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Research article

Preseason Training: The Effects of a 17-Day High-Intensity Shock Microcycle in Elite Tennis Players

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Abstract

Preseasons in tennis are normally reduced to 5 to 7 weeks duration, and coaches should use an integrated approach to conditioning and skill-based work. The aim of the present study was to investigate the effects of adding a high-intensity training (HIT) shock microcycle to the normal training content in several physical performance indicators in the preseason training of high-level male tennis players. Over 17 days, 12 male tennis players performed 13 HIT sessions in addition to their usual training. Physical performance tests (30:15 intermittent fitness test [V_{IFT}], 20 m sprint, countermovement jump [CMJ], repeated sprint ability [RSA]) were conducted before (pre-test) and 5 days after the intervention (post-test). After the shock microcycle, results showed a significant increase in the VIFT ($p < 0.001$; Large ES) and a significant decrease in the mean RSA time (RSAm) ($p = 0.002$; Small ES), while there were no significant changes in the other parameters analysed (e.g., 20 m, CMJ, best RSA time [RSAb]; percentage of decrement in the RSA [%Dec]). Moreover, the training load (TL) during tennis sessions was significantly higher ($p < 0.01$; Large ES) than the TL during the integrated sessions, except during the first training session. A 17-day shock microcycle (i.e., 13 HIT sessions) in addition to the regular tennis training significantly improved parameters that can impact physical performance in tennis. Moreover, additional sessions, including running exercises based on the 30:15ITF and on-court specific exercises, were characterised by significantly lower TL than tennis-training sessions.

Key words: Block periodisation, high-intensity training, intermittent fitness test, repeated-sprint ability, rate of perceived exertion.

Introduction

Tennis is an intermittent sport involving high-intensity efforts interspersed with periods of low-intensity activity, during which active recovery (between points) and passive periods (between changeover breaks in play) take place (Fernandez-Fernandez et al., 2009; Kovacs, 2007). Although the technical and tactical skills are considered the most predominant factors in tennis performance (Smekal et al., 2001), 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 (Fernandez et al., 2006; 2009). During competitive matches, mean heart rate (HR) values range between 70 and 80% of maximum (HR_{max}), and peak values around 90 to 100% of HR_{max}. Average oxygen uptake (VO_2) values correspond to approximately 50 to 60% of maximum oxygen consumption (VO_{2max}), with values above 80% of VO_{2max} during intensive rallies (Kovacs, 2007). Rating of perceived exertion (RPE) has been reported as ranging from 5 to 7 au (arbitrary units on a scale of 1 to 10) (Coutts et al., 2010; Gomes et al., 2013), and 10 to 16 (on the Borg 20-point scale) (Mendez-Villanueva et al., 2010). Thus, it seems that the ability to maintain a high technical efficiency during those phases of high-intensity intermittent exercise (which can result in fatigue) is an important feature of successful tennis players (Mendez-Villanueva et al., 2007).

Elite tennis players travel and compete year round and have a demanding calendar. This can result in athletes focusing on competition and thus compromising training, leading to suboptimal recovery, conditioning, and overall preparation (Duffield et al., 2013; Fernandez-Fernandez et al., 2009). Because of the ever-increasing demands imposed on players, there is a progressive reduction of total training time devoted to preparation, with preseasons normally reduced to 5 to 7 weeks duration. At the highest levels of the game, this preseason is even reduced further with the increase in high-paid exhibition matches or non-sanctioned team events/tournaments. During the preseason, most tennis players do prioritise fitness training during the first couple of weeks, while the maintenance of technical and tactical skills also seems to be a key factor. Thus, 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). High-intensity training (HIT) (i.e., work and rest intervals ranging from 15 s to 4 min; 90–100% velocity at the level of VO_{2max}; HR values ~90% of HR_{max}; work-to-rest ratios of 1:1 to 4:1) (Laursen and Jenkins, 2002) 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 and can be used as a training method aiming to improve tennis-specific fitness levels (Fernandez-Fernandez et al., 2012; Reid et al., 2008). Previous research has shown that the implementation of HIT protocols during preseason conditioning (i.e., 2–3 training sessions per week for 6–10 weeks) leads to enhanced sport-specific performance (Dupont et al., 2004; Fernandez-Fernandez et al., 2012; Sperlich et al., 2011). However, little is known about the integration of HIT in daily training sessions or in short periods of concentrated training.

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As the tennis preseason is probably the shortest of all the major sports, the training schedule and how to organise the main physical abilities in order to achieve optimal training outcome and performance remain unclear. Block periodisation — also described as 'a training cycle of highly concentrated specialized workloads' or shock microcycle (Issurin, 2010), including HIT, in which training periods are divided into shorter periods (1–4 weeks) with the main focus of improving a few specific abilities (i.e., VO_{2max}) — might be an alternative (Garcia-Pallares and Izquierdo, 2011; Issurin, 2008). While the potential benefits of this periodisation model have been theorised (Issurin, 2010), only a few studies have shown its relative effectiveness, mainly in endurance athletes (Breil et al., 2010; Garcia-Pallares and Izquierdo, 2011; Ronnestad et al., 2014). Results have shown that the use of shock microcycles leads to performance improvements in different sports (e.g., rowing, soccer, ski) (Breil et al., 2010; Christensen et al., 2011; Garcia-Pallares et al., 2010; Wahl et al., 2013). However, there is a lack of information about the use of these shock training microcycles in intermittent sports such as tennis. Therefore, the purpose of the present study was to investigate the effects of HIT addition to the normal training content in several physical performance indicators during the preseason training of high-level male tennis players.

Methods

Subjects

Twelve healthy male tennis players (mean ± SD: age 21.9 ± 2.0 years; height 1.82 ± 0.22 m and weight 76.4 ± 5.9 kg) with a ranking between positions 500 and 800 (668.1 ± 105.1) in the Association of Tennis Professionals (ATP) volunteered to participate in this study. Players trained 17 ± 2.5 $h \cdot wk^{-1}$ and had a training background of 12 ± 2 years. All the players were free of cardiovascular and pulmonary disease and were not taking any medications. Prior to any participation, the experimental procedures and potential risks were explained fully to the players, and all provided written informed consent. The study was approved by the local ethics committee and conformed to the Declaration of Helsinki.

Design

A 17-day HIT shock microcycle, including running exercises based on the 30:15 intermittent fitness test (30:15ITF) and on-court specific exercises organised in 13 training sessions (~30 min each), was conducted (Figure 1). Before any baseline testing, all participants attended two familiarisation sessions to introduce the testing and training procedures and to ensure that any learning effect was minimal for the baseline measures. Fitness tests (30:15IFT, 20 m sprint, countermovement jump [CMJ], repeated sprint ability [RSA]) were conducted before (pre-test) and 5 days after the intervention (post-test). Between the last HIT session and the post-test, only on-court training combined with moderate intensity strength training and injury prevention (e.g., core training, shoulder strengthening, and flexibility) sessions were performed. Normal training consisted of 5 training sessions per week (60–90 min each), with the main focus on technical/tactical drills and game-specific situations (e.g., sessions were designed by coaches to address the specific priorities of each athlete). Therefore, players were submitted to an overall training volume of ~22 h during the shock microcycle. The investigation was conducted during the European winter preparatory period (November–December). All tests were conducted on an indoor synthetic court. To reduce the interference of uncontrolled variables, all subjects were instructed to maintain their habitual lifestyle and normal dietary intake before and during the study. The subjects were told not to exercise on the day before a test and to consume their last (caffeine-free) meal at least 2 h before the scheduled test time.

Measurements

30-15 Intermittent Fitness Test: Supramaximal intermittent performance with changes of direction was assessed using the 30-15IFT (Buchheit, 2008), which consisted of 30-s shuttle runs interspersed with 15-s passive recovery periods. The athletes had to run back and forth between two lines set 40 m apart at a pace dictated by an auditory signal. The speed was set at 8 $km \cdot h^{-1}$ for the first 30-s run and was increased by 0.5 $km \cdot h^{-1}$ every 45-s stage thereafter. The speed during the last completed stage was noted as velocity obtained in the intermittent fitness test (V_{IFT}). The reliability of V_{IFT} has been shown to be good (intraclass correlation coefficient [ICC] = 0.96; typical error [TE] 0.33 $km \cdot h^{-1}$) (Buchheit et al., 2008). HR was monitored and recorded at 5-s intervals during the test (Polar S610, Kempele, Finland), and maximum HR (HR_{max}) was determined as the highest 5-s mean value.

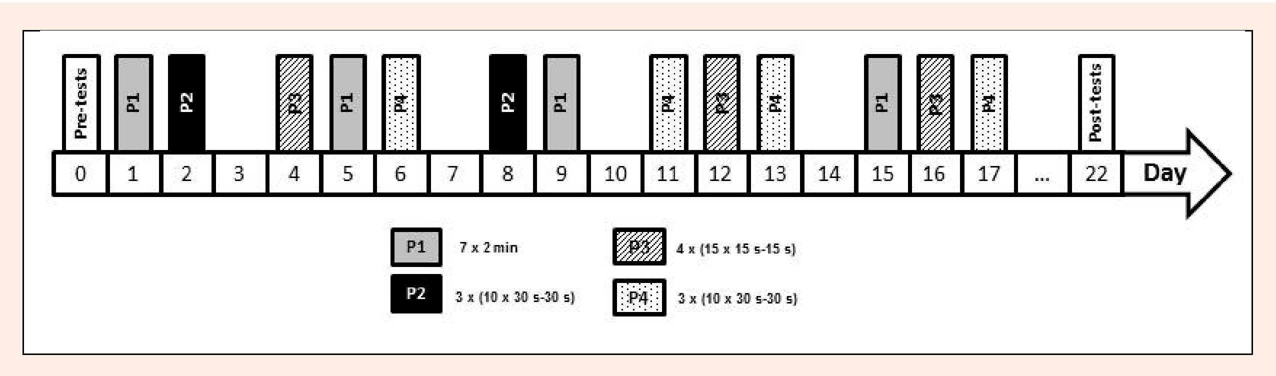

Figure 1. Schematic representation of the training intervention.

Table 1. Descriptions of tennis training drills performed.

Drill Category	Description	Example
"Suicide"	Movement along the baseline (i.e., maximal efforts and jogging) combined with forehand and backhand strokes	Figure 3.1
"Big X"	Diagonal movements inside/outside the court (i.e., maximal efforts and jogging) combined with forehand and backhand strokes	Figure 3.2
Recovery/Defensive	Two players must both hit cross-court strokes, recover past centre mark after each stroke, then hit down the line strokes.	Figure 3.3
Open Pattern	One player remains in a corner, hits alternating (e.g., free) cross-court strokes, then down the line. Other player must return ball to same corner.	Figure 3.4

Speed Test: Running speed was evaluated by 20-m sprint times (standing start). Time was recorded with photoelectric cells (Time It; Eleiko Sport, Halmstad, Sweden). Each sprint was initiated 50 cm behind the photocell gate, which started a digital timer. Each player performed two maximal 20-m sprints, separated by at least 90 s of passive recovery (Buchheit et al., 2010). The best performance was recorded. The ICC and TE of the 20-m sprint were 0.96 and 0.06 s, respectively.

Vertical Jumping: A CMJ without arm swing was performed on a contact-time platform (Ergojump®, Finland) according to Bosco et al. (1983). Each player performed two maximal CMJs interspersed with 45 s of passive recovery, and the best height for each was recorded. The ICC and TE of the CMJ were 0.96 and 1 cm, respectively.

RSA Test: The RSA test involved six repetitions of maximal 2 x 15-m shuttle sprints (~6 s) departing every 20 s (Buchheit et al., 2010). During the approximately 14-s recovery between sprints, subjects were required to stand passively. Two seconds before starting each sprint, the subjects were asked to assume the start position as detailed for the 20-m sprints and await the start signal from a supervisor. The best sprint time (RSAb, s), mean sprint time (RSAm, s), and the percent sprint decrement (%Dec: 100 – (mean time / best time × 100) were calculated. The ICC was 0.87, while the TE of the RSA test total time was 0.62 s.

Training Programme: Before all training sessions, subjects performed a standardised dynamic warm-up (~15 min) followed by submaximal 40-m shuttle runs at an intensity of 60 to 70% of HR_{max} and four acceleration sprints during the runs based on the V_{IFT}. During the on-court sessions, the 40-m shuttles and acceleration sprints were substituted by 6 to 8 min of tennis-specific activity (e.g., ground strokes, volleys, and serves).

The shock microcycle included 13 HIT sessions with different protocols (Table 1 and Figures 2 and 3) designed with a similar training volume but a different work-to-rest-ratio. The first HIT protocol (P_1) consisted of seven sets of 2 min intervals performed at intensities between 90 and 95% of HR_{max} with 90 s of passive recovery in between. Players were required to perform forehand and backhand strokes in different positions on three tennis courts (i.e., hard court) following the methods previously described (Figure 2) (Fernandez-Fernandez et al., 2011). Three players performed the session at the same time, and thus the 12 players finished the training in a time window of ~80 min. An experienced professional coach, standing in the centre 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 (i.e., self-selected) (Reid et al., 2008) at a frequency of approximately one ball every 3 s, ± 85 cm over the net, near designed landing circles (i.e., 60 x 90 cm). All players were required to move as fast as possible, hit with maximal effort, and try to maintain stroke accuracy.

HIT protocols 2 (P_2; three sets of 10 repetitions of 30 s work and 30 s rest, with 2 min rest between sets) and 3 (P_3; four sets of 15 repetitions of 15 s work and 15 s rest, with 90 s rest between sets) were intermittent runs performed over 40-m shuttles performed at individualised intensities ranging from 90 to 95% of the V_{IFT}.

HIT protocol 4 (P_4) consisted in the combination of different tennis drills (similar to previously described in different studies) (Table 1) selected by five qualified coaches with whom the athletes worked (Duffield et al., 2013; Reid et al., 2008, 2013). Drills involved specific groundstroke/open play from the baseline, with repeated strokes from different positions under pressure, but most specifically during baseline play (Figure 3) (Reid et al., 2013). An experienced professional coach hand-fed new tennis balls as in P_1. Irrespective of the drill, all players were instructed to move and hit with maximal effort, directing all shots to the target areas placed in the baseline (Figure 3). Drills were performed on three tennis courts, with two players on each court. The 12 players finished the training in a time window of ~40 min.

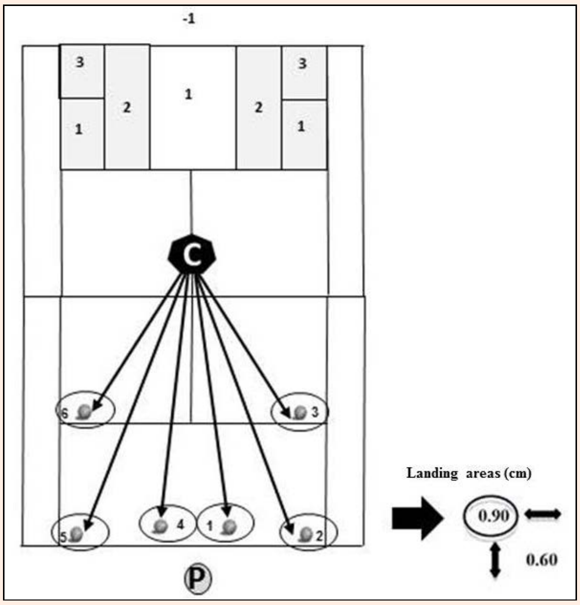

Figure 2. Schematic representation of the HIT training protocol 1 (P1). C: coach; P: player

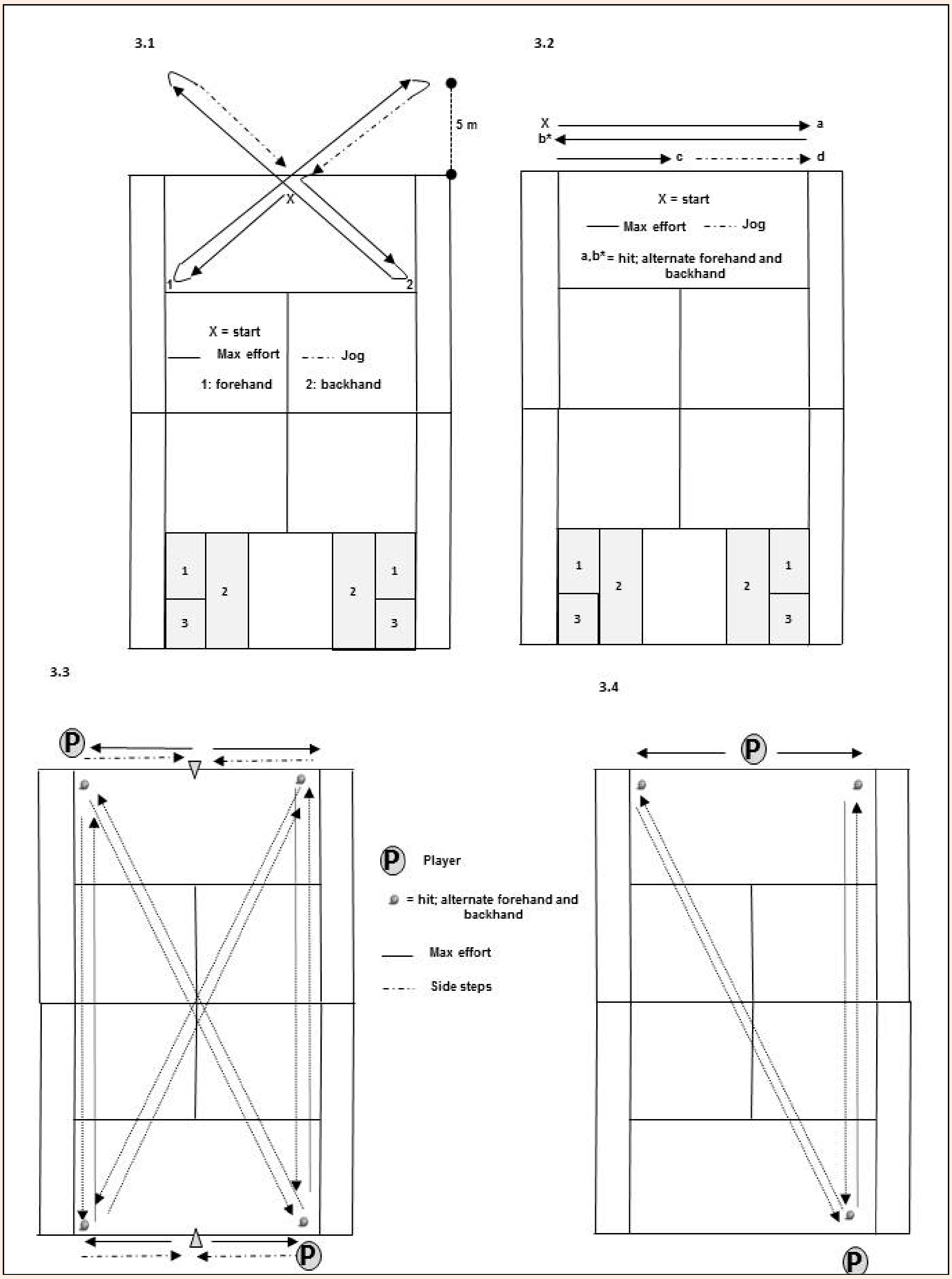

Figure 3. Schematic representation of the HIT training protocols (P4). 3.1: "Big X"; 3.2: "Suicide"; 3.3: "Recovery/Defensive"; 3.4: "Open Pattern"

HR was monitored during training sessions (Polar S610, Kempele, Finland). The data obtained from the HR monitors was downloaded onto a portable PC using the manufacturer's software. The training load (TL) for each session was calculated using the Session-RPE method for each subject during the intervention (Foster et al., 2001). TL was established post-session through multiplication of session-RPE (Borg CR-10) and duration. The following morning (09:00 h), players also provided the total quality recovery (TQR) (6–20 Likert scale) and the perceived muscle and joint soreness (1–10 Likert scale) (Duffield et al., 2013; Galambos et al., 2005).

Statistical analysis

Descriptive statistics of the data are presented as means ± standard deviation (± SD). To test if a 17-day high-intensity shock microcycle improves performance in elite tennis players, differences between pre- and post-test were calculated by a t-paired test, and two-way ANOVA (4 x 7) with different HIT protocols and physiological (e.g., HR, $\%HR_{max}$) and perceptual (e.g., RPE, session-RPE, TQR, perceived muscle and joint soreness)

Table 2. Changes in the physical performance measurements obtained during the pre- and post-tests. Values are presented as mean (± SD).

Measurements	Before training	5 days after training	*P*	ES	% of change
30-15IFT (kmh)	19.3 (.7)	20.6 (.6)	< .001*	1.88	6.5 (2.9)
20 m (s)	3.01 (.07)	3.01 (.08)	.13	.14	-.4 (.7)
CMJ (cm)	41.1 (2.4)	41.2 (2.2)	.62	.04	.2 (1.5)
RSAb (s)	6.01 (.08)	6.00 (.10)	.32	.25	-.3 (.9)
RSAm (s)	6.12 (.07)	6.10 (.10)	.002*	.43	-.5 (.3)
%Dec	-1.7 (.6)	-1.5 (.6)	.35	.09	-13.0 (4.4)

* Significant differences compared to pre-training; ES: effect sizes; CMJ: countermovement jump; RSAb: best time in the RSA; RSAm: mean time in the RSA; %Dec: percentage of decrement

variables was used. When a significant difference was found for either main effect, a Bonferroni post-hoc analysis was performed in the measurements among the different training sessions. Moreover, Cohen's effect size (ES) was calculated for the comparison of variables analysed. The criteria to interpret the magnitude of the ES were: 0.0–0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large, and >2.0 very large (Hopkins, 2000).

Results

A detailed analysis of the different training sessions (Table 2) showed the acute physiological and perceptual responses (Table 3) obtained in the four protocols used in the present study. Results showed that there were no significant differences in the parameters analysed except in the TL (e.g., session RPE), which was significantly higher in P1 and P4 (DSX) compared to P2 and P4 (DOP) ($p < 0.01$; ES ranging from 1.2 to 1.4 [moderate to large]). Values for all variables at baseline and post intervention (e.g., 5 days after training) are presented in Table 2. Results showed a significant increase in the V_{IFT} ($p < 0.001$; Large ES) and a significant decrease in the RSAm ($p = 0.002$; Small ES), while there were no significant changes in the other parameters analysed (e.g., 20 m, CMJ, RSAb, %Dec).

A more detailed analysis of the TL induced by the training protocols used in the study and tennis training sessions is presented in Figure 4. Results show that the TL during tennis sessions was significantly higher ($p < 0.01$; ES: 1.6 [Large]) than the TL during the training sessions using the training protocols, except during the first training session, where no differences were found.

Discussion

Preseasons in professional tennis are short and traditional models of training periodisation seem to be unsuitable for high-level players. The aim of this study was to investigate the effects of HIT addition to the normal training content in several physical performance indicators during the preseason training of high-level male tennis players. The main results obtained were that a 17-day shock microcycle including 13 additional HIT sessions to the regular on-court tennis training significantly improved parameters (e.g., V_{IFT}, RSAm) that can impact physical performance in tennis. Moreover, additional sessions, including running exercises based on the $30{:}15_{ITF}$ and on-court specific exercises, were characterised by significantly lower TL than tennis-training sessions.

Several studies from intermittent sports — mostly football — have shown that HIT is an effective training strategy to enhance the aerobic capacity without negatively affecting strength, power, or sprint performance (Buchheit and Laursen, 2013). Despite the growing effectiveness from these training strategies in team sports (Iaia et al., 2009), to the authors' knowledge, only two previous studies have focused on the specific effects of a 6- to 8-week intervention using different HIT programmes (i.e., on- and off-court HIT) in competitive and young tennis players (Fernandez-Fernandez et al., 2012; Srihirun et al., 2014) with positive results in aerobic fitness levels (e.g., VO_{2max}). Thus, a severe increase in HIT volume for several consecutive days followed by a sufficient recovery seemed to provide a very time-efficient way for improving aerobic capacity (Breil et al., 2010). During the present 17-day intervention, tennis players performed 13 HIT sessions, resulting in large improvements in the V_{IFT} (e.g., 6.5%) and small improvements in the RSAm (e.g., -0.5%). Although we were not able to show major improvements in VO_{2max} due to the shock microcycle, as players did not perform a laboratory test, the results are similar to those reported in a previous study analysing the effects of a 6-week intervention using different HIT

Table 3. Mean (± standard deviation) of acute physiological/perceptual responses obtained during the different training protocols. Values are presented as mean (± SD).

Measurements	P_1	P_2	P_3	P_4 DSX	P_4 DOP
HR_{av}	187 (4)	179 (5)	178 (3)	187.4 ± 2.9	177.8 ± 2.0
$\%HR_{max}$	94.8 ± 1.9	90.9 ± 2.1	90.3 ± 1.4	95.1 ± 1.2	90.3 ± 1.1
RPE	7.3 ± 0.8	5.8 ± 1.0	6.4 ± 0.5	7.4 ± 0.8	5.6 ± 1.3
Training load (AU)	218.3 ± 23.4*#	172.5 ± 30.3	191.7 ± 14.7	222.5 ± 22.9*#	167.5 ± 38.3
TQR	13.7 ± 1.0	13.1 ± 1.4	9.9 ± 0.7	13.3 ± 1.4	13.7 ± 1.5
Muscle Soreness	4.9 ± 0.9	5.5 ± 0.7	7.0 ± 0.8	7.3 ± 0.7	5.8 ± 0.8
Joint Soreness	4.9 ± 1.0	3.3 ± 0.9	4.5 ± 1.3	6.4 ± 0.8	6.9 ± 0.8

* Significantly higher than P2; # Significantly higher than P4 (DOP); HRav: average HR; %HRmax: percentage of maximum HR; RPE: rate of perceived exertion; AU: arbitrary units; TQR: total quality recovery

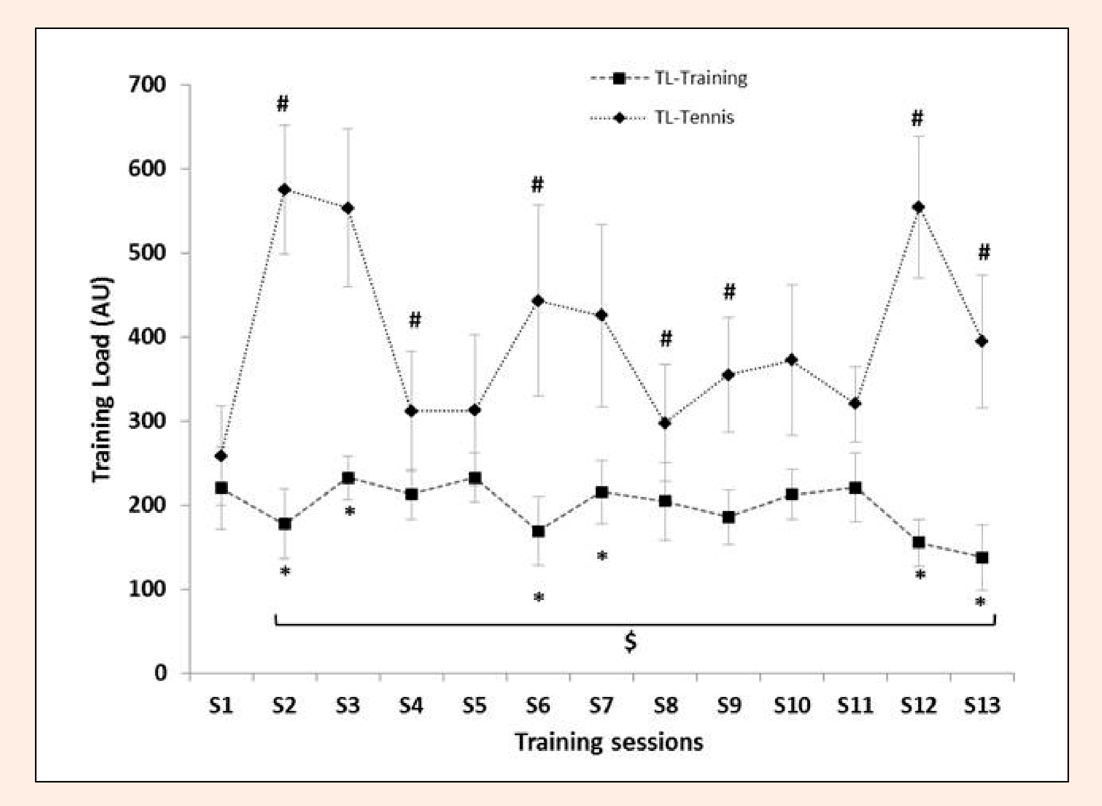

Figure 4. Mean ± standard deviation of the training load (TL) during the shock microcyle in both tennis sessions (TL-Tennis) and HIT training protocols (TL-Training). *, # Significantly different than the previous session; $ Significantly higher than specific-training sessions; TL: training load; S: session

programmes, with 4 to 6% improvements in the players' aerobic fitness levels, including the improvement in a tennis-specific endurance test (Fernandez-Fernandez et al., 2012). It has been reported that HIT can improve performance (e.g., time-trials) without the detection of concurrent increases in VO_{2max} in well-trained endurance athletes (Lamberts et al., 2009; Swart et al., 2009; Wahl et al., 2013), with similar improvements in endurance performance (~6%) as reported here. In addition, the present results are also similar to previous studies conducted with male soccer players, showing medium to large improvements (ES ranging from 0.8 to 1.9) in RSA and Yo-Yo intermittent recovery test level 2 (Yo-YoIR2) performance after a similar HIT block (e.g., 15 sessions) (Christensen et al., 2011; Wahl et al., 2014).

Improvements in the endurance performance in intermittent sports athletes seem to depend on training intensity (Baar, 2006; Iaia et al., 2009), and several previous studies have shown the practical effect of training time spent at intensities ~90% of the individual HR_{max} on aerobic fitness and performance variables in young and professional athletes (Dupont et al., 2004; Sperlicht et al., 2011; Wahl et al., 2014). Average intensities of the training protocols used in the present study ranged from 90 to 95% of HR_{max}, with training volumes of ~30 min per training protocol (i.e., ranging from 23 to 36 min). In this regard, previous research showed that the training time spent with HR >90% of the HR_{max} positively affected aerobic fitness (e.g., speed at 2 and 4 $mmol \cdot L^{-1}$) as well as Yo-YoIR1 performance (Castagna et al., 2011, 2013).

The actual shock-microcycle also led to a small (ES = 0.4) improvement in the RSA test values (-0.5% in the RSAm). Training protocols used in the study included shuttle runs and on-court specific exercises. The involvement of the same muscles during acceleration and deceleration movements could lead players to positive changes in specific coordination during the RSA test, which is in line with previous studies using HIT protocols in tennis and soccer players (Fernandez-Fernandez et al., 2012; Ferrari-Bravo et al., 2008). Moreover, the lack of significant improvements in the CMJ or sprint time (20 m) could be related to the lack of overload and focus on speed and power training (Vescovi and McGuigan, 2008). Thus, a different combination of training methods (e.g., power and strength) should be included.

It is well known that optimal TL is crucial to achieve training outcomes and to improve performance. Although the risk of overreaching or even overtraining exists, it seems that intensive sessions are needed to generate adaptations and increases in performance (Foster, 1998). The present study reported RPE values during training sessions of 6.5±1.5 AU, while values averaged 5.6±1.3 AU during tennis sessions. Several previous studies specifically reported the RPEs of athletes following completion of training sessions as well as matches (under real or simulated conditions). The present data were similar to previous research analysing TLs associated with on-court drills as well as simulated match-play (e.g., 5–7 AU) (Coutts et al., 2010; Gomes et al., 2013; Murphy et al., 2014; Reid et al., 2013). A previous study described the RPE and TL during real tournament conditions, with a weekly TL during competition of ~2900 AU and ~2400 during a preparation week before the competitive period (Coutts et al., 2010). The weekly TL obtained in the present study was 2583 ± 996.4 AU, similar to the values reported by Coutts et al. (2010), reflecting a level of preparation for tournament demands. Comparisons are difficult because other factors might influence the RPE values during elite competition (i.e., audience, ranking/prize pressure). Moreover, despite the high demands of the shock microcycle, we can speculate that the TLs reported seem not to be related to overreaching symptoms, as the athletes had positive performance adaptations after the intervention. In this regard, the addition of fatigue-related measures such as TQR and muscle/joint soreness can provide specific information about overreaching/overtraining symptoms, and improved perceptual recovery following training seems to be an important component of athlete recovery (Duffield et al., 2013). In terms of perceptual recovery after training sessions, results showed that players were reasonably well recovered, with average TQR values of ~13 (i.e., values ranging from "very poor recovery" to "reasonable recovery"). Moreover, TQR values did not differ between training protocols. Similar results were obtained for the perceived muscle/joint soreness, with average values of 5 to 6 (i.e., "light" to "moderate" pain) and no differences between protocols. Comparisons are difficult, since there are no studies analysing these parameters during training interventions in tennis, but we could speculate that although training sessions were categorised as "hard" (i.e., RPE values ~6.5), players were following good recovery routines (e.g., sleep hygiene, stretching) which could help them to reduce perceived soreness and fatigue following repeated daily training sessions. Further research examining the effect of volume variation (e.g., on- and off-court) on performance, including stress-related measurements (e.g., hormonal), is warranted. This would be of great interest to more efficiently prescribe effective training in tennis.

Limitations

Although the present study showed positive performance results with the inclusion of an HIT shock microcycle in a short period of time, there are some limitations which must be acknowledged. This study did not use a control group. However, the study was conducted with professional tennis players under a real preparation programme, which makes it impossible to have a control group of similar characteristics. Another limitation is the lack of more detailed fatigue-related measurements (e.g., muscle inflammation) which can provide specific information about overreaching/overtraining symptoms. To get a clearer idea of its practicability, a comparison of different training programmes (e.g., low-intensity training vs HIT) and the exact volume of HIT that has to be performed to sustain the improvements should also be investigated. However, we felt confident based on the performance improvement that this protocol did not negatively impact performance on any of the variables that we were measuring.

Conclusion

In conclusion, a 17-day shock microcycle (i.e., 13 HIT sessions) in addition to the regular on-court tennis training significantly improved parameters (e.g., V_{IFT}, RSAm) that can impact physical performance in tennis. Moreover, additional sessions, including running exercises based on the 30:15ITF and on-court specific exercises, were characterised by significantly lower TL than tennis-training sessions. Although the results were positive, further research examining the effect of volume variation (e.g., on- and off-court) on performance, including stress-related measurements (e.g., hormonal), is warranted.

Practical applications

Tennis professionals have to deal with short preparation schedules, ranging from 5 to 7 weeks. 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 (Fernandez-Fernandez et al., 2011). However, to the best of our knowledge, there is no information about the specific preparation of professional tennis players. The results of the present study showed that an HIT shock microcycle, including running exercises based on the $30{:}15_{ITF}$ and on-court specific exercises (e.g., training intervals ranging from 15 to 120 s; ~90-95% HR_{max}), increases performance-related parameters in professional tennis players in a short period of time. Coaches should be aware of TL (e.g., RPE) and fatigue-related parameters (e.g., muscle soreness) in order to avoid overreaching symptoms. Regarding the use of these shock microcycles, further investigations should be directed to answer the questions "How much is too much?" and how many HIT sessions are needed to sustain this improvement throughout the subsequent training periods (Breil et al., 2010).

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References

Baar, K. (2006) Training for endurance and strength: lessons from cell signaling. *Medicine and Science in Sports and Exercise* **38(11)**, 1939-1944.

Bosco, C., Mognoni, P. and Luhtanen, P. (1983) Relationship between isokinetic performance and ballistic movement. *European Journal of Applied Physiology and Occupational Physiology* **51(3)**, 357-364.

Breil, F.A., Weber, S.N., Koller, S., Hoppeler, H. and Vogt, M. (2010) Block training periodization in alpine skiing: effects of 11-day HIT on VO_{2max} and performance. *European Journal of Applied Physiology* **109(6)**, 1077-1086.

Buchheit, M. (2008) The 30-15 intermittent fitness test: accuracy for individualizing interval training of young intermittent sport players. *Journal of Strength and Conditioning Research* **22(2)**, 365-374.

Buchheit, M. and Laursen, P.B. (2013) High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Medicine* **43(5)**, 313-338.

Buchheit, M., Laursen, P., Kuhnle, J., Ruch, D., Renaud, C. and Ahmaidi, S. (2009) Game-based training in young elite handball players. *International Journal of Sports Medicine* **30(4)**, 251-258.

Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M. and Ahmaidi, S. (2010) Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. *Journal of Strength and Conditioning Research* **24(10)**, 2715-2722.

Buchheit, M., Millet, G., Parisy, A., Pourchez, S., Laursen, P. and Ahmaidi, S. (2008) Supramaximal training and postexercise parasympathetic reactivation in adolescents. *Medicine and Science in Sports and Exercise* **40(2)**, 362-371.

Castagna, C., Impellizzeri, F.M., Chaouachi, A., Bordon, C. and Manzi, V. (2011) Effect of training intensity distribution on aerobic fitness variables in elite soccer players: a case study. *Journal of Strength and Conditioning Research* **25(1)**, 66-71.

Castagna, C., Impellizzeri, F.M., Chaouachi, A. and Manzi, V. (2013) Preseason variations in aerobic fitness and performance in elite-standard soccer players: a team study. *Journal of Strength and Conditioning Research* **27(11)**, 2959-2965.

Christensen, P.M., Krustrup, P., Gunnarsson, T.P., Kiilerich, K., Nybo, L. and Bangsbo, J. (2011) VO_2 kinetics and performance in soccer players after intense training and inactivity. *Medicine and Science in Sports and Exercise* **43(9)**, 1716-1724.

Coutts, A.J., Gomes, R.V., Viveiros, L. and Aoki, M.S. (2010) Monitoring training loads in elite tennis. *Revista Brasileira de Cineantropometria y Desempenho Humano*, **12(3)** 217-220.

Duffield, R., Murphy, A., Kellett, A. and Reid, M. (2013) Recovery from repeated on-court tennis sessions: combining cold water immersion, compression and sleep recovery interventions. *International Journal of Sports Physiology and Performance* **9(2)**, 273-282.

Dupont, G., Akakpo, K. and Berthoin, S. (2004) The effect of in-season, high-intensity interval training in soccer players. *Journal of Strength and Conditioning Research* **18(3)**, 584-589.

Fernandez, J., Mendez-Villanueva, A. and Pluim, B. (2006) Intensity of tennis match play. *British Journal of Sports Medicine* **40(5)**, 387-391.

Fernandez-Fernandez, J., Sanz-Rivas, D. and Mendez-Villanueva, A. (2009) A review of the activity profile and physiological demands of tennis match play. *Strength and Conditioning Journal* **31(4)**, 15-26.

Fernandez-Fernandez, J., Sanz-Rivas, D., Sanchez-Muñoz, C., de la Aleja Tellez, J.G., Buchheit, M. and Mendez-Villanueva, A. (2011) Physiological responses to on-court vs running interval training in competitive tennis players. *Journal of Sports Science and Medicine* **10(3),** 540-545.

Fernandez-Fernandez, J., Zimek, R., Wiewelhove, T. and Ferrauti, A. (2012) High-intensity interval training vs. repeated-sprint training in tennis. *Journal of Strength and Conditioning Research* **26(1)**, 53-62.

Ferrari-Bravo, D., Impellizzeri, F.M., Rampinini, E., Castagna, C., Bishop, D. and Wisloff, U. (2008) Sprint vs. interval training in football. *International Journal of Sports Medicine* **29(8)**, 668-674.

Foster, C. (1998) Monitoring training in athletes with reference to overtraining syndrome. *Medicine and Science in Sports and Exercise* **30(7),** 1164-1168.

Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P. and Dodge, C. (2001) A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research* **15(1)**, 109-115.

Galambos, S., Terry, P., Moyle, G. and Locke, S. (2005) Psychological predictors of injury among elite athletes. *British Journal of Sports Medicine* **39(6)**, 351-354.

García-Pallarés, J., García-Fernández, M., Sánchez-Medina, L. and Izquierdo, M. (2010) Performance changes in world-class kayakers following two different training periodization models. *European Journal of Applied Physiology* **110(1)**, 99-107.

García-Pallarés, J. and Izquierdo, M. (2011) Strategies to optimize concurrent training of strength and aerobic fitness for rowing and canoeing. *Sports Medicine* **41(4)**, 329-343.

Gomes, R.V., Moreira, A., Lodo, L., Nosaka, K., Coutts, A.J. and Aoki, M.S. (2013) Monitoring training loads, stress, immune-endocrine responses and performance in tennis players. *Biology of Sport* **30(3),** 173-180.

Hopkins, W.G. (2000) Measures of reliability in sports medicine and science. *Sports Medicine* **30(1)**, 1-15.

Iaia, F.M., Rampinini, E. and Bangsbo, J. (2009) High-intensity training in football. *International Journal of Sports Physiology and Performance* **4(3)**, 291-303.

Issurin, V.B. (2008) Block periodization versus traditional training theory: a review. *Journal of Sports Medicine and Physical Fitness* **48(1)**, 65-75.

Issurin, V.B. (2010) New horizons for the methodology and physiology of training periodization. *Sports Medicine* **40(3)**, 189-206.

Kovacs, M.S. (2007) Tennis physiology: training the competitive athlete. Sports Medicine **37(3)**, 189-198.

Lamberts, R.P., Swart, J., Noakes, T.D. and Lambert, M.I. (2009) Changes in heart rate recovery after high-intensity training in well-trained cyclists. *European Journal of Applied Physiology* **105(5),** 705-713.

Laursen, P.B. and Jenkins, D.G. (2002) The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Medicine* **32(1)**, 53-73.

Mallo, J. (2011) Effect of block periodization on performance in competition in a soccer team during four consecutive seasons: a case study. *International Journal of Performance Analysis in Sport* **11(3)**, 476-485.

Mendez-Villanueva, A., Fernandez-Fernandez, J., Bishop, D. and Fernandez-Garcia, B. (2010) Ratings of perceived exertion-lactate association during actual singles tennis match play. *Journal of Strength and Conditioning Research* **24(1)**, 165-170.

Mendez-Villanueva, A., Fernandez-Fernandez, J., Bishop, D., Fernandez-Garcia, B. and Terrados, N. (2007) Activity patterns, blood lactate concentrations and ratings of perceived exertion during a professional singles tennis tournament. *British Journal of Sports Medicine* **41(5)**, 296-300.

Murphy, A., Duffield, R., Kellett, A. and Reid, M. (2014) A descriptive analysis of internal and external loads for elite-level tennis drills. *International Journal of Sports Physiology and Performance* **9(5)**, 863-870.

Reid, M., Duffield, R., Dawson, B., Baker, J. and Crespo, M. (2008) Quantification of the physiological and performance characteristics of on-court tennis drills. *British Journal of Sports Medicine* **42(2)**, 146-151.

Reid, M., Duffield, R., Minett, G.M., Sibte, N., Murphy, A.P. and Baker, J. (2013) Physiological, perceptual, and technical responses to on-court tennis training on hard and clay courts. *Journal of Strength and Conditioning Research* **27(6)**, 1487-1495.

Ronnestad, B.R., Ellefsen, S., Nygaard, H., Zacharoff, E.E., Vikmoen, O., Hansen, J. and Hallen, J. (2014) Effects of 12 weeks of block periodization on performance and performance indices in well-trained cyclists. *Scandinavian Journal of Medicine and Science in Sports* **24(2)**, 327-335.

Smekal, G., von Duvillard, S.P., Rihacek, C., Pokan, R., Hofmann, P., Baron, R., Tschan, H. and Bachl, N. (2001) A physiological profile of tennis match play. *Medicine and Science in Sports and Exercise* **33(6)**, 999-1005.

Sperlich, B., De Marées, M., Koehler, K., Linville, J., Holmberg, H.C. and Mester, J. (2011) Effects of 5 weeks' high-intensity interval training vs. volume training in 14-year-old soccer players. *Journal of Strength and Conditioning Research* **25(5)**, 1271-1278.

Srihirun, K., Boonrod, W., Mickleborough, T. D. and Suksom, D. (2014) The effect of on-court vs. off-court interval training on skilled tennis performance and tolerance to fatigue in young male tennis players. *Journal of Exercise Physiology Online* **17(5)**, 11-20.

Swart, J., Lamberts, R.P., Derman, W. and Lambert, M. (2009) Effects of high-intensity training by heart rate or power in well-trained cyclists. *Journal of Strength and Conditioning Research* **23(2)**, 619-625.

Vescovi, J.D. and McGuigan, M.R. (2008) Relationships between sprinting, agility, and jump ability in female athletes. *Journal of Sports Sciences* **26(1)**, 97-107.

Wahl, P., Güldner, M. and Mester, J. (2014) Effects and sustainability of a 13-day high-intensity shock microcycle in soccer. *Journal of Sports Science and Medicine* **13(2)**, 259-265.

Wahl, P., Zinner, C., Grosskopf, C., Rossmann, R., Bloch, W. and Mester, J. (2013) Passive recovery is superior to active recovery during a high-intensity shock microcycle. *Journal of Strength and Conditioning Research* **27(5)**, 1384-1393.

Key points

- HIT shock microcycle increases performance in professional tennis players in a short period of time.
- The inclusion of additional sessions, with running exercises based on the 30:15ITF and on-court specific exercises, was characterised by a significantly lower TL than tennis-training sessions alone.
- Coaches should be aware of TL (e.g., RPE) and fatigue-related parameters (e.g., muscle soreness) in order to avoid overreaching symptoms.

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