

# Frequency of High Intensity Circuit Training and diet. Effects on performance and health in active adults: Randomized Controlled Trial

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## Summary

**Introduction:** High intensity circuit training (HICT) has been proven to be one of the most efficient methods to improve physical and physiological parameters using short training sessions. The objective of this study was to discern the effects of a 6-week HICT program in active persons, modifying the training frequency.

**Methods:** Group A trained two days a week (n=7), group B trained 3 days a week (n=7), while the control group did not perform any training (n=7). All groups followed a diet program adapted to the strength training requirements. The training sessions were comprised of 4 series of 10 self-loading exercises, including sprints and supporting materials, with 1-2 minute rests between series, exerting an 80-95% maximum cardiac frequency intensity. A 1:1 training load density was used, with 20-25 second intervals between work and recovery.

**Results:** Groups A and B significantly improved in body composition and strength tests (bench press and back squats), compared to the control group as well as in the intragroup analysis when comparing before and after the intervention. However, no significant differences were observed when comparing the two experimental groups. No changes in blood pressure were observed in any inter- or intragroup analysis.

**Conclusion:** An adapted nutritional program and a 2-day/week HICT program seems to be sufficient in order to obtain significant improvements in strength and body composition in healthy active subjects, although blood pressure was not affected.

## Key words:

Body composition.  
Muscle mass. Fat mass.  
Circuit training.  
Functional training.

## Frecuencia de entrenamiento en circuito de alta intensidad y dieta. Efectos sobre rendimiento y salud en adultos activos: Ensayo Controlado Aleatorizado

### Resumen

**Introducción:** El entrenamiento en circuito de alta intensidad (HICT) ha demostrado ser uno de los métodos de entrenamiento más eficaces por la mejora de parámetros físicos y fisiológicos utilizando cortos periodos de entrenamiento. El objetivo de este estudio fue conocer los efectos de un programa de 6 semanas de entrenamiento HICT en personas activas, modificando la frecuencia de entrenamiento.

**Método:** El grupo A entrenó con una frecuencia de 2 días a la semana (n=7), el grupo B (n=7) 3 días a la semana y el grupo control no realizó ningún entrenamiento (n=7). Ambos grupos siguieron un programa dietético adaptado a los requerimientos de los entrenamientos de fuerza. Realizaron un mismo entrenamiento compuesto de 4 series de 10 ejercicios con auto-cargas, con material auxiliar y carreras, con descanso de 1 y 2 minutos entre las series, a una intensidad entre el 80-95% de la FC máx. Se utilizó una densidad de la carga de entrenamiento de 1:1 con intervalos de trabajo y recuperación de 20 a 25 segundos.

**Resultados:** Los grupos A y B mostraron, en comparación al grupo control, mejoras en la composición corporal y en los test de fuerza (*press* de banca y sentadilla) antes y después de la intervención con HICT. Sin embargo, no se obtuvieron diferencias cuando se compararon los resultados obtenidos entre ambos grupos experimentales. Las diferencias se observaron frente al grupo control, ya que tanto el grupo A como el grupo B mostraron mejoras significativas en la composición corporal y la fuerza. La presión arterial no presentó diferencias en las comparaciones inter e intragrupo.

**Conclusión:** Un programa dietético nutricional adaptado y una frecuencia de entrenamiento de HICT de dos días parece ser suficiente para obtener mejoras en la fuerza y la composición corporal, aunque no para mejorar la presión arterial en sujetos sanos activos.

## Palabras clave:

Peso corporal.  
Masa muscular. Masa grasa.  
Entrenamiento en circuito.  
Entrenamiento funcional.

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## Introduction

High intensity circuit training (HICT)<sup>1</sup> is a training method where high intensity repetitions are performed, followed by complete pauses or active recoveries before commencing another repetition at the same programmed intensity<sup>2</sup>. The activities are generally of short duration but vigorous, with complete rests or low-intensity exercises performed between series. This method dramatically stimulates the body and causes a physiological readjustment, as well as requiring significantly less time and fewer exercises<sup>3</sup>.

The most relevant responses or acute effects that occur during and after HICT exercises are the use of fat as energy substrate as well as other physiological adaptations, such as increased catecholamine and cytokine production<sup>4</sup>. At the peripheral level, both blood vessels and muscles develop functional and structural adaptations<sup>5,6</sup>. In this sense, HICT is becoming of increased interest for glycaemic control in type II diabetes, having a higher and more prolonged post-exercise hypoglycaemic effect than moderate intensity exercises of the same or longer duration<sup>7</sup>. Other chronic adaptations include increased resting glycogen storage<sup>1</sup> and improved resting blood pressure levels<sup>8</sup>.

In this context, HICT can exert significant changes in adult body composition, especially regarding fat mass. This morphological change is one of the most health-related factors, as lower fat mass is associated with decreased mortality and co-morbidity risks<sup>9</sup>. Furthermore, these changes can be further enhanced with a nutritional-diet intervention, as combining exercise with an individualized adapted diet can positively affect body compositions of strength-related athletes<sup>10</sup>.

The ACSM (American College Sports Medicine) recommendations regarding sports practice<sup>11</sup> present healthy sports practice guidelines, and grades them in relation to the level of scientific evidence (graded A-D). These recommendations include those related with frequency, intensity, training type, volume, etc. In this sense, regarding resistance training, there is no consensus if 2 or 3 days/week training is preferable. Certain authors, such as Westcott and colleagues<sup>12</sup> have already questioned this and have tried to study their effects on body composition and blood pressure, among other parameters, in resistance training but not HICT.

Therefore, the aim of this study is to understand the effect HICT exerts on sports performance variables, body composition and blood pressure. To this end, two different HICT programmes with different weekly frequencies were compared, with the hypothesis that increasing the number of training days per week, at the same duration, the subjects would obtain better results in the variables studied.

## Material and method

### Design

A quasi-experimental design was performed for 6 weeks in 2 experimental groups and one randomized control group (blind distribution). The variables (explained below) were assessed in all the subjects one week before the intervention, as well as week 0 and 7, performed by the same researcher using the same protocol and at the same moment of the day.

### Sample

The volunteers were taken from different sports centres in Spain, Región de Murcia, choosing from adult males. A meeting was held with the interested collaborators to inform of the research, the conditions and requirements, as well as the possible benefits and inherent risks of the training program. Ethical approval was given by the Ethical Committee of San Antonio Catholic University of Murcia in Spain, and was performed in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national) and with the Helsinki Declaration of 1975 revised in 2008.

The inclusion criteria were: functionally independent males of 21-40 years of age; no muscular, ligament, bone, nerve or articular pathology that may interfere with the training program; no cardiovascular or cardiorespiratory problems. Also, the volunteers must be considered to be physically active for the past 5 years, based on the definition published in Martin *et al.*<sup>13</sup>, where an active individual is that who exercises or trains (aerobic, resistance or mixed) at least 3 times a week in non-consecutive days, and must have at least 5 years of experience in resistance training.

The exclusion criteria are: under pharmacological treatment or supplements; performs other sports activities that may influence in the results of the study; does not respect the training program or attend the training sessions; does not fulfil one of the inclusion criteria.

A total of 21 male volunteers were selected. A simple randomized sampling was performed to group the volunteers into two experimental (n=7 each) and one control group (C, n=7) (Figure 1). Both experimental groups performed the same HICT training program, with the only difference being the number of weekly sessions (2 per week in Group A, 3 per week in Group B). The program lasted a total of 6 weeks. Group C did not perform any physical exercise. Because all participants used smartphones, the physical activity of the control group and the experimental groups outside the intervention program were controlled by "Google fit" app (step count) free for iOS and android.

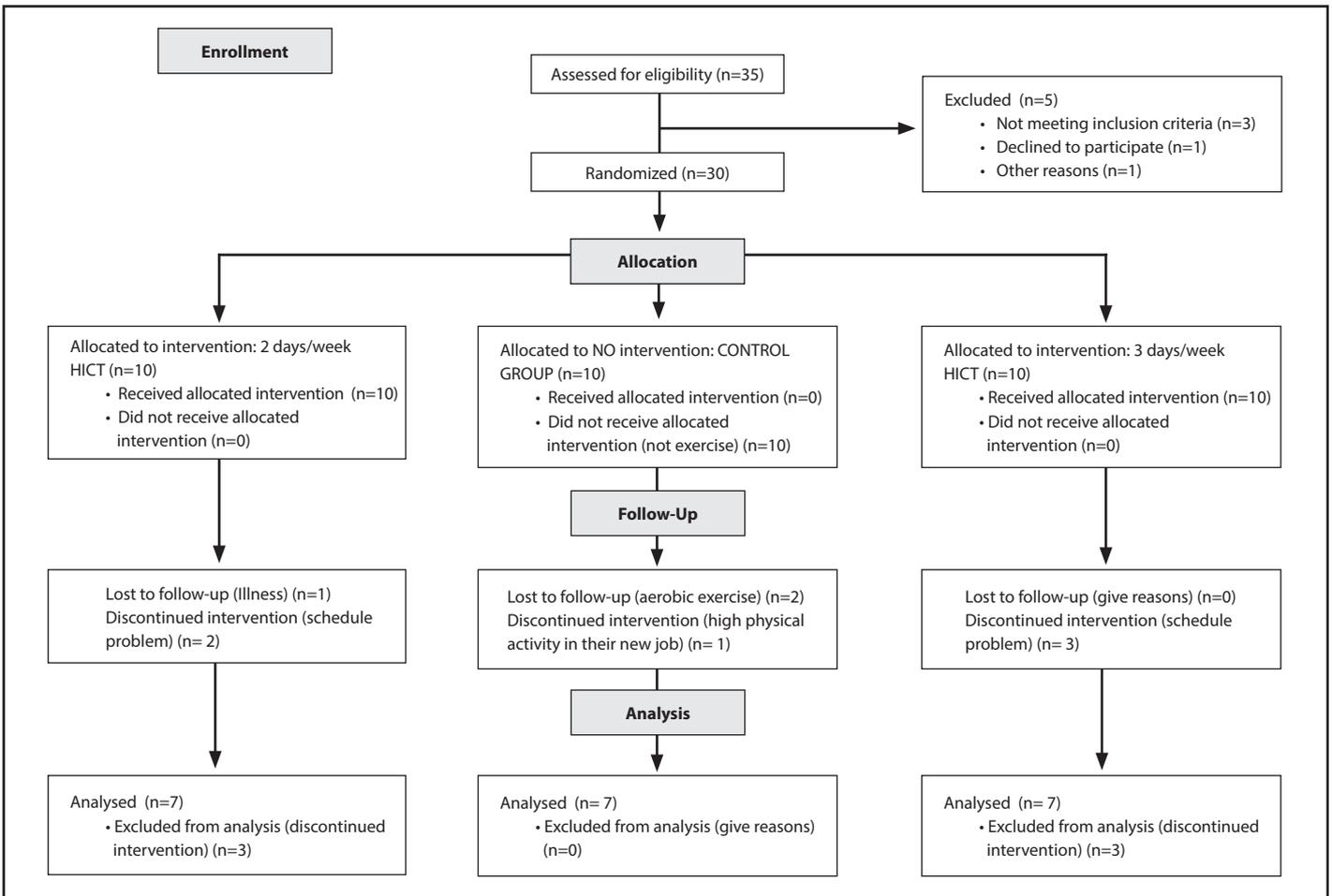
### Body composition

The ISAK protocol was used in order to normalize the body composition values of the volunteers<sup>14</sup>. The anthropometric variables<sup>10</sup> used to estimate fat mass (percentage and weight) using Carter's formula were measured with the following materials: Harpenden plycometer (Baty International Ltd., West Sussex, United Kingdom) with a 2 mm precision and flexible metallic metric tape with 1mm precision; weight was measured using a digital scale<sup>15</sup> Tanita BC-418 MA (Tanita Corporation, Arlington Heights, IL) with a 100 g precision. Standing height without shoes was measured using a Seca 202 stadiometer (Seca, Hamburg, Germany) to the nearest 0.1 cm.

### Blood pressure

Arterial blood pressure was measured in all the participants at the beginning and end of the intervention. This was performed at rest, with the volunteers seated for at least 10 minutes. The measurement was performed with a digital tensiometer (Omron MX3 Plus, model HEM-742-E)<sup>16</sup>, following the recommendations published in Schoenfeld *et al.*<sup>17</sup>

Figure 1. Consort flow diagram.



## Strength test

The 1 REP MAX (1RM) bench press and squat tests were performed following NSCA recommendations described by Schoenfeld in 2016<sup>18</sup>.

## Maximum cardiac frequency

Cardiac frequency was measured using Polar Team for Apple systems and Polar H7 Bluetooth pulsometers<sup>19</sup>.

## Diet program

All the participants of the experimental groups and control group followed the same diet program, adapted to their energy requirements<sup>14</sup>. Before commencing the training intervention, the control and experimental groups assisted a nutritional education workshop to inform them of the diet plan. The diet plan consisted in 2 g/kg body weight proteins, 5-8 g/kg body weight carbohydrates and 1 g/kg body weight lipids<sup>20</sup>. An isocaloric diet was provided, with no energy restriction. All the participants were given indications as to what foods could be consumed and when to eat. A dietitian was provided for the participants to contact in case of any doubt.

## Training program

The training program lasted 6 weeks. Group A performed 2 HICT sessions per week at a 1:1 density, group B performed 3 sessions, while Group C did not perform any training.

The duration of the intervals was established at 20-25 seconds of effort, with an intensity of 80-95% HRmax.

Metabolic exercises were performed, with self-loads. These exercises were organized into 3 exercises for upper body muscle groups, 3 for lower hemisphere muscles, 2 for core muscles (abdominal and lumbar) and 2 running muscle groups. Also, they were divided in calisthenics, with materials and runs.

Therefore, a total of 10 exercises were performed, with a focus on metabolic exercises with self-load, multi-muscle, poly-articulate, and of intramuscle coordination. The participants were supervised by a graduate in Sports Science in order to ensure that the voluntary fatigue was achieved in a safe manner, and that proper resting periods were performed. The total training time was of approximately 50 minutes (4 series).

The training session commenced with a general warm-up, consisting in a continuous run, adding dynamic exercises every 3 minutes.

Afterwards, 2 minutes of vegetative activity was performed, at a 50-60% maximum CF intensity. Dynamic stretching of the muscle groups to use in the training session was executed. Once the training session was completed, 2 progressive 10-15 metre sprints were performed, with no rests between them. See Annex for the specifications of the training program.

## Statistics

The SPSS® software (version 24.0 IBM for Windows) was used for the statistical analysis. Results were presented as mean  $\pm$  standard deviation (SD). Were performed descriptive analysis, Kolmogorov-Smirnov normality distribution test, T-test for related samples, and inter-subject one-way ANOVA as well as post-hoc tests (Tukey and Games-Howell) depending on if the variances were homogenous. Parametric tests were used as the data analysed presented a normal distribution. The 95% confidence interval (95% CI) were calculated. Level of significance was fixed at  $p < 0.05$ .

A correlation analysis for each group was performed separately, and a linear regression was assessed with the variables that presented a certain level of significance. Effect Size (ES) was calculated according to Cohen guidelines<sup>21</sup>. Threshold values for Cohen ES statistics were  $>0.2$  (small),  $>0.6$  (moderate), and  $>1.2$  (large).

## Results

The descriptive analysis of the samples divided by groups and moment (pre or post-intervention) is shown in Table 1, as well as the results of the inter-group and intra-group means.

The comparison analysis of related samples indicated that both groups presented significant differences after the 6-week HICT intervention. On one hand, group A significantly improved in the reduction of triceps skinfolds (95%CI=[0.23736 -3.04836]; ES=0.319), as well as in the abdominal (95%CI=[0.41479-6.44236]; ES= 0.463) and total sum of the 6 folds (95%CI=[3.02456-17.97544]; ES=1.388). Also, decreased fat

**Table 1. Description data of the sample and significant results after related sample comparison and differences between groups.**

	GROUP A (n=7): 2 HICT sessions		Group B (n=7): 3 HICT sessions		Group C (n=7): Control	
	Pre-Intervention Mean SD	Post-Intervention Mean SD	Pre-Intervention Mean SD	Post-Intervention Mean SD	Pre-Intervention Mean SD	Post-Intervention Mean SD
Age	31.1 $\pm$ 7.9	31.1 $\pm$ 7.9	27.4 $\pm$ 5.9	27.4 $\pm$ 5.9	30.8 $\pm$ 5.8	30.8 $\pm$ 5.8
<b>Body composition</b>						
Weight (kg)	77.2 $\pm$ 8.1	77.2 $\pm$ 7.0	70.5 $\pm$ 7.1	70.0 $\pm$ 6.5	77.5 $\pm$ 8.3	77.6 $\pm$ 8.3
Height	178.1 $\pm$ 10.9	178.1 $\pm$ 10.9	172.1 $\pm$ 2.7	172.1 $\pm$ 2.7	179.4 $\pm$ 9.3	179.4 $\pm$ 9.3
BMI (kg/m <sup>2</sup> )	24.4 $\pm$ 1.3	24.4 $\pm$ 1.6	23.9 $\pm$ 2.7	23.7 $\pm$ 2.5	24.3 $\pm$ 1.4	24.3 $\pm$ 1.5
Waist (cm)	82.6 $\pm$ 6.1	81.4 $\pm$ 5.8	78.9 $\pm$ 5.6	78.4 $\pm$ 6.1	82.7 $\pm$ 6.3	83.3 $\pm$ 6.8
Hip (cm)	96.5 $\pm$ 5.3	95.9 $\pm$ 3.4	67.4 $\pm$ 39.2	92.1 $\pm$ 4.3	96.4 $\pm$ 5.2	96.5 $\pm$ 5.3
Waist-Hip Ratio	0.8 $\pm$ 0.0	0.8 $\pm$ 0.0	0.8 $\pm$ 0.0	0.8 $\pm$ 0.0	0.9 $\pm$ 0.0	0.9 $\pm$ 0.0
Triceps skinfold (mm)	13.2 $\pm$ 5.3	11.6 $\pm$ 4.7 <sup>a</sup>	12.5 $\pm$ 4.7	8.8 $\pm$ 3.4 <sup>**a</sup>	13.2 $\pm$ 5.3	13.4 $\pm$ 5.2
Subscapular skinfold (mm)	13.6 $\pm$ 5.0	11.5 $\pm$ 2.5	11.3 $\pm$ 1.6	10.6 $\pm$ 2.1	14.6 $\pm$ 5.0	14.8 $\pm$ 5.0
Supraespal skinfold (mm)	15.2 $\pm$ 3.3	14.6 $\pm$ 2.7	15.1 $\pm$ 1.9	14.0 $\pm$ 1.7 <sup>*</sup>	16.2 $\pm$ 3.7	16.4 $\pm$ 3.5
Abdominal skinfold (mm)	24.1 $\pm$ 8.0	20.6 $\pm$ 7.1 <sup>a</sup>	22.6 $\pm$ 7.9	19.6 $\pm$ 8.1 <sup>a</sup>	22.1 $\pm$ 9.0	22.4 $\pm$ 9.1
Thigh skinfold (mm)	15.4 $\pm$ 6.0	14.0 $\pm$ 7.1	14.6 $\pm$ 3.9	13.9 $\pm$ 4.3	17.0 $\pm$ 5.8	17.2 $\pm$ 6.3
Calf skinfold (mm)	9.4 $\pm$ 4.1	8.1 $\pm$ 2.6	10.3 $\pm$ 4.6	7.4 $\pm$ 2.9 <sup>*</sup>	9.7 $\pm$ 4.4	9.7 $\pm$ 4.0
Skinfold sum of 6 (mm)	80.9 $\pm$ 27.9	70.4 $\pm$ 22.5 <sup>a</sup>	76.4 $\pm$ 19.5	64.1 $\pm$ 18.1 <sup>**a</sup>	81.2 $\pm$ 28.1	82.4 $\pm$ 28.1
Fat mass (%)	11.1 $\pm$ 2.9	10.0 $\pm$ 2.4 <sup>a</sup>	10.6 $\pm$ 2.1	9.3 $\pm$ 1.9 <sup>**a</sup>	14.8 $\pm$ 4.2	15.0 $\pm$ 4.2
Fat mass (kg)	8.6 $\pm$ 2.7	7.8 $\pm$ 2.3 <sup>a</sup>	7.5 $\pm$ 1.8	6.5 $\pm$ 1.5 <sup>a</sup>	11.6 $\pm$ 3.9	11.8 $\pm$ 3.9
<b>Strength test Results</b>						
Bench Press RM (kg)	76.3 $\pm$ 14.2	85.4 $\pm$ 11.8 <sup>**a</sup>	75.0 $\pm$ 17.4	82.9 $\pm$ 15.2 <sup>a</sup>	74.6 $\pm$ 11.2	75.1 $\pm$ 13.5
Squat RM (kg)	104.7 $\pm$ 19.2	120.0 $\pm$ 18.2 <sup>a</sup>	103.7 $\pm$ 22.0	121.4 $\pm$ 20 <sup>**b</sup>	102.7 $\pm$ 21.2	98.9 $\pm$ 19.8
<b>Blood pressure Results</b>						
Systolic pressure (mmHg)	138.9 $\pm$ 10.3	116.0 $\pm$ 46.6	134.7 $\pm$ 8.8	130.7 $\pm$ 10.4	139.6 $\pm$ 9.3	140.1 $\pm$ 9.6
Diastolic pressure (mmHg)	77.0 $\pm$ 4.4	62.0 $\pm$ 24.7	62.7 $\pm$ 25.3	53.7 $\pm$ 36.0	78.3 $\pm$ 4.4	77.9 $\pm$ 5.5

HICT: High Intensity Circuit Training; SD: Standar Deviation; BMI: Body Mass Index; RM: Reptetitium Maximum; \*: Significant difference pre vs post test ( $p < 0.05$ ); \*\*: Significant difference pre vs post test ( $p < 0.01$ ); <sup>a</sup>: Significant difference with Control Group ( $p < 0.05$ ); <sup>b</sup>: Significant difference with Control Group ( $p < 0.01$ ).

mass was observed, both in kg (95%CI=[0.26181-1.45842]; ES=0.319) and percentage (95%CI=[0.31788-1.88922]; ES=0.413). The strength tests also presented significant differences, with improvements observed in the 1RM bench press (95%CI=[-13.62394 - -4.66177]; ES=0.697), and squat (95%CI=[-25.71796 - -4.85347]; ES=0.818). However, no significant differences were observed in the other variables analysed.

On the other hand, group B also presented significant differences in the same skinfolds as group A, as well as in two additional ones: triceps (95%CI=[1.28408 - 6.14449]; ES=0.902), abdominal (95%CI=[0.62703-5.37297]; ES=0.375), supra-spinal (95%CI=[0.13021 - 2.01264]; ES=0.610), leg (95%CI=[0.78559 - 5.07155]; ES=0.754) and the total sum of the six skinfolds (95%CI=[5.28382-19.14475]; ES=0.654). Furthermore, fat mass was significantly decreased, both in kg (95%CI= [0.26473-1.65221]; ES=0.604), and percentage (95%CI= [0.55533-2.01211]; ES=0.649).

Group B also significantly improved after the intervention in 1RM strength tests: bench press (95%CI=[-13.12764 - 2.58664]; ES=0.484), and squat (95%CI=[-24.89231 - -10.53626]; ES=0.842). As in Group A, no significant differences were observed in the other variables analysed.

Group C (control) did not present any significant differences in the intra-group analysis.

The inter-group analysis, comparing the average increase of the variables after the intervention, showed that Groups A and B did not present any significant difference. However, significant differences were observed when the two groups were compared to the control, specifically regarding increased triceps skinfold (Group A: 95%CI=[0.01109-3.632], ES=1.682; Group B: 95%CI=[0.8968-6.9889], ES=2.104); abdominal skinfold (Group A: 95%CI=[0.4801-7.0342], ES=1.682; Group B: 95%CI=[0.0515-6.6056], ES=1.853); total sum of skinfolds (Group A: 95%CI=[2.3194-21.052], ES=2.035; Group B: 95%CI=[4.7174-22.0826], ES=2.509); fat mass percentage (Group A: 95%CI=[0.3053-2.2732], ES=2.208; Group B: 95%CI=[0.5573-2.3816], ES=2.800) and kg of fat mass (Group A: 95%CI=[0.2825-1.7806], ES=2.235; Group B: 95%CI=[0.2611-1.9987], ES=2.056).

With respect to the variables related to sports performance, groups A and B significantly improved after the intervention compared to group C. These variables consisted in increased 1RM in bench press (Group A: 95%CI=[-15.7534 - -4.5323], ES=2.947; Group B: 95%CI=[-15.4579 - -2.2564], ES=2.162) and squat (Group A: 95%CI=[-34.2487 - -8.037], ES=2.508; Group B: 95%CI=[-32.7647 - -14.3781], ES=3.827).

The correlation analysis indicated that, among the two experimental groups, significant negative correlations were detected in the total sum of skinfolds and 1RM bench press at the end of the intervention (Group A: R=-0.851; p=0.015; Group B: R=-0.761; p=0.047). This was also observed in the percentage of fat mass, where a negative correlation was observed between this variable and 1RM bench press (Group A: R=-0.851; p=0.015; Group B: R=-0.761; p=0.047). Similarly, a significant correlation was detected between 1RM squat and 1RM bench press in group B after the intervention (R=0.871; p=0.011).

Lastly, since a significant correlation was detected between fat mass and 1RM bench press, a linear regression analysis was performed. In this sense, 1RM bench press was used as the dependent variable, and percentage of fat mass or total sum of skinfolds as predictors. The results complied with the model both in Group A (R squared=0.670; p= 0.015; Durbin-Watson=1.798) and B (R squared=0.579; p= 0.047; Durbin-Watson=1.809).

## Discussion

The results of the study indicates that a 6-week HICT program is an efficient method to improve maximum strength (1RM) as well as body composition in physically active adult males, independently if the training program is performed 2 or 3 days a week.

Positive results were obtained in the intragroup analysis before and after the intervention, with no significant differences among the two experimental groups, while both significantly improved compared to the control group. These results seem to indicate that a frequency of 2 days/week of HICT is sufficient to obtain positive results in physically active adult males. Despite the short duration of the study (6 weeks), significant results were obtained, and were similar to other studies where a 10-week HICT intervention was used<sup>22</sup>, who also reported a 4.2% decrease in fat mass. Similarly, another study, analysing males and females in a 3 sessions/week, 5-week intervention<sup>23</sup>, also reported a decrease in fat mass, although in this case the training sessions lasted 20 minutes with a ratio of 15 seconds of exercise and 15 seconds of rest, alternating 2 minutes of battle rope with 2 minutes of kettlebell.

Certain authors consider that the changes in body composition observed with this type of training are mainly due to the anaerobic metabolism, due to its intermittent character and high intensity<sup>24</sup>. On the other hand, other authors<sup>3</sup> postulate that the changes could be due to the increased use of fatty acids and caloric expenditure of this type of training. Other possible reasons reported could be due to the increased use of catecholamines<sup>25</sup> or growth hormone<sup>26</sup>, which stimulate lipolysis and subsequently the use of subcutaneous or intramuscular fat. During a HICT intervention, the metabolic adaptations of the skeletal muscle favour lipid oxidation. Tremblay and collaborators<sup>27</sup> have demonstrated that high intensity training sessions increase the activity of muscle glycolytic enzymes, reducing subcutaneous fat while increasing the activity of  $\beta$  hydroxyacyl coenzyme A dehydrogenase, which catalyzes a fundamental step of fat oxidation. Boutcher<sup>28</sup> reported an increase in fat oxidation as a method of eliminating lactate and hydrogens and to resynthesize glycogen. In this sense, it is possible that the metabolism during post-exercise recovery could continue burning calories at the same rate as during the actual exercise<sup>29</sup>. Lastly, it is important to note that a nutritional program intervention with no physical exercise does not improve the body composition of physically active adults.

The applied HICT program corresponded to 20-25 seconds of activity, with the same amount of rests, at a 1:1 ratio, similar to that described by Bisciotti<sup>30</sup>. In this sense, a classic intermittent exercise program with a 1/1-1/2 effort/recovery ratio (6 seconds / 10 seconds – 10 seconds / 10 seconds – 20 seconds / 20 seconds – 30 seconds / 30 seconds) was performed. This results in the cardiac frequency to increase during exercise, reaching at least 70% maximum CF, thus considered as high intensity, as described by the American College of Sports Medicine (ACSM)<sup>31</sup>. Due to the short duration of the rests, the recovery was incomplete, causing the pulse rate to be maintained at a plateau<sup>32</sup>. Also, it is important to note that the training program used follows the ACSM recommendations for cardiovascular exercises (20-60 minutes/session, 3-5 sessions per week)<sup>33</sup>.

These results indicate that this innovative training method presents certain advantages over other established ones. By using a HICT method

while considering training frequency and number of repetitions, the results show that the participants obtain a better physical condition (regarding strength) and body composition, and in a shorter time period than with other training methods.

The study demonstrates that a 6-week HICT program with strength and resistance self-loading significantly improves maximum strength and local muscle resistance. The maximum strength was measured using 1RM tests in bench press and squat, with a 10% and 20% improvement, respectively, in both experimental groups, being these values statistically significant.

In a similar work, Bucley *et al.*,<sup>34</sup> compared 2 groups performing a 6-week HICT program, at a frequency of 3 sessions per week. The first group trained by rowing for 30 minutes, while the second group performed a variety of multidisciplinary exercises at intervals, with 18 repetitions and rests lasting 60 seconds, for a total of 30 minutes. As a result, the first group did not significantly improve in any of the strength tests performed (bench press or squat), while the second group improved by 15% their results in 1RM squat, 70% local muscle resistance in squat, and 12% in 1RM bench press. These results coincide with a previous work by McCarthy, which demonstrated that the strength gained in a concurrent training program (including strength and resistance) are achieved at a frequency of 3 sessions per week or less.

In the present study, significant improvements were detected in 1RM bench press and squat only when the groups were compared before and after the intervention, while no significant differences were observed between groups A and B. However, both groups reported significantly better results compared to group C, who did not perform any HICT.

Similarly, a study published by Dorgo *et al.*<sup>35</sup> developed an 18-week training program with a group of adolescents, who performed 10-14 repetitions of 3-4 exercises using different materials (medicine ball, elastic bands, rope...), with a brief 20-30 second rest between each exercise. At the end of the intervention, the experimental group reported a 30% improvement in upper body resistance strength, which is similar to the values obtained in the present study. The same authors also detected an 83% increase in upper body maximum strength at the end of the intervention.

The results obtained in the present study can also be at least partially due to the type of exercises included in the HICT program (push-ups, burpee, bastard, Squat), which are very similar to the movements that are used in the strength tests.

Regarding the limitations of the study, it is important to note that this intervention was performed with a small number of volunteers (3 groups: 2 experimental and 1 control, n=7 each), although each participant was thoroughly supervised during the whole study. In this sense, regarding body composition, the authors contemplate in future studies the possibility of including additional anthropometric variables, such as muscle or bone mass. Other additional variables that could be included are body composition by densitometry, and how strength training may affect certain parameters such as bone mineral content or density. As for blood pressure, it is possible that a longer intervention period may be necessary for HICT to significantly alter this parameter.

As for sports practice, additional tools could be considered for future intervention studies, such as the first beat, which can monitor all

the weekly sessions and allow the analysis of the variability in cardiac frequency and compare the effects of the training or even the effects of training and/or rests of the sample studied.

In conclusion, a 6-week HICT program combined with an adapted diet plan results in significant improvements in 1RM bench press, squat and body composition, as well as reducing fat mass. This was observed both comparing before and after the intervention as well as compared to the control group, which did not perform any physical activity. However, no significant improvements were detected regarding blood pressure. Similar results were obtained when the program was performed 2 or 3 days a week. Finally, it is important to note that a protein-rich diet by itself, without physical activity, is not sufficient to improve strength or body composition.

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