Original article

Effects of a HIIT protocol including functional exercises on performance and body composition

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Summary

Introduction: High Intensity Interval Training (HIIT) is one of the most effective ways to improve metabolic and cardiorespiratory factors, as well as to increase physical performance. Running or cycling HIIT protocols have been usually performed, but there are few research related to the effects of a HIIT protocol including functional strength exercises
Objectives: To compare the effects of two different HIIT protocols on the performance and the body composition.
Meterial and Method: 14 young males (years: 21,67 ±1,61; height 1,73 ± 0,06 m; weight: 76,07 ± 12,96 kg) took part in the study and they were divided into two randomly balanced groups: Cycling Group (GC) and Functional Training Group (GEF). Both groups worked out 2 days a week during a 4-week-period. GC performed 4 rep. x 30 seconds of bicycle sprint with 3 minutes recovery time. GEF performed a trial based on 30" work (high intensity)/15"rest, with 6 functional strength exercises consisting of elliptical bike, battle rope, agility ladder, kettlebell, burpees and jumps. These exercises were repeated 3 times in combination with 3 minutes recovery time. The following measurements were carried out before and after the training: Body composition, maximum oxygen uptake, T-test, maximum and mean power on cycle ergometer, blood lactate, as well as hear rate, blood pressure and hemoglobin.
Results: Significant changes were observed in the values referred to VO2max, maximum power, fat weight and fat percentage for both groups. Nevertheless, no significant difference was observed between groups.
Conclusion: A HIIT program based on functional strength exercises improved aerobic, anaerobic performance and body composition in a similar way than the HIIT program on a bicycle.

Key words:
HIIT. Functional training. Body composition. Maximum oxygen uptake. Power.

Efectos de un protocolo HIIT con ejercicios funcionales sobre el rendimiento y la composición corporal

Resumen

Introducción: El entrenamiento interválico de alta intensidad (HIIT) es uno de los medios más eficaces para mejorar la función metabólica y cardiorrespiratoria, así como para incrementar el rendimiento físico. Tradicionalmente se han utilizado protocolos HIIT basados en la carrera o el ciclismo, sin embargo pocos estudios han tratado de analizar los efectos de un protocolo HIIT que incluya ejercicios funcionales de fuerza.
Objetivos: Comparar los efectos sobre el rendimiento y la composición corporal de dos protocolos diferentes de HIIT.
Material y método: 14 varones jóvenes (edad: 21,67±1,61 años; altura: 1,73 ± 0,06 metros; peso: 76,07 ± 12,96 kg) participaron en el estudio y fueron divididos de forma balanceada y aleatoria en dos grupos experimentales: Grupo Ciclismo (GC) y Grupo Entrenamiento Funcional (GEF). Ambos grupos entrenaron 2 d/semana durante 4 semanas. El GC realizó 4 rep. x 30 seg. de sprint en bicicleta, con 3 min. de recuperación. El GEF realizó un circuito (30" trabajo/ 15" descanso) con 6 ejercicios funcionales de fuerza (elíptica, battle rope, escalera de agilidad, kettlebell, burpees y multisaltos). Esos ejercicios fueron repetidos 3 veces combinados con 3 minutos de recuperación. Las siguientes valoraciones fueron realizadas antes y después del programa de entrenamiento: Composición corporal, consumo máximo de oxígeno, T-Test, potencia máxima y potencia media en cicloergómetro, lactato, así como valores de frecuencia cardiaca, tensión arterial y hemoglobina.
Resultados: En ambos grupos se observó un aumento significativo de los valores de VO2máx y potencia máxima, así como un descenso en el peso graso y en el porcentaje graso tras el programa de entrenamiento. Sin embargo, no se observaron diferencias significativas entre grupos.
Conclusión: Un programa HIIT basado en ejercicios funcionales de fuerza produce mejoras sobre el rendimiento aeróbico, anaeróbico y la composición corporal similares a las conseguidas por un programa HIIT de sprint repetido en bicicleta.

Palabras clave:
HIIT. Entrenamiento funcional. Composición corporal. Consumo máximo de oxígeno. Potencia.

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Introduction

High-Intensity Interval Training (HIIT) involves intermittent maximal or supramaximal exercise (85-95% HRmax), interspersed with recovery periods[1–4]. Despite having a shorter duration than continuous aerobic training, training of this kind has proven effective when it comes to achieving cardiovascular, metabolic and skeletal muscle improvements[5–7]. HIIT, therefore, is an effective alternative to traditional endurance training because it requires less time and permits a greater volume of high-intensity exercise than continuous exercise[2].

HIIT protocols vary in terms of the type of activity, the intensity and the duration of the periods of activity and recovery. Most previous studies have used HIIT workouts with cycle ergometers and bursts of exercise lasting 10-30 sec. at 90-100% HRmax, repeated 4-6 times and with recovery periods of 1-4 min[8,9]. The study conducted by Whyte *et al.*[10] investigated the effects of HIIT on metabolic and vascular risk factors in sedentary men. The protocol consisted of 2 weeks of 6 sessions of 4-6 repeats of sprints on a cycle ergometer at "all-out" intensity lasting 30 seconds with recovery periods of 4.5 minutes between each repetition. A significant decrease in body weight and waist circumference, together with an increase in VO_2max and improved insulin sensitivity were observed. Rhodes[11] evaluated changes in aerobic and anaerobic metabolism produced by a HIIT workout programme on a cycle ergometer after daily training for 2 weeks involving bouts of exercise at maximum intensity lasting 15-30 seconds with breaks of 45-30 seconds, discovering significant increases in VO_2max and peak power. These studies showed that the adaptations produced depended on the relationship between work and rest. Buchheit *et al.*[12] suggested that in short HIIT workouts, the relationship between work and rest is crucial to maximising exercise time over 90% VO_2max and achieving greater adaptations. They concluded that work to rest ratios of >1 (i.e. exercise times which are longer than rest periods) were better suited to keeping exercise intensities above 90% VO_2max. Short exercise intervals with recovery periods longer than bouts of exercise, however, seemed to improve other physiological parameters, such as VT1, VT2 and anaerobic capacity[13].

Other HIIT programmes based on circuits of strength exercises also exist. Emberts *et al.*[14] showed that a HIIT training session based on the regime designed by Tabata *et al.*[15] consisting of four series x 4 minutes of functional strength exercises led to heart rate, VO_2max, lactate and RPE values above the range set by the American College of Sports Medicine[16] to improve breathing capacity. They also concluded that an intense session of HIIT involving kettlebells caused greater caloric expenditure than a session of repeated cycling sprints and proved effective in stimulating metabolic and cardiorespiratory responses[17].

Not many studies, however, have tried to investigate the effects of HIIT training programmes based on functional exercises (jumping, burpees, lunges, etc.) on performance and health. Buckley *et al.*[18] compared the effects of 6 weeks of training with a rowing HIIT programme with a multimodal form of HIIT based on strength exercises. Their results showed that the multimodal, strength-based HIIT programme led to similar aerobic and anaerobic adaptations to and greater increases in muscle performance than the HIIT rowing programme.

Therefore, the objective of this study was to analyse the long-term effects of a HIIT programme based on functional exercises on performance and body composition, and to compare such a programme with the effects produced by a cycling HIIT programme.

Material and method

Subjects

A total of 14 young men voluntarily took part in the study (age: 21.67±1.61 years old; height: 1.73 ± 0.06 metres, weight: 76.07 ± 12.96 kg).

All the subjects were healthy and physically active, but did not do any kind of specific training on a regular basis. They were all asked to maintain the diets they were following at the time and not to take any supplements. Each subject was informed of the procedure to be followed during the study and they all gave their informed consent in writing. The experiment was developed and carried out with the approval of the Committee of Biomedical Ethics at the University of Extremadura (Spain), respecting the criteria set out in the 2008 Declaration of Helsinki.

Experimental design

The study was conducted over a period of 6 weeks; the first and the last week were used for measurements and the other 4 weeks to follow the training programmes. The experimental design was based on a cross sectional study, in which the 14 participants were randomly divided into two groups: a Functional Training Group (FTG), which did HIIT using a strength circuit, and a Cycling Group (CG), which did HIIT based on cycling. Both programmes were high intensity and involved incomplete recovery times. These protocols were chosen because previous research had shown that the relationship between work and rest used in this study proved effective at causing cardiorespiratory and metabolic adaptations[17].

Each training protocol was carried out twice a week, increasing the training volume in the last two weeks. The two protocols started with a warm-up to favour joint mobility (ankles, knees, hips, shoulders and neck), followed by 5 minutes of cycling at 50-60 rpm.

The FTG followed a training protocol mainly made up of functional exercises involving the major muscle groups.

This consisted of a circuit with 6 different exercises. Each exercise lasted 30" at "all-out" effort, while the rest between exercises lasted 15". On completing the circuit, they rested for 3 minutes (Figure 1). The circuit was repeated 3 times in each session in the first 2 weeks. Then in the last two weeks, it was completed 4 times per session. The workout consisted of the following exercises: elliptical trainer, battle ropes alternating squats and waves, agility ladder, swing kettlebell (10-12 kg), burpees and multi jumps with hurdles.

The CG did HIIT based on cycling, consisting of four repeats of 30-second sprints on a bicycle with power meter (Cycle Ops400 pro, Saris Cycling Group, USA) at between 100 and 120rpm, with a load equal to 100w above the average power of each subject and three minutes'

Figure 1. Diagram - summary of the circuit used in the FTG training protocol.

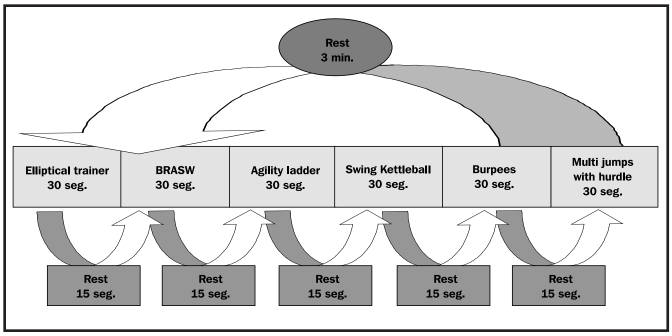
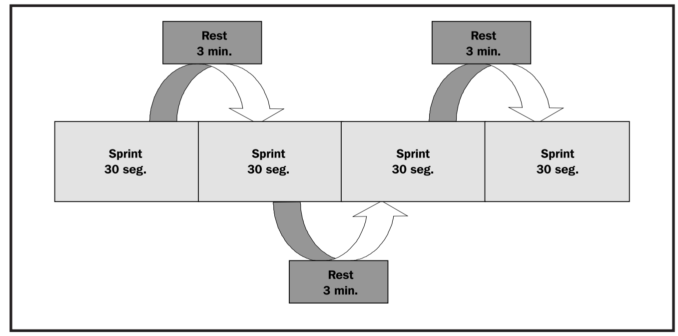


Figure 2. Diagram - summary of the characteristics of the CG training protocol.



rest between each sprint (Figure 2). Each subject's average power was obtained from measurements taken before the training sessions, in the first week. The number of repetitions of the sprints was increased to 6 in weeks 3 and 4.

Measurements

Measurements were taken before and after the 4 weeks of training sessions, in the first and last week of the study, on two different days, with at least 48 hours in between to rule out the influence of fatigue.

On the first day, the subjects were asked to come to the laboratory to have anthropometric measurements taken, according to the criteria established by ISAK[19]. Their height and body weight were measured using a portable stadiometer (Seca 213, Germany) and their body mass index (weight/height^2) was calculated. Their skinfolds and muscle circumferences were also measured in order to estimate their muscle mass and fat mass percentages using anthropometric equations[20].

The subjects were then taken to a sports hall where they performed the T-test and Yo-Yo test.

The T-test allowed us to measure their agility and speed of movement. This test was performed prior to the Yo-Yo test to prevent fatigue from bearing an influence. The T-test was carried out with forward, sideways and backward movements. 4 cones were required. To perform the test, cone A was used as a starting point, cone B was placed 10 yards (9.14 metres) in front of it and cones C and D were placed 5 yards (4.57 metres) to each side of cone B. Photocells (Chronojump; Boscosystem; Spain) were placed at cone A to record the time it took to perform the test. Each participant did the test twice and their best time was chosen.

The Yo-Yo test was used to indirectly measure VO_2max by subsequently applying a set of calculations[21]. This test consisted of running a distance of 20 metres and back, with breaks of 10 seconds in between each shuttle. To establish distances, we used a tape measure and employed a computer with speakers so that the subjects could hear properly. The test ended when each individual could no longer keep up pace.

On the second day, and in all events after 48 hours of rest, the subjects were asked to return to the laboratory, where their blood pressure was taken using a sphygmomanometer, their total haemoglobin was measured using a specific analyser (HemoCue 201, Angeholm, Sweden) and a test was performed on a bicycle with power meter (Cycle Ops400 pro, Saris Cycling Group, USA) to measure their average and maximum power during anaerobic exercise.

To measure their average anaerobic power, the subjects had to maintain maximum effort on the bicycle for 60 seconds and the average watts maintained in this period were recorded. Maximum power was determined on the basis of the peak power (measured in watts) achieved during the first 10 seconds of exercise. The subjects started with a 5 minute warm-up pedalling at 50-60 rpm. Then, just before the 60-second test, they were told to increase their pedalling rate to 120 rpm and the resistance of the power meter was raised, establishing a target power of 500 watts. During the test, the subjects had to maintain a rate of over 120 rpm, so the load was gradually reduced throughout so the rate did not drop. On completing the test, lactate samples were taken and analysed in a lactate analyser using Lactate Scout + (which has a margin of error of 0.2 mmol). During the test itself, maximum heart rate reached and average heart rate during the 60 seconds were recorded. These figures were obtained using a heart rate monitor (PowerCal, CycleOps, USA).

Statistical analysis

When all the data had been collected, the statistics program SPSS 19.0 for Windows was used to analyse them.

The Shapiro-Wilk test was applied to verify normal data distribution and Levene's test was used to assess the equality of variances.

Since the sample consisted of a small number of subjects and the aforementioned requirements were not met, non-parametric tests were used. The comparisons between the conditions of intervention (FTG *vs* CG) for each variable were subjected to the Mann-Whitney U test and the differences in subjects were studied using the Wilcoxon test.

The level of significance was set at $p \leq 0.05$, with a confidence level of 95%. Mean and standard deviation (SD) were used as descriptive statistics. The data were expressed as the mean ± standard deviation.

Limitations

This research has certain limitations. The number of participants was small, thereby conditioning the power of the study. Furthermore, the subject's diets were not comprehensively controlled and during the training sessions, the participants reported that they had exerted themselves to maximum intensity, but no physiological data to quantify internal load, such as heart rate, lactate concentrations, CK or LDH, were taken.

Results

Table 1 shows the performance values. In the FTG, significant increases in VO_2max ($p = 0.013$) and maximum power ($p = 0.040$) were observed. Significant increases in VO_2max ($p = 0.011$) and maximum power ($p = 0.015$) were also noted in the CG, as was an increase in average power ($p = 0.019$). However, no significant differences were observed between the groups.

Table 2 shows the body composition and anthropometry values. In the FTG, significant decreases were observed in fat weight ($p = 0.047$) and fat percentage ($p = 0.049$). Similar results were observed in the CG, with significant decreases in both fat weight ($p = 0.025$) and fat percentage ($p = 0.022$). No significant differences were observed between the groups.

Table 3 shows the blood pressure and haemoglobin values. No significant differences were observed.

Discussion

The results of this study show that, regardless of the type of protocol used (functional exercises or cycling), HIIT improves performance and body composition parameters.

An increase in VO_2max was observed after training in both groups. Other studies have also shown that HIIT (4-6 sessions per week) over several weeks improves VO_2max in active people[4,22,23].

This improvement in VO_2max may be due just as much to adaptations in muscle oxidative potential as it is to increases in mitochondria and mitochondrial enzyme activity, permitting greater use of the energy available[24].

Furthermore, the increase in cardiac contractility and pumping capability resulting from high-intensity exercise could also explain the increase in VO_2max through an increase in stroke volume[25,26].

Table 1. Performance values (Mean ± SD).

	FTG (n=7)		CG (n=7)	
	Pre	Post	Pre	Post
T-test (sec.)	10.03 ± 0.35	10.01 ± 0.41	10.44 ± 0.81	10.32 ± 0.69
VO_2max (ml x min/kg)	44.96 ± 1.69	47.31 ± 3.07*	45.37 ± 3.91	49.21 ± 5.79*
Maximum power (W)	573.50 ± 37.56	643.66 ± 54.68*	572.71 ± 134.82	684.42 ± 128.20*
Average power (W)	312.82 ± 32.12	329.66 ± 31.77	295.85 ± 67.77	336.71 ± 57.12*
Maximum HR (ppm)	183.33 ± 3.55	180.33 ± 5.60	178.57 ± 4.57	181.00 ± 6.00
Average HR (ppm)	176.50 ± 5.35	173.50 ± 4.54	169.14 ± 7.88	172.42 ± 11.47
End lactate (mmol/L)	14.40 ± 1.88	12.43 ± 2.22	13.08 ± 2.08	13.90 ± 3.62

*Significant difference between groups ($p \leq 0.05$).

Table 2. Body composition and anthropometry values (Mean ± SD)

	FTG (n=7)		CG (n=7)	
	Pre	Post	Pre	Post
Weight (kg)	75.38 ± 9.89	75.03 ± 9.99	76.67 ± 15.92	76.64 ± 15.05
BMI	25.15 ± 2.79	25.03 ± 2.79	24.98 ± 3.95	24.97 ± 3.59
Muscle weight (kg)	36.17 ± 4.70	36.28 ± 5.06	36.67 ± 8.26	37.19 ± 7.47
Muscle %	48.03 ± 1.95	48.37 ± 2.18	48.14 ± 3.61	48.65 ± 3.85
Fat weight (kg)	10.35 ± 2.59	9.98 ± 2.47*	10.98 ± 4.33	10.44 ± 4.36*
Fat %	13.61 ± 2.00	13.20 ± 2.03*	14.09 ± 3.96	13.33 ± 4.12*

*Significant difference between groups ($p \leq 0.05$).

Table 3. Blood pressure and haemoglobin values (Mean ± SD)

	FTG (n=7)		CG (n=7)	
	Pre	Post	Pre	Post
Systolic pressure (mmHg)	116.33 ± 8.64	120.16 ± 16.57	120.00 ± 8.96	122.42 ± 14.16
Diastolic pressure (mmHg)	64.33 ± 10.83	67.66 ± 10.09	64.42 ± 9.39	72.42 ± 10.13
Haemoglobin (g/dL)	14.40 ± 1.59	13.78 ± 0.40	14.00 ± 1.37	14.31 ± 1.33

After training, increases in maximum power and average power (in the latter case, only in the CG) on the bicycle with power meter were also observed. Most previous studies involving short-term high-intensity interval training show improvements in maximum and average power[27.28]. Such improvements could be explained by the peripheral adaptations that HIIT causes, such as improvements in the rapid replenishment of phosphocreatine (PC) stores and optimisation of the role played by oxymyoglobin as an intracellular oxygen store[12].

In the initial phase of exercise of this kind, oxygen does not reach the values of the real demand for it due to delayed VO_2 kinetics. Consequently, the energy needed for ATP resynthesis must be obtained from stored intracellular oxygen and/or via the anaerobic pathway, oxymyoglobin and phosphocreatine playing important roles.

Other research concludes that improved power levels may be due to neuromuscular adaptations, with an increase in the recruitment or activation of motor units[29], a significant increase in type IIa fibres and a decrease in type I fibres[30].

An increase in average power was only observed in the CG. This could be because the CG did cycling training, so the evaluation test carried out was more specific for this group than it was for the FTG. Previous studies conclude that the results of evaluation tests are better when more specific tests involving mechanical components similar to those used in training are employed[31,32]. On this basis, we can say that average power only increased in group B (the group which trained on bicycles) due to the specificity of the test chosen to measure power.

As for the body composition measurements, decreases in fat weight (kg) and body fat percentage were observed. Similar results have been obtained in previous studies in which decreases in fat percentage were recorded after monitored HIIT programmes involving a cycle ergometer[33-35].

According to several authors, this decrease in fat mass could be due to increases in catecholamines[36], the growth hormone[37] and β hydroxyacyl-CoA dehydrogenase activity[38]. These factors play an important role in the stimulation of lipolysis and the release of subcutaneous and intramuscular fat tissue. Boutcher[8], meanwhile, concluded that after HIIT, there is an increase in the oxidation of fatty acids due to the need to remove lactate and hydrogen ions, and resynthesize muscle glycogen.

Finally, no significant difference was observed between one group and the other in terms of performance and body composition. While it is true that few studies have examined the effects produced by functional strength exercise HIIT, those studies reviewed obtained results similar to ours. Buckley *et al.*[18] concluded that multimodal HIIT including strength exercises caused the same aerobic and anaerobic adaptations as rowing HIIT. In the same line, McRae *et al*.[39] studied the effects of HIIT based on full body movement (burpees, jumps, mountain climbers, etc.) after 4 weeks of training, finding improvements in aerobic capacity similar to those produced by continuous treadmill training.

This similarity could be because both protocols involved very high intensities and the physiological adaptations were similar. We should not ignore the fact that HIIT has consistently demonstrated increases in aerobic and anaerobic performance compared with aerobic endurance exercise[40,41]. This could indicate that the exercise intensity variable may play a more important role than the type of exercise in training of this kind, although more research is required in this area. Our research, however, has certain limitations. The number of participants was small, thereby conditioning the power of the study and meaning that the results should be interpreted with caution, especially if intending to extrapolate them to other contexts. Furthermore, the subject's diets were not comprehensively controlled and during the training sessions, the participants reported that they had exerted themselves to maximum intensity, but no physiological data to quantify internal load, such as heart rate, lactate concentrations, CK or LDH, were taken. Therefore, more research needs to be carried out to find out more about the physiological, metabolic and functional-anatomical effects that HIIT protocols based on functional strength exercises can have on the body.

Conclusions

We can conclude that a HIIT programme based on functional strength exercises led to improvements in aerobic and anaerobic performance and body composition similar to those achieved with a HIIT programme involving repeated cycling sprints. These findings may have important implications for the way in which personal trainers and fitness specialists design sessions and plan training.

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Conflict of Interests

The authors declare that they are not subject to any type of conflict of interest.

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