

Research article

Physiological responses to on-court vs running interval training in competitive tennis players

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Abstract

The aim of this study was to compare heart rate (HR), blood lactate (LA) and rate of perceived exertion (RPE) responses to a tennis-specific interval training (i.e., on-court) session with that of a matched-on-time running interval training (i.e., off-court). Eight well-trained, male ($n = 4$) and female ($n = 4$) tennis players (mean \pm SD; age: 16.4 ± 1.8 years) underwent an incremental test where peak treadmill speed, maximum HR (HR_{max}) and maximum oxygen uptake (VO_{2max}) were determined. The two interval training protocols (i.e., off-court and on-court) consisted of 4 sets of 120 s of work, interspersed with 90 s rest. Percentage of HR_{max} (95.9 ± 2.4 vs. $96.1 \pm 2.2\%$; $p = 0.79$), LA (6.9 ± 2.5 vs. 6.2 ± 2.4 mmol·L⁻¹; $p = 0.14$) and RPE (16.7 ± 2.1 vs. 16.3 ± 1.8 ; $p = 0.50$) responses were similar for off-court and on-court, respectively. The two interval training protocols used in the present study have equivalent physiological responses. Longitudinal studies are still warranted but tennis-specific interval training sessions could represent a time-efficient alternative to off-court (running) interval training for the optimization of the specific cardiorespiratory fitness in tennis players.

Key words: Tennis; heart rate; blood lactate; rate of perceived exertion.

Introduction

Technical and tactical skills are considered the most predominant factors in tennis competitive performance (Smekal et al., 2001). However, competitive tennis players also need a mixture of fitness qualities such as speed, agility and power combined with a well-developed aerobic fitness in order to achieve high levels of performance (Kovacs, 2007). Physical exertion in tennis involves intermittent, high-intensity efforts interspersed with periods of low-intensity activity, during which active recovery (between points) and passive periods (between change-over breaks in play) take place (Fernandez-Fernandez et al., 2009; ITF, 2002). The ability to maintain a high technical efficiency during those phases of high-intensity, intermittent exercise is an important feature of successful contemporary tennis players (Mendez-Villanueva et al., 2007). Because maintaining technical skills is determinant and training time is premium, coaches are increasingly relying on an integrated approach to conditioning and skill-based work; often resulting in the programming of game-specific, on-court exercises that include both technical and tactical assignments as part of sport-specific

conditioning (Buchheit et al., 2009; Reid et al., 2008).

Tennis-specific, interval training that incorporates skills and movements specific to the sport has been reported to result in physiological responses that mirrored aspects of both average and maximal match-play (Fernandez-Fernandez et al., 2009; Reid, 2008). However, it is not known whether tennis-specific interval training is as effective as traditional (running), interval-based conditioning, namely the attainment of optimal exercise intensities to heavily tax the aerobic system (e.g., 90-95% of maximum heart rate (HR_{max}) (Helgerud et al., 2007; Impellizzeri et al., 2006), as the technical/constraints inherent to the game can prevent maximal intensities from being reached (Stone and Kilding, 2009; Buchheit et al., 2009). Therefore, to improve our understanding of the physiological strain associated with on-court, tennis-specific interval training, we compared heart rate (HR), blood lactate (LA) and rate of perceived exertion (RPE) responses to a tennis-specific interval training session with that of a matched-on-time running interval training session.

Methods

Overview

The present study was designed to compare selected physiological and perceptual responses to two interval training sessions (i.e., off- and on-court interval training exercises) in young tennis players. All players performed a laboratory incremental treadmill test two weeks prior to the two training sessions. The interval training sessions were randomly conducted after two familiarisation sessions and within three consecutive days. Sessions were performed at the same time of the day and consisted in either an off-court interval training protocol (running) or an on-court (tennis) interval training exercise. Selected physiological (i.e., HR, LA and perceptual i.e., RPE) responses were monitored during both training sessions.

Subjects

Eight well-trained tennis players (4 male and 4 female) participated in this study. The players were ranked between 1 and 20 in the Spanish junior singles ranking, trained 13 ± 3 h·wk⁻¹ and have a training background of 8 ± 1 years, which focused on tennis-specific training (i.e., technical and tactical skills), aerobic and anaerobic train-

ing (i.e., on and off-court exercises) and resistance training. Prior to any participation, the experimental procedures and potential risks were explained fully to the subjects and all provided written informed consent. The study was approved by the local ethic committee and conformed to the Declaration of Helsinki.

Procedures

Laboratory test

Each player completed an incremental test to volitional exhaustion on a treadmill (Technogym Runrace; Italy). The test started at a running speed of 6 km·h⁻¹ (females) and 8 km·h⁻¹ (males) with a stepwise 0.5 km·h⁻¹ speed increment every 30 s until the player stopped due to volitional exhaustion. If the last stage was not fully completed, the peak treadmill speed (PTS) was calculated using the formula of Kuipers et al. (1985): $PTS = Sf + (t/30 \times 0.5)$, where Sf was the last completed speed in km·h⁻¹ and t the time in seconds of the uncompleted stage. Inclination was maintained at 1% over the duration of the test. Gas exchange was continuously measured during the test using a breath-by-breath analyzer (Vmax29, Sormedics, USA). The breath-by-breath samples were analyzed for oxygen consumption (VO₂, L·min⁻¹), carbon-dioxide production (VCO₂, L·min⁻¹), pulmonary ventilation (VE, L·min⁻¹), end-tidal volume PO₂ (PETO₂%) and PCO₂ (PETCO₂%). The gas-analysis system was calibrated before each test using the manufacturer's recommendations. During the incremental test, the breath-by-breath gas samples were averaged every 30 s and HR was monitored and recorded at 5-s intervals during the exercise (S610, Polar Electro, Kempele, Finland). Maximum oxygen uptake (VO_{2max}) and HR_{max} were determined as the highest 30- and 5-s mean values, respectively (Doherty, 2003).

Interval training sessions

Players were advised not to have strength or endurance training at least 48 h prior to the interval training sessions and to take a similar rich carbohydrate meal 2 h before testing. Prior to each interval training session, players performed a standardized 10 minute warm-up consisting of slow running, dynamic movements, flexibility exercises and 3 x 100 m progressive accelerations (for the off-court) or 5 min playing tennis (ground strokes and volleys plus overhead plays (on-court)) (Mendez-Villanueva et al., 2007). For both training sessions, subjects performed 4 sets of 2 min at intensities between 90%-95% of HR_{max} with 90 s of passive recovery in between. Intensity and duration of the work bouts and recovery periods employed in our interval training sessions were selected based on previous experiences, pilot studies and prior published research in which similar sport-specific (i.e., soccer) high-intensity aerobic sessions have been reported to be effective in improving aerobic fitness (Christensen et al., 2011; Hill-Haas et al., 2011). Speeds for both training sessions were individually chosen by trial and error practice during previous training sessions to allow players to sustain the highest possible speed across all the work bouts of each interval session. Players were regularly updated about the time remaining in each interval (Seiler and Hetlelid, 2005).

Off-court training session

During the off-court sessions, players were required to perform traditional interval running, which consisted in running on a 400-m athletics track. Players were asked to treat each interval session as a "high-intensity" interval session as were also instructed to attempt to maintain the highest average running velocity they could across the 4 work bouts as previously described (Seiler and Hetlelid, 2005). Players were fully familiar with this off-court training protocol, as high-intensity interval training with running distances ranging from 200-m to 100-m was an important component of their training program. Players performed the work bouts without feedback about their actual running velocity or blood lactate concentration (Seiler and Hetlelid, 2005).

On-court training session

During the on-court session, subjects were required to perform forehand and backhand strokes in different positions on a *Greenset* tennis court (i.e., hard court) (Figure 1). An experienced professional coach, standing in the center line of the opposite service boxes, hand-fed new tennis balls to the player at a speed determined by the completion of the previous shot and movement of the participant to the next shot (i.e., self-selected) (Reid et al., 2008), at a frequency of approximately one ball every 3 s, ± 85 cm over the net, and landing ±60 cm from the opposite baseline, inside a designed landing circles (i.e., 60 x 90 cm). Ball location followed a fixed order and was previously explained to the player, who performed forehand strokes (1: neutral ball; 2: defensive ball; 3: offensive ball) and backhand strokes (4: neutral I ball; 5: defensive ball; 6: offensive ball). All players were required to move as fast as possible, hit with maximal effort and maintain the stroke accuracy (i.e., number of balls inside the single court). The number of balls played was counted as an indicator of work completed during each set.

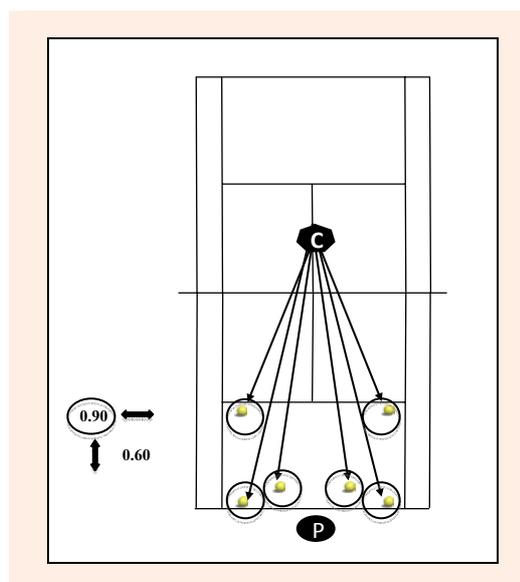


Figure 1. Schematic representation of the on-court interval training protocol. P: player; C: Coach feeding balls; (1,2,3) forehand strokes; (4,5,6) backhand strokes

Table 1. Physical characteristics and physiological responses to the incremental treadmill test in tennis players. Data are means (\pm SD).

	Age (years)	Height (m)	Body Mass (kg)	PTS ($\text{km}\cdot\text{h}^{-1}$)	$\text{VO}_{2\text{max}}$ ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	HR_{max} ($\text{beats}\cdot\text{min}^{-1}$)
Males	16.4 (1.8)	1.74 (.06) *	68.9 (5.6) *	17.9 (1.3) *	66.3 (6.9) *	202 (2) *
Females	16.3 (2.2)	1.71 (.03)	65.0 (5.8)	15.1 (.9)	53.0 (.7)	191 (4)
All	16.4 (1.8)	1.75 (.07)	68.8 (8.0)	16.7 (1.7)	59.3 (8.1)	196 (7)

PTS: peak treadmill speed; $\text{VO}_{2\text{max}}$: Maximum oxygen uptake; HR_{max} : Maximum heart rate. *Significant differences between genders.

Measures

During both training sessions players were equipped with a short-range telemetry system which allowed measurement of HR (Polar S610, Kempele, Finland). The data obtained from the HR monitors was downloaded on a portable PC using the manufacturer's software. HR data was classified based on percentage time spent in five zones: 1) < 60% HR_{max} ; 2) 61-70% HR_{max} ; 3) 71-80% HR_{max} ; 4) 81-90% HR_{max} ; 5) > 91% HR_{max} (Banister et al., 1986). Time spent in each zone was calculated for each player. Blood samples from hyperemized earlobe (Finalgon, FHER laboratories, Barcelona, Spain) for LA concentrations (Lactate Pro, Arkray, Kyoto, Japan) and a 6 to 20 RPE scale (Borg, 1998) were taken immediately at the end of each set.

Statistical analyses

All values are reported as mean \pm SD. Before using parametric statistical test procedures, the assumptions of normality and sphericity were verified. Since women involved in the present study presented similar responses to both interval sessions compared with the men, and all analyses were based on within-subjects changes, data from women and men were pooled. The impact of interval training protocol on the principal dependent variables (HR, LA and RPE) was analyzed using two-way repeated-measures ANOVA, one factor being interval training protocol (with two levels: off-court and on-court) and the other being set (with four levels corresponding to the four sets). In the case of significant interval training protocol \times set interactions, *post hoc* comparisons were made using Bonferroni tests. The SPSS statistical software package (Version 12, SPSS Inc., Chicago, IL) was used for statistical calculations. Statistical significance was accepted at $P < 0.05$.

Results

The physical characteristics and physiological responses to the incremental treadmill test are shown in Table 1.

The average speed attained during the off-court interval training session was $89.6 \pm 4.6\%$ of PTS with no differences between sets ($p = 0.32$). The number of balls played completed during each set averaged 53.0 ± 1.4 ,

with no differences between sets ($p = 0.43$). Table 2 shows selected physiological and perceptual parameters recorded during the off- and on-court training protocols.

No effect of the training protocol was observed for HR (off-court, $189 \pm 3 \text{ b}\cdot\text{min}^{-1}$ ($95.9 \pm 2.4\% \text{ HR}_{\text{max}}$) vs. on-court, $188 \pm 3 \text{ b}\cdot\text{min}^{-1}$ ($96.1 \pm 2.2\% \text{ HR}_{\text{max}}$); $p = 0.83$), LA (off-court, $6.9 \pm 2.5 \text{ mmol}\cdot\text{L}^{-1}$ vs. on-court, $6.2 \pm 2.4 \text{ mmol}\cdot\text{L}^{-1}$; $p = 0.73$) and RPE (off-court, 16.7 ± 2.1 vs. on-court, 16.3 ± 1.8 ; $p = 0.80$). When compared with the first set of the series, there was a significant increase in HR ($p < 0.001$), LA ($p < 0.001$) and RPE ($p < 0.001$) in sets 2 to 4.

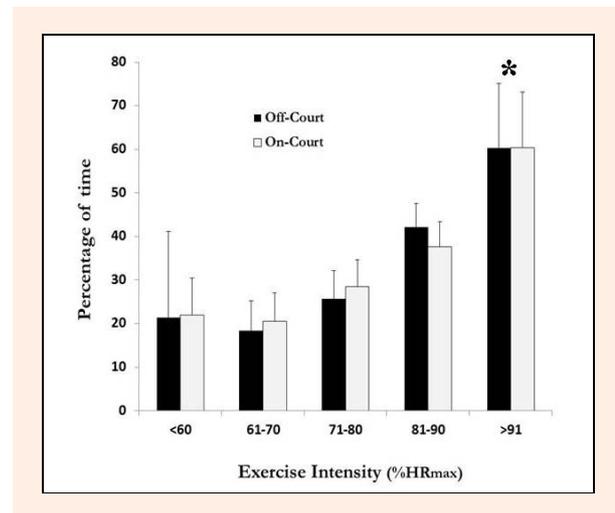


Figure 2. Percentage of time spent by players in the different heart rate (HR) categories during the off and on-court interval training sessions. * Significantly higher ($P < 0.05$) than any other HR category.

Figure 2 shows the percentage of time spent by players in the different HR categories during the training sessions. Players spent $452.5 \pm 110.8 \text{ s}$ and $452.5 \pm 96.1 \text{ s}$ of the total training time at intensities above 91% of HR_{max} , which corresponded to $60.3 \pm 15.0\%$ and $60.3 \pm 13.0\%$ of the training time, during the off- and on-court interval training sessions ($p = 0.99$), respectively, with individual ranges varying from 4 min to 9 min 55 s during the off-court, and from 5 min to 9 min 20 s during the on-court training session.

Table 2. Physiological/perceptual responses of tennis players during the off-court and on-court interval training sessions. Data are means (\pm SD).

Parameters	Set 1		Set 2		Set 3		Set 4		Interaction (IT \times Set)
	Off-Court	On-Court	Off-Court	On-Court	Off-Court	On-Court	Off-Court	On-Court	
% HR_{max}	93.8 (2.5) ^{a,b,c}	94.2 (2.9) ^{a,b,c}	96 (2.1) ^{b,c}	95.7 (2.0) ^{b,c}	96.9 (1.7) ^c	96.6 (1.4) ^c	97.5 (1.8)	97.5 (1.1)	.93
LA	3.4 (.7) ^{a,b,c}	4.4 (2.2) ^{a,b,c}	6.7 (1.3)	6.8 (2.3)	7.3 (1.8)	6.7 (1.6)	8.1 (1.6)	7.2 (2.2)	.64
RPE	14.8 (2.1) ^{a,b,c}	15.1 (1.8) ^{a,b,c}	16.3 (2.2) ^{b,c}	16.1 (1.3) ^{b,c}	17.3 (2.1) ^c	16.6 (1.5) ^c	18 (1.9)	17.3 (1.6)	.50

% HR_{max} : percentage of maximum HR; LA: blood lactate concentration ($\text{mmol}\cdot\text{L}^{-1}$); RPE: ratings of perceived exertion; IT: interval training; a: significant difference vs. Set 2 ($p < 0.05$), b: vs. Set 3, c: vs. Set 4.

Discussion

We have compared for the first time physiological and perceptual responses to two interval training protocols in young well-trained tennis players. The results of this study did not show differences between an off- and on-court interval training sessions in the average physiological (i.e., HR, LA, RPE) variables selected for the investigation.

As designed, both interval training sessions enabled players to spend most of their training time around 95% of HR_{max} (i.e., 95.9% and 96.1% of HR_{max} during the off- and on-court training sessions, respectively). A more detailed analysis of training HR distribution showed that, during both training protocols, players spent approximately ~60% of the exercise time at intensities above 91% of HR_{max} . In this regard, the amount of high-intensity exercise (i.e., $HR > 91\%$ of HR_{max}) accumulated during training has been positively related to changes in aerobic fitness in professional soccer players (Castagna et al., 2011). Thus, HR responses during both training sessions were within the “target intensity” (>91% of HR_{max}) thought to be effective in enhancing aerobic fitness in response to interval training protocols (Ferrauti et al., 2003; Hoff et al., 2002; Impellizzeri et al., 2006; Stone and Kilding, 2009). It should be noted, however, that as previously suggested by several authors (Buchheit et al., 2009; Hoff et al., 2002; Hill-Haas et al., 2009; Smekal et al., 2001), the use of these on-court exercise with players already possessing high fitness levels (i.e., VO_{2max}) may have a ceiling effect for developing aerobic endurance in those individuals. Therefore, it may be preferential to add specific rules (e.g., adding additional on-court movements) in order to obtain similar workloads in players differing in cardiorespiratory fitness levels (Buchheit et al., 2009; Hill-Haas et al., 2009; Rampinini et al., 2007). While VO_2 measurements and longitudinal assessment of the cardiorespiratory effectiveness of such on-court interval training protocol are still warranted, present results suggest that these tennis-specific intervals might be appropriate to optimize the development of cardiorespiratory fitness in competitive tennis players.

In addition to be appropriate for the development of cardiorespiratory fitness, the ability of interval training sessions to elicit similar or exceed competition match play intensity has been also considered. HR responses during competitive tennis have been reported to range from 71 to 80% of HR_{max} (Fernandez-Fernandez et al., 2009). In addition, female tennis players have been reported to spent ~13% of the total match time at exercise intensities higher than 90% of HR_{max} (Fernandez-Fernandez et al., 2007; 2008). Thus, the format of the present interval training sessions can exceed mean match exercise intensities as well as simulate the most intense periods of matches. Similar to the present study, Reid et al. (2008) identified four on-court training drill which can be recommended to fit the profile of a highly intensive on-court drill, matching “target” intensities. However, results from this study are difficult to interpret and compare as players’ HR_{max} was not determined (Reid et al., 2008). Thus, coaches can choose the present interval training sessions,

which are more intense than match demands, to overload the players under conditions that replicate the technical and physical demands of a competitive match.

Average LA levels attained in the present study were 6.9 ± 2.5 $mmol \cdot L^{-1}$ and 6.2 ± 2.4 $mmol \cdot L^{-1}$ for the off- and on-court training sessions, respectively, with individual maximal responses attaining 12.2 $mmol \cdot L^{-1}$. Values were similar those reported by Reid et al. (2008) (e.g., 2 to 10 $mmol \cdot L^{-1}$). LA levels during actual tennis match play have been reported to be rather low, with average values ranging from 1.8 to 2. $mmol \cdot L^{-1}$ (Fernandez-Fernandez et al., 2009; Kovacs, 2007; Mendez-Villanueva et al., 2007; Murias et al., 2007). However, during long and intense rallies under actual match play conditions, increases in circulating LA levels (up to 8 $mmol \cdot L^{-1}$) can occur, reflecting periodic increases in glycolytic activity (Mendez-Villanueva et al., 2007). Given the importance of training activities resembling those experienced during match-play, so the groups of muscles engaged in tennis are training and the specific coordination abilities developed (Ferrauti et al., 2001; Mendez-Villanueva et al., 2007; Reid et al., 2008; Stone and Kilding, 2009), the on-court training session employed in the present study could be used to train specific technical drills coupled with a highly taxed glycolytic participation. Although RPE measures have been used as a quantification of internal load in other sports with intermittent profiles (Rampinini et al., 2007; Impellizzeri et al., 2004; Coutts et al., 2009), few studies have described RPE responses during tennis practice (Fernandez-Fernandez et al., 2007, 2008; Mendez-Villanueva et al., 2007; Reid et al., 2008). Similar to HR and LA, RPE responses were not different between the on- and off-court training sessions. This suggests that the perceptual responses to both interval training sessions were also similar. The fact that RPE exhibited analogous increases with HR and LA as the interval training sessions progressed (i.e., from set 1 to 4; Table 2) further support the use of RPE as a marker of exercise intensity during tennis practice (Mendez-Villanueva et al., 2007).

Conclusion

In conclusion, the main result of this study is that an on-court interval training protocol (e.g., 4 x 2 min; 90%-95% of HR_{max} , with 90 s of passive recovery) can be used as an alternative to running interval training to elicit high percentage of HR_{max} and high LA levels, and for the optimization of both the cardiorespiratory fitness and game-specific endurance in tennis players.

Practical application points

An on-court interval training protocol (e.g., 4 x 2 min with 90 s of passive recovery) can be used as an alternative to running interval training to elicit high percentage of HR_{max} .

Within a periodized training plan, some technical/tactical training should be performed under conditions that replicate the physical and technical demands of a competitive match. Because of the ever-increasing demands imposed on competitive tennis players resulting in reductions of total training time, it can be speculated that

during the competitive season tennis on-court training might be preferred to off-court training, especially when coaches' priority is to solicit high levels of exercise intensity (overload) while maintaining high technical (i.e., stroke efficiency and accuracy) demands, as well as high levels of motivation.

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Key points

- On-court interval training protocol can be used as an alternative to running interval training
- Technical/tactical training should be performed under conditions that replicate the physical and technical demands of a competitive match
- During the competitive season tennis on-court training might be preferred to off-court training

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