TIME-MOTION CHARACTERISTICS, NOTATIONAL ANALYSIS AND PHYSIOLOGICAL DEMANDS OF TENNIS MATCH PLAY: A REVIEW

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Review paper

Abstract

Tennis is a sport characterized by a combination of physical actions such as running at different speeds, acceleration, turns, strokes and game-specific actions. In this regard, competitive tennis players require not only well-developed aerobic endurance and anaerobic capacity, but also technical and tactical skills to achieve high levels of performance during training and matches. The aim of this review was to investigate the demands of competitive tennis match play in terms of physiological responses, time-motion characteristics and match analysis. Three sport science journal databases PubMed, ISI Web of Knowledge and SPORT Discus were screened for papers published until May 2018. The following keywords were used in various combinations with tennis: "notational analysis", "physiological demands", "simulated match", "time-motion", and "match characteristic". In this review, studies had to meet follow inclusion criteria: cross sectional or longitudinal design, case control studies, or experimental studies electronically published in English. All studies demonstrated high methodological quality. This review presents a useful synthesis of all research into match performance in tennis, including the investigation of the internal and external load of the tennis match play and helps to guide for future research.

Key words*: performance, simulated tennis match, match characteristics, total distance, maximum oxygen consumption, heart rate*

Introduction

Upper-level tennis tournaments, including over 60–80 female and male categories, are held in different countries and on different court surface types in accordance with International Tennis Federation [ITF] rules (Fernandez-Fernandez et al., 2006; ITF, 2016). Tennis is a popular competitive sport that is played by millions of people of all ages, as well as athletes, with tournaments that takes place at different levels almost every week of the year (Fernandez-Fernandez et al., 2006; Fernandez-Fernandez et al., 2009b; Renström, 2008). The tennis match includes repeated high-intensity running (e.g. acceleration, deceleration, changes of direction) and variety strokes with different speeds and angles, requiring the contribution of upper muscle groups. Thus, this sport involves anaerobic metabolism in which these actions occur in a short period using maximal or near-maximal force (Banzer et al., 2008; Hoppe et al., 2014; Murias et al., 2007; Perry et al., 2004; Reid et al., 2013). Tennis is typically played on different court surfaces (clay, hard, grass) with different kinds of balls (fast, medium, slow). It is known that characteristics of court surface and ball type have effected on the physical and physiological responses during a tennis match (Fernandez-Fernandez et al., 2006; Filipčič and Filipčič, 2006; Smekal et al., 2001). Previous studies have shown that various factors such as sex, level of players and court surface performance of players during tennis trainings and matches (Filipčičet al., 2015; Hizan et al., 2010; Hornery et al., 2007; Kilit et al., 2016; Kilit and Arslan, 2017; Martínez-Gallegoet al., 2013; O'Donoghue and Ingram, 2001; Reid et al., 2016). Therefore, the most appropriate training program can be designed by making use of these variables in terms of time-motion characteristics (speed, total distance covered [TDC], deceleration [DC], acceleration [ACC]) (Cooke et al., 2011; Duffield et al., 2010; Galé-Ansodi et al., 2016a; 2016b; Hoppe et al., 2014; Kilit and Arslan, 2017; Pereira et al., 2016a; Pereira et al., 2016b; Reid et al., 2008), notational analysis (rally duration [RD]; rest time [RT]; work-to-rest ratio [W:R]; effective playing time [EPT]; strokes per rally [SPR]; total match time [TMT]) (Fernandez-Fernandez et al., 2007; Fernandez-Fernandez et al., 2008; Mendez-Villanueva et al., 2007; Mendez-Villanueva et al., 2010; Smekal et al., 2001) and describes physiological demands (heart rate [HR], oxygen consumption [VO_2], blood lactate concentrations [LA], rating of perceived exertion [RPE]) (Fernandez-Fernandez et al., 2007; Fernandez-Fernandez et al., 2008; Ferrauti et al., 2001; Mendez-Villanueva et al., 2007; Mendez-

Villanueva et al., 2010; Reid et al., 2008). Many studies have been published on the physiological demands and notational analysis of competitive tennis matches. However, no review study has examined time-motion characteristics with regard to simulated tennis matches. The aim of the present narrative review was to investigate the demands of competitive tennis match play in terms of physiological responses, time-motion characteristics and match analysis.

Methods

The reference search was performed in the databases the PubMed, ISI Web of Knowledge and SPORTDiscus until May 2018. The following keywords were used in various combinations with tennis: "notational analysis", "physiological demands", "simulated match", "time-motion", and "match characteristics". The inclusion criteria of the study were: 1) articles electronically published in English, 2) full text papers with cross sectional or longitudinal design, case control studies, or experimental studies, 3) the focus was on players with healthy population. The following papers were excluded: 1) articles were not written in English, 2) conference abstracts only, 3) articles with wheelchair players (Figure 1). After meeting the inclusion criteria, all research studies are classified in three sections in this review. The first section focus on the time-motion characteristics in tennis. The second section reviews the results of notational analysis from simulated tennis matches. The third section describes physiological demands obtained during tennis matches contains four variables such as HR, LA, VO_2 and RPE. This narrative review shows a useful knowledge about tennis, including time-motion characteristics, notational analysis and physiological demands of tennis match play and helps to identify areas for future research and preparing training program.

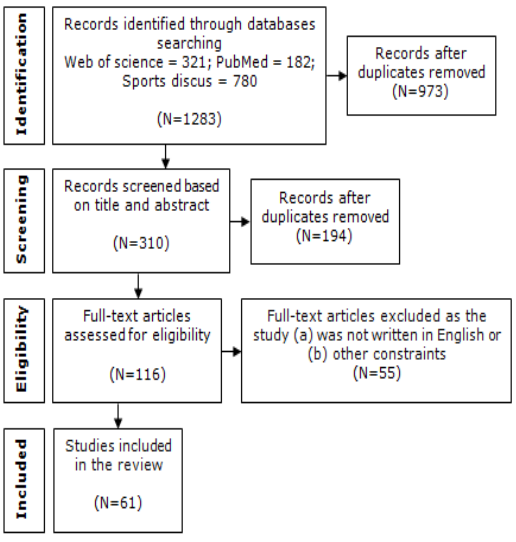

Figure 1. Flow diagram shows each stage of the review process

Time-Motion Characteristics

Many previous studies have shown that time-motion characteristics of tennis players during simulated match play include spontaneous, short-term, high-intensity movements (Girard and Millet, 2009). The recent development of technological tools such as wearable and multivariable monitoring devices including GPS features offer a highly practical way of monitoring external loads of players such as TDC, ACC and DC movements during tennis training and matches (Galé-Ansodi et al., 2016a; Kilit and Arslan, 2017; Pereira et al., 2016a). These systems give better results than video-based analysis, describing time-motion characteristics of tennis players during simulated match play and on-court training performance (Filipčič and Filipčič, 2009; Kilit and Arslan, 2017; Martínez-Gallego et al., 2013; Pereira et al., 2016b; Reid et al., 2013; Reid et al., 2016;). Speed zones have been classified into different categories (walking [0-7 $km.h^{-1}$], low [7-12 $km.h^{-1}$], moderate [12-18 $km.h^{-1}$], and high [18-24 $km.h^{-1}$] intensity running) (Duffield et al., 2011; Fernandez-Fernandez et al., 2009a; Galé-Ansodi et al., 2016a; Hoppe et al., 2014; Kilit and Arslan, 2017; Pereira et al., 2015; Pereira et al., 2016a; Pereira et al., 2016b). In previous studies, the running activities of players are characterized by high ACC [0±2 $m.s^{-1}$] and DC during tennis matches. In addition, a major part of the covered distance in tennis match have been generally showed between 0 and 7 $km.h^{-2}$ (Galé-Ansodi et al., 2017; Hoppe et al., 2014; Kilit and Arslan, 2017). In another study showed that the players in national and regional levels performed at low-speed zone with 0.5-1.5 $m.s^{-2}$ ACC during tennis matches (Pereira et al., 2015). The another similar study showed that the ACC values of the players in the hard court surface found higher compared to clay court surface (Galé-Ansodi et al., 2016a). Contrast to this study results, the ACC values of the players in the clay court surface found higher compared to clay court surface [~1.7-2.2 $m.s^{-2}$ respectfully] (Ponzano and Gollin, 2017). As high-intensity rally numbers rises, the running activities especially ACC values increases in matches or training exercises in young and adult tennis players (Hoppe et al., 2014; Kilit and Arslan, 2017). Previous studies have shown that covered distance during tennis matches was measured between 1.2–3.1 km and depending various factors such as sex and court surfaces (Fernandez-Fernandez et al., 2009b; Galé-Ansodi et al., 2017; Hoppe et al., 2014; Kilit and Arslan, 2017; Pereira et al., 2016a; Pereira et al., 2016b; Reid et al., 2016). In a study by Cui et al. (2017), the total covered distance was found between 2.0–2.6 km in the 2015–2017 Grand Slam men's singles match. Furthermore, covered distance in the women's singles final match in 2016-2017 Grand Slam tennis tournaments was found between 0.9–1.2 km, while in the men's singles final matches found between 1.1–3.4 km (Australian Open, 2017; French Open, 2016; Wimbledon, 2017; US Open, 2017). During competitions, 80% of all strokes were made at a distance of 2.5 m, and the players

covered about 3 m distance per stroke and a distance of about 8–12 m per point during an active game (Cui et al., 2017; Davey et al., 2003; Kovacs, 2007; Kramer et al., 2016; Whiteside et al., 2016). The covered distance per point in women's single final matches was found to be 7.6–11.5 m and men's single final match was 6.8–15.3 m during Grand Slam tournaments (2016–2017) (Australian Open, 2017; French Open, 2016; Wimbledon, 2017; US Open, 2017). This difference might be due to the different scoring systems used in men's and women's final matches. In addition to this, the covered distance per point varies between the simulated matches and the professional matches, depending on different court surfaces and the sex of the athlete. Time-motion characteristics of tennis match play in Table 1 presents calculated percentage of average velocity at various speeds zone.

Table 1. Time-motion characteristics of tennis match play

Reference	Sex	Surface	TDC (m)	DRP (m)	AS ($km.h^{-1}$)	0-7 ($km.h^{-1}$) (%)	7-12 ($km.h^{-1}$) (%)	12-18 ($km.h^{-1}$) (%)	18-24 ($km.h^{-1}$) (%)	>24 ($km.h^{-1}$) (%)
Fernandez-Fernandez et al., 2009a	M (AV)	Clay	3569±532	NR	3.8±0.3	~84	~11.1	~3.8	~0.8	~0.3
	M (RV)		3174±226	NR	5.0±0.3	~77	~13.6	~6.8	~2.2	~0.4
Hoppe et al., 2014	M	Clay	3362±869	NR	2.5±0.3	~34	~55.7	~7.7	~1.6	~0.4
Pereira et al., 2016b	M	Clay	3160±880	5.3/5.8	NR	~79	~17	~3.7	~0.3	NR
Pereira et al., 2016a	M	Clay	2657±220	NR	NR	~87	~12.7		~0.3	
		Hard	2012±296	NR	NR	~90	~9.8		~0.2	
Pereira et al., 2015	M (N)	Hard	2717±203	NR	NR	~79	~20.1		~0.9	
	M (R)		1989±346	NR	NR	~90	~9.4		~0.6	
Hoppe et al., 2016	M (Y)	Clay	3477±889	NR	2.5±0.3	~97	~3			
	M (A)		3244±894	NR	2.2±0.3	~97	~3			
Galé-Ansodi et al., 2016a	M, F	Clay	NR	NR	10.1±2.1	~92	~7	~1	NR	
		Hard	NR	NR	11.5±1.4	~87	~12.6	~0.4	NR	
Galé-Ansodi et al., 2017	F	Hard	3154±1204	NR	10.2±1.4	~91	NR	NR	NR	
Kilit and Arslan, 2017	M	Hard	3289±386	NR	2.5±2	~89	~8.8	~2.1	~0.1	
Cui et al., 2017	M	Hard	2190-2361	9.7-10.5	NR	NR	NR	NR	NR	
		Clay	2219-2567	11.2-11.8						
		Grass	1999-2133	8.7-9.7						
		Hard	2227-2253	9.4-10.8						

TDC: total distance covered; DRP: distance ran per point; AS: average speed per rally; M: male; F: female; N: national; R: regional; AV: advanced veteran; RV: recreational veteran; Y: young; A: adult; NR: not reported.

Notational Analysis

Tennis is a sport that is characterized by movements repeated in short durations and at the submaximal intensity (~10 s), and intermittent exercises with long rest periods (~120 s) (Chrissmass et al., 1998; Ferrauti et al., 2001; Mendez-Villanueva et al., 2007). The average score of high-level tennis players is 5–10 s, the average resting time is 10–20 s and the W:R ratio is 1:2–4 (Kovacs, 2004; Reid and Duffield, 2014; Torres-Luque et al., 2011a; Torres-Luque et al., 2011b;). The distance points in women's singles matches (7.1 s) were reported to be considerably longer in men's single matches (5.2 s) (O'Donogheu and Ingram, 2001). Previous studies have shown that the estimated effective game duration varies on different court surfaces (Martin et al., 2011; Reid and Duffield, 2014; Torres-Luque et al., 2011a). In general, the EPT is 7–8% on grass court, compared to 30% on clay court (Schönborn, 2000). The minimum W:R ratio played on different court surfaces is observed on fast court surfaces (grass) (Maquirriain et al., 2016; O'Donoghue and Ingram, 2001;), although the rallies are longer and the number of strokes is higher on slow court surfaces than on fast surfaces (Murias et al., 2007). Approximately 2–6 strokes were observed per point during the competition, depending on the ball type, court surface, sex of the athlete and tactical strategies (Fernandez-Fernandez et al., 2009b; O'Donoghue and Ingram, 2001; Torres-Luque et al., 2011a; Torres-Luque et al., 2011b). In these studies, TMT was recorded as between 50–119 min (Hornery et al., 2007 Smekal et al., 2001). Additionally, high-level players make >1000 strokes during a tennis match (Reid et al., 2016). Changes to the court and the type of ball used in matches are known to affect the activity demands of a match (Smekal et al., 2001). For instance, the serve-volley game style, which is based on speed and strength, is required when the game is played on grass. In contrast, matches played on clay court take longer and require more endurance due to the increased number of rallies (Cross and Pollard, 2009; Del Corral, 2009; Miller, 2006; Norton and Clarke, 2002). There is no time limit for tennis matches, and they can be lasted from one to five hours (five-set matches) (Kovacs, 2007; Reid and Duffield, 2014). For example, in the 2010 Wimbledon tennis tournament, the match between John Isner and Nicolas Mahut lasted for approximate 11 hours (The longest match in history, 2015), and the match between Novak Djokovic and Rafael Nadal at the 2012 Australian Open was completed in 5 h 53 min (Reid and Duffield, 2014).

Table 2. Notational analysis of tennis match play

References	Level & Sex	Surface	SPR (n)	DR (s)	RT (s)	EPT (%)	W:R ratio	TMT (min)
Chrıstmass et al., 1998	M (N)	Hard	4.6±0.1	10.2±0.3	16.8±0.2	23.3±1.4	1:1.7	90
Smekal et al., 2001	M (N)	Clay	NR	6.4±4.1	NR	29.3±12.1	1:~1-6	50
Fernandez-Fernandez et al., 2007	F (I)	Hard	2.8±1.7	8.2±5.2	17.7±6.5	21.9±3.8	1:2.1	~80.6±24.4
Mendez-Villanueva et al., 2007	M (I)	Clay	2.7±2.2	7.5±7.3	16.2±5.2	21.5±4.9	1:2.2	105±35.7
Hornery et al., 2007	M (I)	Clay	4.5±2	7.5±3	17.2±3.3	NR	NR	79±13
		Hard	4.7±1.4	6.7±2.2	25.1±4.3	NR	NR	119±36
Fernandez-Fernandez et al., 2008	F (I)	Clay	2.5±1.6	7.2±5.2	15.5±7.3	21±6.1	1:2.1	~64.7±30.3
Morante and Brotherhood, 2008	M-F (N)	Hard	NR	5.8±1.3	NR	23.7±5.2	NR	82.5±25.3
Fernandez-Fernandez et al., 2009a	M (AV)	Clay	2.1±1.3	6.3±4.1	14.5±5.2	21.7±5	1:2.3	60
	M (RV)		2.3±1.6	7.6±5.5	13.9±5.5	23.6±5.4	1:1.8	
Mendez-Villanueva et al., 2010	M (I)	Clay	2.7±2.2	7.5±7.3	16.2±5.2	21.5±4.9	NR	~104.9±35.7
Martin et al., 2011	F-M (N)	Clay	NR	8.5±0.2	NR	26.2±1.9	NR	56.9±5
		Hard	NR	5.9±0.5	NR	19.5±2.0	NR	56.0±10.1
Torres-Luque et al., 2011a	M (N)	Hard	5.9±0.1	9.1±0.7	21.1±0.3	30.1±3.4	1:2.5	108.3±16.1
	F (N)		5.5±0.2	9±0.5	19.1±0.4	31.1±3.2	1:2.2	99.6±18.5
Kilit et al., 2016	M (I)	Hard	3.9±2.9	6.7±4.7	20.2±4.7	26.3±3.2	1:3	60
Kilit and Arslan, 2017	M (N)	Hard	5.7±4.2	12.1±10.8	24.7±16.7	26.3±4.6	1:2.1	77.2±15.2

SPR: shots per rally; DR: duration of the rally; RT: resting time; EPT: effective playing time; W:R: work-to-rest ratio; TMT: total match time; M: male; F: female; AV: advanced veteran; RV: recreational veteran; I: international; N: national; NR: not reported.

Physiological Demands

HR is influenced by different variables during training and competition. HR measurement provides instant information regarding the internal loading of simulated tennis matches. The mean HR of trained tennis players aged 20–30 years old has been determined as 140–160 bpm, although this figure increases to 190–200 bpm in longer and faster rallies (Fernandez-Fernandez et al., 2006; Fernandez-Fernandez et al., 2009b; Kovacs, 2007). This corresponds to a mean HR measured in tennis matches of between 60–80% of the HR_{max} (Fernandez-Fernandez et al., 2006; Kovacs, 2007). These values show that both the lower and upper extremities of the body are highly active during such exercise (Fernandez-Fernandez et al., 2006). In studies, the HR of the serving player was found to be higher than the player receiving the serve, which may be because the player performs a high-intensity stroke to deliver faster serve, while the player receiving the serve is more active because he or she has an offensive role in the game (Fernandez-Fernandez et al., 2007; Kilit et al., 2016;). The average HR responses of defensive players were higher than offensive players (Smekal et al., 2001). It might be explained by greater number of strokes causes more physiologically loading. Another important factor is different court surfaces affects HR responses. In a study by Martin et al. (2011), the mean HR was observed to be higher on clay than on a hard court (154±12 bpm, 141±9 bpm, respectively). It was further reported that women had higher HR responses than men, which is based on that there are more rallies on slow courts and the active game duration is longer for women (Fernandez-Fernandez et al., 2007; Morante and Brotherhood, 2007). Considering all this information, different tactical behaviors in matches can be seen to change the physiological structure of the game. The concentration of LA accumulation in the blood is another physiological response which shows that exercise is performed in an anaerobic capacity, and many studies have been conducted measuring LA to garner knowledge about exercise or the intensity of the game (Fernandez-Fernandez et al., 2007; Fernandez-Fernandez et al., 2008; Ferrauti et al., 2001; Martin et al., 2011; Mendez-Villanueva et al., 2007; Mendez- Villanueva et al., 2010; Murias et al., 2007; Ojala and Häkkinen, 2013; Smekal et al., 2001). When the results of these studies are examined, LA concentrations are low throughout the game but may increase in longer and more intense rallies (Fernandez-Fernandez et al., 2006; Kovacs, 2007). For example, the LA concentrations of the serve game players were reported to be 4.4–4.6 $mmol.L^{-1}$, compared to 3–3.2 $mmol.L^{-1}$ in players in return game (Mendez-Villanueva et al., 2007; Mendez-Villanueva et al., 2010). This difference in LA concentrations can be explained by the more active role of the serve game for player. In contrast to these results, no significant difference was found between serve and return games' LA concentrations during a match (Fernandez-Fernandez et al., 2007; Fernandez-Fernandez et al., 2008; Smekal et al., 2001). Technically, LA measurements cannot be performed continuously during a tennis match, meaning that LA concentrations only reflect the level of activity immediately before the measurement (Smekal et al., 2001). In this respect, in order to evaluation of LA concentration should be used in combination of physiological responses such as HR and RPE (Kilit et al., 2016; Kilit and Arslan, 2017). Measuring VO_2 with a portable gas analyzer is another way to determine the physiological demands of players in training and simulated tennis matches (Fernandez-Fernandez et al., 2009a Smekal et al., 2001). The average VO_{2max} values were determined as 45 $ml.kg^{-1}.min^{-1}$ for women and 55 $ml.kg^{-1}.min^{-1}$ for men (Fernandez-Fernandez et al., 2006; Kovacs, 2007). While the average VO_2

values measured during the match were determined to be about 23–29 $ml.kg^{-1}.min^{-1}$, the amount of oxygen consumed during the match was found to be between 50% and 70% of VO_{2max}. The players game strategies (offense-defense) during competition are also known to affect VO_2 (Fernandez-Fernandez et al., 2009b; Girard et al., 2006; Kilit et al., 2016; König et al., 2001; Murias et al., 2007; Smekal et al., 2001). The mean VO_2 values of defensive players during the competition were reported to be 25–36 $ml.kg^{-1}.min^{-1}$, compared to 22–32 $ml.kg^{-1}.min^{-1}$ for offensive players (Smekal et al., 2001). From this, it can be concluded that defensive players playing from the baseline consume more energy than offensive players. Additionally, the VO_2 values of serving players were observed to be higher than the players receiving the serve (Kilit et al., 2016), which may be because players make effective strokes at high speed when serving. VO_2 values are affected by different court surfaces. In a study by Girard and Millet (2004), VO_2 values measured on a clay court surface during the competition were observed to be higher than on a hard court. Another method used in studies to determine exercise intensity is the determination of the RPE. The Borg scale, which has different versions, is easy to perform, that requires no expertise and reflects a subjective assessment, although it is thought to provide a more accurate evaluation, along with other measured physiological demands, such as HR and LA. In recent studies, Borg scale has been reported to reflect the severity of activity during tennis matches (Borg, 1982; Coutts and Duffield, 2010; Reid et al., 2008). The difficulty level of the competition in elite tennis players was reported to be 12–14 (6–20 scale) on this scale (Duffield et al., 2014; Kilit and Arslan, 2017; Kilit et al., 2016; Murphy et al., 2014; Ojala and Häkkinen, 2013). RPE values, which are highly correlated with activities in competition, may change depending on the sex of the athlete and the level of the game. In some studies, RPE values have been determined to be higher during serve game compared to return game (Mendez-Villanueva et al., 2007; Mendez-Villanueva et al., 2010; Kilit et al., 2016), although other studies found no such relationship (Fernandez-Fernandez et al., 2008; Kilit and Arslan, 2017), which may be attributed to that the match performances of players differ depending on the sex and level of the athlete. In the light of this data, that the findings suggest that physiological demands may be affected by variables, such as different court surfaces, gameplay (serve-return) and sex of the athlete. Accordingly, it may be more useful to interpret HR, LA, VO_2 and RPE values together when attempting to determine the physiological demands of training and simulated matches.

Table 3. Physiological demands of tennis match play

References	Sex	Surface	HR (bpm)	LA (mmol. L^{-1})	VO_2 ($ml.kg^{-1}.min^{-1}$)	RPE (6-20)
Ferrauti et al., 2001	F	Clay	141±19	1.2±0.4	23.1±3.1	NR
	M		142±13	1.7±0.5	25.6±2.8	NR
Smekal et al., 2001	M	Hard	151±19	2.1±0.9	29.1±5.6	NR
Fernandez- Fernandez et al., 2007	F	Hard	161±5	2.0±1.0	NR	NR
Hornery et al., 2007	M	Hard	152±15	NR	NR	NR
		Clay	146±19	NR	NR	NR
Mendez-Villanueva et al., 2007	M	Clay	NR	3.8±2	NR	13±2
Morante and Brotherhood, 2007	M	Hard	140±13	NR	NR	12.9±1.8
	F		150±6	NR	NR	13.2±1
Fernandez- Fernandez et al., 2008	F	Clay	NR	2.2±0.8	NR	12.1±2.3
Morante and Brotherhood, 2008	M-F	Hard	137±14	NR	NR	12.9±1.9
Fernandez- Fernandez et al., 2009a	AVM	Clay	150±8	NR	24.5±4.1	NR
	RVM		149±7	NR	23.3±3	NR
Mendez-Villanueva et al., 2010	M	Clay	NR	4.4±2.4 / 3.0±1.3	NR	13.5±1.9 / 12.2±2
Martin et al., 2011	F, M	Clay	154±12	5.7±1.8	NR	NR
		Hard	141±9	3.6±1.2	NR	NR
Ojala and Häkkinen, 2013	M	Hard	142/150	3.4/4.1	NR	12.8/14.4
Hoppe et al., 2014	M	Clay	159±12	NR	NR	NR
Kilit et al., 2016	M	Hard	143±9	NR	26.6±2.7	12.7±2.1
Kilit and Arslan, 2017	M	Hard	164±15	NR	NR	13.9±2.5

HR: heart rate; LA: lactate concentratıon; VO_2: oxygen consumption; RPE: rating of perceived exertion; M: male; F: female; AVM: advanced veteran male; RVM: recreational veteran male; NR: not reported.

Another method used in studies to determine exercise intensity is the determination of the RPE. The Borg scale, which has different versions, is easy to perform, that requires no expertise and reflects a subjective assessment, although it is thought to provide a more accurate evaluation, along with other measured physiological demands, such as HR and LA. In recent studies, Borg scale has been reported to reflect the severity of activity during tennis matches (Borg, 1982; Coutts and Duffield, 2010; Reid et al., 2008). The difficulty level of the competition in elite tennis players was reported to be 12–14 (6–20 scale) on this scale (Duffield et al., 2014; Kilit and Arslan, 2017; Kilit et al., 2016;

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Conclusion

This narrative review documented time-motion characteristics, notational analysis and physiological demands of tennis players during single tennis matches. Studies results have shown that physiological responses such as HR ranging from 120–180 bpm, LA 1–8 $mmol.L^{-1}$, VO_2 10–40 $ml.kg^{-1}.min^{-1}$, RPE 9–17 have been reported during simulated tennis matches. In addition, tennis players covered a distance between 1.0 and 3.4 km and match effective activity (0–7 $km.h^{-1}$) including accelerations (0–2 $ms^{-}2$) accounts for approximately 80–90% of the total distance covered during tennis matches. Match notational analysis, such as rally duration (5-10 seconds), effective playing time (10-30% of total time), and resting time (10-20 seconds), are also reported in studies. Considering all of studies results, external and internal loadings should be assessed together in order to evaluate the intensity of match and training. This evaluation provide that coaches and practitioners can successfully use effective, time-efficient and sport-specific training to improve desired physical conditioning of tennis players.

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KARAKTERISTIČNI POKRETI, ANALIZA I FIZIOLOŠKI ZAHTJEVI U TENISU: PREGLED ISTRAŽIVANJA

Sažetak

Tenis je sport obilježen kombinacijom fizičkih akcija kao što su trčanje na različitim brzinama, ubrzanje, okretaje, udarci i akcije specifične za igru. U tom smislu, natjecateljski tenisači zahtijevaju ne samo dobro razvijenu aerobnu izdržljivost i anaerobni kapacitet, već i tehničke i taktičke vještine za postizanje visokih performansi tijekom treninga i utakmica. Cilj ovog rada bio je ispitati zahtjeve tenisa u smislu fizioloških odgovora, vremenskih pokretljivosti i analize meča. Sljedeće ključne riječi korištene su u različitim kombinacijama s teniskom: "notational analysis", "physiological requirements", "simulated match", "simulated match", "time-motion" i "match characteristic". U ovom pregledu, studije su morale zadovoljiti kriterije za uključivanje: presjek ili longitudinalne, studije kontrole slučaja ili eksperimentalne studije elektronski objavljene na engleskom jeziku. Sve su studije pokazale visoku metodološku kvalitetu. Ovaj pregled predstavlja korisnu sintezu svih aspekata tenisa, uključujući i istraživanje unutarnje i vanjske igre u tenisu, te je svakako korisna za smijer budućih istraživanja.

Ključne riječi*: performanse, simulirani teniski meč, karakteristike utakmice, ukupna udaljenost, maksimalna potrošnja kisika, broj otkucaja srca*

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