MORPHOLOGICAL AND PHYSIOLOGICAL PROFILE INDICATORS OF PHYSICAL FITNESS IN MALE TENNIS PLAYERS AGED 12, 14 AND 16 YEARS

Petar Barbaros Tudor, Vlatko Vučetić, Dragan Milanović, Dario Novak and Bernard Dudašek

Faculty of Kinesiology, University of Zagreb, Croatia

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Abstract:

The establishment of differences in certain morphological characteristics and aerobic energy supply ability among three age categories of Croatian male teenage tennis players was the aim of this cross-sectional study. The sample consisted of 60 players classified into three categories by age: U12 (n=20; 12.1±0.4 years), U14 (n=20; 14.0±0.6 years) and U16 (n=20; 15.9±0.4 years). Nine morphological body measures were taken: body height; body mass; skinfolds of the back, upper arm, chest, abdomen, thigh, lower leg and suprailiocristal. Also, six variables of cardiopulmonary function were obtained using spirometry and spiroergometry testing. Basic statistical parameters were calculated and ANOVA was applied using Tukey's *post-hoc* method. Statistically significant differences were obtained in the variable *maximum treadmill speed* ($p<.01$) and *maximum treadmill speed at the anaerobic threshold* ($p<.01$). Aerobic levels of the Croatian U12, U14 and U16 tennis players were in line with the requirements of high-performance tennis. The results indicated that the conducted physical conditioning and tennis-specific training programmes had a positive effect on the development of aerobic energy capacity indicators in the examined young tennis players. However, due to the age of subjects, the effect of dynamic processes of growth and maturation on the obtained results in the aerobic capacity test cannot be overlooked.

Key words: *tennis, younger age categories, morphological characteristics, cardiopulmonary ability, aerobic endurance, progressive all-out test, boys, teenagers, oxygen consumption, anaerobic threshold, running speed*

Introduction

Growing interest in top-level sports achievements inspired a series of scientific research into tennis as well. It mostly regards research of principles, structure and requirements of the sport, then anthropological dimensions of tennis players of various ages, quality and play style, as well as various performance factors. Fitness characteristics of younger-aged tennis players is an interesting research area due to a turbulent period in lives of these children and teenagers, characterized by an extremely dynamic motor and psychosocial development and maturation. These rapid changes are reasons why young athletes' general physical and mental status in a formative stage, as well as particular sport-relevant characteristics, must be observed. Careful monitoring and detailed analyses, that is, a minute diagnostics of actual states, starting from the initial, when a boy or a teenager enters into any selection or sports training programme, through various kinds of transitive states up to the final, desired fitness states, are crucial in modern sports training technology. The purpose of the diagnostic procedures is to provide a timely insight into abilities in which the observed tennis player is below his/her peers in order to pay special attention to the development of particular, required, dimensions in the following cycles of sports preparation. Therefore, quality diagnostics of the status of abilities, characteristics and motor skills significantly contributes to both tennis development and sport achievements (Reid & Schneiker, 2008). Optimal diagnostic procedures are, on the one hand, an issue of numerous research studies and an indispensable component of everyday sports practice on the other. Top-level sports achievements are results of well-oriented training programmes based on the actual states of tennis-specific and relevant abilities, characteristics and motor skills of athletes. Therefore morphological, physiological, biochemical, biomechanical, motor, social and psychological indicators must be continually monitored and interpreted through comprehensive analyses and training programmes (Milanović & Heimer, 1997). It is of paramount importance for prepubertal children since aerobic capacity in child tennis players considerably exceeds their anaerobic capacity and tolerance to high dosages of anaerobic training or competition stimuli (Crespo & Miley, 1998; Girard, Chevalier, Leveque, Micallef & Millet., 2006; Banzer, Thiel, Rosenhagen & Vogt, 2007; Issurin, 2008).

Each tennis player is unique as regards his/her specific physical features, fitness profile, social skills, intellectual capacities and personality traits. To design an optimal sports training programme for a particular athlete, we must understand his/her individual weak and strong sides. A lack of timely insight into an individual physical fitness profile and possible application of inappropriate training contents and loads, i.e. training stimuli, as well as training methods are the most common causes of the states of either undertraining or overtraining in young tennis players. These states can further lead to a premature drop-out from competitive tennis in childhood or early adolescence (Crespo & Miley, 1998).

Younger age categories of tennis players are in their formative, highly dynamic years of growth and maturation. The basic purpose of the current cross-sectional study was to establish quantitative differences between male tennis players aged 12, 14 and 16 years in their physical fitness as expressed in the variables of their morphological characteristics and in parameters assessing their aerobic cardiopulmonary capacity.

Methods

Sample of subjects

The sample included young male tennis players with training experience of at least two years who were positioned on the Croatian Tennis Federation ranking list. Only the athletes meeting these criteria were included in the study.

The recruited male tennis players and their parents or legal guardians were fully informed of all experimental procedures before they gave their written informed consent. The study design, in accord with the Helsinki Declaration, was approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb.

The sample consisted of sixty young Croatian male tennis players, twenty tennis players per age group: U12—Mean±SD=12.1±0.4 years, U14—14.0±0.6 years, and U16—15.9±0.4 years. All the subjects participated in standard laboratory diagnostic procedures determining their morphological characteristics and assessing motor and physiology functioning abilities. The testing was performed at the Sports Diagnostics Centre of the Zagreb's Faculty of Kinesiology.

Variables

Laboratory testing was conducted during morning hours (8–12 a.m.). Measurement procedure per athlete lasted about two hours. According to the protocol used, first the morphology measurement was conducted followed by spirometry and spiroergometry testing procedures.

All morphological measurements were collected according to the standards and instructions of the International Biological Program (Weiner & Lourie, 1969). Nine morphological body measures were taken: body height (BH) and body mass (BM); as well as skinfolds of the back, upper arm, chest, abdomen, thigh, lower leg and suprailiocristal. Body composition (percentage of lean body mass and body fat), body mass index (BMI; kg/m^2) and somatotype components (according to Carter and Heath, 1992) were calculated from the obtained anthropometric measures. Body composition of athletes was assessed through the method of skinfold measurements (Mišigoj-Duraković, 1996) and by using the equation for the assessment of body density (BD). The value of body density was inserted into the equation (Siri, 1956) for the estimation of body fat percentage (% of body fat = (495/BD – 450).

Description of spyroergometric protocol on the treadmill

The measurement procedures were conducted at the Sports Diagnostic Centre, University of Zagreb, Faculty of Kinesiology. Variables estimating aerobic energy capacity were obtained with the standardized test protocol. All parameters were analysed after the progressive load running treadmill test (Cosmed, Quark b^2, Italy).

Each subject was first familiarized with the goals and protocol of the all-out treadmill testing. Afterwards he put on a size-tailored face-mask, and a band for heart rate telemetric monitoring was fixed on his chest (Polar Electro OY CE 0537, Finland). The utilized measuring instruments (Cosmed, Quark b^2 "breath by breath" spiroergometer, treadmill Technogym – Runrace Competition HC1200, and telemetric heart rate monitor – Polar Electro OY CE 0537) provided a direct, on-line monitoring and analysis of ventilation and metabolic parameters. High reliability of the measured data was also ensured by the constant microclimate conditions inside the laboratory. Also, prior to each subject measuring, the turbine was calibrated using 3-L pump, whereas the same was done for the analyser using the gas mixture of the accurate concentration (16.1% O_2, 5.2% CO_2 and NO_2 residue).

After the phase of 1-minute rest, the test started with a 2-minute walking at speed of 3 km/h. After that, the treadmill speed was increased by 1 km/h every minute. The treadmill inclination of 1.5% remained constant. The subjects walked during first four load stages (up to 6 km/h), then started to run (speed of 7 km/h and above). When the test was completed with a volitional cessation, the maximum speed was established by the last load level the subject had managed to run through for half a minute. During the recovery phase the subject continued to walk at 5 km/h speed while the spiroergometric parameters were monitored. The test is regularly performed as an all-out one, if there are no contraindications or limiting factors. However, subjects occasionally do not demonstrate their plateau under the maximal loads, that is, their oxygen uptake stabilization. Instead, oxygen consumption rises until the final exertion level, which opens space for a doubt whether the subject has exerted to his/her maximum or not. Therefore, to determine if the actual maximal values had been achieved in the test, the following criteria were also applied (Green & Dawson, 1996; Brisswalter, Legros, & Durand, 1996):

1) VO_2 increment reached its plateau (the increment bellow 2 mL/kg/min or <5%) while load was still being increased
2) Heart rate ranged within up to 10 bpm, or 5% regarding the age-relative HR maximum
3) RQ (respiratory quotient) >1.10 or >1.15
4) VE/VO_2 (respiratory equivalent) >30
5) Blood lactic acid concentration >8 mmol/L.

The first (aerobic) and the second (anaerobic) ventilatory thresholds were determined using V-slope method (higher increments of VCO_2 than VO_2); also VE/VO_2 and VE/VCO_2 changes were tracked according to Walsh and Davis (1990). The maximum oxygen uptake in VO_{2max} test during any 30-second interval was marked as the peak VO_2 (VO_{2max}).

The conducted spirometry and spiroergometry provided the following variables:

1. v_{max} (km/h) − *treadmill maximum speed*
2. v_{ant} (km/h) − *treadmill speed at the anaerobic threshold*
3. HR_{max} (bpm) − *maximum heart rate*
4. HR_{ant} (bpm) – *heart rate at the anaerobic threshold*
5. $VO_{2max\ rel}$ (ml/kg/min) – *relative oxygen uptake*
6. $VO_{2rel\ ant}$ (ml/kg/min) – *relative oxygen uptake at the anaerobic threshold*

Statistical analysis

Basic statistical parameters of the variables were computed using descriptive statistical procedures: mean (Mean), standard deviation (SD), the minimum (Min) and maximum (Max) value. Univariate analysis of variance (ANOVA) was employed (using Tukey's *post-hoc* method) to establish significance of differences among the three independent groups of tennis players in means on every variable of basic morphological characteristics and fitness level of aerobic energy supplying ability. Significance was set at p<.05. Statistical analyses were carried out using Statistica 11.0 for Windows (StatSoft Inc., Tulsa, USA).

Results

The average body height was 157.79±0.43 cm, 170.43±9.86 cm, and 178.86±7.79 cm of U12, U14

Table 1. Central and dispersive parameters of the variables and significance tests of the differences between U12, U14 and U16 tennis players in morphological (1−3) and physiological (4−9) characteristics

Variables	N	U12 (n=20) Mean± SD Min-max	U14 (n=20) Mean± SD Min-max	U16 (n=20) Mean± SD Min-max	p
Body height (cm)	20	157.79±0.43 145.00-182.10	170.43±9.86 152.20-190.10	178.86±7.79 159.50-195.20	$, €, £
Body mass (kg)	20	45.07±7.68 31.00-59.50	56.56±10.22 39.70-69.00	66.85±7.38 52.00-79.00	$, €, £
% body fat	20	17.27±6.18 8.00-26.30	14.39±3.76 8.10-20.70	13.71±3.33 5.50-19.00	ns
v_{max} (km/h)	20	14.88±1.06 14.00-18.00	16.45±1.00 15.00-19.00	17.85±0.71 17.00-19.50	$, €, £
v_{ant} (km/h)	20	11.33±0.94 9.80-13.50	12.45±0.91 11.00-14.80	13.41±0.82 11.00-14.50	$, €, £
HR_{max} (beat/min)	20	200.45±7.27 184.00-214.00	197.15±8.96 186.00-217.00	198.30±8.30 180.00-212.00	ns
HR_{ant} (beat/min)	20	181.80±8.75 162.00-199.00	177.65±12.55 161.00-203.00	176.90±9.03 155.00-194.00	ns
$VO_{2max\ rel}$ (ml/kg/min)	20	57.15±5.24 46.60-69.00	57.80±5.65 46.70-70.13	59.99±5.47 48.30-68.60	ns
$VO_{2rel\ ant}$ (ml/kg/min)	20	47.85±4.17 39.90-54.10	48.37±5.80 37.50-62.32	50.07±4.93 41.80-60.40	ns

Note: v_{max} − *treadmill maximum speed;* v_{ant} − *treadmill speed at the anaerobic threshold; HRmax − maximum heart rate; HRant − heart rate at the anaerobic threshold;* VO_2*max rel − relative oxygen uptake;* VO_2*rel ant – relative oxygen uptake at the anaerobic threshold. Values are means±standard deviation(SD) and min−max;* U12 – *tennis players under 12 years*; U14 – *tennis players 12−14 years*, U16 – *tennis players 14−16 years*; ANOVA: $ – *significant* U12:U14, p<.01, € – *significant* U12:U16, p<.01; £ – *significant* U14:U16, p<.01; ns – *not significant.*

and U16 players, respectively. The differences in body height were significant ($p<.01$). If the significant differences ($p<.01$) in body mass are also taken into account (45.07±7.68 kg, 56.56±10.22 kg, 66.85±7.38 kg for U12, U14, and U16, respectively), than a conclusion may be drawn that these results indicate the investigated subjects were, both chronologically and biologically, in the period of intensive growth and maturation (Figures 1 and 2). Also, the differences in body fat percentage were noticed, but they were not significant.

In the spiroergometry test the average maximum treadmill speed ranged from 14.88 to 17.85 km/h. More precisely, the average was 14–18 km/h, 15–19 km/h, and 17–19.5 km/h for the U12, U14 and U16 subjects, respectively. The *treadmill speed at the anaerobic threshold* ranged in U12 from 9.8 to 13.5 km/h, in U14 11–14.8 km/h, and in U16 from 11 to 14.5 km/h.

A significant improvement in the energy supplying abilities was established, mostly in the variable *treadmill maximum speed* (v_{max}; Fig. 3), in which the average for the U12 players was 14.87 km/h, for the U14 players it was 16.40 km/h and for the players up to 16 years of age 17.85 km/h. Statistically significant differences were obtained among all the three age groups at the significance level of $p<.01$, meaning that the older age category subjects were able to sustain a higher treadmill speed. Similar results were obtained in the variable assessing speed at the anaerobic threshold (v_{ant}; Figure 4) with the following averages: 1.32 km/h, 12.45 km/h and 13.41 km/h for the U12, U14 and U16 players, respectively. Almost a linear progression of results was obvious, making all the differences (U12 vs U14, U14 vs U16 and U12 vs U16) statistically significant at the reliability level of 0.99 ($p<.01$). Based on the previous two variables it can be stated that functional fitness improved linearly in the investigated sample.

The obtained maximum heart rate values were 184–214 bpm for U12, 186–217 bpm for U14, and 180–212 bpm for U16 tennis players. The average heart rate at the anaerobic threshold was 162–199 bpm, 161–203 bpm and 155–194 bpm in the U12, U14 and U16 subjects, respectively.

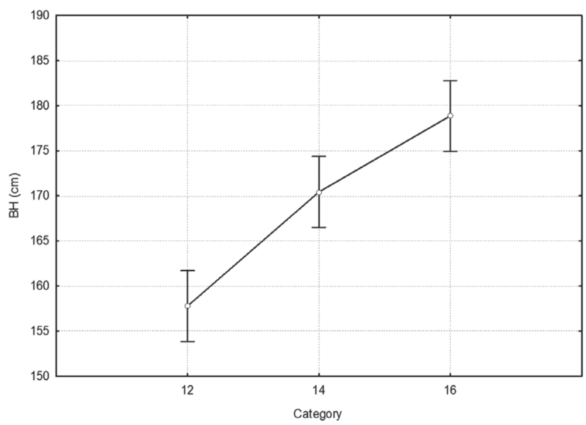

Figure 1. Differences in body height (cm) values between U12, U14 and U16 tennis players.

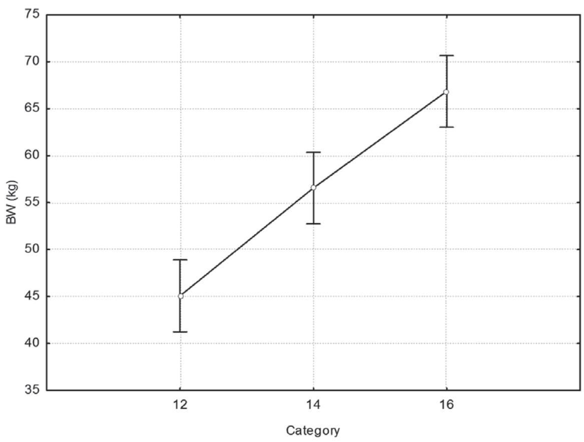

Figure 2. Differences in body mass (kg) values between U12, U14 and U16 tennis players.

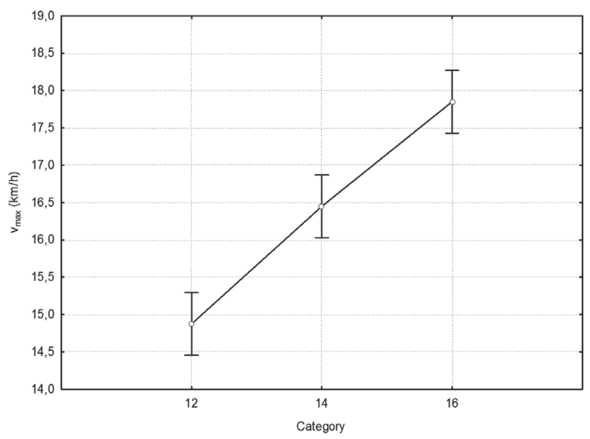

Figure 3. Differences in the treadmill speed (Vmax; km/h) among U12, U14 and U16 tennis players.

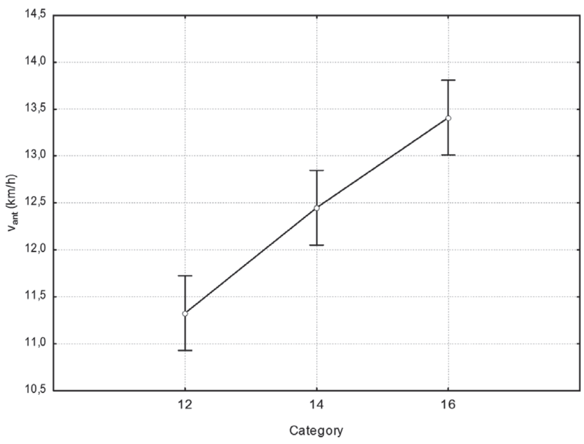

Figure 4. Differences in the treadmill speed at the anaerobic threshold (Vant; km/h) among U12, U14 and U16 tennis players.

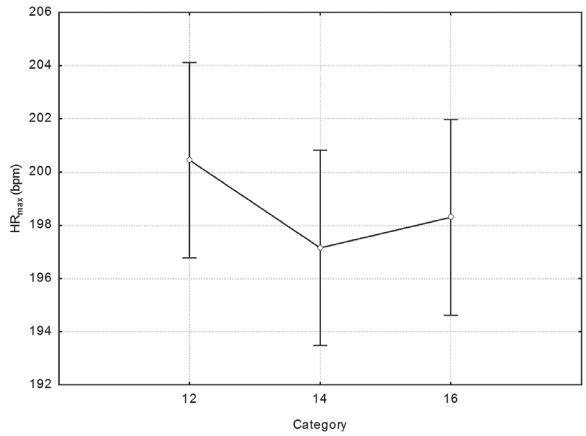

Figure 5. Differences in maximum heart rate (HRmax; bpm) among U12, U14 and U16 tennis players.

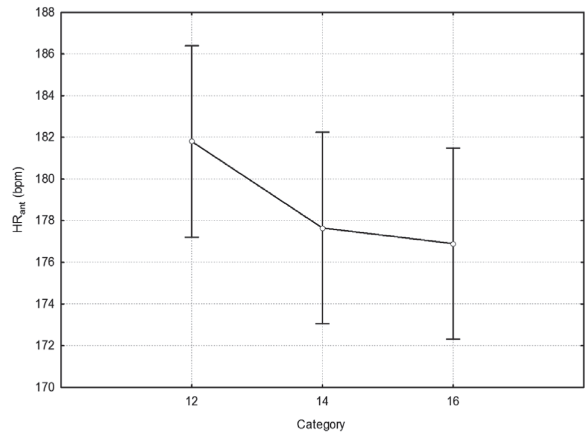

Figure 6. Differences in heart rate at the anaerobic threshold (HRant; bpm) among U12, U14 and U16 tennis players.

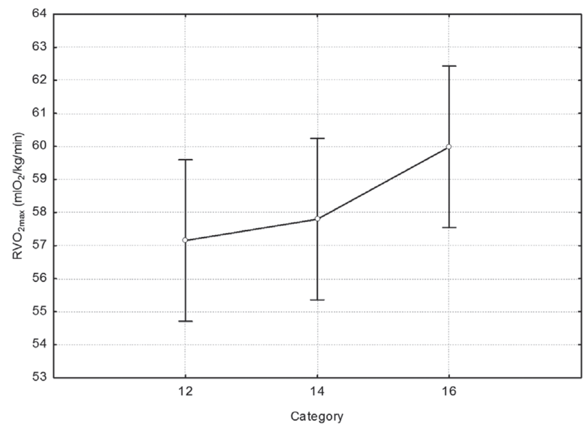

Figure 7. Differences in relative maximal oxygen uptake (VO_{2max} rel; ml/kg/min) among U12, U14 and U16 tennis players.

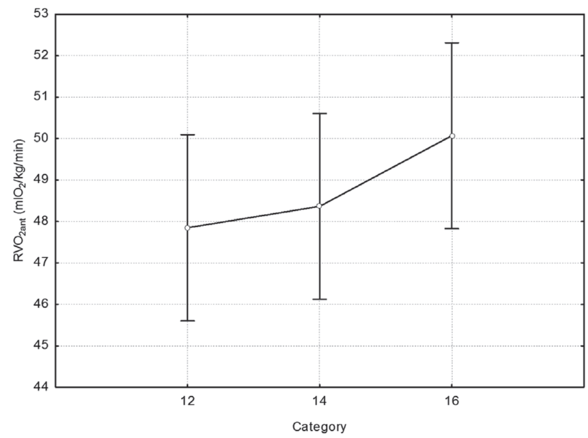

Figure 8. Differences in relative oxygen uptake at the anaerobic threshold (VO2rel ant; ml/kg/min) among U12, U14 and U16 tennis players.

In the variable *maximum heart rate* (HR_{max}; Figure 5) no significant differences were obtained between the results of three age categories of tennis players (mean U12=200.45 bpm, U14=197.15 bpm, U16=198.30 bpm). This finding can be related to and explained by the obtained differences in treadmill speed. Namely, the individually achieved highest treadmill speed values increased progressively with age categories, and so did exertion. Also, lower values of *heart rate at the anaerobic threshold* were registered in U14 and U16 (HR_{ant}; Mean U12 181.80 bpm; U14 177.65 bpm, U16 176.90 bpm), indicating a somewhat better physiological level of fitness. However, the differences between age categories in this variable were not statistically significant (Figure 6).

Relative oxygen uptake (VO_{2max}) in U12 averaged 57.15 ml/kg/min with the $VO_{2rel\,ant}$ ranging between 39.90−54.10 ml/kg/min. In U14 the average of VO_{2max} was 57.80 ml/kg/min with the $VO_{2rel\,ant}$ ranging between 37.50−62.32 ml/kg/min. In U16 tennis players the average relative oxygen uptake was 59.99 ml/kg/min and the values of relative oxygen uptake at the anaerobic threshold ranged between 41.80 and 60.40 ml/kg/min.

Figures 7 and 8 make it obvious that no significant differences were registered in either relative oxygen uptake or in the relative oxygen uptake at the anaerobic threshold between tennis players aged 12, 14 and 16 years.

Discussion and conclusions

The statistically significant differences in the variables of body height and body mass between the participants 12, 14 and 16 years of age indicate they are in the stage of extensive growth. When the results obtained in the current study are compared to the results of the age-matched non-selected general population (Mišigoj-Duraković, 2008), it can be seen that our subjects are taller (6 cm) and heavier (5 kg) on average. If lower values of subcutaneous fatty tissue in tennis players than in the non-selected general population members 14 and 16 years of age are considered, then it is feasible to say that the targeted tennis-specific training and physical conditioning had a positive effect on the muscular development and subcutaneous fatty tissue reduction. Consequently, active muscular mass has a greater contribution to the total body mass of young tennis players, which would also imply a greater contribution to higher levels of strength/power and, further, to a higher game-play intensity as manifested in performance of some game elements: services, baseline shots, start acceleration and quick cuts.

In the game of tennis the proportion of particular energy supply systems, i.e. aerobic and anaerobic energy capacities, varies in relation to court surface characteristics (Kovacs, 2006; Barbaros Tudor, 2008), then in relation to individual tactics, game style, age category and gender of a player. The contribution of energy supplying systems in adult tennis players has been estimated as follows: 70% anaerobic alactic (phosphagen), 20% anaerobic lactic (glycolitic) system and 10% aerobic (cardiopulmonary) capacity (Crespo & Miley, 1998). Based on the mentioned, tennis can be classified as a predominantly anaerobic sporting activity. However, a high level of aerobic fitness is also required in tennis, since it facilitates recovery of players between points, games and sets (during the so-called passive parts of a match), thus comprehensively increasing fatigue tolerance (Davey, Thorpe, & Williams, 2002; Kovacs, 2006; Fernandez, Mendez-Villanueva, & Pluim, 2006).

Since the number of ever younger tennis players involved in sports training and competition is growing, it is important to know what level of energy supply capacity fitness is indispensable, that is, which are age-related optimal referent values of functional fitness indicators. This implies an age-related contribution of particular energy systems as well. For example, in children aged 12–14 years aerobic energy capacity is the most performance-relevant in tennis (Novak, Barbaros Tudor, & Matković, 2006), probably due to a lower play intensity (in younger-aged children) and longer point duration, both of which make aerobic endurance the most important contributor to tennis performance, especially at the end of a match (Banzer, et al., 2007; Girard, et al., 2006). The here observed tennis players (U12, U14 and U16) are still in the period of growth, so their morphological characteristics as well as their energy supply (functional) capabilities are still developing. Therefore, the obtained progression of fitness indicators across age categories can be partially attributed to the biological determinants of growth and development, but they can also be regarded as the effects of the well programmed, managed and monitored tennis-specific training programmes and physical conditioning.

Some authors, for example Crespo and Miley (1998), indicate that players aged up to 12 years win their matches primarily due to their better technical skills, whereas importance of aerobic fitness progresses from that age throughout the phase of puberty until after the age of 16, when aerobic fitness should be developed to the level expected for high-performance tennis players, thus becoming a very important performance factor.

Therefore, when working with trainees of that age (12–16 years), tennis teachers and coaches should continually implement physical conditioning programmes of basic and versatile nature to adequately prepare their young athletes for more intensive training programmes aiming at the development of anaerobic capacities, explosive strength, power, and agility, within the frame of a more detailed tennis-specific and situational physical conditioning.

The findings of the current study are similar to the findings of recent investigations on aerobic capacity of tennis players up to the age of 12 and 14 years (Novak, et al., 2006; Petračić, Šentija, & Novak, 2007), hence it becomes obvious that almost identical results were obtained in particular fitness (functional) variables (for example, VO_{2max} 57.49 vs 56.50 ml/kg/min). Therefore, the inference can be drawn that the assessed functional fitness of our subjects is in conformity with their age and sport-specific demands.

However, the comparison with not so recent studies reveals that the young athletes U12 and U14 from the current study improved their aerobic capacity. This progress can probably be attributed to a larger sports training volume the present-day generations of tennis players are subjected to than the generations of players ten years ago (Janković, Ružić, & Matković, 2004; Petračić, 2005). This corroborates the assumption that the implemented physical conditioning programmes, focused specifically on the development of aerobic and anaerobic energy systems, respected critical phases in the development of aerobic endurance.

Though no significant difference was obtained, we would like to highlight somewhat better aerobic capacity values in tennis players 14–16 years of age as manifested in a higher level of oxygen consumption at the anaerobic threshold. The statistically significant differences among the measured parameters were obtained in two variables: *maximum treadmill speed* ($p<0.01$) and *treadmill speed at the anaerobic threshold* ($p<.01$). The comparison of those findings with the findings from previous research studies (Reid & Schneiker, 2008; Novak, et al., 2006; Petračić, et al., 2007) reveals that our subjects achieved somewhat higher values of maximum running speed and running speed at the anaerobic threshold. Thus, because our subjects were better fitted to sustain higher loads, we can presume that more attention had been paid to quality of physical conditioning during the previous perennial training process of the investigated sample of tennis players (12, 14 and 16 years of age) and that the focus had been on the functional capacity developmental programmes.

When the current study findings are juxtaposed to the results of adult elite tennis players, it becomes obvious that older tennis players of junior and senior age category have a larger muscle mass and that is why they can generate stronger services and baseline shots. This regularly results in a comprehensive acceleration of game-play (Morante, 2006; Kovacs, 2006; Fernandez, et al., 2006; Weber, 2007) with the average point play duration of 4–10 s (Pluim, 2006), or 3–15 s (Kovacs, 2006), and consequently to a more intensive anaerobic load during play. Despite the mentioned, a high level of aerobic fitness is still very important in high-performance adult tennis players. Namely, aerobic capacity is expected to ensure not only proper recovery and injury prevention, but it should also foster performance consistency during a long-lasting competition period. Commonly, the maximal oxygen consumption is investigated as an indicator of functional fitness. In adult high-performance tennis competitors it usually ranges between 44–60 ml/kg/min, with most studies indicating values over 50 and even 55 ml/kg/min (Kovacs, 2006; Green, Crews, & Bosak, 2003; Bergeron, et al., 1991; Christmass, Richmond, & Cable, 1994; Bergeron, Armstrong, & Maresh, 1995). Such values of oxygen consumption classify senior tennis players among aerobically very well prepared athletes (Green, et al., 2003).

In this respect we can assert that functional fitness of our tennis players U12, U14 and U16 is in line with the requirements of high-performance tennis. Although it has been established that the greatest biological increase in values of maximum oxygen consumption in young MEN occurs between 14 and 15 years of age (Reid & Schneiker, 2008; Crespo & Miley, 1998; Malina & Bouchard, 1991; Issurin, 2008), with its continual progression up to adult age, it must be stressed that no significant difference was obtained in the current study between the subjects 14 and 16 years of age in the values of maximum oxygen consumption. The mentioned can be explained through oxygen uptake results of the U12 and U14 tennis players which differed significantly from the results of general population peers (Malina & Bouchard, 1991; Medved, Matković, Mišigoj-Duraković & Pavičić, 1989; Prebeg, 2002; Živičnjak, 1994).

The findings of the current study suggest a final consideration regarding an optimal level of functional fitness, particularly aerobic capacity as a key factor of aerobic endurance of the population of the Croatian tennis players aged 12–16 years. Apparently, physical conditioning of the observed sample of young tennis players, and especially the development of their aerobic fitness, was properly conducted. So, an assertion is viable that all the preconditions have been created to expose those tennis players to more demanding sports preparation programmes in the next phases of their sports development. In these programmes other important components of integral fitness should be addressed as well to enhance play and competition performance in junior and mature adult/senior age category.

The present study analysed the differences in basic morphological characteristics and in the parameters assessing aerobic energy capacity between tennis players 12, 14 and 16 years of age. The significant differences were established in the variables *treadmill maximum speed* and *treadmill speed at the anaerobic threshold* during the progressive load test. No statistically significant differences were established in other variables. It is feasible to presume that training stimuli of physical conditioning and of technical-tactical training, as well as tennis competitions had positive effects on the development of energy supply physiological systems in the investigated teenagers playing tennis. Yet, the influence of biological motor and psycho-social maturation must not be exclu-ded from the consideration, since it probably reinforced transformation effects of training programmes, competitions and recovery measures applied to players of that age. Intensive growth and development at this age causes increases of body height and body mass in 16-year olds, and those increments in body height and body mass are still significant in adolescent men as opposed to the same parameters in younger age boys in whom these values are almost insignificant. Since these morphological measurements are used to compute relative oxygen consumption, it might be presumed that they also affected the obtained differences in the objectively assessed levels of aerobic energy capacity.

This fitness to sustain high workloads and ability to recover quickly may also contribute to self-confidence and psychological stability of tennis players, which eventually enhances their performance and sports achievements (Crespo, Reid, & Quinn, 2006).

The current findings suggest optimal level of morphological characteristics and functional capacities, especially of the aerobic energy supply capacity in the observed Croatian tennis players 12 to 16 years of age. Active muscular mass has ever greater contributions to total body mass. The achieved level of aerobic fitness should satisfy energy requirements imposed by prolonged training sessions and matches, as well as ensure effective restoration of depleted anaerobic energy resources.

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Correspondence to:
Prof. Petar Barbaros Tudor, Ph.D.
Faculty of Kinesiology, University of Zagreb
Horvaćanski zavoj 15
10000 Zagreb, Croatia
Phone: +385 91 3097978
E-mail: petar.barbaros.tudor@kif.hr