High-intensity specific intermittent training (SIT) in the preparation of the tennis player

David Suárez Rodríguez[1], Miguel Del Valle[2]

[1]Universidad Internacional de La Rioja. [2]Universidad de Oviedo.

Received: 02.05.2018
Accepted: 15.06.2018

Summary

The ability to perform actions repeatedly at high speed has a very clear relationship with the manifestation of endurance in sports such as tennis. The training in which there are interspersed periods of work of high intensity with others of recovery turns out to be a type of training more specific than continuous type. Within the interval systems, the intermittent training of high intensity (Intermittent training-IT) suppose a specially suitable method to improve aerobic and anaerobic endurance. Through this training will we be able to act on the adaptations related to the recovery between points, which has a direct relationship with the performance in the matches. In addition, the high intensity and low volume of training allows an optimal synergy with qualities such as explosive force and speed, so important in sports in which periods of work and recovery are interspersed. However, tennis has some specific characteristics that differentiate it from other intermittent sports such as brief recoveries and techniques of displacement and hitting the ball, so the use of intermittent training using typical movements of tennis (Specific Intermittent Training-SIT) is an especially suitable system. The choice of the intensity of the effort of the relationship between work and recovery times, and the degree of skill of the player are determining factors when carrying out specific training at high intensity.

In this review we try to show the interest of SIT training as a basic tool to encourage the improvements of the different factors of performance in tennis players.

Key words:
Tennis. Intermittent training. Specific training. SIT. Endurance. Recovery. Explosive strength. Elastic strength. Speed.

El entrenamiento intermitente específico de alta intensidad en la preparación del jugador de tenis

Resumen

La capacidad de realizar acciones a alta velocidad de forma repetida tiene una relación muy clara con la manifestación de la resistencia en deportes como el tenis. El entrenamiento en el que se intercalan periodos de trabajo de alta intensidad con otros de recuperación resulta un tipo de entrenamiento más específico que el de tipo continuo. Dentro de los sistemas interválicos, los entrenamientos intermitentes de alta intensidad (Intermittent Training-IT) suponen un método especialmente adecuado para mejorar la resistencia aeróbica y anaeróbica. Mediante este entrenamiento se podrá actuar sobre las adaptaciones relacionadas con la recuperación entre puntos, lo que tiene una relación directa con el rendimiento en los partidos. Además, la alta intensidad y el bajo volumen de entrenamiento permite una óptima sinergia con cualidades como la fuerza explosiva y la velocidad, tan importantes en deportes en los que se intercalan periodos de trabajo y recuperación. Sin embargo, el tenis tiene unas características específicas que lo diferencian de otros deportes intermitentes, como son las recuperaciones breves, y la técnica de desplazamiento y de golpeo de la pelota, por lo que la utilización del entrenamiento intermitente usando movimientos propios del tenis (Specific Intermittent Training-SIT), es un sistema especialmente adecuado. La elección de la intensidad del esfuerzo, de la relación entre tiempos de trabajo y recuperación y el grado de destreza del jugador, son factores determinantes a la hora de realizar entrenamientos específicos a alta intensidad.

En esta revisión se intenta mostrar el interés del entrenamiento SIT como herramienta básica para potenciar las mejoras de los diferentes factores del rendimiento en tenistas.

Palabras clave:
Tenis. Entrenamiento intermitente. Entrenamiento específico. SIT. Resistencia. Recuperación. Fuerza explosiva. Fuerza elástica. Velocidad.

Correspondence: David Suárez Ródriguez.
E-mail: david.suarez@unir.net

Introduction

In the course of a tennis match, a series of actions are performed at different intensities and durations, with changes of pace, turns and direction. Therefore, a variety of unique kinetic and kinematic actions occur in this sport, though there are similarities with other intermittent sports. However, the type of movement is also specific, with constant frontal, sideways and cross-step movements taking place, with variations in the length of strides to align distances with the ball, and the stable execution of hits, whilst simultaneously combining different tactical decisions related to fatigue, confidence and competitive stress.

These characteristics determine the aspects to train, and how the trainer should focus the tennis player's preparation. Tennis performance does not just depend on resistance, rather also on other factors such as explosive strength, speed, agility of movement, technique, tactics and mental factors. Yet all of these factors occur together and with great complexity, and are therefore interrelated. To assess the level of our players, as well as to prepare them, it would be useful to create multifactorial systems specific to tennis[1].

One of the most important characteristics in the manifestation of resistance, and in general, sporting performance in intermittent game sports, is the ability to repeat sprints[2]. In tennis, it is a question of repeating specific actions of the game at high intensity, and not just performing linear movements at maximum speed. To achieve the best results in this aspect, systems should be found that adapt most optimally to achieving this objective[3].

This review aims to analyse the importance of specific intermittent training (SIT) as a basic tool to boost improvements in performance of tennis players.

Methodology

To create this descriptive review article, a literary search was performed using various documental sources to locate the documents. Searches were carried out on the databases of PubMed (NLM), Cochrane Library, Scopus, Scielo, Embase and Sport Discus, as well as on the Google Academic search engine.

The search was based on articles published between January 2000 and March 2018.

The key words used to perform the review (isolated or combined), were: tennis, intermittent training, specific training, resistance and recovery.

When selecting the articles included in the review, factors considered were: the methodology, the quality of the research, and if the studies were performed on humans. Any article that was not directly related to the study object, any based on personal opinion and any that did not include valid measurement instruments, were excluded.

Specificity in tennis

Knowing the work and recovery time involved in tennis is an important factor when preparing players. Recovery time between points is set at 20 seconds for Grand Slam tournaments, and at 25 seconds for other tournaments in the professional circuit. However, often the time available is not used, generally being shorter and sometimes even closer to just 10 seconds[4]. Regarding point duration time, by analysing Grand Slam tournaments O'Donoghue & Ingram[5] discovered average times of between 6.3 and 7.7 seconds. The work: recovery ratio (W:R) oscillates between 1:2 and 1:4 on average[5,6], establishing a real play time of 20-26%[7,8]. However, often efforts are made with an above-average duration, and work-recovery ratios of 1:1 and 1:2 when long points lasting over 20 seconds are played. This is particularly interesting because the dynamics of the game, the duration of the work and recovery times, and the ratio between work and recovery, will substantially alter the magnitude of the load borne by the tennis players[9].

The intensity of play and the duration of the efforts determine the type of metabolism used. When points are very short and explosive, it is at the expense of ATP and phosphocreatine, with an aerobic recovery process during breaks, and with moderate lactate concentration clarification below 4 mmol. On other occasions, various long and intense points can occur, which cause a greater demand for oxygen consumption and for the glycolytic pathway, with higher levels of lactate production[10].

Break and work times, as well as the movement types, enable higher levels of strength to be produced in a short space of time, and the manifestation of explosive strength in the game's actions is a decisive factor in performance, and the capacity to repeat this explosive strength during the match is fundamental during play. The production of intermittent strength can generate fatigue on a central level, as well as in processes of excitation and contraction on a muscle fibre level, which can be reflected in losses of performance during the development of tennis matches[11]. This fatigue can be related to the rapid call for strength, as deterioration has been observed after stretching-shortening cycle exercises[12], or as a consequence of the frequent call for eccentric-type actions[13,14].

The displacements are not linear, and they present changes of direction, turns and speed, with special coordinative and neuromuscular patterns[15]. Continuous slowing-down and direction changing actions can lead to fatigue. In recent years, there have been hypotheses regarding a type of fatigue related to the demand for these kinds of eccentric actions, and the existence of a capacity to improve tolerance to this kind of tension in a specific way[16].

We must add that tennis has a high technical, tactical and psychological component, entailing the need to give preparation a complex focus that covers - on many occasions simultaneously - all performance factors. Within this focus, it is worth remembering that a large part of the movements are made laterally or with a crossed step, and there are continuous acceleration and deceleration actions occurring in a complex way, more often than not at the same time as the hits and tactical decisions[17,18].

Intermittent training characteristics

Despite the importance of having suitable maximum oxygen consumption values and a high lactate threshold[19], for optimum recovery between points, training sessions and matches[20], some studies have not found a direct relationship between the capacity to perform repeated

sprints or specific explosive actions within intermittent sports and the maximum oxygen consumption, whilst they have found a relationship between explosive strength and jumping capacity[20,22]. A clear relationship has been observed between explosive strength levels with running efficiency and the ability to repeat high intensity actions[23,24]. In turn, the characteristics of the game require a manifestation of explosive and specific strength[25-27]. Therefore, improvements should be made to neuromuscular characteristics to increase the performance of a specific action, and also so that these actions can be repeated over a lengthy period[28]. The systems that provide aerobic and anaerobic improvements simultaneously achieve positive synergies with the manifestation of strength and speed, making them particularly important in preparing tennis players (Table 1).

Continuous training has occasionally revealed a negative effect on the appearance of explosive strength and speed, even when used concurrently with strength training[29]. Losses have also been observed in the capacity to apply strength and power after high-intensity interval training (HIIT), for example with work and recovery times of 4 minutes: 4 minutes[30]. However, the correct handling of the intensity and duration of the effort can significantly modify this effect[31].

In order to respect the tennis-specific characteristics, training systems must be used that intersperse work phases with high intensity and, sometimes, variable intensity, with other passive rest phases, which is what occurs during play, acting on the ATP and phosphocreatine regeneration processes. From a metabolic perspective, intermittent resistance training (IT) fulfils the requisites of interspersing work with

Table 1. Most relevant studies about intermittent training.

Reference	Sample (n)	Protocol	Contribution
Castagna *et al*. 2008[21]	16 basketball players	10x30 m sprint. 30 s of recovery.	No relationship was observed between VO_{2max} and sprint repetitions.
Stojanovic *et al*. 2012[22]	24 basketball players	10x30 m. Measurement of performance loss	No relationship was observed between VO_{2ma}x and sprint repetitions. Relationship found with CMJ.
Denadai *et al.* 2017[24]	Review	16 studies on concurrent and resistance training	Positive relationship between explosive strength training and the ability to repeat sprints.
Mikkola *et al.* 2012[2]	36 untrained males (16 strength, 11 resistance, 11 concurrent)	21 weeks Strength, resistance and concurrent training	Negative effect of the continuous and concurrent training on explosive strength.
Wilson *et al.* 2012[30]	Review	21 studies on concurrent and resistance training	The mode, volume, intensity and work-recovery relationship modify explosive strength.
Dupont *et al*. 2004[31]	22 football players	10 weeks 12-15x15 s 15 s recovery 12-15x40 m 30 s recovery	Micro-intervals of recovery improve intensity, speed and resistance.
Juel *et al*. 2004[32]	6 subjects	7 weeks 15x1 min / 150% VO_{2max} They trained one leg with extensions compared to contralateral exercises	Avoids loss of speed, improving resistance and tolerance to acidity.
Belfry. 2010[33]	Different samples: 7 males 8 males 14 males	10 s high-intensity and 5 s low-intensity protocols	Increases the recruitment of type II fibres, improving their aerobic capacity.
Rozenek *et al.* 2007[34]	12 males	15:15-s / 100:50% VO_{2max} 30:30 s 30:15 s 60:15 s	Ratio 2:1 mixed work. Ratio 4:1 anaerobic work and rapid presence of fatigue.
Boutcher. 2011[35]	Review	Study on fat loss, physical fitness, resistance to insulin, and skeletal-muscle	Causes greater efficiency in the use of carbohydrates and an enhanced capacity to use fatty acids.
Gerber *et al*. 2014[36]	8 males	20 s / 150% VO_{2max}	Greater use of fatty acids. Higher post-effort expenditure.
Helgerud *et al.* 2007[37]	24 males	Long distance 70% VO_{2max} Continuous high intensity 15:15 s / al 90-95:70% 4:3 min / al 90-95:70%	Greater improvements in oxygen consumption than with continuous training with lower load volume.
Tabata *et al*. 1996[38]	7 males (continuous) 7 males (intermittent)	60 min / 70% VO_{2max} 7-8x20 s 170% VO_{2max} 10 s recovery	Intense stimulus of aerobic and anaerobic systems by training at high intensity and low volume. Intense stimulus of aerobic and anaerobic systems by training at high intensity and low volume.

recovery periods, with the option of adjusting these times to those frequently found in tennis and varying them in accordance with the training objectives.

Introducing rest periods enables greater work intensity and an effect on aerobic and anaerobic adaptations[31]. IT training sessions comprise work and recovery periods of ≤ 30 seconds, with a work-recovery ratio (W:R) that can be of 1:1, 1:1.5, 1:2, 1.5:1 or 2:1. Short, high-intensity intermittent work can limit or override losses in speed, particularly efficient in improving the buffer capacity of muscle acidity[32], whilst achieving similar or greater increases in the maximum oxygen consumption than with continuous work[37,40]. Intermittent effort protocols with very short periods of work and recovery increase the recruitment of type II fibres, acting on their aerobic capacity[33] whilst allowing for improved speed at the same time[31].

IT training has revealed important local and peripheral improvements; meaning major increases in the oxidative capacity and muscle performance[41]. Yet the ratio between work and recovery phases is also a decisive factor when it comes to causing different adaptations. In exercises with an intensity nearing maximum oxygen consumption, a mixed aerobic-anaerobic activation has been observed when the ratio is 2:1, compared to more anaerobic adaptations when this ratio is 4:1, with a quick onset of fatigue[34].

This kind of work allows for increased efficiency in the use of carbohydrates as an energy source, but also, in the past decade, it has been proven that IT and HIIT training can also increase the capacity to use fatty acids[42,35,36]. In addition there is a greater use of fats in these high-intensity exercises during the post-effort period[36].

Despite observations revealing kinetics in the faster oxygen consumption when explosive actions and sprints are carried out[43], a delay can take place in the first repetitions or intermittent exercises within a set, with an ascending trend reflected in the heart rate[44,45], which is why a precise design of the sets with adequate intermittent work-recovery periods should be established for the initial phases[46,47].

One of the advantages of interval training is the capacity to improve oxygen consumption with much lower work volumes. Helgerud *et al*. [37] indicate that high-intensity interval training such as intermittent training (15 seconds: 15 seconds) is more effective in increasing oxygen consumption than continuous training sessions, with a lower work volume.

A lower work volume would allow for less interference with determining qualities in performance, such as explosive strength and speed[48]. It is also particularly interesting to reduce the load volume, as tennis is a sport involving a high volume of technical and tactical work and a long and busy schedule of matches.

Therefore, applying the IT training sessions can have an intense effect on the metabolic systems in a mixed way, triggering important improvements to anaerobic and aerobic capacity[34] whilst preserving manifestations of strength and speed.

Intensity-specificity relationship

The possibility of performing more comprehensive work, with mixed resistance training encompassing speed and agility, with direction changes and turns, whilst also introducing technical, tactical and mental elements, is enormously beneficial in the quest to achieve high performance, though it is necessary to monitor the degree of intensity achieved with these kinds of session (Table 2).

Regarding the type of movement, turns and direction changes, these entail different neural and biomechanical behaviour, meaning that performance markers are specific[38]. Training sessions using linear sprints do not appear to have a clear relationship with improvements in movement in terms of agility and direction changes[49]. A positive relationship has been observed between explosive strength and performance in changing direction or turning, as well as in the ability to repeat these actions. At the same time, improvements have been made in explosive strength using intermittent training sessions with direction changes[50].

Various studies have observed greater intensity with higher lactate concentrations in short efforts when direction changes are included, as opposed to when they are not[51]. At the same time, the skill required to perform turns and direction changes at high speeds is decisive in tennis performance[49].

Specific team-sport and fighting-sport training sessions have revealed similar or superior intensities to running[52,56-59]. In a high-intensity HIIT-type training session (2 minute intervals of work with 90 second recovery times) revealed high intensities, similar to those seen in running, using tennis exercises[53]. Suárez Rodríguez and Del Valle[54] discovered higher heart and lactate rate values in tennis-specific exercises in both IT and HIIT sessions, compared to HIIT in running.

As with running actions, the increased volume of work – increasing the number and duration of explosive actions found in intermittent sports – reduces the anaerobic glycolytic participation, though on occasions, it is accompanied by an increase in the intervention of phosphagen metabolisms[60].

Resistance training sessions with specific and short efforts with recovery periods and motor actions pertaining to the game, can be a suitable way of improving maximum oxygen consumption without having a negative effect on game-decisive qualities, such as strength or speed in intermittent-type sports with a high technical component[56]. This will allow for an improvement in the ability to perform explosive actions whilst improving resistance[31,61,62]. This type of training session offers a good response to the concurrence of strength work with improvements in resistance and speed[63].

One strategy that could be particularly interesting, consists in performing technical and tactical work in a situation of fatigue, as this can be decisive in final performance[53,54].

With exercises using actions pertaining to the game, with continuous changes of pace, turns and direction, there is a much greater demand upon the muscle-tendon system, with an intense accumulation of mechanical work, which is why work loads should be controlled carefully[55].

One relevant factor when choosing training sessions that respect the specific motor structure of tennis is the correct execution and the effect of fatigue upon this. As well as the athlete's physical level, other factors such as the player's level of play, moment of the season, age or perception of effort should also be considered[64]. With regards to the

Table 2. Most important studies about the intensity-specificity relationship.

Reference	Sample (n)	Protocol	Contribution
Brughelli *et al*. 2008[49]	Review	Relationship between ability to change direction and strength training	Different behaviour in the movements with changes compared to linear movements.
Young *et al.* 2001[50]	36 males	6 weeks. Sprints over 20-40 m. 20-40 m with 3-5 direction changes	Linear training exercises did not reveal a relationship between improvements in agility movements and direction changes.
Lakomy, Haydon. 2004[51]	18 elite hockey players	6x40 m test Deceleration 6 m Recovery 30 s	Positive explosive strength and speed relationship with the capacity to decelerate and change direction and repeat. Improvements in explosive strength via IT with direction changes.
Dellal *et al.* 2010[52]	10 elite football players	30:30 s / 100% VO_{2max}. 15:15-s / 105-110-115%VO_{2max}. Straight line run Football exercises	Higher lactate concentrations when direction changes are introduced with football-specific actions.
Fernández-Fernández *et al*. 2011[53]	4 male tennis players 4 female tennis players	4x120 s. 90 s recovery. 95% maximum heart rate Run vs. tennis exercises	Similar intensities. Specific exercises can be used as an alternative to running. Interesting to sometimes work on the technical aspect of fatigue.
Suárez Rodríguez, del Valle. 2017[54]	13 competition-level tennis players	3x3x120 s. Recovery at 120-130 beats HIIT run HIIT forehand-backhand hits SIT forehand-backhand hits	Heart and lactate rates higher in tennis-specific exercises. Lower subjective perception of fatigue in specific efforts in terms of running exercises. Controlling intensity and loss of technical efficiency by recording hits and errors.
Hader *et al.* 2014[55]	11 team-sport players	2x10x22 m 2x10x16.5 m with two 90º changes	Working with direction changes entails intense mechanical load.

subjective assessment of fatigue using the Borg Scale, a lower perception has been observed in tennis-specific exercises compared to running work using equal or lower heart rate intensity[54].

Controlling the number of hits made, evolution during the exercise and maintenance of the motor efficiency registering the precision or number or errors made, could be a good strategy for keeping the training session suitable[54]. Fatigue will cause a progressive loss of control over technical motion and hitting quality[65], which is why specific training sessions should keep particular control over the magnitude of the load. Controlling volume and intensity, as well as choosing a suitable relationship between the work and recovery micro-intervals, will ensure optimum technical execution throughout the different sets.

Recovery training

In sports in which the most important component of resistance is the capacity to repeat high-intensity actions, recovery time between play is a useful time for the body to recompose its metabolic and neuromuscular balance, or at least part of it[60]. A good post-effort response, with a quick lowering of the heart rate, is the sign of a good adaption to specific effort, which is why suitable training targeting the specific dynamics of each sport is decisive[66]. In SIT training, type II fibres are activated and players' levels of explosive strength remain at more optimum levels, with a clear relationship shown between the capacity to generate high levels of strength and the capacity to recover between high-intensity sets (Table 3).

Intense 15-second exercises generate post-effort heart rate increments[70]. Paradoxical behaviour has been observed among tennis players with post-effort elevations in heart rate when SIT training sessions are performed compared to immediate and rapid rates in running HIIT training sessions, and the immediate but slow rates in specific HIIT training, which would reiterate the importance of specificity in terms of the dynamics of work and recovery times, as well as the motor actions specific to the game[46].

The greater activation of type II fibres produces a superior effect over the activation of the sympathetic nervous system and deactivation of the parasympathetic system[67]. This can explain the slower heart rate recovery in intermittent-type efforts and with technical actions that involve acceleration, deceleration and turns and changes of direction[68,46].

The improvement in the oxidative capacity of the muscle with the increase of oxidative enzymes, mitochondrial capacity and myoglobin concentration is, without doubt, a factor that facilitates recovery between sets. The oxygen present in the muscle fibre plays an important role in ATP resynthesis processes between points[69]. Moreover, the capacity to clear lactate and tolerate muscle acidity, as well as the resynthesis of phosphocreatine, are decisive factors in the capacity to recover from a high-intensity action and to repeat it many times[3].

As we can see, the dynamics of recovery and the factors related to it will influence the capacity to recover between points, a decisive factor in performance. At the same time, the dynamic of interspersing appropriate work and recovery periods will have an efficient effect on the tennis-specific adaptive processes.

Table 3. Most outstanding recovery training studies.

Reference	Sample (n)	Protocol	Contribution
Suárez Rodríguez, 2015[46]	15 competition-level tennis players	1-3 exercises lasting 14 min: continuous running, rallies and points. 2- 3 split exercises 3x3x2 min: one running, one hitting, one intermittent hitting. Recovery at 120-130 beats/min.	Quicker heart rate recovery is observed in running efforts than in tennis-specific exercises. Post-effort elevated heart rate in intermittent exercises.
Buchheit *et al*. 2009[67]	20 team-sport players	30:15 s test vs. continuous test	Superior effect over sympathetic activation and the parasympathetic deactivation in specific intermittent efforts.
Kang *et al.* 2007[68]	24 males 24 females	4 protocols lasting 30 min: 1- Continuous at 75 W 2- Alternating 50-100 W every 5-min 3- Alternating 100-50 W 4- Alternating 25-125 W	Slower heart rate recovery in efforts when there are changes in intensity.
Girard, Millet. 2009[69]	Review	Neuromuscular fatigue in racket sports.	Oxygen in muscle fibre is important in the resynthesis of ATP between points in a tennis match.

Therefore, by using concurrent specific high-intensity and strength training sessions, major adaptations can be achieved in resistance, strength and speed. This complex training also produces improvements in players' technical and tactical capacities. However, we believe that the load intensity used should be carefully monitored so as to achieve effective physiological effects, and motor efficiency should be controlled with an assessment of the loss of precision and quality of execution[54].

Conclusions

- High-intensity intermittent training sessions reveal a clear relationship between the appearance of explosive strength and speed and the manifestation of resistance.
- In terms of high-intensity specific intermittent training sessions, intensities are reached that are the same or greater than those in running. Pace, turns and direction changes can lead to higher physical demand, with stronger stimuli.
- The intensity and relationship between work and recovery times are decisive factors in adjusting the load.
- The perception of fatigue is usually lower in specific-type efforts, with a lower ratio with the heart rate or lactic intensity.
- Different behaviour has been observed in recovery in specific and intermittent efforts, which is why it would be advisable to act on the recovery mechanisms using training with movements and displacements specific to the game, as well as specific work and recovery times.

Conflict of interests

The authors declare to have no conflict of interest whatsoever.

Bibliography

1. Hornery DJ, Farrow D, Mujika I, Young W. Fatigue in tennis. Mechanicisms of fatigue and effect on performance. *Sports Med*. 2007;37:199-212.
2. Glaister M. Multiple-sprint work: methodological, Physiological, and experimental issues. *Int J Sports Physiol Perform.* 2008;3:107-12.
3. Bishop D, Spencer M, Duffield R, Lawrence S. The validity of a repeated sprint ability test. *J Sci Med Sport.* 2002;4:19-29.
4. Fernández-Fernández J, Méndez-Villanueva A, Pluim BM. Intensity of tennis match play. *Br J Sports Med*. 2006;40:387-91.
5. O'Donoghue PO, Ingram B. A notational analysis of elite tennis strategy. *J Sports Sci.* 2001;19:107-15.
6. Kovacs MS. Applied physiology of tennis performance. *Br J Sports Med*. 2006;40:381-85.
7. Méndez-Villanueva A, Fernández-Fernández J, Bishop D. Exercise induced homeostatic perturbations provoked by singles tennis match play with reference to development of fatigue. *Br J Sports Med.* 2007;41:717-22.
8. Fernández-Fernández J, Sanz-Rivas D, Fernández-Garcí B, Méndez-Villanueva A. Match activity and physiological load during a clay-court tournament in elite female players. *J Sports Sci.* 2008;26:1589-95.
9. Kovacs MS. Energy system-specific training for tennis. *Strength Cond J*. 2004;26:10-3.
10. Morante JC, Brotherhood JR. Automatic and behaviouralthermoregulations in tennis. *Br J Sports Med*. 2008;42:679-85.
11. Girard O, Lattier G, Maffiuletti NA, Micallef J-P. Millet GP. Neuromuscular fatigue during a prolonged intermittent exercise: Application to tennis. *J Electromyography Kinesiol.* 2008;18:1038-46.
12. Strojnik V, Komi PV. Fatigue after submaximal intensive stretch-shortening cycle exercise. *Med Sci Sports Exerc.* 2000;32:1314-9.
13. Martin V, Guillaume YM, Lattier G, Perrod L. Why does knee extensor muscles torque decrease after eccentric-type exercise?.*J Sports Med Phy Fit.* 2005;45:143-51.
14. Verrall GM, Slavotinek JP, Barnes PG. The effect of sports specific training on reducing the incidence of hamstring injuries in professional Australian Rules football players. *Br J Sports Med.* 2005;39:363-68.
15. Lees A. Science and the major racket sports: a review. *J Sports Sci.* 2003;21:707-32.
16. Matthews MJ, Heron K, Todd S, Tomlinson A, Jones P, Delextrat A, *et al.* Strength and endurance training reduces the loss of eccentric hamstring torque observed after soccer specific fatigue. *PhysTher Sport.* 2017;25:39-46.
17. Kovacs M, Roetert P, Ellenbecker E. Fixing the brakes! Deceleration: the forgotten factor in tennis specific training. *ITF Coaching Sport Sci Rev*. 2008;15:6-8.
18. Kovacs M. Movement for Tennis: The Importance of Lateral Training. *Strength Con J.* 2009;31:77-85.
19. Rampinini E, Sassi A, Azzalin A, Castagna C, Menaspà P, Cromagno D, *et al.* Physiological determinants of Yo-Yo intermittent recovery tests in male soccer players. *Eur J Appl Physiol.* 2010;108:401-9.
20. Tomlin DL, Wenger HA. The relationship between aerobic fitness and recovery from high intensity intermittent exercise. *Sports Med*. 2001;31:1-11.
21. Castagna C, Abt G, Manzi V, Annino G, Padua E, D'Ottavio S. Effect of recovery mode on repeated sprint ability in young basketball players. *J Strength Cond Res.* 2008;22:923-9.

22. Stojanovic M, Ostojic SM, Calleja-González J, Milosevic Z, Mikic M. Correlation between explosive strength aerobic power and repeated sprint ability in elite basketball players. *J Sports Med Phys Fit.* 2012;52:375-81.
23. Hoff J, Helgerud J. Endurance and strength training for soccer players - Physiological considerations. *Sports Med.* 2004;34:165-80.
24. Denadai BS, de Aguiar RA, de Lima LC, Greco CC, Caputo F. Explosive training and heavy weight training are effective for improving running economy in endurance athletes: A systematic review and meta-analysis. *Sports Med.* 2017;47:545-54.
25. Elliott B. Biomechanics and tennis. *Br J Sports Med.* 2007;40:392-6.
26. Reid M, Crespo M, Lay B, Berry J. Skill acquisition in tennis: Current research and practice. *J Sci Med Sport.* 2007;10:1-10.
27. Reid M, Schneiker K. Strength and conditioning in tennis: Current research and practice. *J Sci Med Sport.* 2008;11:248-56.
28. Glaister M. Multiple sprint work. *Sports Med*. 2005;35:757–77.
29. Mikkola J, Rusko H, Izquierdo M, Gorostiaga EM, Häkkinen K. Neuromuscular and cardiovascular adaptations during concurrent strength and endurance training in untrained men. *Int J Sports Med.* 2012;33:702-10.
30. Wilson JM, Marín PJ, Rhea MR, Wilson SM, Loenneke JP, Anderson JC. Concurrent training: a meta-analysis examining interference of aerobic and resistance exercises. *J Strength Cond Res.* 2012;26:2293-307.
31. Dupont G, Akakpo K, Berthoin S. The effect of in-season, high-intensity interval training in soccer players. *J Strength Cond Res*. 2004;18:584-9.
32. Juel C, Klarskow C, Nielsen JJ, Kustrup P, Mohr M, Bangsbo J. Effect of high-intensity intermittent training on lactate and H+ release from human skeletal muscle. *Am J Physiol Endocrinol Metab.* 2004;286:245-51.
33. Belfry GR. Effects of a Short Work/Shorter Rest Intermittent Exercise on Muscle Metabolic Status, VO_2, Hemoglobin Saturation and Performance. Doctoral Thesis. Department of Exercise Science. University of Toronto. 2010. Disponible en: https://tspace.library.utoronto.ca/.../Belfry_Glen_R_201011_PhD
34. Rozenek R, Funato K, Kubo J, Hoshikawa M, Matsuo A. Physiological responses to interval training sessions at velocities associated with VO_2max *J Strength Cond Res*. 2007;21:188-92.
35. Boutcher SH. High-Intensity Intermittent Exercise and Fat Loss. *J Obesity*. Revista electrónica. 2011(consultado 0412/2017). Disponible en: https://www.hindawi.com/journals/jobe/2011/868305/
36. Gerber T, Borg ML, Hayes A, Stathis CG. High-intensity intermittent cycling increases purine loss compared with workload-matched continuous moderate intensity cycling. European *J Appl Physiol.* 2014;114:1513-20.
37. Helgerud J, Hoydal K, Wang E, Karlsen T, Berg P, Bjerkaas M, *et al.* Aerobic high-intensity intervals improve VO_2max more than moderate training. *Med Sci Sports Exerc.* 2007;39:665-71.
38. Tabata I, Nishimura K, Kouzaki M, Hirai Y, Ogita F, Miyachi M, *et al.* Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO_2max. *Med Sci Sports Exerc.* 1996;28:1327-30.
39. Mueller SM, Aguayo D, Zuercher M, Fleischmann O, Boutellier U, Auer M, *et al.* High-Intensity Interval Training with Vibration as Rest Intervals Attenuates Fiber Atrophy and Prevents Decreases in Anaerobic Performance. *PlosOne*. 2015; 10: e0116764.
40. Wisloff U, Ellingsen O, Kemi OJ. High-intensity interval training to maximize cardiac benefits of exercise training? *Exerc Sport Sci Rev.* 2009;37:139-46.
41. Krustrup P, Hellsten, Y, Bangsbo J. Intense interval training enhances human skeletal muscle oxygen uptake in the initial phase of dynamic exercise at high but not at low intensities. *J Physiol*. 2004;559: 335-45.
42. Perry CGR, Heigenhauser GJF, Bonen A, Spriet LL. High-intensity aerobic interval training increases fat and carbohydrate metabolic capacities in human skeletal muscle. *App Physiol Nut Met.* 2008;33:1112-23.
43. Tordi N, Perry S, Harvey A, Hughson R. Oxygen uptake kinetics during two bouts of heavy cycling separated by fatiguing sprint exercise in humans. *J. Appl Physiol.* 2003;94:533-41.
44. Tuimil JL, Iglesias E, Dopico J, Morenilla L. Efectos del entrenamiento continuo e interválico de carga externa similar sobre la frecuencia cardiaca. *Motricidad Eur J Human Mov.* 2005;12:107-18.
45. Seiler S, Hetlelid KJ. The impact of rest duration on work intensity and RPE during interval training. *Med Sci Sports Exerc.* 2005;37:1601-7.
46. Bailey SJ, Romer LM, Kelly J, Wilkerson DP, DiMenna FJ, Jones AM. Inspiratory muscle training enhances pulmonary O(2) uptake kinetics and high-intensity exercise tolerance in humans. *J Appl Physiol.* 2010;109:457-68.
47. Suárez Rodríguez D. Entrenamiento de la Resistencia en el tenis. Tesis Doctoral. Universidad de Oviedo. 2015. Disponible en: http://hdl.handle.net/10651/36701
48. Jones TW, Howatson G, Russell M, French DN. Performance and neuromuscular adaptations following differing ratios of concurrent strength and endurance training. *J Strength Cond Res.* 2013;27:3342-51.
49. Brughelli M, Cronin J, Levin G, Chaouachi A. Understanding Change of Direction Ability in Sport: A Review of Resistance Training Studies. *Sports Med*. 2008;38;1045-63.
50. Young WB, McDowell MH, Scarlett BJ. Specificity of sprint and agility training methods. *J Strength Cond Res.* 2001;15:315-9.
51. Lakomy J, Haydon DT. The effects of enforced, rapid deceleration on performance in a multiple sprint test. *J Strength Cond Res.* 2004;18:579-83.
52. Dellal A, Keller D, Carling Ch, Chaouachi A, Wong DelP, Chamari K. Physiologic effects of directional changes in intermittent exercise in soccer players. *J Strength Cond Res.* 2010;24:3219-26.
53. Fernandez-Fernandez J, Sanz-Rivas D, Sanchez-Muñoz C, de la Aleja Tellez JG, Buchheit M, Méndez-Villanueva A. Physiological responses to On Court *vs* running interval training in competitive tennis players. *J Sports Sci Med.* 2011;10:540-5.
54. Suárez Rodríguez D, del Valle Soto M. A study of intensity, fatigue and precision in two specific interval trainings in young tennis players: high-intensity interval training versus intermittent interval training. *BMJ Open Sport Exerc Med.* Revista elecrónica. 2017 (consultado 0412/2017). Disponible en: http://bmjopensem.bmj.com/content/3/1/e000250.info
55. Hader K, Mendez-Villanueva A, Ahmaidi S, Williams BK, Buchheit M. Changes of direction during high-intensity intermittent runs: neuromuscular and metabolic responses. *BMC Sports Sci Med Rehabil.* 2014;6:2.
56. McMillan K, Helgerud J, Macdonald R, Hoff J. Physiological adaptations to soccer specific endurance training in professional youth soccer players. *Br J Sports Med.* 2005;39:273-7.
57. Impellizzeri FM, Marcora SM, Castagna C, Reilly T, Sassi A, Iaia FM, *et al*. Physiological and Performance Effects of Generic versus Specific Aerobic Training in Soccer Players. *Int J Sports Med.* 2006;27:483-92.
58. Little Th, Williams AG. Measures of exercise intensity during soccer training drills with professional soccer players. *J Strength Cond Res.* 2007; 21:367-71.
59. Hill-Hass SV, Dawson B, Impellizzeri FM, Coutts AJ. Physiology of small-sided games training in football: a systematic review. *Sports Med.* 2011;41:199-220.
60. Spencer M., Bishop D, Dawson B, Goodman C. Physiological and metabolic responses of repeated-sprint activities: specific to field-based team sports. *Sports Med.* 2005;35:1025-44.
61. Bravo DF, Impellizzeri FM, Rampinini E, Castagna C, Bishop D, WisloffU. Sprint *vs*. Interval training in football. *Int J Sports Med*. 2008;29:668-74.
62. Dellal A, Varliette C, Owen A, Chirico EN, Pialoux V. Small-sided games *versus* interval training in amateur soccer players: effects on the aerobic capacity and the ability to perform intermittent exercises with changes of direction. *J Strength Cond Res.* 2012;26:2712-20.
63. Wong P-l, Chaouachi A, Chamari K, Dellal A, Wisloff U. Effect of preseason concurrent muscular strength and high-intensity interval training in professional soccer players. *J Strength Cond Res.* 2010;24:653-60.
64. Zafeiridis A, Sarivasiliou H, Dipla K, Vrabal IS. The effects of heavy continuous versus long and short intermittent aerobic exercise protocols on oxygen consumption, heart rate, and lactate responses in adolescents. *Eur J Appl Physiol.* 2010;110:17-26.
65. Vergauwen L, Spaepen AJ, Lefevre J, Hespel P. Evaluation of stroke performance in tennis. *Occup Health Ind Med.* 1998;39:238-9.
66. Haydar B, Haddad HA, Ahmaidi S, Buchheit M. Assesing inter-effort recovery and change of direction ability the 30-15 intermittent fitness test. *J Sports Sci Med.* 2011;10:346-54.
67. Buchheit M, Al Haddad H, Millet GP, Lepretre PM, Newton M, Ahmaidi S. Cardiorespiratory and cardiac autonomic responses to 30-15 intermittent fitnestes in team sports players. *J Strength Cond Res.* 2009;3:93-100.
68. Kang J, Mangine GT, Ratamess NA, Faigenbaum AD, Hoffman JR. Influence of intensity fluctuation on exercise metabolism. *Eur J Appl Physiol.* 2007;100:253-60.
69. Girard O, Miller GP. Neuromuscular fatigue in racquet sports. *Phys Med Rehabil.* 2009;20:161-73.
70. Hamar D, Komadel L, Tkac M, Kuthanova O. Cinética de los parámetros ventilatorios y de intercambio de gases durante el ejercicio intermitente. *Arch Med Deporte.* 1989;21:11-5.