to Banzer et al. [19], one's ATP tennis ranking correlates with maximal oxygen uptake ($\dot{V}O_{2max}$). These authors mention in their study that such correlations also occur in other sports (cycling, skiing, soccer). Since the subjects were classified in different rankings, it was impossible to verify this assumption. However, it must be taken into consideration that tennis player's training is extremely demanding and comprehensive. In order to sustain it, to exercise more and with more intensity, one needs high $\dot{V}O_{2max}$ which determines the effectiveness of capacity adaptation they develop when training.

Based on the implications mentioned in literature and concerned with the significance of lactate concentration (LA), a correlation between LA and accuracy obtained in the Weber test was calculated. The correlation, however, did not find any relationship. Fernandez et al. [8] noted that maximal values of LA during a tournament in professional players amount to circa 8,6 mmol $\cdot$ l^{-1}. At the same time, the authors claim that LA analysis during a tennis match should be interpreted with considerable caution, because the value of LA concentration is affected by physical preparation, stress, time of measurement, environmental conditions, etc. Besides, due to the natural intervals in game play, the LA level measures an activity level that the player had reached a few minutes before the blood sample was taken (in the case examined here – a minute of effort).

Periods when the player is walking on the court or resting probably enable a reduction in LA in the blood and muscles, which can have an influence on the results obtained in the test. It is possible to say that the higher intensity of effort, the higher LA concentration will be in the blood. An increase in LA concentration in the Weber test is not correlated significantly with accuracy.

Comparative characteristics of the player with the best accuracy to the player with the worst accuracy showed that physiological parameters (LA, $\dot{V}O_{2max}$) and total work (W_{tot}) were at a higher level in the player whose stroke accuracy was the best. The player was 47.88% more accurate than the worst one (Fig. 3). The results indicate that technical skills (with high endurance as well) were decisive, in this case, in the accuracy measured in the trials.

Parameters such as $\dot{V}O_{2max}$, $\dot{V}O_2$, HR, and LA are found in the available literature to be also important in assessing the training effects in tennis. Ferrauti [7] claims that anaerobic and aerobic capacities are among the most important factors influencing a tennis players' ability, second only to agility and speed. Smekal et al. [35] maintain – that after having compared one test in the lab to one on a tennis court – that higher values are achieved by a player in the trials performed in a laboratory, which can be taken into consideration when assessing a tennis players' general endurance. The same authors believe that more information on the "specific" preparation of a player can be deduced from tests performed on the court. Ferrauti et al. [9] claim that a tennis player's endurance training should be focused on shaping all-round endurance, semi-specific and tennis-specific in appropriate training periods.

That is why conducting tests in the laboratory and on the court can help coaches evaluate the true state of fitness in a given player. The Weber test, as applied in this study, can be an example of a "semi-specific" endurance assessment. Exercises that shape tennis-specific endurance should be executed under conditions of a real match. To this purpose various exercises which simulate game play (by using fragments of game play) are employed in maintaining restitution as close as possible to a match. In the literature, no test imitating mutch condition, has been found. The latest test used to assess endurance on the tennis court is "The Hit & Turn Tennis Test", elaborated by Alessandro Ferrauti in 2008 [36], which reflects only " tennis semi-specific" endurance. The best assessment of specific endurance (an athlete's level of fitness) is the performance achieved in tournaments.

Conclusions

1. A significant correlation was observed between the anaerobic capacity characteristics and accuracy achieved in the Weber test, which can suggest the validity of both tests in assessing endurance and the effects of training.
2. Maximal oxygen uptake ($\dot{V}O_{2max}$), measured in the progressive test, correlates with accuracy, which indicates an important role of the parameter in tennis.
3. LA concentration does not correlate with accuracy (in the Weber test).

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