Coll. Antropol. **37** (2013) Suppl. 2: 107–112
Original scientific paper

Differences in Energy Capacities between Tennis Players and Runners

Dario Novak, Vlatko Vučetić and Sanja Žugaj

University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia

A B S T R A C T

The primary purpose of this study was to determine differences between elite athletes and tennis players in order to provide a clearer picture regarding the energy demands in modern tennis. Forty-eight (48) athletes and 24 tennis players from Croatian national leagues were compared in morphological and physiological parameters of an all-out incremental treadmill test with gas exchange measurements. Tennis players' HR^{max} (192.96±7.75 bpm) shows values that are most different to 400-meters sprinters (200.13±6.95 bpm). Maximum running speed of tennis players on the treadmill (v^{max}) is no different with the speed achieved by sprinters, while there are significant differences among other athletes. Values in running speed at anaerobic threshold (v^{AnT}) show no statistically significant difference with the values for athlete sprinters and 400-m sprinters. Values of RvO_2^{max} for tennis players indicate significant similarities with athlete sprinters and 400-m sprinters while the values of RvO_2^{AnT} are nearly identical with the values for sprinters and show no statistically significant differences ($p<0.05$). The results indicate that values achieved by tennis players approximate most different those of the middle and long distance runners. This singles out the possible importance of the anaerobic capacity and the high level of sprint endurance in tennis players. Knowing these characteristics is the basis for planning and implementing training systems that will enable the increase and optimal usage of energy capacities of tennis players in possibly improving sports results.

***Key words**: fitness testing, assessing physiological demands of physical activity, sport and exercise psychology, elite performance, endurance*

Introduction

The development of energy capacities is of key importance to achieve success in tennis because the game consists of a number of different explosive and powerful situational actions happening in a very small space[1–3] and some matches can last up to several hours. Proper development of energy capacities has, among other things, a positive influence on injury prevention[4,5] as well as general health improvement[6]. It also has a positive impact on psychosocial characteristics such as self-confidence, self-respect, and mental health[7,8]. Although tennis is characterized by periods of high-intensity exercise, it has been argued that the overall metabolic response resembles prolonged moderate-intensity exercise[9]. Coaches and athletes should infer from this that competitive tennis is a moderate-intensity sport. The average metabolic response does not take into account bursts of high-power output necessary for competitive tennis. In fact, it is the ability to perform during these high-intensity bursts of energy that often determines the outcome of a point. To consistently hit 130 mph serves and equivalent ground strokes, the ability to produce ATP rapidly is very important. As most points in competitive tennis last less than 10 seconds[9], it would be inappropriate to train tennis players in a traditional, aerobic fashion at moderate intensity for long durations. However, this is still how many coaches and tennis players train for a competition. Bergeron and colleagues (1991)[10] concluded that because blood plasma lactate does not change during a tennis match (although this result was not supported by other research[11]), conditioning for tennis should generally emphasize at near, but not beyond, anaerobic threshold. However, this method of training might not suffice to achieve the aerobic power and explosiveness needed to produce effective strokes and movements in tennis players.

The evolution of tennis, especially in terms of athletic preparation of the players to answer demands of higher

Received for publication Septembar 13, 2012

intensity of the game, requires specific training methods and corresponding physiological adaptations of the players[12]. To initiate specific physiological adaptations, we need to know which type of endurance is crucial in modern tennis – aerobic or anaerobic. Trained runners, competing in different running events, may serve as role models through the whole range of endurance capacities, from purely anaerobic to ultra-distance aerobic endurance. Therefore, the primary purpose of this study was to compare tennis players with runners in parameters of an all-out incremental treadmill test with gas exchange measurements and to determine differences between them. These differences will provide a clearer picture regarding the energy demands. They will show what group of athletes is the most different to tennis players regarding energy capacities.

Methods

Participants

Forty-eight (48) athletes (13 sprinters, 12 400-meters runners, 11 middle-distance runners and 12 long-distance runners) and 24 tennis players from Croatian national leagues volunteered to participate in this study. The examinee samples included athletes in running disciplines from 100-m runners to marathon runners, as well as tennis players in the senior category with the condition that they have been training for at least 3 years and positioned on the Croatian Athletic Alliance, that is, Croatian Tennis Alliance's ranking list among the first 20 in their main discipline. Only athletes who met these criteria were included in the study. They were informed of the purpose and methods of the study before providing their written consent. None of the participants were taking any form of medication. The experimental protocol received approval from the local University's (University of Zagreb, Faculty of Kinesiology) Ethics Committee. Table 1 provides the physical and training characteristics of the participants at the start of the study.

Instruments

The selected sample of the entity was measured using measuring instruments of assessing morphological characteristics: age (yrs), body height (cm), body mass (kg); and for assessing physiological characteristics: maximum heart rate (HR^{max}, bpm), heart rate at anaerobic threshold (HR^{AnT}, bpm), maximum speed of treadmill (v^{max}, km/h), speed of treadmill at anaerobic threshold (v^{AnT}, km/h), absolute and relative maximum oxygen intake ([vO_2^{max}, (LO_2/min)]; RvO_2^{max}, mL/kg/min), absolute and relative maximum oxygen intake at anaerobic threshold ([vO_2^{AnT}, (LO_2/min)]; RvO_2^{AnT}, mL/kg/min), time of running in the anaerobic zone (t^{AN}, min), and metres covered in the anaerobic zone (ANm, m).

Description of spyroergometric protocol on the treadmill

Aerobic endurance was analysed after the running treadmill test (Cosmed, Quark b^2, Italy). The inclination of the treadmill was constant, and it measured 1.5%. The test was performed until the examinee was exhausted, unless there were no contraindications or any limiting factors. After a minute-long phase of rest, the test commenced with walking at the speed of 3 km/h for 2 minutes, after which the speed of the treadmill was increased by 0.5 km/h every 30 seconds. The examinee was walking during the first eight levels of load (up to 6.5 km/h) to warm up and to adapt the athlete, then went on running from 7 km/h. The maximum speed and the completion of the test were determined by the last level of load, during which the examinee managed to run full course. A reconvalescing examinee continued to walk for 2 minutes at the speed of 5 km/h, with further monitoring of spyroergometric parameters.

Data processing methods

Means (X) and standard deviations (SD) were used to describe quantitative variables. Analysis of variance (ANOVA) was used to determine significant differences between selected samples. Data in the text and figures are expressed as X±SD. Statistical significance was set at $p<0.05$. All data were analysed using Statistical Package for Social Sciences (v18.0, SPSS Inc., Chicago, IL).

Results and Discussion

Descriptive indicators of morphological characteristics show that the differences in the level of statistical significance of the values in the tennis players' body height and body mass are most similar with the sprinter athletes (Table 2). Today's increasing volume of the tennis players' training is directed toward the demands of tennis play, with increasing interval work similar to that

TABLE 1
ANTHROPOMETRIC AND SPORT-SPECIFIC EXPERIENCE DATA FOR THE ATHLETES AT THE START OF THE STUDY

	Tennis (N=24)	S (N=13)	S4 (N=12)	MD (N=11)	LD (N=12)
	X±SD	X±SD	X±SD	X±SD	X±SD
Body height (cm)	184.80±8.11	184.93±4.83	180.89±4.24	180.40±5.69	179.06±6.74
Body mass (kg)	75.82±9.48	76.61±4.36	73.04±6.26	68.64±6.24	69.47±6.96
Age (yrs)	19.05±1.55	20.53±3.01	19.96±3.47	18.71±2.30	26.97±5.75
Sport-specific experience (yrs)	5.7±3.8	5.2±3.6	5.0±3.2	5.8±3.8	6.7±3.7

Tennis – tennis players, S – sprinters, S4 – 400-metre runners, MD – middle-distance runners, LD – long-distance runners

TABLE 2
DESCRIPTIVE PARAMETERS OF MEASURED VARIABLES OF ATHLETES AND TENNIS PLAYERS

	Tennis (N=24)	S (N=13)	S4 (N=12)	MD (N=11)	LD (N=12)	F	p
	X±SD	X±SD	X±SD	X±SD	X±SD		
Age (yrs)	19.05±1.55	20.53±3.01	19.96±3.47	18.71±2.30	26.97±5.75	13.85	0.00
Body height (cm)	184.80±8.11	184.93±4.83	180.89±4.24	180.40±5.69	179.06±6.74	2.55	0.05
Body mass (kg)	75.82±9.48	76.61±4.36	73.04±6.26	68.64±6.24	69.47±6.96	2.76	0.03
HR^{max} (bpm)	192.96±7.75 *	194.20±6.66	200.13±6.95	196.40±7.29	186.54±7.25	6.56	0.00
HR^{AnT} (bpm)	170.71±8.06 *	175.30±7.54	181.33±9.81	179.30±7.72	168.62±9.92	5.73	0.00
v^{max} (km/h)	17.75±1.25 *,‡	17.15±1.38	19.53±0.77	21.35±1.13	21.65±1.38	37.53	0.00
v^{AnT} (km/h)	13.04±1.07 ‡	12.35±0.97	13.87±0.97	16.40±1.41	17.00±1.59	37.64	0.00
vO_2^{max} (L O_2/min)	4.26±0.58 †	4.33±0.23	4.28±0.41	4.39±0.47	4.75±0.47	2.50	0.05
RvO_2^{max} (mL O_2/kg/min)	56.28±5.32 ‡	55.94±3.47	59.40±4.10	63.76±3.36	68.48±4.24	18.30	0.00
vO_2^{AnT} (L O_2/min)	3.52±0.47 †	3.62±0.28	3.76±0.33	3.80±0.45	4.13±0.45	4.81	0.00
RvO_2^{AnT} (mL O_2/kg/min)	46.49±3.91 *,‡	46.63±2.50	51.62±3.77	55.11±3.46	59.46±4.37	29.92	0.00
t^{AN} (min)	4.71±0.69 *	4.80±0.92	5.67±0.72	4.95±0.55	4.65±0.66	5.50	0.00
ANm (m)	1251.7±221.9 *,‡	1227.1±291.8	1621.7±195.0	1593.1±1519	1532.9±205.4	11.39	0.00

Legend: Tennis – tennis players, S – sprinters, S4 – 400-metre runners, MD – middle-distance runners, LD – long-distance runners, HR^{max} – maximum heart rate, HR^{AnT} – heart rate at anaerobic threshold, v^{max} – maximum speed of treadmill, v^{AnT} – speed of treadmill at anaerobic threshold, vO_2^{max} – absolute maximum oxygen intake, RvO_2^{max} – relative maximum oxygen intake, vO_2^{AnT} – absolute maximum oxygen intake at anaerobic threshold, RvO_2^{AnT} – relative maximum oxygen intake at anaerobic threshold, t^{AN} – time of running in the anaerobic zone, ANm – metres covered in the anaerobic zone
* – statistically significant difference ($p < 0.05$) in relation to S4, † – statistically significant difference ($p < 0.05$) in relation to LD, ‡ – statistically significant difference ($p < 0.05$) in relation to MD, LD

of the sprinters, which results in changes of morphological characteristics in that area.

Tennis players' HR^{max} (192.96±7.75 bpm) shows values that are most similar to sprinters (194.20±6,66 bpm) (Table 2). HR^{max} and HR^{AnT} are statistically significantly different only from sprinters who run 400 m (Figure 1 and Figure 2). This is the result of specific fitness demands of tennis play, which requires good development of aerobic and anaerobic capacity, although the indication of heart rate is not the best indicator of the development of energy capacities. In the U.S. Open finals in 1988–2003, 93% of all points lasted less than 15 seconds[13], which demanded a high level of development of anaerobic capacities, while on the other hand, tennis matches at two won sets usually last around 1.5 hours[14], which points to the significance of aerobic capacity.

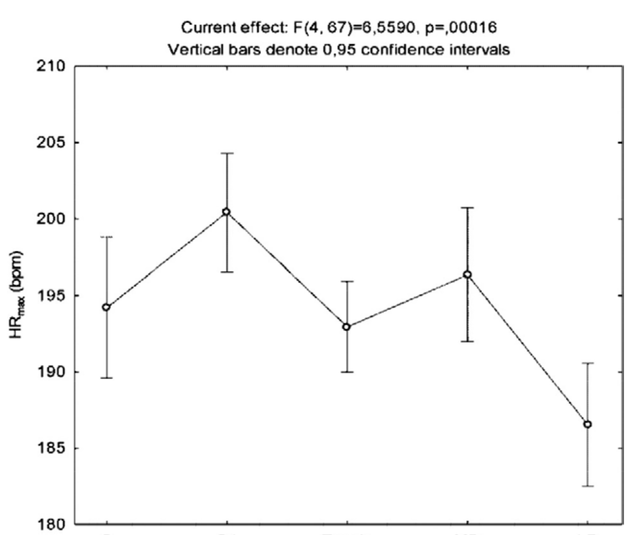

Fig. 1. Differences in values of HR^{max} among the monitored entity groups.

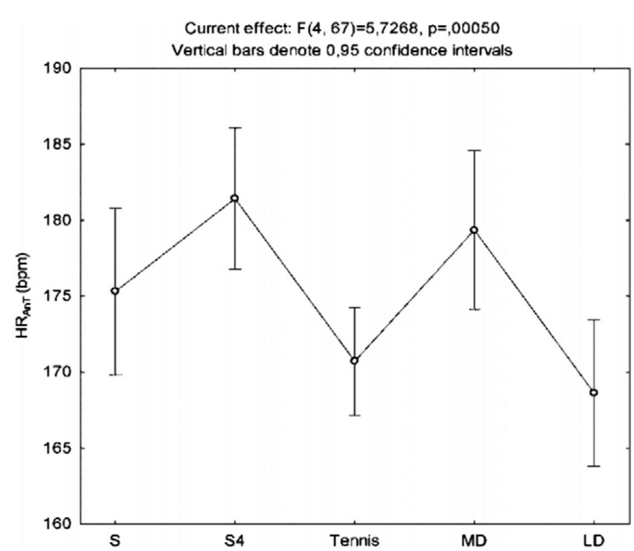

Fig. 2. Differences in values of HR^{AnT} among the monitored entity groups.

Maximum running speed of tennis players on the treadmill (v^{max}) is no different with the speed achieved by sprinters, while there are significant differences among other athletes (Figure 3). Values in running speed at anaerobic threshold (v^{AnT}) show no statistically significant difference with the values for athlete sprinters and 400-m sprinters (Figure 4). This indicates that tennis players, according to the indicators of their fitness readiness at anaerobic threshold, are most similar to sprinters and 400-m sprinters. This suggests that conditioning for tennis should generally emphasize at near, and beyond, anaerobic threshold. This method of training might be suffice the aerobic power and explosiveness needed to produce effective strokes and movements in tennis players. Majority of the points last less than 10 seconds[13]. Competitive tennis points typically last between 5 and 20 seconds, indicating the utilization of the phosphagen and the glycolytic energy system during the point[9].

Values of RvO_2^{max} for tennis players, one of the most important parameters for assessing aerobic energy capacity, indicate significant similarities with athlete sprinters and 400-m sprinters (Figure 5), while the values of RvO_2^{AnT} are nearly identical with the values for sprinters (Table 2) and show no statistically significant differences (Figure 6). For parameters vO_2^{max} and vO_2^{AnT}, tennis players are only different from long-distance athletes (Table 2). This can be explained by the fact that during a match, there is a combination of periods of maximal or near-maximal work and longer periods of moderate- and low-intensity activities[15].

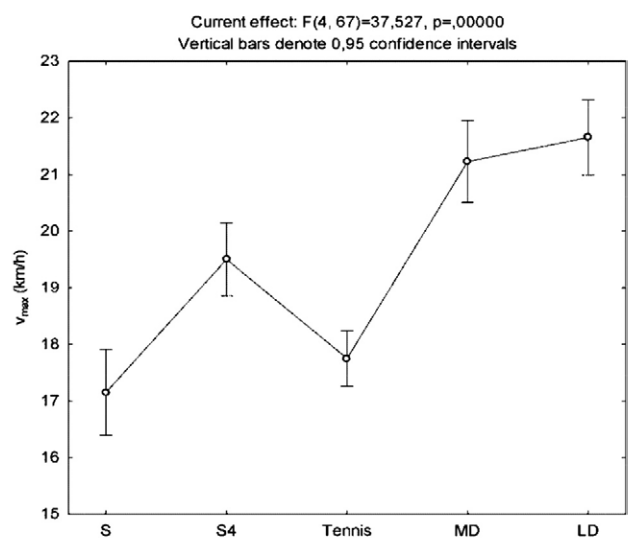

Fig. 3. Differences in values of vmax among the monitored entity groups.

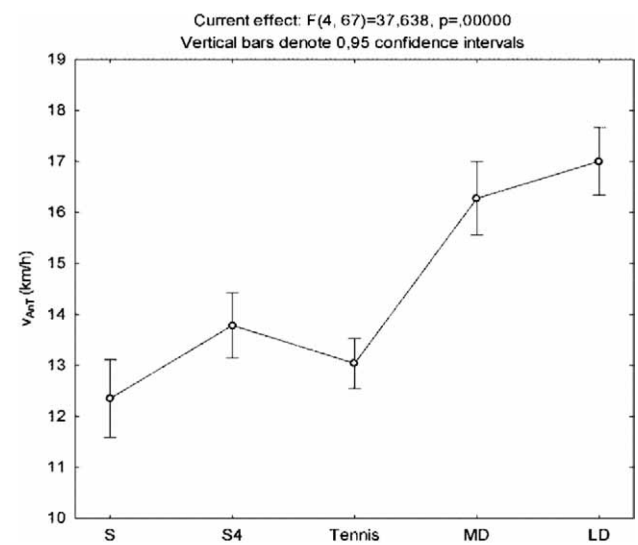

Fig. 4. Differences in values of v^{AnT} among the monitored entity groups.

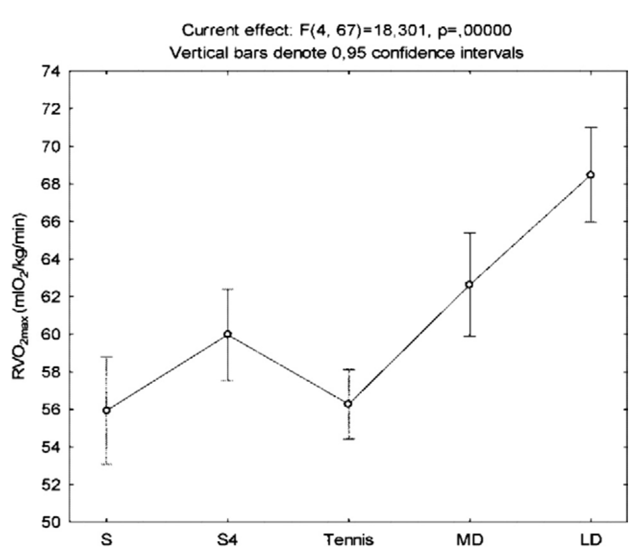

Fig. 5. Differences in values of RvO_2^{max} among the monitored entity groups.

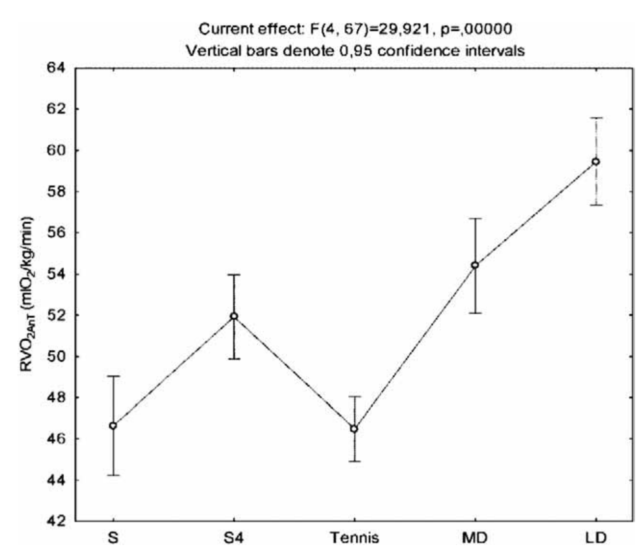

Fig. 6. Differences in values of RvO_2^{AnT} among the monitored entity groups.

Significantly, the longest running time in the anaerobic zone (t^{AN}) in 400-m sprinters can be explained with developed anaerobic and lactal system that enables 40–60 seconds of maximum physical activity, which is the essence of the discipline of 400-m sprint. Energetic demands of the disciplines of sprint, as well as middle- and long-distance running, do not call for creating energy through anaerobic degradation of glycogen, that is, glucose. It is also proven that the levels of plasma lactates during tennis match are not increasing[10,14,16,17], indicating that training that includes significant increases of lactates is not useful for tennis players who are most similar to sprinters in this aspect (tickling the threshold). The distance covered in the anaerobic zone (ANm) also indicates the statistically significant similarity between tennis players and sprinters.

The results of the key energetic parameters (RvO_2^{max}, v^{max}, v^{AnT}) show that tennis players are most similar to sprinter athletes, which is in line with the development of tennis play. Tennis requires multiple bursts of activity, requiring anaerobic energy production and focused movement patterns throughout a match or training. Aerobic training should occur during the rest and recovery periods of high-intensity exercise if the work-to-rest ratios are appropriate. As tennis players are athletes who perfom high-intensity and short-duration sprint activities throughout a match, these athletes should be trained for aerobic development using multiple-duration sprint (<1 minute) with adequate rest (1:3 work/rest ratio) to achieve aerobic training benefits[9,13]. Competitive tennis points typically last between 5 and 20 seconds[9]. Majority of the points last less than 10 seconds[13] indicating the utilization of the phosphagen energy system during the point. It should also be considered that aerobic capacity is important to train and compete at a high level, as recovery between points utilizes aerobic metabolism[13].

Unlike the discipline of sprinting, where such an activity is only performed once, consecutive repetition of points in tennis requires fast recovery, and fast recovery requires an adequate amount of relative oxygen intake, which accounts for higher oxygen intake values in tennis players than in sprinters. These findings regarding the short duration of points in a tennis match, as well as regarding the similarities between tennis players' and athletes' energy parameters, should be our guiding thread in developing a programme for the conditioning preparations of tennis players. The classic aerobic training methods, such as running 1000 to 8000 metres, interval trainings in the form of 400 to 800 metres, and sprints lasting up to 1 or 2 minutes that are often used for developing aerobic, as well as phosphagenous and glycolytic anaerobic endurance, do not simulate the actual conditions of tennis play. In developing specific tennis programmes for developing endurance and in line with the points of similarity between tennis players and sprinters in terms of physiological parameters, it is necessary to plan higher number of exercises that are shorter than 15 seconds and to not allow for more than 45 seconds of exercise without an appropriate time of rest. The exercise-to-rest ratio has to be in accordance with playing a match, and for each second of exercise, it is necessary to plan 2–4 seconds of rest. Moreover, in simulating breaks between games after every 10–15 repetitions, there should be an extended period of rest[18].

Conclusion

The results of this study indicate that when comparing physiological parameters from an all-out incremental treadmill test between tennis players and trained runners, the values achieved by tennis players approximate most closely those of the 100-m and 400-m runners. This singles out the possible importance of the anaerobic capacity and the high level of sprint endurance in tennis players. The conditioning programmes should include elements of the specifics of tennis play, primarily from the aspect of lasting of the load and the length of breaks, as well as the emphasis on particular ways of movement that are used in tennis play. Knowing these characteristics is the basis for planning and implementing training systems that will enable the increase and optimal usage of energy capacities of athletes in possibly improving sports results. Implementing such programmes enables tennis players to properly develop anaerobic and aerobic abilities, considering the demands of tennis play.

Key points

- This study compares tennis players with runners in parameters of an all-out incremental treadmill test.
- The results indicate that values achieved by tennis players approximate most closely those of the 100-m and 400-m runners. This singles out the possible importance of the anaerobic capacity and the high level of sprint endurance in tennis players.
- Knowing these characteristics is the basis for planning and implementing training systems that will enable the increase and optimal usage of energy capacities of tennis players in possibly improving sports results.

R E F E R E N C E S

1. MCCARTHY J, J Strength Cond Res, 20 (1998) 23. DOI: 10.1519/1073-6840(1998)020<0023:TPR>2.3.CO;2. — 2. KATIC R, BALA G, BAROVIC Z, Coll Antropol, 36 (2012) 563. — 3. KATIC R, MILAT S, ZAGORAC N, ĐUROVIC N, Coll Antropol, 35 (2011) 341. — 4. BILCHECK HM, J Strength Cond Res, 11 (1989) 60. DOI: 10.1519/0744-0049(1989)011<0060:EIIYA>2.3.CO;2. — 5. FAIGENBAUM AD, J Strength Cond Res, 15 (1993) 20. DOI: 10. 1519/0744-0049(1993)015<0020:STAGFT>2.3.CO;2. — 6. FAIGENBAUM AD, J Strength Cond Res, 17 (1995) 28. DOI: 10. 1519/1073-6840 (1995)017<0028:PBOPST>2.3.CO;2. — 7. FAIGENBAUM AD, ZAICHKOWSKY LD, WESTCOTT WL, LONG CJ, LAROSA-LOUD R, MICHELI LJ, OUTERBRIDGE AR, J Sport Behav, 20 (1997) 164. — 8. KOVACS MS, Sport Med, 37 (2007) 189. DOI: 10.2165/00007256-2007 37030-00001. — 9. BERGERON MF, MARESH CM, KRAEMER WJ, ABRAHAM A, CONROY B, GABAREE C, Tennis: a physiological profile during match play. Int J Sports Med, 12 (1991) 474. DOI: DOI: 10.1055/s-2007-1024716. — 10. THERMINARIAS A, DANSOU P, CHIRPAZ-ODDOU MF, GHARIB C, QUIRION A, Int J Sports Med, 12 (1991) 10. DOI: 10.1055/s-2007-1024647. — 11. CHANDLER TJ, ARNOLD EC, Bioener-

getics. In: Conditioning For Strength And Human Performance. Eds: CHANDLER TJ, BROWN LE (Williams and Wilkins, Baltimore, 2008). DOI: 10.1519/SSC.0b013e318164b66e. — 12. KOVACS MS, STRECKER E, CHANDLER WB, SMITH JW, PASCOE DD, J Strength Cond Res, 18 (2004) 364. — 13. BERGERON M, KEUL J, (2002) The physiological demands of tennis. In: Tennis: handbook of sports medicine and science. Ed: RENSTROM PA (Blackwell Publishing Co., Oxford, 2002). — 14. FERNANDEZ J, MENDEZ-VILLANUEVA A, PLUIM B, Brit J Sport Med, 40 (2006) 387. DOI: 10.1136/bjsm.2005.023168. — 15. FERRAUTI A, WEBER K, WRIGHT PR, Endurance, semi-specific and specific. In: Strength and conditioning for tennis. Eds: REID M, QUINN A, CRESPO M. (ITF, London, 2003). — 16. SMEKAL G, VON DUVILLARD SP, RIHACEK C, POKAN R, HOFMANN P, BARON R, TSCHAN H, BACHL N, Med Sci Sports Exerc, 33 (2001) 999. DOI: 10.1097/ 00005768-200106000-00020. — 17. KOVACS MS, ITF Coaching and Sport Science Review, 38 (2006) 2.

D. Novak

University of Zagreb, Faculty of Kinesiology, Horvaćanski zavoj 15, 10 000 Zagreb, Croatia
e-mail: dario.novak@kif.hr

RAZLIKE U ENERGETSKIM KAPACITETIMA IZMEĐU TENISAČA I ATLETIČARA

S A Ž E T A K

Osnovi cilj ovog istraživanja bio je utvrditi razlike vrhunskih atletičara i tenisača kako bi se dobila jasnija slika o energetskim zahtjevima u modernom tenisu. Četrdeset i osam (48) atletičara i 24 tenisača hrvatskih nacionalnih liga uspoređeni su prema morfološkim i fiziološkim parametrima spiroergometrijskog protokola na pokretnom sagu uz mjerenje izmjene plinova. Vrijednost maksimalne frekvencije srca (HR^{max}) tenisača (192,96±7,75 o/min) značajno je različita u odnosu na atletičare sprintere na 400 metara (200,13±6,95 o/min). Maksimalna brzina trčanja tenisača na pokretnom sagu (v^{max}) ne razlikuje se od postignute brzine sprintera na 100 metara, dok su uočene značajne razlike s ostalim atletičarima. Vrijednosti brzine trčanja tenisača pri anaerobnom pragu (v^{AnT}) ne pokazuju statistički značajnu razliku sa atletičarima sprinterima na 100 i 400 metara. Vrijednosti relativnog maksimalnog primitka kisika ($RvO_2{}^{max}$) tenisača upućuju na značajnu sličnost sa sprinterima na 100 i 400 metara, dok su vrijednosti relativnog maksimalnog primitka kisika pri anaerobnom pragu ($RvO_2{}^{AnT}$) tenisača gotovo identične vrijednostima sprintera na 100 metara i ne pokazuju statistički značajnu razliku ($p<0,05$). Rezultati istraživanja ukazuju kako su tenisači postigli vrijednosti različitije od onih kod trkača na srednje i duge pruge. To upućuje na moguću važnost anaerobnog kapaciteta i visoke razine sprinterske izdržljivosti kod tenisača. Navedene karakteristike temelj su planiranja i provođenja sustava treninga koji će omogućiti optimalni razvoj energetskih kapaciteta tenisača te unaprjeđenje sportskih rezultata.