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Original Article

The effects of low-volume combined training on health-related physical fitness outcomes in active young adults: A controlled clinical trial

Ricardo Martins [*], Nuno Loureiro

Department of Arts, Humanities and Sports, School of Education, Polytechnic Institute of Beja, Laboratory of Physical Activity and Health, Beja, Portugal

A R T I C L E I N F O

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A B S T R A C T

The effects of combined training (CT) on improving general health are well known, however, few studies have investigated the effects of low-volume CT. So, the aim of this study is to investigate the effects of 6 weeks of low-volume CT on body composition, handgrip strength (HGS), cardiorespiratory fitness (CRF) and affective response (AR) to exercise. Eighteen healthy, active young adult man (mean ± *SD*, [20.06 ± 1.66] years; [22.23 ± 2.76] kg/m^2) performed either a low-volume CT (EG, $n = 9$), or maintained a normal life (CG, $n = 9$). The CT was composed of three resistance exercises followed by a high intensity-interval training (HIIT) on cycle ergometer performed twice a week. The measures of the body composition, HGS, maximal oxygen consumption ($\dot{V}O_{2max}$) and AR to exercise were taken at baseline and after training for analysis. Furthermore, an ANOVA test of repeated measures and *t*-test paired samples were used with a $p \leq 0.05$. The results showed that EG improved HGS (pre: [45.67 ± 11.84] kg vs. post: [52.44 ± 11.90] kg, $p < 0.01$) and $\dot{V}O_{2max}$ (pre: [41.36 ± 5.16] ml·kg^{-1}·min^{-1} vs. post: [44.07 ± 5.98] ml·kg^{-1}·min^{-1}, $p < 0.01$). Although, for all measures the body composition had not significant differences between weeks ($p > 0.05$), nevertheless the feeling scale was positive in all weeks and without significant differences between them ($p > 0.05$). Lastly, for active young adults, the low-volume CT improved HGS, CRF and had a positive outcome in AR, with less volume and time spent than traditional exercise recommendations.

Introduction

Physical inactivity is considered the fourth leading cause of mortality worldwide and is being associated with a higher prevalence of developing chronic and cardiac diseases, poor general health status and environmental consequences of public health.[1,2] Nonadherence to physical exercise programs can contribute to the physical inactivity, since the main barriers are occupation and time constraints.[3,4] In this context, it may be difficult to follow the recommendations stipulated by the World Health Organization for the practice of physical activity,[1] and consequently health implications.[1,2] For busy subjects and with little time, shorter and then more attainable exercise protocols (about 90 min per week) are sufficient to decrease the risk of mortality from all causes by 14% and to increase life expectancy by up to 3 years compared to inactive individuals.[3]

The combined training (CT) is defined by performing resistance training (RT) plus aerobic training (AT) in the same session. It is a strategy used to develop various aspects of physical fitness (PF) associated with sports performance, such as muscle strength,[5–7] muscle hypertrophy,[6,8] cardiorespiratory fitness (CRF).[5,7] Despite this, it has been widely studied to include in the treatment of various pathologies such as diabetes, obesity, hypertension, and kidney diseases, among others and to improve the pathological condition of the patient,[9–12] being also effective in the prevention of chronic diseases and to improve health.[6] Another advantage of adding CT in the training routine is to be more effective in reducing mortality from all causes, than doing only RS or AT alone.[13] This strategy also allows a reduction of the total training time spent in performing the RT and AT in a separate way,[14] without affecting chronic adaptations to exercise.[5,6]

AT, particularly low-volume high-intensity interval training (HIIT) is distinguishing by training protocols that are below than the weekly volume recommended by American College of Sports Medicine (i.e., ≥ 500 metabolic equivalents - MET/min per week).[15] These protocols seem to be able to improve the CRF, however low-volume high intensity HIIT is not enough to obtain changes in body composition.[16] Furthermore, these protocols have the potential of health improvement in individuals with heart and/or metabolic diseases.[17] The low-volume RT is designed by single sets, high load and few repetitions with a low weekly exercise frequency,[18] resource able to increase strength in untrained

* Corresponding author.
E-mail address: ricardo1999jcm@gmail.com (R. Martins).

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Abbreviations

1 RM	1 maximal repetition
AR	Affective response
AT	Aerobic training
BIA	Bioelectrical impedance analysis
BMI	Body mass index
CEIPBeja	Polytechnic Institute of Beja ethics committee
CG	Control group;
CRF	Cardiorespiratory fitness
CT	Combined training
EG	Experimental group;
FFM	Free fat mass
FM	Fat mass
FS	Feeling scale
GXT CE	Graded exercise test on cycle ergometer
HGS	Handgrip strength
HIIT	High intensity-interval training
MET	Metabolic equivalents
PF	Physical fitness
RPM	Repetitions per minute
RT	Resistance training
TBM	Total body mass
$\dot{V}O_{2max}$	Maximal oxygen consumption
W	Watts
W_{max}	Maximal aerobic power

individuals.[15,18,19] It also has other advantages, such as being more practical, it displays a better affective response (AR) when compared to exercise, being more time-efficient and more adaptable to the individual daily routine, leading to a greater adherence to exercise, culminating in higher quality of life and life expectancy.[19]

CT is recognized as an excellent training to improve health status and sports performance, as well as low-volume training programs that showed good improvements in PF. Nevertheless, there is a lack of evidence to analyze the effects of weekly low-volume CT on indirect health indicators and AR to exercise. Thus, the aim of this study was to verify the effects of low-volume CT for 6 weeks on body composition, handgrip strength (HGS), CRF and AR to exercise in young active adults.

Materials and methods

Experimental design and subjects

Using a non-randomized, between groups design (experimental group [EG] and control group [CG], respectively). Eighteen healthy active young males were recruited students from the sports degree to participated in this study. The subjects were not involved in any training routine, either RT or AT or both, for at least 6 months before the beginning of the study but, were involved in moderate intensity physical activities associated with the undergraduate study plan, such as football, handball and fitness activities up to 4 h per week. During the experimental period, participants were not involved in any more recreational activities or any type of physical exercise. All subjects underwent pre-exercise screening to ensure they had no established cardiovascular, metabolic, or respiratory disease nor signs or symptoms of disease, musculoskeletal injuries, health problems or required medication. The use of any type of supplementation or ergogenic substance was not permitted and, subjects were instructed not to change their diet or lifestyle over the experimental period. The physical characteristics of each group are shown in Table 1. All subjects signed a written informed consent and voluntarily agreed to participate in this study, and all procedures were approved by the Polytechnic Institute of Beja ethics committee (CEIPBeja).

To investigate the potential effects of CT on the body composition, HGS, CRF and AR to exercise measures of total body mass (TBM), fat mass (FM), free fat mass (FFM) through bioelectrical impedance analysis (BIA), HGS, relative maximal oxygen consumption ($\dot{V}O_{2max}$) on graded exercise test on cycle ergometer (GXT CE) and the feeling scale (FS) were performed before/after the 6 weeks intervention period.

Procedures

The first physical contact with the subjects was a familiarization trial followed by pre-test measures and later a familiarization training session.

Table 1
Descriptive characteristics of the groups at baseline.

Variables	CG ($n = 9$)		EG ($n = 9$)		
	Mean	*SD*	Mean	*SD*	*p*
Age (years)	19.56	1.59	20.56	1.67	0.21
TBM (kg)	70.36	10.67	69.51	10.59	0.87
Height (m)	1.79	0.08	1.76	0.07	0.39
BMI (kg/m^2)	21.99	2.78	22.46	2.88	0.73
FM (%)	13.09	5.35	13.42	3.77	0.88
FFM (kg)	60.72	6.32	59.87	6.79	0.79
HGS (kg)	44.89	7.67	45.67	11.84	0.871
Relative $\dot{V}O_{2max}$ (ml·kg^{-1}·min^{-1})	42.79	4.91	41.36	5.16	0.55

Note: The data are presented with the mean ± *SD*. CG = Control group; EG = Experimental group; TBM = Total body mass; BMI = Body mass index; FM = Fat mass; FFM = Free fat mass; HGS = Handgrip strength; $\dot{V}O_{2max}$ = maximal oxygen consumption. Statistically significant values ($p < 0.05$) are presented with *.

The following weeks were the intervention period, culminating with the post-test, in the last week. Each pre- and post-tests were performed in the laboratory with the supervision of the investigator, guarantying the same conditions at all times. All subjects were asked to avoid vigorous and intense physical activities at least 48 h before tests. An order of evaluation was established, equal to all subjects and evaluations: HGS before the evaluation of the CRF in the cycle ergometer.[20] The subjects were allocated in two groups, the CG ($n = 9$), that did not perform any experimental procedure and followed their daily routine and the EG ($n = 9$), who underwent a RT followed by a HIIT on the cycle ergometer as explained below. No dropouts or injuries were reported during the experimental period and the adherence was 100%.

Measures

Anthropometry and body composition

Height was measured using a stadiometer with an accuracy of 1 cm (Seca mod. 213) and the subjects were measured without shoes. The TBM was measured using a calibrated SC-330 scale with an accuracy of 0.1 kg (Tanita corp, Tokyo, Japan). Body mass index (BMI) was calculated by dividing the TBM by height into meters squared (kg/m^2).

Body composition was measured using BIA with a scale, according to the manufacturer instructions (Tanita SC-330 corp, Tokyo, Japan). Only %FM and FFM were analyzed. To avoid errors related to hydration status, subjects were instructed to not have a full bladder before the evaluation and not to drink alcohol, caffeine drinks or other diuretics 24 h before the test. Measurements were performed during the morning in a normal hydration state and after night fasting.[21]

Handgrip strength

HGS was measured using a hydraulic manual dynamometer (JAMAR® Performance Health Supply, inc, China), according to the manufacturer instructions. The subjects were assessed sitting in a straight-back chair, with feet flat on the floor, shoulders adducted and neutrally rotated, elbow flexed at 90°, forearm and hand in neutral position. Before performing the measurement, the subjects were explained how to test correctly, encouraging maximal strength, and how to use the dynamometer. Three measurements were taken with about 60 s of rest between tries, the most obtained value was recorded.[22,23] Only the dominant hand was evaluated.

Cardiorespiratory fitness

The CRF was measured by a maximal GXT CE with mechanical calibration (Ergomedic 828 E, Monark, Sweden), under the supervision of the investigator and in accordance with the protocol.[24] The warm-up consisted of 2 min with a 60 W of load with a pedal rate of 60 repetitions per minute (RPM), after that the intensity was increased by 15 Watts (W) every minute. The test was interrupted when it was no longer possible to maintain 60 RPM or until the subjects reach their limit of tolerance. The protocol was adapted in the warm-up, to not cause loo long tests and avoid prediction.[25] Subjects were verbally encouraged before and during the test administrators to provide a true maximal effort. Maximal aerobic power (W_{max}) was recorded in the final stage only when this stage was fully completed. The prediction of $\dot{V}O_{2max}$ (ml/min) was calculated using a validated equation, which used W_{max}, TBM and the age of the subject.[24] Afterwards, the value obtained from the absolute $\dot{V}O_{2max}$ (ml/min) was divided by its current TBM to obtain the relative value of $\dot{V}O_{2max}$ in (ml·kg^{-1}·min^{-1}).

Affective response to exercise

The AR to exercise evaluates the changes in mood (pleasure and unpleasure) given through the exercise and was measured by the scale “The Feeling Scale”. The scale is presented in 11 bipolar points with the poles raking from −5 associated for bad, to +5 associated for good feelings. Verbal anchors are provided at the 0 point and at all odd numbers, +5 = very good, +3 = good, +1 = fairly good, 0 = neutral, - 1 = fairly bad, −3 = bad, and −5 = very bad.[26] Before starting the study, instructions to properly how to use the scale were given to the subjects. The values were registered immediately after the session and the mean of the AR of the two weekly workouts was calculated to obtain a weekly value.

Training protocol

The CT was realized twice a week with 48 h of interval between each training session for 6 weeks in a row, with the investigator always supervising the training sessions. General warm-up consisted of performing 5 min of exercises with low intensity (i.e., jumping jacks and split jacks), 2 sets of 20 repetitions each, followed by a gentle stretching and joint mobilization. The specific warm-up was 1 submaximal set of 6 repetitions with 60% of 1 maximal repetition (1 RM) to enhance the force production and power during the work sets.[27] The CT consisted in a session of RT with free weights (i.e., bars, benches, racks from BH FITNESS, XFIT and BOXPT, respectively) before a HIIT on cycle ergometer (i.e., Monark 828 E). For the RT, 2 sets of three multi-joint exercises, squat with a hexagonal bar, flat bench press with bar and 30° incline bench pull with bar, always with this order, were performed. A recovery time of 2 min between sets and exercises was strictly controlled, and each strength training session lasted for 15–20 min. The subjects were instructed to perform the repetition movement velocity in 3–4 s for eccentric phase and a maximal intended velocity in the concentric phase. All exercises and sets were performed of an intensity between 80% and 85% of 1 RM (6–8 RM) during all intervention. The subjects were instructed to perform all sets to concentric failure or close to (i.e., one or two repetitions in reserve). The load progression was made according to the 2-by-2 rule (2%–5% for upper limbs and 5%–10% for lower limbs).[28] After 3 min of passive rest, the HIIT started, on a cycle ergometer. The warm-up consisted in 2 min with 15–45 W at 60 RPM. Then, 5 sets of 60 s at 80 to 90 RPM with 95% W_{max} with 90 s of active pause at 50–60 RPM with a self-suggested load up to 60 W were performed. The work:rest ratio was 1:1.5 and in the end the calm down was 2–3 min at 50 to 60 RPM with a self-suggested load.

Statistical analysis

The normality and homogeneity (Shapiro–Wilk and Levene test, respectively) were conducted in all data before analyzes. All data were presented in mean ± *SD* and was adopted 95% confidence intervals. For the comparison between groups, an independent samples *t*-test was used. An ANOVA of repeated measures was used to analyze the effects tempo, groups and the interaction temp group of all of the dependent variables (TBM, %FM, FFM, HGS, $\dot{V}O_{2max}$ and FS). The paired-samples *t*-test was used to compare the means between groups in the pre and post measures. The alpha criterion for significance was set at $p \leq 0.05$. All data processing was performed in the Statistical Package for Social Sciences (IBM SPSS Statistics for Windows, Version 27.0, IBM Corp., Armonk, NY, USA).

Results

There was not a significance differences for baseline measures between groups in the analyzed variables ($p > 0.05$).

Body composition

The ANOVA analysis performed in the measurements of the TBM, %FM and FFM (Table 2) presented a main effect Time Z (1.16) = 5,062, $p = 0.039$ only for %FM. All other measurements did not show significant differences ($p > 0.05$) for both groups.

Handgrip strength

A significant group × time interaction was observed for Z (1,16) = 13.745, $p = 0.002$. One more detailed analysis of the effects of interest, showed that after 6 weeks of training, only EG significantly improved HGS (Pre: [45.67 ± 11.84] kg vs. Post: [52.44 ± 11.90] kg, $p < 0.01$), presented in Fig. 1.

A significant group × time interaction was observed for Z (1,16) = 12.049, $p = 0.003$. One more detailed analysis of the effects of interest, showed that only EG significantly improved the $\dot{V}O_{2max}$ (Pre: [41.36 ± 5.16] vs. Post: [44.07 ± 5.98] ml·kg^{-1}·min^{-1}, $p < 0.01$) following 6 weeks of training. Details on Fig. 2.

For FS, the ANOVA analysis did not show a significant main effect ($p > 0.05$), as shown in Fig. 3.

Discussion

This study evaluated the chronic effect of 6-week low-volume CT on the body composition, HGS and CRF of young active adults. The main results showed that low-volume CT improved the HGS and CRF, with a positive AR to exercise however, for body composition measures there were no significant changes.

Regarding body composition, CT was able to lower abdominal subcutaneous fat, %FM and TBM in relation to control conditions.[29,30] Nevertheless, these studies used overweight or obese, sedentary, or inactive populations, the training protocols had higher weekly training volumes, and in some studies a strict and controlled diet was prescribed. All these conditions may be more favorable to achieve these results.[31,32] The results of our research are in accordance with Kerksick et al. where there were no significant differences in the measure of %FM in the group that only underwent CT and a diet was not prescribed.[33] In this sequence

Table 2
Baseline and post training body composition measurements.

Variables	CG			EG			p		
	Pre	Post	Δ (%)	Pre	Post	Δ (%)	Time	G × T	Group
TBM (kg)	70.36 ± 10.67	70.29 ± 10.32	0.09	69.51 ± 10.59	70.37 ± 10.68	1.23	0.17	0.16	0.94
FM (%)	13.09 ± 5.35	13.40 ± 5.32	2.38	13.42 ± 3.77	13.97 ± 4.13	4.06	0.04	0.55	0.84
FFM (kg)	60.72 ± 6.32	60.46 ± 6.41	0.44	59.87 ± 6.79	60.31 ± 6.71	0.74	0.69	0.12	0.87

Note: Statistical analysis of ANOVA of related measures 2 (group) × 2(time). The data are presented in mean ± *SD*. CG = Control group; EG = Experimental group; TMB = Total body mass; FM = Fat mass; FFM = Free fat mass; G × T = interaction between group and time; Δ = percentual of variation between pre to post measures.

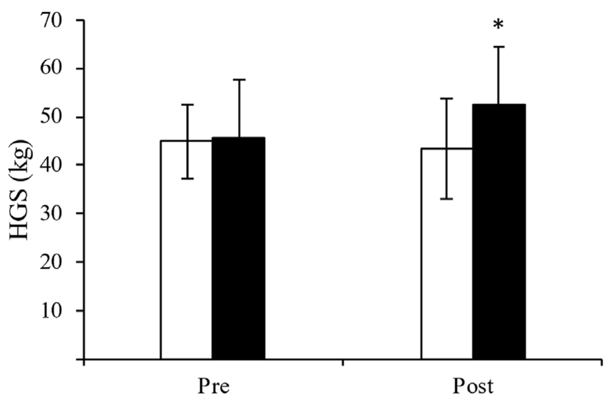

Fig. 1. HGS between the pre and post measurement of both groups. * represents $p < 0.01$ vs. pre of the same group. CG = Group control; EG = Experimental group; HGS = handgrip strength.

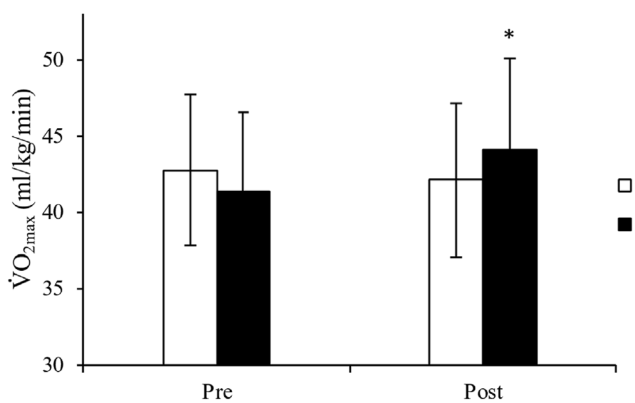

Fig. 2. $\dot{V}O_{2max}$ between the pre and post measurement of both groups. * represents $p < 0.01$ vs. pre of the same group. CG = Control group; EG = Experimental group; $\dot{V}O_{2max}$ = maximal oxygen consumption.

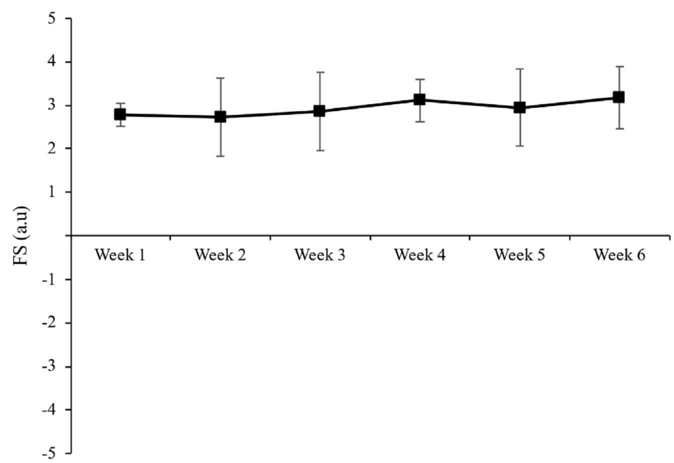

Fig. 3. Weekly FS during weeks 1, 2, 3, 4, 5 and 6 in the EG. FS = Feeling scale; a. u = arbitrary units; EG = experimental group.

and without nutritional prescription, two studies with active subjects did not find significant differences in %FM and FFM after the training period.[34,35] An investigation carried out by Winett et al. who studied low volume CT for 12 weeks in untrained individuals did not obtain significant results in terms of body composition (i.e., TBM and %FM).[36] However, Ghahramanloo et al. reported significant improvements in %FM and FFM for the group that performed CT in college students.[37] One possible explanation may have been the longer duration of the investigation (i.e., 8 weeks) and the largest weekly training volume used. In terms of perform only low-volume RT in young inactive adults, the results also did not show differences in 6 months of training for %FM and FFM.[38] A systematic review, which included 11 studies that evaluated body composition, did not find significant differences between the groups that performed only low-volume HIIT and the control groups in %FM and FFM.[16] The results suggest that the body composition low-volume CT was insufficient, possibly because a diet with a recommended protein supply was not attributed[39] and for the low weekly training volume.[31,40]

One of the most studied health-related PF is muscle strength. The HGS is an indicator of overall strength and upper limbs function,[41] predictive of health status, several pathologies, mortality and average life expectancy,[41–43] even being considered as a biomarker and a vital sign related to health.[41,43] In addition, there is evidence that the higher peak of muscle strength in young-adulthood, smaller it is the decrease over life[44] and this muscle strength in adolescents and young adults, accessed by HGS, is inversely related to mortality and average life expectancy.[45] Despite being well investigated, according to our knowledge this was the first study that investigated the effects of low-volume CT in young adults active in HGS. There is evidence that favors the use of CT in other populations to improve HGS, such as medically stable elderly,[46] kidneys complications,[47] obese elderly,[48] elderly with arterial stiffness[49] and adult women with fibromyalgia.[50] A 12-week study with pre-obese adults showed that CT performed 4 times a week significantly improved HGS.[51] An investigation has shown that performing CT through dance as AT and calisthenic exercises as RT, it is possible to improve HGS in healthy, untrained middle-aged women.[52] In relation to articles that studied the low volume of CT in muscle strength, measured through other resources, we can verify that after 12 weeks of CT reported a significant increase in the 6 RM test in various resistance exercises, in untrained adult men and women.[36] Another study investigated the effects of CT by performing only half of the target repetitions of each series in the RT, "*effort character*" of 50%, which culminated in a lower training volume at the end of the 8 weeks, however, the results revealed a significant increase in 1RM in several resistance exercises in untrained hospital workers.[53] Despite the lack of evidence, traditional CT in active young adults generates significant increases in muscle strength.[8,34] Through the results obtained in this article, it is suggested that low-volume CT may be a good strategy to increase muscle strength levels related to health, due to the significant improvement of HGS.

The CRF, according to various evidence, is the component of PF that best responds to CT, regardless of the chosen order, due to the little influence of "interference effect" on chronic adaptations of $\dot{V}O_{2max}$.[5,7,30] In addition to that, it seems which the high intensity exercise has a superiority to improve CRF through a low-volume protocol than moderate intensity.[16] Thus, the results obtained in improving the $\dot{V}O_{2max}$ with CT are supported. These responses can be explained especially for inactive individuals due to an increase in myofibrillar and mitochondrial protein synthesis and mitochondrial biogenesis after CT.[54] A study who performed a low-volume CT protocol also achieved significant and similar improvements in the $\dot{V}O_{2max}$ in untrained individuals during 12 weeks of training.[36] When addressing CT with a higher volume there is a wide literature that points to the significant improvement of $\dot{V}O_{2max}$.[55–57] Regarding the magnitude of improvement in untrained young adults among CT with higher volumes than the present study, we can verify that higher volume CT in both protocols (RT + AT) tend to increase slightly more the $\dot{V}O_{2max}$,[55–57] than the improvement obtained in this study 6.56% nevertheless, both volumes are significatively effective to improve it. In terms of health, increases in CRF are associated with reduced risk of mortality from all causes, cardiovascular diseases and cancer.[58–60] In addition to that, it seems to exist of a dose-response relationship of $\dot{V}O_{2max}$ to reduce the risk of mortality in 5%–12% per 1 MET.[59,60] Including this information with the main result of $\dot{V}O_{2max}$ by low-volume CT in 6 weeks can be a way to reduce the mortality by increasing $\dot{V}O_{2max}$,[59,60] since the improvement was 0.78 MET.

Exercise programs that aim for retention with the goal of improving health through exercise should generate positive AR to exercise.[61] AR to an exercise, especially aerobic, may have a positive relationship with future participation in physical exercise programs.[62] For the RT, the AR can be an important interpersonal factor to promote behaviors of adherence to training.[63] For different intensities of RT loads (i.e., 40%, 60%, and 80% of 1 RM) the AR does not seem to be different between both and remains positive.[64] For the AT, the literature indicates a slight advantage for continuous moderate intensity training in relation to HIIT in AR[65,66] however, HIIT seems to provide greater fun.[66,67] Nevertheless, both protocols get positive responses.[67] Despite this, intensities above the respiratory compensation point negatively affect the AR due to the physiological responses of anaerobic metabolism,[65] as well as many HIIT series carried out successively.[68] Nonetheless, this negative response can be attenuated with a longer rest interval between series[67] and reducing the series performed in the same training session.[68] According to this, the positive results of FS throughout all weeks of our study are plausible. Although we are not aware of studies evaluating the AR of low-volume CT in young adults. An article conducted by Lacharité-Lemieux et al. in menopausal women, analyzed the AR to a CT protocol performed in a circuit with aerobic exercise and with resistance exercises with elastics and the results were positive throughout the 1^{st}, 6^{th}, and 12^{th} week.[69] Based on these results, we can consider low-volume CT as a way to generate a positive AR and expect a better retention behavior in this program to improve health status.

This investigation has some limitations and should be considered before taking conclusions. The group sample is small and that can affect the statistical power and by being associated with a group of students of the sports degree who already practiced physical activity before and during the experimental period. Nevertheless, there was a CG that had the same characteristics of the EG, but they did not perform the training. The duration of training protocol was only 6 weeks, although it was already possible to see significant differences in PF. The prediction of $\dot{V}O_{2max}$ was adapted in warm-up setting because the characteristics of the sample and to not impair the duration or the intensity increments of each stage. This adaptation was designed to not affect the results due to a longer duration of the GXT.[25] Nutritional habits were not controlled, which may have influenced the results of the composition cable, although participants were asked to keep their usual routines and do not alter any nutritional habit or another, nor use supplements or ergogenic resources. The training sessions were not always given on the same days or at the same time, but the researchers always tried to ensure an interval of 48 h between workouts to ensure a good recovery. All evaluations, training and data treatment were carried out by the researcher supervised. Finally, all the results obtained can only be considered for the investigated population and conclusions should not be drawn for populations with other characteristics.

In future investigations it will be necessary to use a more representative sample with a randomized controlled trial design and with another type of population, as overweight and obese subjects, so that we can draw more conclusions. Perhaps in overweight or obese individuals, sedentary it is already possible to verify changes in body composition and greater results even with low training volumes. It may be interesting to create an extra group that performs even less volume to draw more conclusions at about a minimal dose of exercise. Including analysis cardiovascular and metabolic health indicators, such as inflammatory markers, lipid profile, blood glucose control, blood pressure, among others, to obtain a more accurate response in relation to the health effects of low-volume CT. Within these hypotheses it would be beneficial to control the diet, by what means a prescription of a high protein diet[39] and hypocaloric for the reduction of %FM,[70] during the experimental period. Longer experimental periods may lead to more significant results.[37] However, this remains hypothetical and requires further investigation to elucidate these topics.

Conclusions

This study found that 6 weeks of low-volume CT is sufficient to significantly improve HGS and cardiorespiratory condition in young active adults. It is suggested that low weekly exercise volume associated with high intensity exercise may be an efficient strategy to increase these components of PF, with less time invested than traditional recommendations and generate a positive AR to exercise over the weeks. In contrast, was not sufficient to significantly generate a FM loss, nor an increase in FFM. From practical point view, this study adds to literature that low-volume with high intensity CT can be used as a time-efficient resource to increase PF, improve health, and also to generate pleasure in the practice of exercise in young active adults, being able to increase exercise adherence. Also indicating, which in an early phase, for active young adults the traditional volumes perhaps were unneeded to improve health-related PF and easier to perform for busy individuals however more studies are required to confirm these results.

Submission statement

The manuscript has not been published and is not under consideration for publication elsewhere. If accepted, this manuscript will not be published elsewhere including electronically in the same form or in any other language, without the written consent of the copyright-holder. All authors approve publication of this work. Still, while this manuscript is being reviewed for this journal, the manuscript will not be submitted elsewhere for review and publication.

Ethical approval statement

The study was performed following the Declaration of Helsinki and was approved by the ethics committee of Polytechnic institute of Beja (CEIPBeja). The participants were volunteers, without a monetary incentive and were informed about the use of their information. Informed consent from each participant was obtained.

Authors' contributions

RM: Writing – original draft, Formal analysis, conceived of the study, managed the database, performed statistical analyses, interpreted results, drafted the manuscript, NL: Writing – original draft, conceived of the study, interpreted results, drafted the manuscript All authors provided critical reviews and manuscript edits before approval of the final version.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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