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Physiological demands of match-play in elite tennis: A case study

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ORIGINAL ARTICLE

Physiological demands of match-play in elite tennis: A case study

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Abstract

The physiological and perceptual demands together with match notation of a four-set tennis match were studied in two elite professional players during the preparation for the 2008 Davis Cup. The design of this case report is unique in that it is the first to describe the demands of prolonged match-play (197 min) over four sets in ecologically valid conditions. The variables measured before and after each set included blood lactate and glucose concentrations, body mass, and perception of effort. Stroke count for each rally and heart rate were recorded during each set while salivary cortisol concentration was determined before and after the match. The rally length decreased as the match progressed. The results showed significant physiological stress, with each player losing greater than 2.5% of body mass (as fluid) and having elevated salivary cortisol concentrations after the match. Heart rate and perception of effort were also increased following each set indicating increasing stress. However, blood lactate decreased following the fourth set while blood glucose was maintained. The results also suggest that elite players may adjust work rates or tactics to cope with the increased perception of effort. This report shows that four sets of tennis are associated with increasing stress and fatigue.

Keywords: *Racket sports, match analysis, fatigue, physiological demands, perception of effort*

Introduction

Tennis requires players to perform short bursts of high-intensity exercise interspersed with periods of rest or low-intensity activities for a prolonged period (Fernandez, Mendez-Villanueva, & Pluim, 2006; Kovacs, 2007; Mendez-Villanueva, Fernandez-Fernandez, & Bishop, 2007a). Previous investigations have reported the heart rate responses, blood metabolite changes, estimated energy expenditure and oxygen consumption during competitive tennis matches and training, providing considerable information on the physiological demands of tennis (for reviews, see Fernandez et al., 2006; Kovacs, 2007; Mendez-Villanueva et al., 2007a). At present, however, there is relatively little information available on the stressors of prolonged tennis match-play, especially at the elite level (Mendez-Villanueva, Fernandez-Fernandez, Bishop, Fernandez-Garcia, & Terrados, 2007b).

The physiological responses to tennis match-play have been reported to be moderate, with factors such as individual playing style, court surface, and game situation all influencing the response (Fernandez et al., 2006; Kovacs, 2007; Mendez-Villanueva et al., 2007a). In general, these previous studies have reported mean heart rates of 60–80% of maximum (Ferrauti, Weber, & Wright, 2003; Kovacs, 2007) and mean blood lactate concentrations of less than 4.0 $mmol \cdot l^{-1}$ during matches consisting of three sets (Fernandez et al., 2006; Fernandez-Fernandez, Mendez-Villanueva, Fernandez-Garcia, & Terrados, 2007). However, the major international tournaments (e.g. Grand Slam events and Davis Cup) are determined by the best of five sets (the first player to win three sets wins the match) with the longest matches lasting for more than 5 h. There have been few reports of the stressors of tennis in professional male players, and none have reported on the responses to matches that are longer than three

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sets. Therefore, more information is required on the demands of professional tennis for matches that are longer than three sets.

Here, we report on the physiological, perceptual, and time–motion demands of a four-set tennis match played by top-level professional players during preparation for the 2008 Davis Cup. The primary aim of this case report was to describe the stressors of match-play in elite professional tennis players. We hypothesized that the physiological and perceptual demands would increase as playing time increased and that these would impact on physical performance. The findings of this report are relevant to a very specific population of professional tennis players, and provide new information that can be used to guide the preparation of elite tennis players.

Methods

Experimental approach

It is important to understand the physiological demands of top-level sporting events, so that specific training and recovery strategies can be developed. Limited data are available on the match demands of professional tennis players, particularly over long periods (i.e. five sets). This study was designed to describe the physiological, perceptual, and performance demands of professional tennis in conditions similar to the 2008 Davis Cup. We examined these responses under match-like conditions in top professional players who were preparing for international competition. However, it should be acknowledged that the competitive training match did not impose the same psychological stress as a competitive match.

Participants

Two members of the Brazilian team (player 1: ATP ranking = 78, height 1.87 m, body mass 82.4 kg, age 20 years, maximum heart rate 187 beats $\cdot$ min^{-1}, $\dot{V}O_{2max}$ 57 ml $\cdot$ kg^{-1} $\cdot$ min^{-1}; player 2: ATP ranking = 120, height 1.77 m, body mass 76.5 kg, age 26 years, maximum heart rate 183 beats $\cdot$ min^{-1}, $\dot{V}O_{2max}$ 53 ml $\cdot$ kg^{-1} $\cdot$ min^{-1}) agreed to participate in a best of five-set practice match as part of the preparation for the 2008 Davis Cup. The Institutional Ethics Review Board provided approval for the study.

Competition procedures

The players were asked to prepare for the match in the same way they would for any major competition. Before the match, they received a standard breakfast (carbohydrate 1 g $\cdot$ kg^{-1}). *Ad libitum* food and fluid intake (e.g. water, sports beverages, fruits, and cereal bars) was recorded during the match. Carbohydrate intakes (solid and liquid) during the match were similar between the players (player 1: 1.0 g $\cdot$ kg^{-1}; player 2: 0.8 g $\cdot$ kg^{-1}). The match started at 10:00 h.

The match was completed under International Tennis Federation (ITF, 2002) competition regulations, and was officiated by ITF-accredited umpires and line judges. The match was best of five sets and was played on an outdoor hard tennis court. The number of sets (i.e. best of five sets), the balls used (balls were changed after the first seven games and then every nine games thereafter), and time breaks (i.e. between points, change overs and sets were kept to 20, 90, and 120 s, respectively) were in accordance with ITF regulations. The match was played in hot environmental conditions (temperature: 26.0–27.5°C; humidity: 66–70%).

Heart rate (HR) was monitored and recorded at 5-s intervals during the match using a chest monitor (Polar Team System©, Polar, Kempele, Finland). After the match, the heart rate data were downloaded to a computer and then categorized into heart rate zones to indicate time spent in low- (<70% HR_{max}), moderate- (70–85% HR_{max}), and high-intensity (>85% HR_{max}) zones using the Polar Team System software. Maximum heart rate was determined prior to testing during regular maximal oxygen consumption tests conducted in a sports science laboratory. Exercise intensity was also measured using the CR-10 ratings of perceived exertion (RPE) scale at the end of each set (Borg, Ljunggren, & Ceci, 1985). Session RPE was also measured 30 min after the match (Foster et al., 2001). Changes in body mass were determined by weighting between sets, plus adding fluid intake to derive a body mass difference (as fluid).

A lancet was used to puncture the ear lobe and draw capillary blood. Blood lactate and glucose concentrations were determined by Accucheck© monitors (Roche©, Germany). All blood samples were drawn while the players were seated during breaks after each set. Cortisol was assessed by saliva samples collected before the warm-up and immediately after the match using Salivettes© swabs. Saliva was analysed in duplicate for cortisol concentration using enzyme-linked immunosorbent assay kits (Salimetrics©, USA).

A simple match notation analysis was conducted by line judges manually with pen and paper by counting the number of strokes each player played during each rally.

Results

Total match duration was 197 min. Player 2 won the match in four sets: 5–7 (60 min; player 2 won),

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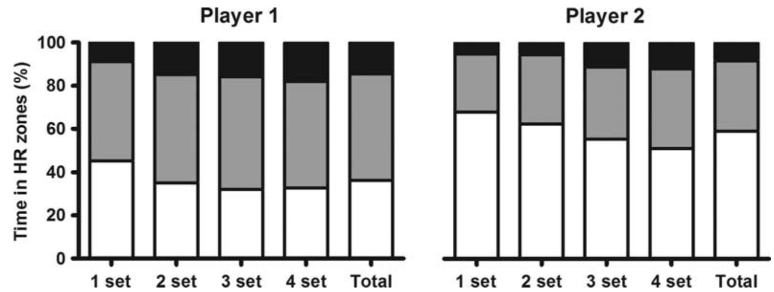

Figure 1. Percentage of time spent in low- (open), moderate- (grey), and high-intensity (black) heart rate (HR) zones for each set, and the overall tennis match.

3–6 (48 min; player 2 won), 7–6 (45 min; player 1 won), 4–6 (44 min; player 2 won). Figure 1 shows the proportion of time spent in the low-, moderate-, and high-intensity heart rate zones during each set and the entire match. The proportion of strokes per rally during the tennis match play is shown in Figure 2.

During the match, player 1 and player 2 lost 3.5% and 2.6% of body mass, respectively (Table I). The physiological and perceptual responses during the match of both players are shown in Table II. Salivary cortisol concentration increased by 25% (from 17.1 to 21.3 mmol $\cdot$ l^{-1}) and 16% (from 22.9 to 26.6 mmol $\cdot$ l^{-1}) in player 1 and player 2, respectively. Session RPE scores were 8 and 6 for player 1 and 2, respectively.

Discussion

In agreement with our initial hypothesis, the present results show that four sets of elite-level tennis played provides significant physiological and perceptual stress. Together with an increase in internal training load, we observed a decrease in rally length as the match progressed. Collectively, these results also show that players may adopt a different playing strategy in an attempt to cope with increasing physiological and perceptual stress.

In the present study, rally length was reduced as the match progressed. Indeed, in the third and fourth sets more than 60% of the rallies had two strokes or less, whereas in the first two sets most rallies were of 2–4 strokes. It is not clear if this was due to a change in tactics or fatigue (i.e. carbohydrate depletion or dehydration); however, it is possible that an increased sense of effort was involved in regulating the external loads during the match.

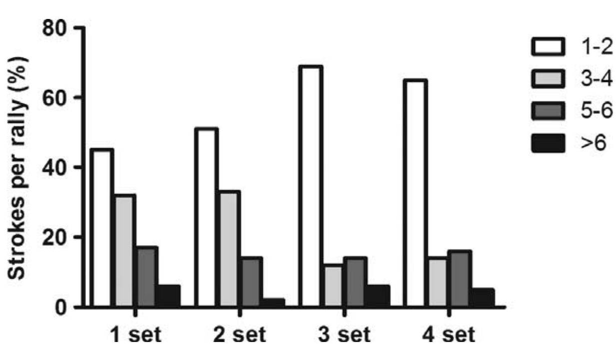

Figure 2. Proportion of strokes per rally during tennis match-play.

The heart rate responses during the match were similar to those in previous tennis studies (Fernandez et al., 2006; Hornery, Farrow, Mujika, & Young, 2007; Smekal et al., 2001) that demonstrated a moderate aerobic load in professional tennis. A novel finding of the present study is the upward drift in the proportion of time spent in the moderate and higher heart rate zones by both players as the sets progressed. This effect was greater in player 1 who also lost most body mass (3.5%). These findings suggest that "cardiovascular drift" may occur during prolonged tennis match-play and highlight the importance of appropriate hydration strategies when playing in the heat. In fact, both players suffered a significant body weight loss due to dehydration.

It is well known that training strain modulates the secretion of stress hormones, particularly catecholamines and glucocorticoids (Hill et al., 2008; Leal-Cerro et al., 2003). As expected, post-match salivary cortisol concentration was increased compared with pre-match values, reinforcing our initial hypothesis that a prolonged match imposes a significant internal load.

The blood lactate concentration of the players in this match were similar to the values reported during a round robin tournament in eight professional tennis players on a clay court (3.8 ± 0.2 mmol $\cdot$ l^{-1}) (Mendez-Villanueva et al., 2007b), but higher than that of 20 nationally ranked players (2.1 ± 0.9 mmol $\cdot$ l^{-1}) (Smekal et al., 2001) during three-set tennis. It has previously been reported that blood lactate concentration in tennis players is influenced

Table I. Changes in body mass, fluid intake, and sweat rate during the tennis match

	Player 1	Player 2
Change in body mass (%)	3.5	2.6
Fluid intake (ml)	1970	2530
Sweat rate (ml $\cdot$ h^{-1})	1500	1360

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Table II. Physiological and perceptual responses to each set of tennis match-play

	Player 1	Player 2
First set		
RPE (CR-10)	3	4
Lactate (mmol · l^{-1})	2.8	3.2
Glucose (mg · dl^{-1})	97	88
Mean heart rate (range)	137 (86–176)	128 (70–169)
Change in body mass (kg)	−0.4	−0.4
Second set		
RPE (CR-10)	4	5
Lactate (mmol · l^{-1})	3.2	3.7
Glucose (mg · dl^{-1})	100	98
Mean heart rate (range)	144 (90–171)	138 (85–160)
Change in body mass (kg)	−1.2	0.0
Third set		
RPE (CR-10)	5	5
Lactate (mmol · l^{-1})	4.1	5.0
Glucose (mg · dl^{-1})	100	98
Mean heart rate (range)	152 (93–177)	143 (87–166)
Change in body mass (kg)	−0.7	−0.9
Fourth set		
RPE (CR-10)	8	8
Lactate (mmol · l^{-1})	2.6	2.2
Glucose (mg · dl^{-1})	110	90
Mean heart rate (range)	154 (86–179)	146 (81–173)
Change in body mass (kg)	−1.2	−1.3
Session RPE (CR-10)	8	6

by playing style, court surface, and even the ambient conditions. In this study, blood lactate concentration decreased during the fourth set in both players, despite maintaining blood glucose concentration and having elevated salivary cortisol at the end of the match. The attenuation in blood lactate concentration coincided with shorter rallies but higher heart rates and RPE response in the fourth set, suggesting a progressive increase in fatigue during the last sets of a prolonged tennis match. It is not clear if this was due to tactical changes during the match.

This is the first study to report blood glucose responses in four-set tennis match-play. In agreement with previous investigations of competitive three-set match-play (Bergeron et al., 1991; Hornery et al., 2007) and match simulations (Christmass, Richmond, Cable, Arthur, & Hartmann, 1998; Mitchell, Cole, Grandjean, & Sobczak, 1992), the current investigation showed that hypoglycaemia does not manifest during match-play. Participants displayed relatively high post-match blood glucose concentrations that are comparable to those in studies of simulated tennis match-play over shorter durations (Hornery et al., 2007). The elevated salivary cortisol concentration at the end of the match, in line with findings from soccer (Bangsbo, 1994; Haneishi et al., 2007), indicates that glycogenolysis may be activated to maintain the blood glucose demands during prolonged, high-intensity intermittent exercise.

The players' RPE, mean heart rate, and times in high heart rates zones all increased as the match progressed, showing increasing perceptual and physiological stress. It is likely that the increased stress, and in particular the increased effort perception, contributed to the change in match notation data (Marcora, Staiano, & Manning, 2009). Session RPE has been shown to be a valid global indicator of internal stress during prolonged, high-intensity intermittent exercise. (Foster et al., 2001; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). Interestingly, the higher session RPE score shown by player 1 was associated with more pronounced changes in physiological markers (e.g. heart rate, cortisol concentration, and dehydration status).

Conclusions

This case report is the first to describe the physiological, perceptual, and time–motion responses to four sets of tennis in elite professional players. The results indicate that prolonged tennis match-play is associated with increased fatigue and that these elite players may adjust work rates or tactics to cope with the increased perception of effort. Moreover, it would appear that the greater stress associated with longer tennis matches, as in the Grand Slam events and Davis Cup, demands greater focus on pre-, within-, and post-match recovery strategies (Kraemer et al., 2000; Mitchell, Schiller, Miller, & Dugas, 2001). We suggest that coaches should encourage fluid and carbohydrate replenishment and adopt recovery interventions (e.g. pre-cooling, massage) that may alter perception of fatigue during prolonged tennis matches.

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