Cover Sheet

Study Protocol 11/05/2017

Study title

The Effects of Low-Volume High Intensity Interval Training and Circuit Training on Maximal Oxygen Uptake

Trial Number: NCT03700671

Design

Regular exercise is well known to have a positive effect on health [1,2]. Many of these benefits are associated with improving maximal oxygen uptake ($\dot{V}O_{2max}$) [3,4]. Increasing $\dot{V}O_{2max}$ through exercise training may improve cardiometabolic health, quality of life and increase life-expectancy [5,4]. Popular training methods aimed at improving $\dot{V}O_{2max}$ are circuit and high intensity interval training (HIIT) and are routinely adopted by the general population, health and fitness professionals and researchers [6]. Circuit training (CT) is typically performed at a moderate or high intensity, over a period of 30-50 minutes and involves a range of aerobic, body weight and resistance exercises with minimal rest [7,8]. Low-volume HIIT is defined as 'brief, intermittent bursts of vigorous activity, interspersed by periods of rest or low intensity exercise' [9], typically prescribed at a training intensity between 80 and 100% of heart rate maximum (HR_{max}) [10].

Whole-body CT and low volume HIIT consisting of eight to twelve one-minute interval bouts, interspersed with a similar recovery time have been shown to improve cardiometabolic health and cardiorespiratory fitness (CRF) [8,11-16]. Increases in $\dot{V}O_{2max}$ and the anaerobic threshold (AT) have been observed following CT, however published studies are limited to sedentary and older populations, with further markers of CRF not fully explored [8,17]. Comparable improvements in $\dot{V}O_{2max}$ and the AT have been shown following low volume HIIT, with increases in maximum oxygen pulse ($\dot{V}O_2$/HR) also observed [16,18,19]. However, there is limited evidence directly comparing both training methods across a range of CRF markers, as such it is unknown which approach is most beneficial [20,21].

Direct comparisons have been made investigating low volume HIIT and moderate intensity continuous training (MICT), which is typically 30-60 minutes in duration adopting the same modality of exercise [15,16,14]. The results demonstrate low volume HIIT to be a time efficient method, eliciting greater improvements in $\dot{V}O_{2max}$, although these findings are not consistently shown [22].

While HIIT and CT are feasible and effective at improving CRF, no study has directly investigated the two. Therefore, the aim of this study was to compare the effect of two weekly sessions of low volume HIIT and CT over an eight-week period on $\dot{V}O_{2max}$ in apparently healthy middle-aged adults. We also investigated changes in other markers of CRF such as the first ventilatory anaerobic threshold ($\dot{V}O_2$ at VAT) and maximum $\dot{V}O_2$/HR.

Study Design

Participants were enrolled in a randomised control trial at the University of Hull to either eight weeks of HIIT or CT (two supervised sessions per week, accompanied by an exercise physiologist). A sample size of 38 using G*Power 3.1 software was calculated based on previously published data in which the mean difference between HIIT and MICT was 3.2 $ml \cdot kg^{-1} \cdot min^{-1}$ with a pooled standard deviation of 3 $ml \cdot kg^{-1} \cdot min^{-1}$ [19]. Statistical significance was set at $\alpha = 0.05$ and power set to 0.95. To allow for 10% attrition 42 individuals were recruited to the study. To assess the effectiveness of the interventions as determined by $\dot{V}O_{2max}$, a maximal cardiopulmonary exercise test (CPET) to volitional exhaustion on an electronically braked cycle ergometer at baseline (visit one), and following an eight-week exercise intervention of HIIT or CT (visit two) was conducted. When attending the assessments participants were asked not to take part in any strenuous exercise 24 hours prior to the appointment, to wear suitable comfortable clothing and avoid a large meal. Visit two CPET was performed within six days of completing the exercise interventions. A thorough warm-up and cool down before and after each exercise session. All were asked to maintain their habitual physical activity patterns during the intervention. Body mass index (BMI) was calculated by dividing body weight [23] by height in meters squared and was presented as $kg \cdot m^{-2}$. Resting blood pressure was measured after 15 minutes of rest using a sphygmomanometer (A.C. Cossor & Son Ltd, London UK) and stethoscope (3M Healthcare, St Paul, MN). To provide a comprehensive account of the study the Consensus on Exercise Reporting Template (CERT) was consulted [24].

Participants

Ethical approval was provided by the School of Life Sciences ethics committee at the University of Hull which was in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. A total of 42 apparently healthy men and women between the age of 18-65 years were recruited to the study. Participant characteristics are given in Table 1. Enrolled individuals reported no medical history of cardiometabolic or limiting respiratory disease, were non-smokers, had a body mass index <30 $kg \cdot m^{-2}$, classified as recreationally active [25] and none were taking any medication that would affect heart rate. As a condition of enrolment, those over 45 years obtained written medical clearance from a general practitioner and underwent resting and exercise 12-lead electrocardiogram (ECG) (GE Healthcare, Chalfont St Giles, United Kingdom). Written informed consent and a pre-exercise medical questionnaire was completed by all.

Table 1 here

Cardiopulmonary Exercise Testing

Maximal CPETs were conducted in accordance with the American Thoracic Society (ATS) and the American College of Chest Physicians (ACCP) guidelines [26]. An Oxycon pro (Jaeger, Hoechburg, Germany) breath by breath metabolic cart was used to collect respiratory gas exchange data. Automatic and manual calibration evaluated ambient temperature, humidity, barometric pressure and altitude. Calibration of the air flow volume was conducted using a 3L syringe and by automatic calibration. Two-point gas calibration was also conducted to ensure accurate measures of inspired

O_2 and expired CO_2 [27]. Tests were performed on a GE e-bike ergometer (GE Healthcare, Buckinghamshire, UK) using a ramp protocol [26]. The protocol consisted of a three-minute rest phase, three minutes of unloaded cycling, followed by a personalised ramp test [28] (ramp rate ranged between 15 and 30 watts) with work rate continually increased every one to three seconds. Participants performed the same ramp rate pre and post testing. Participants were asked to pedal at a cadence of 70 rpm until they reached volitional exhaustion at a protocol duration between eight to twelve minutes. Self-reported rating of perceived exertion (RPE) scores using the 6-20 scale [29] and heart rate (HR) (FT1 heart rate monitor, Polar Electro, OY, Finland) was recorded during the last five seconds of each minute of the test, at maximum exercise and during the recovery period. Together with verbal encouragement to volitional exhaustion, $\dot{V}O_{2max}$ was attained by participants achieving at least two of the following criteria: $\dot{V}O_2$ plateau as determined by a failure of $\dot{V}O_2$ increase by 150 ml/min with further increases in workload analysed by breath by breath gas exchange data averaged over 15 seconds [30], respiratory exchange ratio (RER) > 1.10, achieve > 85% age predicated HR_{max} and a RPE > 17 on the 6-20 Borg scale [27]. $\dot{V}O_2$ at VAT was defined using the 'V slope' method [31] and verified using ventilatory equivalents. Peak power output (PPO) (watts) and HR_{max} were defined as the highest value achieved during the CPET with maximum $\dot{V}O_2$/HR determined by the ratio of $\dot{V}O_{2max}$ and HR_{max}.

Training Interventions

The HIIT group were asked to perform ten one-minute HIIT intervals, each followed by one minute of active recovery (AR) (total exercise time 20 minutes). Resulting from the CPET, HIIT was set at > 85% HR_{max} with a specific HR designated for this criterion. Active recovery was set at a load corresponding to 25-50 watts. Sessions were performed on a Wattbike trainer (Wattbike Ltd, Nottingham, UK). The CT group completed a practical seven-station mixed modality exercise circuit (cycle ergometer, rower, treadmill, sit to stand/squats, knee to elbow and leg kickback with bicep curl) at an intensity of 60-80% HR_{max} (calculated from CPET). No resistance equipment was involved, only body weight. Participants initially performed 20 minutes of CT with duration increased by five minutes per week until the desired 40 minutes. Each station was occupied for three to six minutes depending on session duration, moving from one station to the next with minimal rest. During both interventions, HR was measured in last 5 seconds of each station/interval using a FT1 polar heart rate monitor (Polar Electro, OY, Finland) with each CT session timed using a stop watch (Axprod S.L, Guipuzcoa, Spain). Intensity for both interventions was adjusted throughout by the investigator to ensure an appropriate HR range and successful completion of the protocol. Participants were made aware of their HR ranges and verbal encouragement was given by the physiologist to help achieve and maintain these thresholds. Energy expenditure between HIIT and CT was not matched.

To assess the validity of the exercise interventions, participant fidelity to the desired exercise intensity was determined using cut points of >85% HR_{max} and 60-80% HR_{max} for HIIT and CT respectively and reported using previous examples [32,33]. These values were calculated using the participants mean heart rate for each individual interval or station over the 16 sessions and was expressed as a percentage of HR_{max} as determined by CPET at visit 1. Specific fidelity thresholds were consulted to determine low (<50%), moderate (50-70%) and high (>70%) compliance [34]. Adherence was determined as a percentage of completed sessions, with 14 (> 85%) being the threshold for completion.

Statistical Analysis

Statistical analysis was conducted using SPSS version 24 (IBM, New York, USA). An independent t-test was used to identify group differences at baseline. Assumptions of normality were verified using the Shapiro-Wilk test. Skewness and kurtosis of distribution was visually examined. Non-normally distributed data was presented as median and interquartile range (IQR). A two-way (condition x time) repeated measures analysis of variance (ANOVA) was used to compare CRF pre-and post-training. Post-hoc analysis for the main effects and interactions was assessed using a Bonferroni adjustment. Group differences were compared using independent t tests. Variables were displayed as mean with 95% confidence intervals (95% CI) or standard deviation (±) where specified. Partial eta squared (η_p^2) effect sizes were also calculated with 0.01, 0.06 and 0.14 representing small, medium and large effect sizes, respectively [35].