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A study of intensity, fatigue and precision in two specific interval trainings in young tennis players: high-intensity interval training versus intermittent interval training

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ABSTRACT

Background The aim of this study is to find the differences between two specific interval exercises. We begin with the hypothesis that the use of microintervals of work and rest allow for greater intensity of play and a reduction in fatigue.

Methods Thirteen competition-level male tennis players took part in two interval training exercises comprising nine 2 min series, which consisted of hitting the ball with cross-court forehand and backhand shots, behind the service box. One was a high-intensity interval training (HIIT), made up of periods of continuous work lasting 2 min, and the other was intermittent interval training (IIT), this time with intermittent 2 min intervals, alternating periods of work with rest periods. Average heart rate (HR) and lactate levels were registered in order to observe the physiological intensity of the two exercises, along with the Borg Scale results for perceived exertion and the number of shots and errors in order to determine the intensity achieved and the degree of fatigue throughout the exercise.

Results There were no significant differences in the average heart rate, lactate or the Borg Scale. Significant differences were registered, on the other hand, with a greater number of shots in the first two HIIT series (series 1 $p>0.009$; series 2 $p>0.056$), but not in the third. The number of errors was significantly lower in all the IIT series (series 1 $p<0.035$; series 2 $p<0.010$; series 3 $p<0.001$).

Conclusion Our study suggests that high-intensity intermittent training allows for greater intensity of play in relation to the real time spent on the exercise, reduced fatigue levels and the maintaining of greater precision in specific tennis-related exercises.

What are the new findings?

- The use of interval training with specific tennis-based actions allows for very high levels of work intensity.
- Intermittent interval training that includes exercises regularly used in technical training for tennis allows for very high levels of physiology and intensity of play.
- The introduction of rest periods allows for greater precision and the maintaining of motor skills.
- We believe that monitoring intensity and skill through the number of shots and errors is a good way to control intensity and motor control in specific resistance training.

INTRODUCTION

Training for endurance in tennis has, in recent decades, been aimed more specifically at an intermittent and high-intensity workload.[1] At times, high-intensity work is related to anaerobic adaptations, but in recent decades, several studies have been published showing that, with this kind of training, maximum oxygen consumption and the oxidative capacity of muscle fibres are raised through an increase in mitochondria and their enzyme activity.[2]

Nevertheless, when the goal is to work more specifically, exercises should have a similar motor structure to the one carried out during a game. The problem, however, is that this can have a negative effect on technical and tactical skill and this is an important and common concern among trainers when choosing specific training systems and exercises.

A relationship between fatigue and the deterioration of neuromuscular control in different sports has been established, with loss of motor control and modifications in kinetics and kinematics.[3 4] In tennis players, fatigue causes a reduction in the intensity of play and shot precision. There have also been findings that show reduced ability to apply strength in processes of excitability and relaxation after 3 hours of play.[5]

Verwaugen *et al*[6] observed a considerable reduction in the power and precision of baseline shots after 2 hours of play. In other studies, a relationship has also been observed between fatigue and motor quality when executing both baseline and service shots.[7 8]

As part of interval training (IT), high-intensity interval training (HIIT) and workouts with very brief work and recovery intervals are often used. The latter are commonly referred to as intermittent interval training (IIT), which consists of very short work and rest periods of no more than 30 s.[9]

Some authors maintain that the acceleration and deceleration actions that arise during high-intensity intermittent exercises could lead to a less significant reduction in performance compared with more continuous exercises at maximum speeds.[10 11] Acceleration phases, with longer periods spent on the support stage compared with the maximum speed stages, give more time to apply strength. This leads to a reduced loss of performance in the face of repeated explosive stimulants.[12]

In a tennis game, rest periods and the recovery achieved during said periods show a strong relationship with the intensity of play and shot precision.[13] Therefore, it is very important to choose suitable work and recovery times (W/R) in order to achieve goals. The W/R relationship is fundamental; the nature of this relationship and the intensity and duration of both periods will affect the adaptive processes in one way or another.[14–16] However, reaching and maintaining suitable levels of intensity is just as important as achieving and maintaining optimum motor effectiveness.

The study of the number of shots and their evolution over time may be a good way of controlling the intensity of the game and the presence of fatigue, while determining the number of errors made during the training will help discover their connection with fatigue. The relationship between the player's fatigue and the loss of coordination is also highly relevant.[6–8]

In this research, two types of tennis ITs are analysed. The aim is to compare the intensity achieved in two ball exercises with intervals of 2 min. One of them is an intermittent type, in which short periods of work and recovery are alternated. Assessing the heart rate (HR), lactate and Borg Scale, as well as recording the number of strokes and errors, we seek to know the physiological intensity of the game speed and the effect of fatigue on precision. Our hypothesis is that the introduction of brief recovery periods allows high intensities and a greater effect on ball control in specific tennis exercises.

METHODS

The sample consisted of 13 healthy male tennis players. The average age, height, weight, weekly training hours and years of play was 17±2 years, 176.5±4.4 cm, 69.5±3.4 kg, 12±2 hours/week and 7±3 years, respectively. They were previously informed of the characteristics of the study and they all provided their consent at the beginning of the research.

All participants play at national level and each one undergoes an extended preseason training period of around 3 months (compared with a maximum of 4 weeks for professional tennis players), which means they have longer to work on their basic physical qualities.

The players are used to running-based general continuous and IT.

Before carrying out the study, an ergometrics test was carried out in the laboratory. The selected test was a Conconi test, providing us with each player's maximum HR.[17]

The ergometric values were taken at 18:00 hours on different days and the subjects had not undertaken any intense effort during the previous 24 hours or eaten any food in the 2 hours before the values were registered. The test consisted of a progression run with a constant 5% gradient at an initial speed of 5 km/hour, increasing by 1 km/hour every minute.

The experimental study was carried out at the Asturias Regional Sports Centre (Centro Regional de Deportes del Principado de Asturias), during the preseason period.

Two tennis specific IT protocols were carried out focusing on improving endurance: (1) HIIT and (2) IIT.

Both training sessions adopted the same general structure with the number of shots and errors being monitored.

The training was carried out over the space of 2 weeks: first, the long interval exercises and then the short interval ones. Each athlete undertook two tests per week with 72 hours' rest between each test.

TRAINING PROTOCOLS

HIIT was an interval exercise consisting of forehand and backhand shots on both sides of the court (from sideline to sideline), with three series of three 2 min repetitions at an intensity of 90% (3×3×2 min), with recoveries at 130 beats between repetitions and at 120 beats between series for being a HR commonly used in IT. Players were instructed to make cross-court shots behind the service box. It must be highlighted that the movement and shot rate was an individual 90% and set by the player. To do this, the trainer threw the ball over the sidelines using his hand for greater control.

IIT was the same as the HIIT in terms of structure (3×3×2 min), with the same recovery between repetitions and series, but with work and recovery periods within each repetition. Each repetition consisted of 20 s of shots, 20 s of recovery, 20 s of shots and subsequently 15 s intermittence until the 2 min were completed (20W:20R:20W:15R:15W:15R:15W). Once again, the trainer threw the ball at the rate set by the player, hitting with the forehand and backhand and returning to the centre of the court.

Before the exercises, the players warmed up with a gentle rally for 10 min.

The same monitoring approach was used for the two tests. Polar HR monitors were used (Polar RS400 Finland), registering HR data at all times. Blood samples were taken to analyse lactate levels using the Lactate Pro 2 (Arkray, Japan) analyser at the end of the three series, taking a sample volume of approximately 0,3 µL. Shots and errors were recorded to know shot frequency as well as the level of players' control. When the two tests were completed, the Borg Scale (Scale 20) was applied in order to find out the players' rating of perceived exertion.[18]

All the data were organised, analysed and evaluated in the days following the tests.

The two-tailed t-test was used for comparing sample averages, analysing the null hypothesis that the samples' averages are the same compared with the alternative that they are not. The cases in which averages are 95% different are shown. With a p value of 0.05, a significance level of 95% is achieved.

RESULTS

Average HR

As regards the average HR, high percentages were found, with average values—compared with the maximum individual HR—of 90.65% in HIIT and 88.76% in IIT (table 1). No statistically significant differences at 95% of confidence considering a p value=0.05 were found between the two groups in the total end values or when comparing the different series.

Lactate

On completing the test, average lactate values of 8.00 mmol/L in HIIT and 8.20 mmol/L in IIT were found, with no significant differences on concluding the test or in the first two series. Significantly greater values were observed within the HIIT exercise, with higher concentrations in the third series compared with the second and first (0.0307 and 0.0058). On observing the IIT results, however, greater variability may be seen, thus showing differences that are not statistically significant between the different series in this exercise (table 1).

Borg scale

The final Borg Scale values were 16.33 in HIIT and 16.6 in IIT, without significant differences (>0.05). In addition, there were no relevant variations between the different series (table 1).

Number of shots

The number of shots was higher in HIIT than in IIT. Nevertheless, this difference is significant in the first two series, but not in the third (table 2), in which a stark reduction in the number of shots in HIIT took place.

Number of errors

The number of errors was higher in all HIIT series, with significant differences in all the series compared with the intermittent training (table 2). The increase in HIIT is constant, with significantly higher values between the third and the first series (0.03).

DISCUSSION

One of the main factors to improve endurance in high-level athletes is to reach high intensities. HR, lactate and Borg Scale data will show us if the specific tennis exercises that were chosen achieve adequate intensity. The analysis of shots and errors supposes an interesting information that will allow us to know the speed of game during the tests and the effect of the fatigue on players and their technical actions.

Heart rate

Achieving the correct level of intensity is one of the essential requirements for ensuring significant aerobic adaptations. The intense activation of fast-twitch muscle fibres with close-to-maximum intensity loads can only be achieved for short periods of time with high-intensity activities.[19] Intermittent sports such as tennis prioritise a considerable ability for repeating effort at high levels of intensity.[20] It therefore stands to reason to think that IT would best adjust to the characteristics of tennis.

Table 1 Average values in each series and total medial heart rate (HR), Lactate and Borg Scale

	HIIT				IIT			
	Series 1	Series 2	Series 3	Total	Series 1	Series 2	Series 3	Total
HR	179.52	180.19	180.43	180.04	176.10	176.70	175.80	176.29
Lact.	7.04	6.74	8.02		6.97	7.46	8.07	
Borg Scale	16.2	16.26	16.33	16.26	16.26	16.46	16.6	16.44

Statistically significant differences (<0.0.05).
Lact, IIT Series 1<Series 3 0.034/HIIT Series 2<Series 3 0.021/ITT Series one no difference with Series 3 0.283.
HIIT, high-intensity interval training; IIT, intermittent interval training; Lact., lactate.

Table 2 Average values of shot and error numbers in each series and the total number of shots and errors

	HIIT				IIT			
	Series 1	Series 2	Series 3	Total	Series 1	Series 2	Series 3	Total
Shots	139.40	136.13	130.53	406.06	122.86	123.60	124.53	371
Errors	22.,06	24.93	29.20	76.20	17.93	16.80	17.20	51.93

Statistically significant differences (<0.05).
Shots, HIIT Series 1>IIT Series 1 0.009/HIIT Series 2>IIT Series 2 0.056.
Errors, HIIT Series 3>Series 1 0.03/HIIT Series 1>IIT Series 1 0.035 – Series 3 0.010–0.033/HIIT Series 2>IIT Series 1>0.028 Series 2 0.010–0.023/HIIT Series 3>IIT Series 1 0.001 – Series 2 0.001 – Series 3 0.001.
HIIT, high-intensity interval training; IIT, intermittent interval training.

In our study, we have found high HR and high lactate levels in both kinds of specific IT (figure 1). These results are in line with other publications discussing tennis[21] as well as some team sports.[22–24]

The two specific kinds of IT therefore allow for a sufficient level of intensity to promote considerable aerobic and mixed adaptations.

Lactate

In the IIT work, we have obtained more stable lactate values throughout the different series, which may be down to clearance during the recovery stages.[25] The end values did not show major differences, but a final increase in HIIT was observed (figure 2), which may be down to increased fatigue, while lactate levels for IIT remained high. This may be explained by the increased participation of fast-twitch muscle fibres in these kinds of efforts, which feature greater accelerations, decelerations and changes of direction.[23]

The final increase in HIIT comes from the long periods of work without rests leading to increased fatigue and high lactate production.

Borg scale

We have used the subjective value of fatigue to monitor the intensity of work, due to a relationship having been established with the physiological intensity of exercise.[26–28] It was also chosen because it is a non-invasive, convenient system much used in recent years in team sports for training and in competition.[26 29 30]

There are no significant differences between the two types of training and, in both, the load has been slightly underestimated compared with HR taking into account the established connection between career efforts and Borg Scale,[27] with average values at 16 (figure 3). We should bear in mind when using perceived exertion systems that the results may be altered by different factors, such as motivation, skill or how regularly a subject undertakes different types of training. We believe that when using the Borg Scale, we should familiarise the player with this kind of tool[31] and adjust the analysis to the type of exercise and the individual nature of each subject's response.

Monitoring intensity and fatigue: number of shots

The characteristics of play entail manifestations of specific strength with eccentric and stretch-shortening cycle actions will determine the kind of exercises as well as the most convenient systems for ensuring adaptations are significant.[24 32–35]

The study of the number of shots and their variation throughout the exercise may be a good way of monitoring intensity and fatigue levels, along with their relationship with the loss in motor skill. When training with specific exercises, optimum motor action must be controlled, as must the possibility of maintaining suitable levels of intensity and effectiveness.

In figure 4, intensity in absolute values is higher in HIIT, but when the real rally time is considered, that is to say without rests between shot time, intensity or shot frequency is higher in IIT. Systems with very short

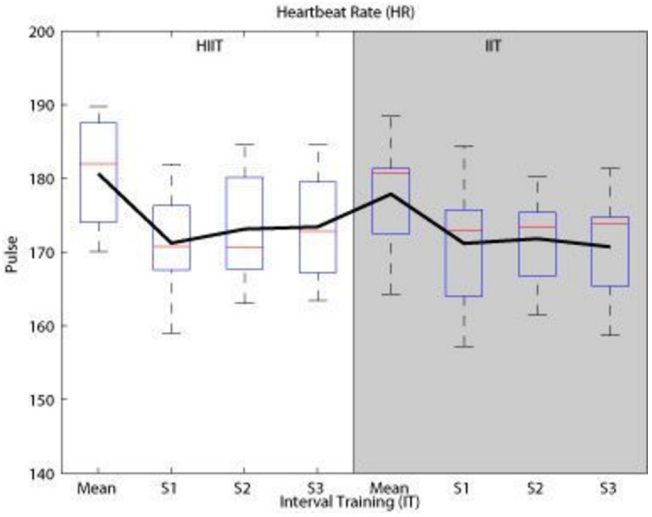

Figure 1 Distribution of average individual heart rate (HR) for high-intensity interval training and intermittent interval training in the first, second and third series (see online supplementary table S1 S2 S3) and mean. The box shows how the sample is scattered, defined by percentiles 25 (lower limit) and 75 (upper limit); the red line shows the median and the black lines the lower and upper limits, outside of which values are considered as outliers. These are marked with red crosses. High average HR values are observed while there are no significant differences between the two exercises.

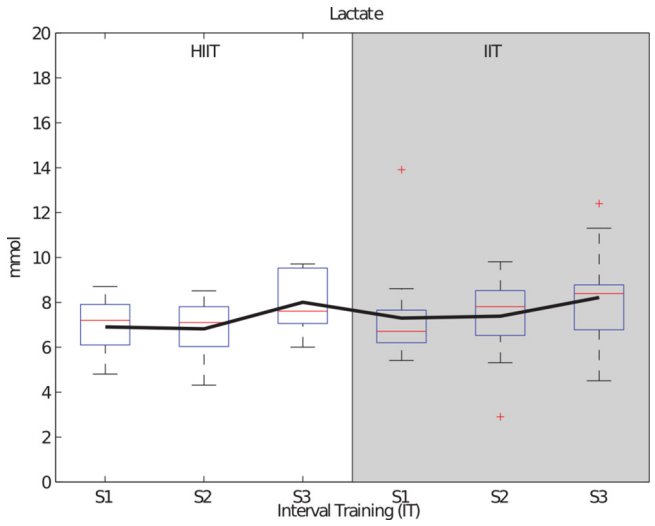

Figure 2 Distribution of individuals' lactate levels in high-intensity interval training (HIIT) and intermittent interval training (IIT), in the first, second and third series (see online supplementary table S1 S2 S3). The box shows how the sample is scattered, defined by percentiles 25 (lower limit) and 75 (upper limit); the red line shows the median and the black lines the lower and upper limits, outside of which values are considered as outliers. These are marked with red crosses. An increase in the last HIIT series is shown. There are significant differences between the first and second series and the third in HIIT.

work and recovery periods may allow for increasing the activation of fast-twitch muscle fibres.[36] This difference in absolute terms was significant in the first two series but not in the third.

Intensity levels are better maintained in IIT. This higher level of relative intensity and its less significant loss is doubtless down to the introduction of rest periods, which allow for greater speeds for longer periods of time.

In our study, greater intensity of play is identified in IIT, along with better capacity for maintaining these high-speed actions over longer periods of training.

Monitoring fatigue: number of errors

The increase in the time spent playing at high speeds leads to fatigue that includes a reduction in the player's ability to control distance to the ball and the placing of the body for the shot. This leads to a drop in shot control.[6 7]

Périard *et al*[37] found peripheral and central fatigue, reflected in the difficulty of undertaking intense contractions during the final stage of games. Similarly, losses in precision and the ability to apply strength after hours of play have also been registered.[7 8 38 39] Local and sensory fatigue may be reflected in terms of shot precision.[32 40]

When undertaking endurance training, we must also take into account the role that fatigue plays in decision-making and the overall development of play. Ferrauti *et al*[13] suggest that when tennis players begin to perceive fatigue, the way shots are prepared and played are modified with the resulting negative effect on technique, a reduction in speed, alteration in decision-making, rashness in terms of play and the consequent increase in errors.

In our study, an increase in the number of errors can be seen continuously in HIIT, becoming significantly higher in each series, and these values are significantly higher than the ones produced in IIT from the first series onward (figure 5). This reduced ability to maintain shot effectiveness can be seen when comparing figures 4 and 5, showing an obvious reduction in the number of shots while the number of errors increased inversely. On the other hand, with IIT, the number of shots and errors committed remains stable.

Efforts carried out in short intervals accompanied by periods of recovery allow for greater effectiveness in terms of shot execution.

Our findings obtained are relevant both for coaches and for physical trainers, allowing them to make good use of specific resistance exercises for tennis players. Training sessions made up of specific exercises with short intervals are effective in improving maximum aerobic capacity and maintaining suitable precision of movement. In this regard, improvements in VO_2 max were observed, while an improvement in quantity and precision in specific actions with football players was also achieved.[9]

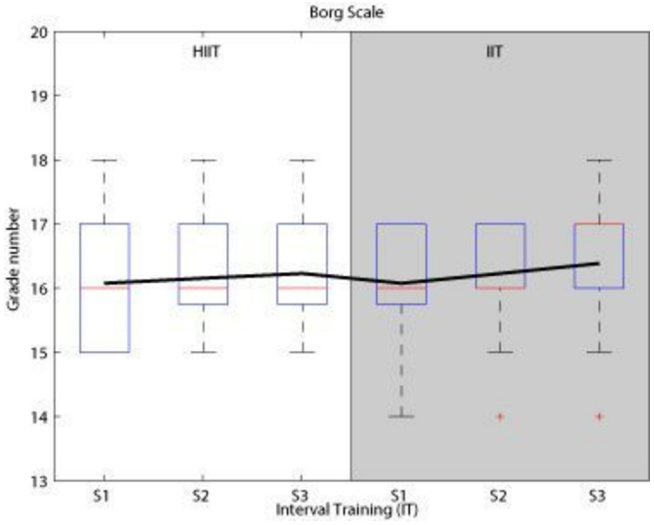

Figure 3 Individuals' distribution on the Borg Scale for high-intensity interval training and intermittent interval training, in the first, second and third series (online supplementary table S1 S2 S3). The box shows how the sample is scattered, defined by percentiles 25 (lower limit) and 75 (upper limit); the red line shows the median and the black lines the lower and upper limits, outside of which values are considered as outliers. These are marked with red crosses. There are no differences between the two types of training.

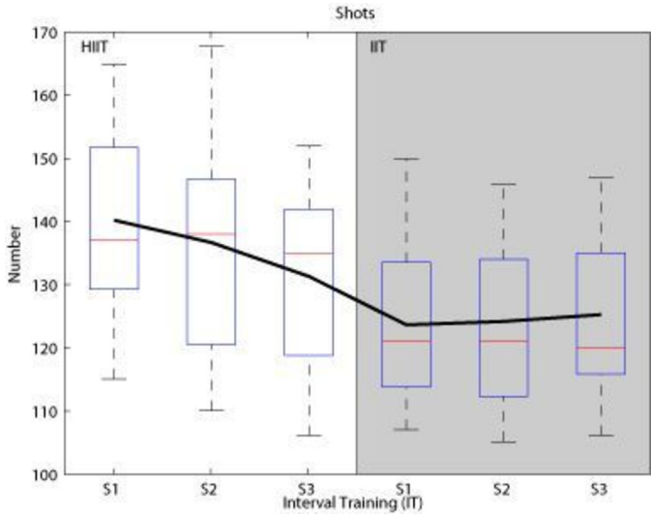

Figure 4 Distribution of average shot numbers for high-intensity interval training (HIIT) and intermittent interval training (IIT), in the first, second and third series (see online supplementary table S1 S2 S3). The box shows how the sample is scattered, defined by percentiles 25 (lower limit) and 75 (upper limit); the red line shows the median and the black lines the lower and upper limits, outside of which values are considered as outliers. These are marked with red crosses. A continuous fall in the number of shots carried out in HIIT can be observed, while in IIT this figure remains stable.

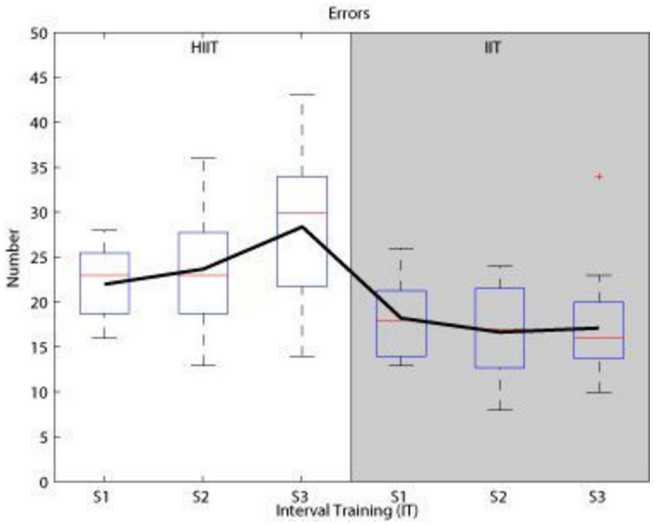

Figure 5 Distribution of average error numbers for high-intensity interval training (HIIT) and intermittent interval training (IIT), in the first, second and third series (see online supplementary table S1 S2 S3). The box shows how the sample is scattered, defined by percentiles 25 (lower limit) and 75 (upper limit); the red line shows the median and the black lines the lower and upper limits, outside of which values are considered as outliers. These are marked with red crosses. A continuous increase in the number of errors in HIIT can be observed, while in IIT this figure remains stable.

While HR, lactate or the speed of movement are highly important factors in these kinds of intermittent sports, factors such as deceleration capacity and technical execution must also be taken into account.

CONCLUSIONS

With the results observed in our study, it can be said that the use of IT with specific tennis-based actions allows for very high levels of work intensity.

IIT that include exercises regularly used in technical training for tennis allows for very high levels of intensity of play, which are shown through a greater number of relative shots compared with when long work intervals are used.

With this kind of intermittent training, considerable stability is achieved in terms of the number of shots executed and, consequently, in the intensity of play.

During high-intensity training with long intervals, a large number of errors are committed. The introduction of rest periods allows for greater precision and the maintaining of motor skills.

We consider monitoring intensity and skill through the number of shots and errors to be worthwhile. In this vein, we also believe it is beneficial to undertake training to specifically develop these skills, taking into consideration the structure of play and its movements in relation to other tactical and cognitive factors.

In summary, in terms of endurance training for tennis players, using specific IT is highly effective and we especially recommend IIT training exercises, which allow for greater intensity and motor effectiveness, along with a reduced presence of fatigue during play.

Competing interests None declared.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

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