# RANKING POSITIONS, AEROBIC AND ANAEROBIC PERFORMANCE AND MOTOR ABILITIES OF JUNIOR FEMALE TENNIS PLAYERS

Aleksandra **DURZYŃSKA** [ABDEF], Anna **DZEDZEJ**[DEF], Anna **GÓRSKA**[BEF], Joanna **JAWORSKA**[ACE], Ewa **ZIEMANN** [ABCDEFG]

*Gdansk University Academy of Physical Education and Sport, Department of Physiology, Gdańsk, Poland*

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- tennis,
- motor abilities,
- female sport.

**Abstract:**
The purpose of the study was to determine the influence aerobic, anaerobic capacity and body composition on the tennis ranking in elite junior female tennis players. In this study participated 17 girls. All the players had a national singles ranking (positions between 1-80) and international ranking (21 to 990 position of ITF). Body composition was assessed via bioelectrical impedance. Maximal aerobic capacity ($VO_2$max) was calculated on Coopers formula. Anaerobic capacity was assessed through specific tennis drill performed on the hard court (6 x times with 30s of rest also with 1:3 work to rest ratio). Blood lactate was obtained from antecubital vein before, immediately after, and 10 min after the series of bouts of specific tennis drill. The motor abilities (starting speed, maximal speed, weight capabilities of upper upper/lower limbs) were additionally determined. The speed running was measured by photoelectric cells Racetime 2 SF by Microgate with an accuracy according to 0,001 second. The main findings of this paper include stating the correlation between the ranking position and aerobic capacity among young female tennis players. International ranking position was also influenced by aerobic capacity determined by maximal oxygen uptake ($r = -0.68$; $p<0.05$). What is more, the ITF position occupied is determined by motor abilities demonstrated on a court emphasizing running.

## INTRODUCTION

Tennis is a sport characterized by diverse exertional intensities, tempos, strokes and prolonged physical performance given the potential variability in games per match, sets per match, and matches per tournament. Since the number of matches and mental strain in a particular tournament are unknown, the players must prepare themselves in terms of the motor, technical- tactic, and mental facets of the game. This is sport with very fast transformations in widely understandable training process aiming at more and more effective control of the game. Given the wide variety of unknown parameters, planning a suitable, specific and effective training program appears to be a complex and demanding task. The International Tennis Federation (ITF) summarized these findings and indicating that coordination, agility, and speed are considered the most important of a tennis player’s motor abilities. Conducted analyses of the games of the best tennis players in the world demonstrated that the speed was this motor ability which distinguishes outstanding out of the best tennis players . Moreover, observation of final years is pointing at decided growth of requirements towards competitors in the professional tennis from the scope of keep-fit arrangements. The reason of this is preferring fast, offensive and aggressive styles of the game. Publications connected with somatic build of competitors show that it is a crucial factor assisting achieving the highest sports results. Tall tennis players are more effective in offensive, defensive actions and more active in the game from deep inside of the court . Sanchez-Munoz tried to summarize the effects of anthropometric characteristics on ranking positions through holding an experiment that compared groups of junior tennis players of both genders, 12 players each, highly and lowly ranked. Hardly any significant differences were observed, except for the height and humeral and femoral breadths disproportions noted within a group of girls. The 12 highly ranked girls were taller, wider humeral and femoral breadths in comparison to lower ranked players . In contrast, no remarks of differences within boys group were noted. However, due to the lack of explicit data available, the influence of both anthropometric parameters and physical performance on a ranking position, requires further investigation and research. Therefore, this study was undertaken to evaluate the relationship between performance on tennis-specific tasks, maximal aerobic and anaerobic power tests, and ranking (national as well as international) for junior, female tennis players.

## MATERIALS AND METHODS

*Subjects.*

Seventeen elite level, junior female tennis players (mean ± SD; age 16.5 ± 1.6 yr; height 167.9 ± 5.4 cm; body mass 58.1±7.7 kg) participated in the study. All the players had a national singles ranking (positions between 1$^{st}$ and 80$^{th}$) and an ITF international ranking between positions 21 to 990. The average total number of years playing tennis was 8.6 ± 1.1 yr, and the average weekly technical/tactical and physical training sessions during the six months before testing were 19-20 hr per week, respectively. The players and their parents were informed in detail about the nature of the experiment and possible risks. Written informed consent was given by each subject's parents and the Human Ethics Committee at Academy of Physical Education and Sport. The schedule of this investigation is following: anthropometric measurements, two hours rest, motor abilities on hard court surface, day rest and Cooper test running track (Table 1).

*Anthropometric measurements.*

Body mass (BM) and body composition were estimated using a bioelectrical impedance floor scale (TBF-300 Body Fat Monitor/Scale Analyzer, Tanita, Japan) calibrated in accordance with manufacturer guidelines prior to each test session. One hour following a light breakfast, participants voided their bladder and bowels and, clad only in briefs, underwent duplicate measures while in the standing position recommended by the manufacturer guidelines. The average of the two values was used for final analysis. Assessment of the participant's biological maturity level was completed using the biological age determination method utilizing standard, gender-specific, height and weight percentile tables as adjusted for children from Warsaw and accepted as universal for Poland. Additionally, to assess the biological age, the half of the birth year (first or second) was taken into consideration (Table 1).

**Table 1.** Characteristics of subjects

| Variable | T15 (n=6) | | | T16 (n=4) | | | T17 (n=7) | | | TG (n=17 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Height (cm) | 164.0 | ± | 6.3 | 169.2 | ± | 2.4 | 170.4 | ± | 4.4 | 167.9 | ± | 5.4 |
| Biological age of height (centyl) | 54.6 | ± | 13.3 | 73.2 | ± | 6.3 | 77.2 | ± | 23.5 | 68.3 | ± | 20.1 |
| Weight (kg) | 54.6 | ± | 10.3 | 73.2 | ± | 6.3 | 77.2 | ± | 20.5 | 68.3 | ± | 15.2 |
| Biological age of weight (centyle) | 55.0 | ± | 18.0 | 71.0 | ± | 11.0 | 72.0 | ± | 20.0 | 65.0 | ± | 18.0 |
| FFM (kg) | 42.7 | ± | 3.8 | 44.4 | ± | 3.5 | 47.6 | ± | 3.6 | 45.1 | ± | 4.1 |
| Fat % | 18.3 | ± | 2.8 | 23.8 | ± | 8.4 | 22.7 | ± | 3.2 | 21.0 | ± | 5.0 |
| Fat (kg) | 10.0 | ± | 2.9 | 14.6 | ± | 6.7 | 14.1 | ± | 2.9 | 12.8 | ± | 4.3 |
| BMI (kg/m$^2$) | 19.0 | ± | 4.2 | 19.7 | ± | 4.6 | 19.4 | ± | 2.8 | 20.4 | ± | 2.1 |
| Amount of playing tennis (yr) | 7.4 | | 0.8 | 8.3 | | 1.0 | 10.2 | | 1.5 | 8.6 | | 1.1 |
| Training (hour/week) | 20.4 | | 1.4 | 19.0 | | 1.5 | 23.4 | | 2.2 | 20.9 | | 1.7 |
| NRP (range of group) | 3 | - | 80 | 1 | - | 24 | 1 | - | 11 | 1 | - | 80 |
| IRP (range of group) | 245 | - | 990 | 21 | - | 713 | 53 | - | 800 | 21 | - | 990 |

*Values are means ± SD, T 15, T 16, T17 – each category of age, TG group of all tennis players; Fat = fat mass, FFM = free fat mass, BMI = body mass index. NRP- national ranking position, IRP – international ranking position (ITF) Values are not different significantly for group.*

*Motor abilities*.

The motor abilities were determined on the hard tennis court. Each trial was repeated 3 times. The best result was recorded and used for analysis.

The following motor abilities were assessed:

- starting speed (SS) - time to cover a 5-m distance with 0.5-m run-up
- maximal speed (MS)- time to cover a 5-m distance with 10-m run-up.
- power of upper and lower body limbs

For the running trials, time was measured using photoelectric cells (Racetime 2 SF, Microgate)with an accuracy of 0.001 s. The start of the movement was signalized by the coach. For the upper body power test, a medicine ball forward throw was performed using a 2-kg ball. The participant held the ball above her head with both hands and flexed her elbows to maximize the tension development of the triceps. The elbows and shoulders were extended as the participant stepped forward to complete the throwing motion. If the starting line was crossed, the trail was not counted. Results were measured to the nearest 0.1 m. A standing long jump was used to assess lower body power. Participants were allowed to utilize a lower body rocking motion with arm swing. The difference between the starting line and the closest heel mark upon landing, measured to the nearest 1 cm, was recorded as the length of the jump. After three hours of rest a tennis-specific drill (TD) was performed. These movements were similar to those made during a tennis match (run-forehand, run-backhand, run for volley and smash). This exercise was performed as fast as possible with a tennis racquet in hand but without a tennis ball. The tennis player touched each post with the racket before. The elapsed time was also measured using photoelectric cells. This tennis drill was repeated six times with a 30s break between drills (Figure 1).

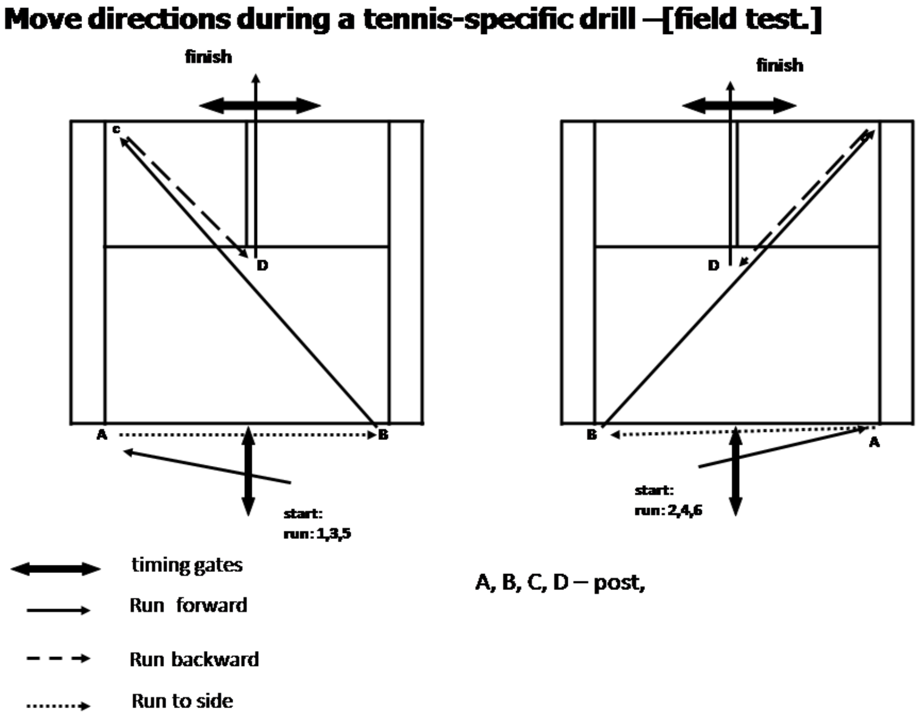


**Figure 1.**Move directions during a tennis-specific drill –[field test.]

*Blood analysis.*

Blood samples were collected from an antecubital vein as part of the baseline. Immediately after collection, the blood was deproteinized by the addition of ice cold 0.4 M perchloric acid. After being thoroughly mixed, the samples were centrifuged at 12,000g for 10 min. Blood lactate was determined using a standard Randox (UK) kit based on the lactate oxidase method (LC2389); assays were performed on a Cecil CE9200 spectrophotometer.

*Aerobic capacity measurement.*

To estimate $\dot{V}O_2max$ participants performed the 12-min Cooper's test. Participants were allowed a 3-min warm up; afterwards, the run was performed individually on an outdoor tartan running track. After a call of "ready" the exercise was begun from a standing start. When the run time elapsed, the participant stopped and her final position was marked on the running track. The run distance, measured to the nearest 5m, was recorded. The test was conducted only once. Maximal oxygen uptake was calculated using the formula $\dot{V}O_2max = 0.0268(\text{distance, meters}) - 11.3$ .

*Statistical analysis.*

Statistical analyses were performed using Statistica 10.0 for Windows. A repeated measurements' analysis of variance (ANOVA) was used to determine the significance of differences between groups for the results of Tennis Drill. The normality of data was tested using the Shapiro-Wilks W-test. To assess the influence of motor abilities, anaerobic and aerobic capacity values on tennis ranking, Pearson correlations were performed. Statistical significance was set at $p < 0.05$ for all analyses.

**RESULTS**

Seventeen junior female tennis players participated in this study. Detailed anthropometric characteristic is presented in the Table 1. Comparison of percentiles of biological age regarding towards weight and height indicated that all the tennis players were commonly in harmonic development; however, only in the group of fifteen year olds chronological age corresponded with biological one. Both groups of sixteen- and seventeen year olds were characterized by accelerated development. Moreover, about 76.5 % of participants were born in the first half year. The average value of the Body Mass Index equaled 20.4 ±2.1 what indicates the lean body mass. Nevertheless, the percentage level of fat mass varied depending on the age group. The lowest level (18.3± 2.8%) was observed in the youngest group, whereas the highest result was noted among sixteen year olds (23.8 ±8.4%). Free fat mass affected the score achieved in the maximal speed test within the whole group ($r=-0.48$; $p<0.05$). However, within a group of T17 only, this conjunction was noted as especially strong ($r=-0.88$; $p<0.05$). Results of motor abilities are presented in the Table 2.

**Table 2.** The motor abilities, physiological response after specific tennis drill and aerobic capacity of female tennis players.

| | **T15** (n=6) | **T16** (n=4) | **T17** (n=7) | **TG** (n=17) |
|---|---|---|---|---|
| **SS [5m]** | 1.06 ± 0.06 | 1.05 ± 0.05 | 1.06 ± 0,08 | 1.06 ± 0.06 |
| **MS [5m]** | 0.72 ± 0.03 | 0.73 ± 0.01 | 0.73 ± 0.01 | 0.73 ± 0.02 |
| **B T [m]** | 8.4 ± 0.9 | 8.4 ± 0.2 | 8.3 ± 1.5 | 8.3 ± 1.09 |
| **LJ [cm]** | 203.3 ± 12.2 | 194.5 ± 4.9 | 197.7 ± 14.3 | 198.9 ± 11.8 |
| **$TD_1$ [s]** | 9.54 ± 0.4 | 9.42 ± 0.3 | 9.78 ± 0.2 | 9.61 ± 0.3 |
| **$TD_2$ [s]** | 9.59 ± 0.3 | 9.39 ± 0.5 | 9.99 ± 0.2 | 9.71 ± 0.2 |
| **$TD_3$ [s]** | 9.53 ± 0.5 | 9.50 ± 0.4 | 9.84 ± 0.2 | 9.65 ± 0.4 |
| **$TD_4$ [s]** | 9.60 ± 0.4 | 9.56 ± 0.5 | 9.87 ± 0.2 | 9.70 ± 0.2 |
| **$TD_5$ [s]** | 9.68 ± 0.6 | 9.50 ± 0.5 | 9.81 ± 0.3 | 9.69 ± 0.4 |
| **$TD_6$ [s]** | 9.63 ± 0.5 | 9.51 ± 0.5 | 9.77 ± 0.3 | 9.66 ± 0.4 |
| **$LA_{rest}$ (mmol $L^{-1}$)** | 1.21 ± 0.3 | 1.02 ± 0.5 | 0.91 ± 0.4 | 1.04 ± 0.2 |
| **$LA_{after\ TD6}$ (mmol $L^{-1}$)** | 8.46 ± 2.0 | 10.0 ± 2.2 | 9.1 ± 1.7 | 9.1 ± 1.9 |
| **$LA_{10`after\ TD6}$ (mmol $L^{-1}$)** | 7.7 ± 1.9 | 8.8 ± 1.6 | 10.1 ± 2.5 | 9.0 ± 2.3 |
| $\dot{V}O_2max$ (mL· $kg^{-1}$·$min^{-1}$) | 59.1 ± 3.1 | 61.7 ± 4.1 | 58.0 ± 5.6 | 59.3 ± 4,.5 |

*Values are means ± SD, Values are not different significantly for group .*
*SS [5m] - starting speed- time to cover a 5-m distance with 0.5-m run-up, MS[5m] maximal speed- time to cover a 5-meter with 10-m run-up, BT [m] - medicine ball throw (2kg) , LJ [m] -long jump, $TD_{(1-6)}$ time of specific tennis drill [s] in each repetition, LA –lactate level*

Obtained values indicate that no statistically significant differences occurred in terms of motor abilities between any of the groups. However, the most important appears the fact that the time achieved in particular repetitions of the tennis drill had a positive influence on international ranking position in junior female tennis players. Figure 2 visualizes correlation's coefficients.

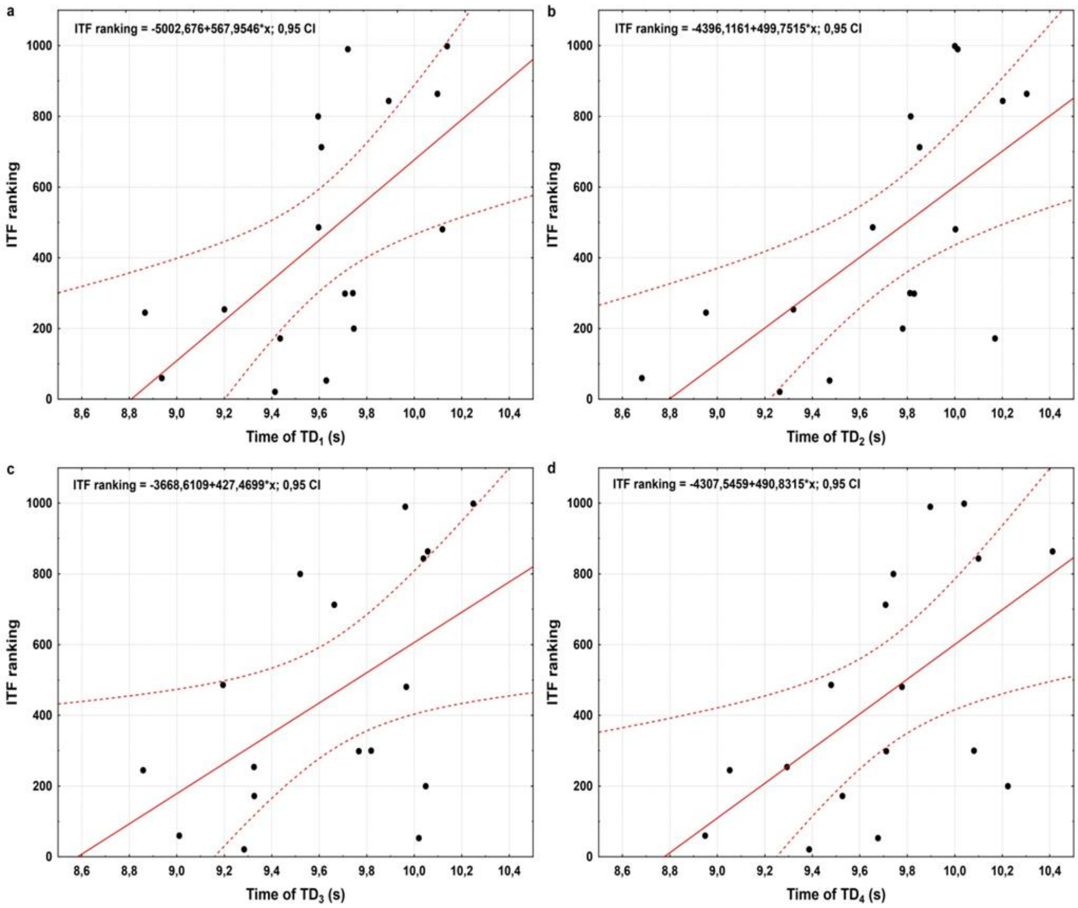


**Figure 2.** The statistically significant positive relationship between time of specific tennis drill (TD) and international ranking position (ITF)
*($TD_{[1]}$ r= 0.60; $TD_{[2]}$ r = 0.64; $TD_{[3]}$ r = 0.52; $TD_{[4]}$ r = 0.57* ; $p < 0.05$*)*

International ranking position was also influenced by aerobic capacity determined by maximal oxygen uptake (Figure 3 r= -0.68; p<0.05). The average distance covered in the Cooper's Test was equal 2635 ± 168m (range from 2635 to 2995m), so the average oxygen uptake equaled 59.3±4.5 after calculations. Striking appears the fact that players who achieved shorter times during each repetition of the exercise, also had higher aerobic capacity results.

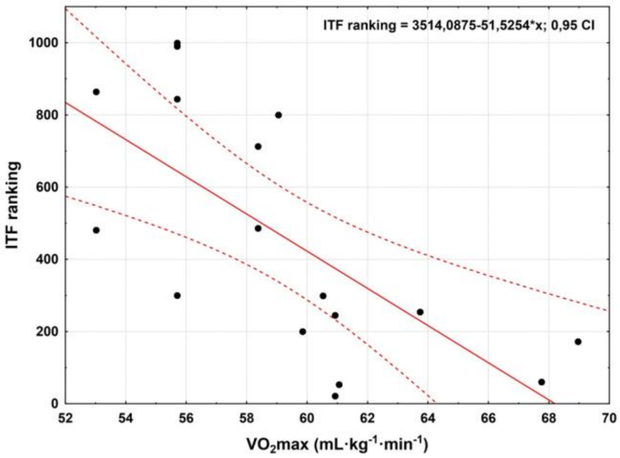


**Figure 3.**The correlation between maximal oxygen uptake ($\dot{V}O_{2max}$) and ranking position in young female tennis players *(r = - 0.68; p<0.05)*

Correlation coefficients between $\dot{V}O_2$ max and time of single tennis drill were equal subsequently ($r = -0.68$; $p<0.05$). Biological age expressed in centyle did not correspond to tennis ranking and exercise capacity in the whole group of participants. Only, among the youngest correlation between date of birth found in the first half of a year and time of specific tennis drill was observed (coefficients $p<0.05$ for following repetitions were: r = -0.88; r = -0.91; r= - 0.68; r= - 0.82; r= -0.62; r= - 0,59). Furthermore, the same part of participants achieved maximal results in the speed running according to the biological age (r= - 0.84), whereas this correlation did not occur among other tennis players. The link between national and international tennis position within the youngest group has been established very precisely (for T15 r=0.96; for T16 r=0.99). The older the participants, the more divergences between both rankings appeared. Physiological response determined with LA after completing all the repetitions of the tennis drill was equal 9.1±1.9 $mmol \cdot L^{-1}$**.** Differences between the groups were not statistically significant; nevertheless the lowest result 8.4± 2.0 $mmol \cdot L^{-1}$ was noted in the group of fifteen year olds, whereas the highest 10.0±2.2$mmol \cdot L^{-1}$ was noted in the group of sixteen year olds.

**DISCUSION**

The main findings of this paper include stating the correlation between the ranking position and aerobic capacity of young female tennis players. Additionally, it was concluded that the occupied ITF position is also determined by motor abilities demonstrated on a court emphasizing running. Subsequent repetitions of the specific tennis drill were performed in shorter time by the group of female tennis players, whose ranking position was considerably higher. Only a few studies analyze the correlation between exercise capacity and tennis ranking position; if so, they rather refer to men , boys . Boys and girls were investigated together but only in terms of anthropometric parameters . Although, Benzer and co-authors evaluated 7-year prospective case report on the relationship between $VO_2$max and the following year's ATP entry ranking, the observation of only one-top tennis player limited the study considerably. Still, these findings emphasized the relevance of aerobic capacity for professional tennis position. On the other hand, the paper of Sánchez-Muñoz involved higher number of participants (66 female and 57 males), who most importantly were the best junior players in the world. Conclusions of this research provide reference values of anthropometric characteristics, body composition and somatotype of elite male and female junior tennis players . In our study anthropometric characteristic: age, weight, height, even free fat mass were very similar to the parameters presented by Sánchez-Muñoz, with an exception of the whole body fat mass values. However, tennis players participating in our study were slimmer than the best junior female in the world . Most of the participants were characterized by slightly accelerated development confirmed by the biological age. Still, in our research group, body composition did not have an influence on tennis ranking position.

The ranking was determined in two categories: national and international (ITF). The ITF position is conditioned by a number of international tennis tournaments played that develop abilities and provide with professional career experience. It's important and significant that international tennis ranking has strong relationship with future position in professional tennis game. Reid defined a regression equation [predicted professional rank = 78.17 + 6.31*(Junior Ranking)] accounted for a significant amount of variance in professional ranking. However this statistical analysis , concerned only boys. In our research we tried to find out if ITF position was determined by two factors: maximal oxygen uptake and already mentioned time of the specific drill, which was presented in the previous paper .

Observations of a professional female junior tennis tournament presented by Fernandez-Fernandez and co-authors stated that the average time of rally duration was 8.20s and range from 0.89-33.s. whereas the number of changes of direction per rally were 2.35 and range 0-9. Specific tennis drill performed by the our participants included all the characteristic and essential tennis elements occurring during a game (forehand, backhand, approach to the net, four fold change of movement direction). It required the effective anaerobic capacity and especially, phosphagenic and glycolitic energy systems. However, it is commonly known that especially the glycolitic energy system is hardly productive during a puberty. We decided applying six times repeated version of tennis drill with ratio work to rest 1:3, due to the fact that insufficient anaerobic capacity is indeed a characteristic feature for puberty, but also for female sex. Time of the specific drill within repetitions ranged between 9.42 to 9.99s. Our previous observations of male junior group have shown that average time of this drill varied from 7.8 to 9.2s. Initially, we assumed that it is female players, who were supposed to achieve very similar results corresponding both to values noted in males group as well as to average time of rally duration (average 8,20s) in female junior tournament established by Fernandez-Fernandez . However, the time of performance of the drill within the investigated female group was longer than it was assumed. This may suggest the speed abilities of the subjects to be insufficient and hinder achieving best results in tournaments. Consequently, achieving better ranking position is also threatened. Improvement of the ATP/CP and glycolytic system-turnover in subsequent repetitions of the tennis drill will increase anaerobic capacity that is crucial in each point of the match. However, the replenishment of the muscle phosphagen during the rest periods demanded supplying the oxygen. In this study, the higher the level of maximal oxygen uptake demonstrated by a player was, the better the results achieved in each TD repetitions were (correlation was statistically significant). Aerobic capacity, crucial in terms of resting periods, was very similar in the whole group. Nevertheless, in the oldest group the discrepancy between national and international ranking positions was observed. One of the possible factors explaining this fact was insufficient anaerobic capacity in turnover. The physiological response expressed in lactate level was the lowest within the youngest group and the highest within the oldest one. Low, maximal activity of glycolytic and glycogenolytic enzymes (glycogen phosphorylase, phosphofructokinase PFK and lactate dehydrogenase) was already claimed as characteristic both for age and gender, which was emphasized by Jaworski . Observation of tournament in junior female player by Fernandez showed that average blood lactate was 2.03 mmol $\cdot L^{-1}$ with range 1.2 – 4.6 mmol $\cdot L^{-1}$ . Our results of lactate level in blood were higher, what might refer to the levels thought to describe values reached during a training. Still, it ought to be taken into consideration that a player who is demanded to play several matches in a short period of time, fatigue might cumulate. Hence, it is worth including in any tennis training programs.

Summing up, physical preparation in terms of anaerobic capacity may have an essential influence on a ranking position. Moreover, specific tennis movement should be especially consider in training of young tennis players.

**PRACTICAL APPLICATIONS**

The most essential part of the article was to provide coaching teams with bases to compare the anthropometric parameters, motor abilities and aerobic capacity in relation to ranking position in a junior female tennis. Specific tennis drill is applied in repetitions enabled not only to verify and observe speed deficiencies but also, improve anaerobic energetic system.

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