International Journal of Kinesiology & Sports Science
ISSN: 2202-946X
www.ijkss.aiac.org.au

Effects of Eight Week High-Intensity Interval Training Program Followed by a Six Week Detraining on Healthy Adult Gym-Users

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ARTICLE INFO

Article history
Received: August 10, 2023
Accepted: October 11, 2023
Published: October 31, 2023
Volume: 11 Issue: 4

Conflicts of interest: None.
Funding: This work is supported by national funding through the Portuguese Foundation for Science and Technology, I.P., under project UID04045/2020

ABSTRACT

Background: The literature has reported that high-intensity training (HIIT) can effectively improve maximum oxygen uptake (VO_2 max) and body composition (BC). Still, contradictory results are reported regarding its impact of HIIT training and post-period detraining on gym users. **Objective:** This study aimed to verify how eight weeks of HIIT affects VO2 maximum and BC in healthy gym users. Additionally, the effect of a six-week detraining period was verified. A group of 10 gym-users (mean ± SD age: 29.03 ± 6.18 years) volunteered for this randomized controlled trial (RCT). **Method:** A HIIT program that included exercises such as jumping air squats, burpees and jumping jacks was applied over eight weeks. After this period, a six-week detraining period was applied. To measure changes in VO_2 max, the Queen's College Step Test (QCST) was applied, while a bioimpedance scale was used to measure BC. **Results:** Eight weeks of HIIT seem to show a tendency to increase VO_2 max and cause positive changes in BC ($p \leq 0.05$) with the exception of two variables (i.e., fat-free mass and fat mass). Furthermore, the results suggest that 6 weeks of detraining may negatively affect gains resulting from the training program, particularly in VO_2 max and body mass index (BMI) $p \geq 0.05$. **Conclusions:** Eight-week HIIT program incorporating short-duration explosive exercises can positively affect VO_2 max and BC in adult gym users.

Key words: Human Body, Health, Exercise, Physical Performance, Maximum Oxygen Consumption, Body Composition

INTRODUCTION

One of the reasons most reported by adults for a sedentary lifestyle is the lack of time for physical activity. In this sense, Prior research suggests that HIIT may be a great solution to mitigate this problem, as well to improve the maximum oxygen uptake (VO2 max) and BC (Reichert et al., 2007; Herazo-Beltrán et al., 2017; Rech et al., 2018). HIIT is characterized as an exercise that involves short periods of maximal or near-maximal effort (≥85% VO_2 max), that exchange with periods of active recovery or rest. HIIT has many attractive advantages over traditional training programs, such as shorter exercise time HIIT has many attractive advantages over traditional training programs, such as shorter exercise time while promoting similar or greater health benefits (according to physical activity guidelines) (Leal et al., 2020; Sabag et al., 2022).

In addition, other benefits have been reported in the literature such as increases in fat burning due to increased metabolic rate (Salim et al., 2022), cardiovascular improvements (Wen et al., 2019) and increased muscle resistance (Menz

Published by Australian International Academic Centre PTY.LTD.

http://dx.doi.org/10.7575/aiac.ijkss.v.11n.4p.1

et al., 2019) which can translate into increased oxygenation capacity of the muscles during exercise (i.e., increased VO_2 max).

In this sense, numerous surveys have proven this type of training (i.e., HIIT) can be effective in improving VO_2 max capacity (Syamsudin et al., 2021;; Iyakrus et al., 2022; Festiawan et al., 2021). This is primarily because high-intensity training requires the body to work at levels close to or above VO_2 max, which can lead to physiological adaptations that improve the capacity to transport and use oxygen throughout the exercise (Wen et al., 2019; Leal et al., 2020; Powell et al., 2019). So far, HIIT training programs have been shown to be effective in several modalities for improving VO_2, swimming (Nugent et al., 2017), soccer (Andersen et al., 2014; Sperlich et al., 2011; Branquinho et al., 2020), volleyball (Jastrzebski et al., 2014), basketball (Sanchez-Sanchez et al., 2018) and in gym-users (Byrd et al., 2019).

Particularly in relation to gym-users, different results have been reported over time. While some investigations showed improvements in VO_2 peak or VO_2 max after HIIT training programs (Trapp et al., 2008; Khammassi et al., 2018;), others report contradictory results in different types of population (Lunt et al., 2014; Hazell et al., 2014; Astorino et al., 2012). For these reasons and considering the lack of consensus this topic still needs to be developed.

A previous investigation (Trapp et al., 2008) sought to clarify the effect of high intensity activities (i.e., high-intensity circuit training) on untrained young women for 15 weeks. Participants performed three sessions per week of circuit training, which consisted of 8-10 exercises performed in sequence (e.g., 10 s of rest and 20 s of exercise). The study found a positive change in VO_2 max after training (9%). In the same line, another study (Maillard et al., 2016) investigated the effect of HITT on gym-users for eight weeks. Participants were encouraged to perform 3 weekly HIIT sessions, which consisted of 5-7 30-second sprints at 120-150% VO_2max, separated by 2-minute recovery periods. The results revealed positive changes in VO_2 max (8%). Contrary to this evidence, a previous study explored the impact of a of HIIT on gym-users for 6 weeks (Hazell et al., 2014). HIIT incorporated 10 60-second sprints at 100% VO2 max, separated by 60-second rest periods, and was performed three times a week. However, the study found no significant improvements in VO_2 max after training. Another investigation (Lunt et al., 2014) reported identical results when investigating a HITT over six weeks in a similar population. Participants completed three weekly sessions, which consisted of 8 20-second sprints at 170% VO_2 max, separated by 10-second rest periods. However, the study found no significant improvements in VO_2 max after training. Another study (Astorino et al., 2013) analyzed the changes induced by HIIT in gym-users for eight weeks. The training consisted of ten exercises (30s) followed by recovery (15s). However, the study found no changes in VO_2 max after training. Still, although the effective effects of HIIT on gym users are recognized, the evidence is still not solid enough regarding the ideal structure and duration of HIIT training, as well as the detraining effect (Lunt et al., 2014; Astorino et al., 2013). Effectively, periods of detraining are common among gym-users due to several factors (e.g., injuries, vacations, time unavailability) (Latella & Haff, 2020). A period of detraining after a period of HIIT can result in a decrease in aerobic capacity, muscle strength and lean mass and an increase in body fat (Lan et al., 2022; Chen et al., 2022), however these issues need to be clarified.

This investigation aimed to verify the effects of an eight-week HIIT program consisting of explosive, short-duration exercises in aerobic capacity (i.e., VO_2 max) and BC in adult gym-users. In addition, the impact of a six-week detraining period on previously acquired gains was verified. The study hypothesis is that eight-weeks of HIIT induces improvements in cardiorespiratory capacity (i.e., VO_2 max) and has positive effects on BC, while a period of detraining causes negative changes in all analyzed indicators.

METHODS

Participants and Study Design

A group of 10 male gym-users (mean ± SD age: 29.03 ± 6.18 years) volunteered for this randomized controlled trial (RCT) (Wessely, 2001). The sample was calculated using specific software (i.e., G*Power 3.1) (Kang, 2021). The test results indicated that the sample should include at least 8 individuals (a priori analysis) (effect size dz: 0.8, error α: 0.05, power: 0.95) (Bradley & Brand, 2013; Shadish & Haddock, 2009). For convenience, 2 elements were added to the to sample. The following inclusion criteria were applied: i) be healthy gym users without associated pathologies (e.g., diabetes, hypertension); ii) must be available to complete the training program over the eight-weeks. On the other hand, no exclusion criteria were applied. Before work related to the study began, participants informed the research team that they were not carrying out any other type of training beyond training at the gym. The research team informed participants that they were not authorized to undertake any additional training until the end of the investigation. The anthropometric characteristics of the gym-users recorded and which were considered dependent variables were: weight (74.86 ± 8.94 kg), BMI (23. 80 ± 3.29%) and height (1.76 ± 0.77 m). Before the start of the study, participants (independent variable considered) underwent physical examinations administered by a doctor, that did not identify any type of problem that would prevent involvement in the study. Furthermore, everyone involved was informed about the genesis and requirements of the study, and answered a questionnaire about their health history. All procedures were carried out in accordance with the principles of the Declaration of Helsinki. The study was validated Scientific Council of the Higher Institute of Educational Sciences of the Douro (PMTF:2;24.9.2018).

Procedures

This study used a quasi-experimental research design. A HIIT program that included exercises such as Jumping Air Squats, Burpees and Jumping Jacks was applied for eight weeks (Table 1.). After this period a six-week detraining period was applied. All participants underwent a battery

Table 1. Training program applied over 8 weeks

	Jumping Air Squats	Burpees	Jumping Jacks
Week 1			
Session 1	4 x 5	4 x 5	4 x 5
Session 2	4 x 5	4 x 5	4 x 5
Week 2			
Session 3	4 x 5	4 x 5	4 x 5
Session 4	5 x 5	5 x 5	5 x 5
Week 3			
Session 5	5 x 5	5 x 5	5 x 5
Session 6	5 x 6	5 x 6	5 x 6
Week 4			
Session 7	5 x 5	5 x 5	5 x 5
Session 8	5 x 5	5 x 5	5 x 5
Week 5			
Session 9	6 x 5	6 x 5	6 x 5
Session 10	6 x 5	6 x 5	6 x 5
Week 6			
Session 11	6 x 5	6 x 5	6 x 5
Session 12	7 x 5	7 x 5	7 x 5
Week 7			
Session 13	6 x 5	6 x 5	6 x 5
Session 14	7 x 5	7 x 5	7 x 5
Week 8			
Session 15	6 x 5	6 x 5	6 x 5
Session 16	6 x 5	6 x 5	6 x 5

of anthropometric tests and a VO_2 max test before starting the training program, which also served to familiarize them with the procedures to be adopted. The experimental procedures were supported by a personal trainer to minimize disruptions to the participants' usual training. Assessments were carried out in an indoor pavilion between October and December 2022. Assessments were carried out at different times (pre-training (PreT); post-training (PostT); detraining (DeT)). To verify the impact of HIIT on VO_2 max, a validated field test was used: QCST (Chatterjee et al., 2004). This test was selected because it provides specific indicators related to VO_2 max. Additionally, anthropometric measurements were taken using a bioimpedance scale.

Training Program

HIIT was applied in two weekly sessions, spaced at least 48 hours apart. Over the eight weeks, the program underwent progressive changes in order to promote adaptations. All training sessions incorporated 3 specific exercises (i.e., Jumping Air Squats, Burpees and Jumping Jacks. The exercises were selected according to exercises previously used in programs with this type of intervention (Schwarz, 2022; Yüksel et al., 2018). Each exercise set lasted approximately 4 minutes and consisted of the prescribed number of exercise repetitions (20 s of work and 10 s of rest) (Feito et al., 2019). All training sessions aimed to perform exercises with maximum intensity. The exercises and the level of intensity with which they were performed were controlled by a specialized personal trainer. The detailed structure of HIIT is detailed in Table 1.

Warm-up

At the beginning of each training and evaluation session, all participants performed a brief warm-up, which incorporated 8 runs of 60 meters with 60-second breaks between repetitions (van den Tillaar et al., 2019). Participants were asked to perform the first run at a self-regulated intensity (≈60%) with successive increases (≈5%) at each new repetition until reaching 95%. In addition, subjects were asked to perform 1 of 7 proposed dynamic exercises during recovery (i.e., arm swing, internal rotation and external rotation, adduction, abduction, ankle rotation, hip flexion/extension. knee rotation, and hip rotation).

Body Composition

BC was recorded using weigh (kg), height (m), fat free mass and fat mass. The average of three measurements was used to calculate body mass and height. To measure body mass (kg), Tanita Corporation, Tokyo, Japan, electronic scale Tanita MC 780-P MA®. Height (cm) was measured using an electronic stadiometer (Seca, Hamburg, Germany). A flexible steel tape was used to measure waist circumference (cm) at the junction of the lower border of the lower perceptible rib and the top of the iliac crest. The measurement was taken three times by the assessor, and the average was chosen for further examination. A nearly perfect agreement was found using the Intraclass Correlation Coefficient (ICC) (ICC = 0.85). The BMI was calculated according to previously reported procedures (Shinagawa & Ishikawa, 1991).

Queen's College Step Test

The indirect protocol (QCST) for assessing VO_2 max was used in accordance with previous investigations (Chatterjee et al., 2001, 2005). The test was performed with a step placed at a height of 41.27 cm. Subjects performed the test during 3 minutes at a rate of 24 steps/m (protocol for men) controlled by a metronome. At the end of the exercise, the carotid pulse rate was recorded for 15 seconds and converted into beats per minute. Finally, the following equation was used to predict VO_2 max (%):

$$VO_{2\ max} = 111{,}33 - (0{,}42 \times \text{pulse rate beats/min})$$

The fitness index score can be used to estimate a person's VO_2 max, which is a measure of their maximal oxygen consumption and a key indicator of cardiovascular fitness. Higher VO_2 max values indicate better cardiovascular fitness. QCST provides an estimate and is not as accurate as direct measurement of VO_2 max through laboratory testing. Additionally, this test might not be suitable for individuals with certain health conditions or those who have difficulty performing step-based activities. As with any fitness test,

it's recommended to consult with a qualified fitness professional or healthcare provider before performing the Queen's College Step Test, especially if you have any underlying health concerns. The literature shows a high intra-class correlation coefficient for this upper step test (ICC = 0.6-.90) (Sartor et al., 2016).

Statistical Analysis

Standardized statistical methods were used to calculate means and standard deviations with 95% confidence intervals (95% CI). The Shapiro-Wilk test was used to assess the normality of the distribution (n <30) and, depending on the condition of normality, parametric or non-parametric tests were used. To compare the variations between the 2 analyzed moments, a t-test and the corresponding non-parametric Wilcoxon test were used. The level of statistical significance was $p \leq 0.05$. Effect sizes (ES) were calculated based on Cohen's d and classified as: 0.2, trivial; 0.6, small; 1.2, large; and >2.0, very large (Cohen, 2013; Hopkins, 2019). It was also calculated the percentage changes between baseline (pre) and post-term (post) assessment [(post-training - pre-training)/pre-training) x100]. All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 27.0 (Armonk, NY: IBM Corp).

RESULTS

The results indicate the existence of significant differences of trivial effect in the comparison between the PreT and PostT for the variable weight (Δ = -2.1, p = 0.017, d = 0.17. In addition, differences were also found at the same time point (i.e., PreT vs. PostT) with a small effect for the BMI and VO_2 max variables (Δ = -3.4, p = 0.008, d = 0.24; Δ = 5.7, p = 0.018, d = 0.43) These results suggest that HIIT appears to have induced a beneficial effect on participants (Figure 1. and Table 2.).

Comparing the moment PostT vs. DeT results indicate significant differences with trivial effect for the weight and VO_2 max variables (Δ = -0.92 p = 0.005, d = 0.07; Δ = -2.16, p = 0.037, d = 0.16) and for the BMI variable with small effect (Δ = 3.43, p = 0.001, d = 0.23). The differences found seem to indicate that the break in the training program may have an influence on the reduction of previously acquired gains (Figure 1. and Table 1.).

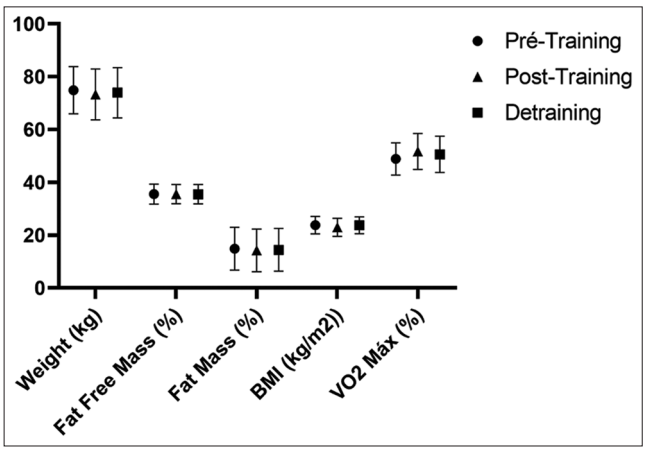

Figure 1. Graphic representation of the differences between the 3 analyzed moments (i.e., PreT, PosT and DeT)

Finally, in the comparison between the PreT moment and the Det moment, significant differences were found in weight and VO_2 max with trivial and small effect respectively (Δ = -1.22, p = 0.047, d = 0.09; (Δ = 0.16, p = 0.008, d = 0.26) In general, the data seem to indicate that the training program was beneficial from PreT and PostT, and that a period of six weeks of detraining has a negative effect on the gains acquired, particularly for weight and VO_2 max(Figure 1. and Table 2.).

DISCUSSION

The main objective of this investigation was to confirm the effects of an eight-week HIIT program consisting of explosive, short-duration exercises on aerobic capacity (VO_2 max) and BC in adult gym-users. Furthermore, the consequences of a six-week detraining period on previously acquired gains was verified.

According to our findings, the proposed HIIT intervention seems to promote significant improvements particularly in weight, BMI and VO_2 max at PreD *vs.* PostT. Although fat mass and fat-free mass do not present significant differences, a positive trend is observed in both. Furthermore, significant differences in PostT vs. DeT indicate that the interruption of the training program can influence the reduction of previously acquired gains. Along these lines, Trapp et al. (2008) concluded that applying a HIIT program over 15 weeks had greater benefits compared to steady-state physical training on BC. The study concluded that there was a positive trend in the HIIT group for leg fat loss and central abdominal fat loss. Lean body mass was higher in the HIIT group. Other lean tissue changes were insignificant (Trapp et al., 2008).

Another investigation (Gremeaux et al., 2012) also reported that HIIT induced improvements in BC. Along the same line of reasoning, Shing et al. (2013) reported a reduction in body fat percentage as a result of a four-week HIIT program in healthy individuals. These results seem to corroborate the idea that a short period of HIIT may be enough to change BC (Fatemeh et al., 2016).

The eight-week training period had a positive effect on BC, with reductions in weight, body mass index percentage of fat mass and this is in line with the results of a 12-week study that used a HIIT program in a group of adults (Amaro-Gahete et al., 2019). Furthermore, another study observed a decrease of fat mass (16.2%) in 14 healthy adults who over eight weeks were exposed to a running based HIIT protocol. (Soylu et al., 2021).

In our study, BC changed over the course of eight weeks of HIIT and this result corroborates several previous studies that also reported a reduction in BMI (Miladpour et al., 2017; Racil et al., 2016;Corte de Araujo et al., 2012) and body fat percentage (Tjønna et al., 2009; Lau et al., 2015). However, these findings are not transferable because they were conducted on obese adolescents rather than a healthy and active population. However, few studies have reported a decrease in body fat after 7 (Kranen et al., 2023), or

Table 2. Differences found between pre – training, post – training and detraining

	Pré Training	Post Training	Detraining	PreT vs. PostT			PostT vs. DeT			PreT vs. Det		
	(PreT)	(PostT)	(DeT)	*p*	Δ (%)	*d*	*p*	Δ (%)	*d*	*p*	Δ (%)	*d*
Weight	74.86 ± 8.94	73.26 ± 9.62	73.94 ± 9.49	0.017*	-2.1	0.17	0.005**	0.92	0.07	0.047*	-1.22	0.09
Fat Free Mass	35.58 ± 3.77	35.59 ± 3.65	35.51 ± 3.66	0.587	0.02	0.01	0.476	-0.22	0.02	0.838	-0.19	0.01
Fat Mass	14.91 ± 8.12	14.25 ± 8.07	14.46 ± 8.09	0.088*	-4.4	0.001	0.138	1.43	0.02	0.080	-3.01	0.05
BMI	23.80 ± 3.29	22.98 ± 3.43	23.77 ± 3.19	0.008**	-3.4	0.24	0.001***	3.43	0.23	0.810	-0.12	0.01
VO_2 max	48.87 ± 6.11	51.70 ± 6.79	50.58 ± 6.86	0.018*	5.7	0.43	0.037*	-2.16	0.16	0.008**	3.49	0.26

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; d = Cohen's d; p = p-value; DeT= Detraining; PreT = Pré – Training Program; PostT= Post – Detraining Program; Δ (%) = Pre – post change

8 weeks of HIIT in young people with normal weight. Thus, it is apparent that long-term exercise training has a significant impact on BC. Most research on this field states that the extent of physical training has a direct influence on its effectiveness in BC indicators. Thus, it appears that differences in results may be related to training duration and methodology (Fatemeh et al., 2016).

In addition to the improvement in parameters related to BC as a result of a HIIT program, our results also seem to reveal that this type of HIIT training seems to stimulate improvements in aerobic performance, particularly VO_2 max. In general, VO_2 max is regarded as the most accurate predictor of aerobic and cardiovascular fitness. Although endurance training and other long-term training are widely used to improve VO2 max in sport, recent research suggests that the results of HIIT are similar (Fatemeh et al., 2016).

The results of this study corroborate previous evidence (Astorino et al., 2012) with other predicted results that revealed that short-term HIIT influenced cardiorespiratory fitness and blood pressure, muscle strength and predictors of VO_2 max change in active men and women. Although training had no effect on resting heart rate or blood pressure, it did improve VO_2 max, carbon dioxide production, and O_2 pulse.

Recent research has revealed that the benefits of using HIIT are identical to those of long-term training if the objective is to improve anerobic power (Engel et al., 2018) and this may be related to high intensity and intervals during training sets. HIIT, according to reports, increases VO_2 max by 5-14%. The current study found increased VO2 max performance which is in line with previous reports. In this regard, Laursen et al. (2005) reported that a four-week HIIT intervention increased VO_2 max in cyclists. Research gives peripheral adaptations a greater responsibility for improving performance compared to central adaptations. According to same study (Laursen et al., 2005), increased activity of oxidative enzymes is one mechanism for increasing aerobic power. Emphasizing the findings, (Castagna et al., 2010) investigated physiological determinants of HIIT and found that some indicators were related to the futsal training program (i.e., speed, aerobic threshold, maximum speed and VO2) (Castagna & Álvarez, 2010).

In recent reviews (Engel et al., 2018), the large magnitude of effect of HIIT on VO_2 was proven Compared to other training stimuli in adults and young people (Bacon et al., 2013; Milanovíc et al., 2015; Costigan et al., 2015). Taking into account that the ES of VO_2 in this report only showed a minor ES, it appears this information is contradictory to what was previously reported in different populations (Milanović et al., 2015 Costigan et al., 2015). In addition to the current ES based comparison, HIIT improved VO2 peak compared to alternative training methods (Engel et al., 2018). According to the literature, each HIIT session can result in a 0.26 ± 0.2 ml•min1•kg1 increase in VO_2 peak, compared to 0.15 ± 0.2 ml•min1 •kg1 with alternative training. However, the improvement in VO2 peak after HIIT and other types of training revealed significant standard deviations in relation to the average values, which suggests that there are significant variations in the body's response to HIIT and other types of training (Engel et al., 2018). In addition, the increase in VO_2 max observed in this study contradicts previous investigations that used a similar short-term HIIT young people of both sexes. Previous investigations (Burgomaster et al., 2008; Laursen et al., 2005) found no change in VO_2 max in men who completed sprint training for 8 weeks, which was consistent with early data from men (Astorino et al., 2012). Variance in results may derive the specificity of the participants (i.e., trained vs. untrained), as well as the duration of the intervention. Research has reported that HIIT improves the heart's ability to pump blood and this may be part of the explanation for the increase in VO2 max after HIIT in some studies. In addition, the rate of aerobic phosphorylation increases after the trainings. In fact, this adaptation appears to be caused by an increase in oxidative enzyme activity in muscles, what can enhance the increase in VO2 max.

In addition, the improvement of the VO_2max after the HIIT intervention is altered quickly after four weeks of detraining. According to several studies, detraining leads to a progressive decrease in VO2 max, regardless of the athlete's level or inactivity time. Short periods of detraining (< 4 weeks), tend to show a decrease of 4 to 14% of VO_2 max in high level athletes. In poorly trained or formerly sedentary athletes, the loss is less significant. It would be between 3.6 to 6%. This can be explained by the fact that the higher the athlete's VO_2 max, the greater the loss after the period of inactivity (Chen et al., 2022; Coyle et al., 1984).

Finally, we must point out how limitations, the sample dimension and the fact that the VO_2 max was analyzed through indirect methodologies (i.e., QCST) mean that the results should be interpreted as a starting point for future investigations based on estimated test error. Future research should widely explore the impact of HIIT training and detraining on other interest variables (e.g., excess post-exercise oxygen consumption, heart rate variability and well being (Stavrinou et al., 2018, Grässler et al., 2021). Furthermore, more relevance should be given to the variables of strength, flexibility and agility. Moreover, the HITT has gained popularity due to its efficiency in improving cardiovascular fitness, increasing metabolic rate, and promoting fat loss (Chen et al., 2022; Engel et al., 2018). Thus, HITT should be incorporated in clients' routines, especially when the aim is to increase cardiovascular capacity and BC.

CONCLUSIONS

Finally, the current study explored the changes induced by an eight-week HIIT program consisting of explosive and short-duration exercises on VO_2 max and BC in adult gym users. It was also demonstrated that a six-week detraining period is sufficient to cause significant losses in the variables studied for Gym users. The results support the use of HIIT programs during the season. This type of program is simple to implement and takes up little time in the training unit. Furthermore, it has the added benefit of being applied without the need for large investments by clubs, making it applicable to all clubs worldwide.

ACKNOWLEDGMENTS

The authors wish to thank all volunteers for their participation in the study.

AUTHOR CONTRIBUTION

L.B. and P.F. conceptualized the study; The intervention methodology was defined by L.B. P.F. and R.F. L.B. and R.F. validated the study. L.B., P.F., J.E.T. and R.F performed the formal data analysis. L.B., P.A.G., L.F., D.B., S.H., H.G., T.S., A.M., J.E.T., P.F., and RF participated in the preparation of the original draft; Writing - review and editing was carried out by L.B., H.S., J.E.T., PF, R.F. The project was supervised and managed by L.B., P.F. and RF, which was also responsible for acquiring financing. All authors read and agreed to the published version of the manuscript.

Ethical Approval

The study was validated Scientific Council of the Higher Institute of Educational Sciences of the Douro (PMTF:2;24.9.2018).

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