Contents

Abstract

Purpose: This study aimed to determine whether in middle-aged adults, High-Intensity Interval Training (HIIT) elicits similar effects on Cardiovascular risk factor (CVRF) profiles when compared to Steady State Training (SST).

Methods: Participants (n=13, age:49±5years) were recruited by CP+R onto a 24-week programme consisting of 12 weeks SST, twice weekly (within the heavy domain) followed by 12 weeks HIIT, twice weekly (alternating between moderate and severe domains). 3 laboratory visits took place (baseline, post-SST, post-HIIT). Laboratory preliminary visits consisted of CVRF measurements including blood pressure, blood cholesterol and glucose, resting heart rate and body composition, followed by Cardiopulmonary Exercise Testing.

Main findings: Results suggested that HIIT may be an appropriate adjunct to SST by maintaining and in some cases improving CVRF profiles. Blood pressure, cholesterol and glucose levels did not significantly change between conditions, whereas the cardiorespiratory measurements improved significantly. Predicted VO_2 max significantly improved by 9.4% post-HIIT, whereas no statistical difference was observed throughout VO_2 max data at ventilatory threshold 1 and 2.

Conclusion: HIIT maintains improvements in CVRF's obtained by SST and elicits superior improvements in cardiorespiratory fitness in low-risk adults. Future research may consider between sex analysis and the possibility of implementing HIIT in higher risk populations.

Keywords: Cardiovascular, Risk-Factor, Cardiorespiratory, HIIT, SST

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Introduction

In the UK, 7.4 million people are currently living with Cardiovascular Disease (CVD), with 460 deaths per day due to Heart or Circulatory Disease (Bhf, 2020). Each day 280 individuals are admitted to hospital due to a heart attack. Hypertension affects approximately 28% of adults in the UK and is the prime known CVD risk factor (CVRF) (Bhf, 2020 and Kokubo and Matsumoto, 2016). High cholesterol is also a leading risk factor for circulatory and heart disease, with an estimated 50% of adults in the UK having cholesterol levels greater than the national maximal guideline of 5mmol/L. Due to the high percentage of adults exceeding the 5mmol/L guidelines, 7-8 million adults are currently on lipid lowering statins in the UK (Bhf, 2020).

Those with hypertension are increasingly likely to develop Coronary Artery Disease due to increased force on the artery walls leading to damage of the arterial system. This damage makes the arteries more susceptible to narrowing and plaque build-up associated with atherosclerosis (Hollander, 1976). High cholesterol levels can also cause the build-up of plaque in the arteries (Rafieian-Kopaei et al, 2014). The blockage and narrowing of the arteries may cause decreased oxygen supply to vital organs and blood clots, with the potential to result in life threatening strokes and heart attacks (NHS, 2020). Blood vessels can also become narrow and damaged with the CVRF hyperglycaemia, especially in those with type-2 diabetes, as heightened glucose levels can decrease nitric oxide availability which is an important atrial vasodilator (Diabetes, 2020 and Tessari et al, 2010). The recommended blood glucose levels for non-diabetics is 4.0-5.9mmol/L pre-prandial and under 7.8mmol/L post-prandial (Diabetes, 2020a).

The high prevalence of CVD and related risk factors results in a large strain on the NHS due to increasing hospital admissions and medication demand. A national CVD prevention programme was implemented in 2019 to enhance diagnosis and treatment, and to minimise individual CVRF's (NHS England, 2020). Despite a section of the programme dedicated to cardiac rehabilitation, there was no mention of widening the current awareness of the importance of physical activity in the initial prevention of CVRF's.

Cardiovascular exercise has been reviewed in the literature as an alternative to pharmacological interventions in the reduction of CVRF's; hypertension, high cholesterol levels and hyperglycaemia. A meta-analysis reviewing 391 randomised-control trials clarified that the systolic blood pressure (BP) lowering effect of exercise in hypertensive individuals (endurance−4.88; resistance-3.50; isometric−5.65; and combination of endurance and resistance−6.49mmHg) had similar physiological effects to the commonly prescribed antihypertensive medications (ACE-I:−7.33mmHg) (Naci et al, 2018). Due to this, steady state training (STT) has previously been prescribed for the management and prevention of CVD, especially in lowering primary CVRF levels. It has previously been recommended to perform endurance exercise at a moderate intensity (40-60%HRR) for at least 30-minutes per day, 5 days per week (Dendale and Hansen, 2017 and Who, 2020). According to the World Health Organisation, more than 1.4 billion adults globally are at risk of CVD due to inactivity (Who, 2016). This shocking statistic may be due to lack of available time and perceived enjoyability. Approximately 50% of people are suggested to withdraw from an exercise programme within the first 6-months due to lack of time as the most influential factor (Thum, 2017). A 2011 study found that High-Intensity Interval Training (HIIT) was perceived as more enjoyable, suggesting that short bouts of HIIT may result in higher exercise adherence levels compared to the recommended 30-minutes of longer, continuous SST. HIIT resulted in an overall higher rating of perceived exertion which may have caused enhanced enjoyment due to the heightened release of endorphins (Bartlett et al, 2011). HIIT has recently been considered a potential alternative to SST, inducing improvements in CVRF to a similar or superior extent (Hussain, Macaluso and Pearson, 2016). HIIT may be a more attractive alternative to SST for many adults as HIIT is less time consuming and can be completed at home in short bouts often requiring no equipment.

A generally consistent theme throughout the literature suggests that HIIT allows the athlete to perform a greater intensity of work during short intermittent bouts with brief rest periods of low-intensity exercise. HIIT can be work-matched to provide the same volume of work as SST. SST is considered a more time consuming, form of exercise. HIIT is generally recognised as bouts of anaerobic exercise performed above the maximal steady state within the severe intensity domain, with periods of rest or moderate intensity training (Campbell and Rutherford, 2018). According to 'Tabata training', a well-known form of interval training, HIIT consists of roughly eight, 20-second all out exercise bouts followed by 10 seconds of rest (Emberts et al, 2013). SST is regularly aerobic exercise performed below the maximal lactate SS and critical power within the moderate or heavy domains, often between ventilatory thresholds 1(VT1) and 2 (VT2) (Jones et al, 2019). Aerobic exercise has also been proven to increase VO_2 max by ~9%, whereas anaerobic HIIT has shown greater improvements in VO_2 max of ~15% (Milanović, Sporiš and Weston, 2015). HIIT was initially regularly used for improving Olympic athletic performance in the early 20th century and popularised once Olympic champion Emil Zatopek won the 1952 Helsinki Olympic 10,000m race after employing HIIT into their training programme to increase Cardiovascular fitness (Ross, Porter and Durstine, 2016).

Implementing HIIT for CVD treatment and prevention for sedentary or low-level physically active adults is different to highly active athletes applying HIIT to their training programmes. This is because highly active athletes are likely to adapt to the high intensity quicker than those that do not partake in regular exercise as they are likely to already be training within the higher intensity domains. This also means that athletes regularly training in the severe domain may have already reaped the physiological benefits that sedentary athletes have yet to gain within this domain. HIIT can be safely tailored to the individual’s needs, making intervals differing durations and intensities which is extremely beneficial when applying this form of training to a varied range of populations (Ross, Porter and Durstine, 2016). Kessler, Sisson and Short (2012) suggested that the premises of HIIT occur due to vigorous activity segments promoting greater adaptations via increased cellular stress, yet the short recovery intervals allow even untrained individuals to work harder than they usually would during SST.

High intensity exercise improves stroke volume due to the body’s heightened need for oxygenated blood, this helps to supply the body with oxygen more efficiently, increasing cardiorespiratory fitness. During HIIT, BP is increased more than other forms of exercise, however this causes a larger decrease in the long term due to HIIT reducing the stiffness of the artery walls. A decreased stiffness in the arterial walls is due to an increase in aortic nitric oxide bioavailability and is important in the prevention of atherosclerosis, myocardial infarction and strokes (Hasegawa et al, 2018 and Sethi et al, 2014).

Various studies support the use of HIIT in rehabilitation and prevention of CVRF and found that HIIT had similar or superior effects on CVRF to SST (Ross, Porter and Durstine, 2016, Hannan et al, 2018, Kessler, Sisson and Short 2012 and Hussain, Macaluso and Pearson, 2016). Taylor et al (2019) stated that HIIT is now recognised as an international clinical based exercise guideline as an appropriate adjunct to SST, however without a revised framework, safety concerns remain a common barrier. Hannan et al (2018) found that no deaths or hospitalisation of cardiac rehabilitation patients occurred during HIIT training, with adverse events just as likely to occur in SST (n=14-angina, pericardial effusion, knee injury, gastrointestinal bleed) as in HIIT (n=9-ankle fracture, hip pain, gastroenteritis, intermittent claudication).

Similar to Taylor et al (2019), Hannan et al (2018) found that HIIT was significantly superior to SST for improvements in cardiorespiratory fitness for cardiac rehabilitation patients. HIIT was significantly superior at improving VO_2 peak (SMD 0.43mL/kg/min) compared to SST for interventions of 7-12 weeks, and improvements in cardiorespiratory fitness were seen from 6-weeks, with the largest cardiovascular improvements occurring during 8-12 week duration programmes (Hannan et al, 2018). Kessler, Sisson and Short (2012) provided a similar pattern, stating that a 12-week HIIT programme was required to demonstrate a reduction in BP levels and fasting glucose. Contrasting this, Cuddy, Ramos and Dalleck (2019) found that only an 8-week programme was required to provide reductions in CVRF of 12% throughout a HIIT programme compared to a 7% reduction during SST training programmes. During this study HIIT also elicited a larger improvement in systolic BP (SBP) (-5%) compared to SST (-2%). Despite the improvements in BP apparent throughout the literature, Kessler, Sisson and Short (2012) found that no studies attained an improvement in other primary CVRF's such as total cholesterol and low-density lipoproteins (LDL). Contrasting this, Duval et al (2017) found that following a 14-day study on the implementation of HIIT in 16 male participants, high-density lipoprotein (HDL) levels significantly decreased, however the triglyceride/HDL-cholesterol ratio did not change. As the ratio did not change, this suggests that the total cholesterol levels must have also beneficially dropped for the ratio to stay consistent. A 12-week study on the effects of HIIT training compared to control found that LDL and HDL cholesterol levels remained unchanged throughout both groups (Khammassi et al, 2018). A study reviewing the effect of HIIT on 8 patients with type-2 diabetes found that the average blood glucose levels dropped significantly after training (from 7.6±1.0 to 6.6±0.7mmol/l) (Little et al, 2011).

Throughout the literature, young muscle appears to be more responsive to HIIT. This may be due to adults taking longer to recovery from vigorous exercise (~5 days more) than younger athletes (Herbert et al, 2017). This finding also suggests that HIIT guidelines may need to be widely altered with regards to recovery time and age.

The full extent to which HIIT is able to reduce or reverse the CVRF profiles of middle-aged adults is not yet entirely understood within the current literature (Hussain, Macaluso and Pearson, 2016). Participants may also already be regular steady state exercisers and the early adaptations may have already occurred, however HIIT may be what is needed to stimulate further improvements. This study aims to investigate whether a work-matched 12-week HIIT programme is as effective at improving CVRF's and cardiorespiratory fitness as SST in middle-aged adults. We hypothesised that HIIT would elicit similar if not superior effects on CVRF profiles and cardiorespiratory fitness than SST.

Methods

CP+R

This study was organised between The University of Exeter and CP+R, a rehabilitation clinic in Central London providing tailored lifestyle, health and exercise programmes to a varied range of athletes from many differing backgrounds and medical conditions.

Ethical Approval

Following a successful data sharing agreement between The University of Exeter and CP+R (appendix 1), the Department of Sport and Health Sciences Ethics Committee granted study approval. All participants involved in the study received a detailed information letter outlining the purpose of the research alongside how their data would be prospectively stored and released to The University of Exeter (appendix 2). As the participants were already taking part in the programme, there were no additional health risks to be explained to the participants. Participants content with the release of their data to The University of Exeter provided informed written consent at CP+R (appendix 3).

Participants

13 participants were recruited voluntarily, solely through CP+R (male=9, female=4, means±SD; age:49±5years, body mass:73.6±12.6kg). Following completion of the CP+R physical activity readiness questionnaire, preliminary measures were taken from the suitable athletes. The exclusion criteria consisted of anybody not granting consent to the release of their data to The University of Exeter, as well as unstable angina, uncontrollable arrythmias, significant stenosis, cancer and

uncontrolled hypertension. In order to be included in this study the participants were expected to already be athletes at CP+R and have provided informed consent to the release of their data to The University of Exeter. Any pharmacological medications prescribed by medical professionals prior to the study were continued and unchanged throughout the duration of the training.

Experimental design

The current study was a repeated measured study including two exercise conditions (SST and HIIT). The experimental protocol included 3 laboratory visits over 24 weeks in total. Laboratory visits took place prior to the SST programme (baseline/pre-SST), 12 weeks later post-SST and a further 12 weeks later post-HIIT training programme. Cardiopulmonary Exercise Testing (CPET) as well as preliminary measurements took place during each laboratory visit. The training programme sessions for both interventions were completed either at CP+R or at the participants home and compliance and adherence was tracked through heart rate data.

Preliminary measures

During the laboratory visits, resting BP was measured through a digital BP monitor (manual Littmann Classic III stethoscope with standard aneroid sphygmomanometer, Prestige) (Littmann, 2020) and total cholesterol, HDL and LDL levels were measured through a lipoprotein panel test (CardioChek PA Blood Analyser with PTS cholesterol test strips) (Pts Diagnostics, 2018). Resting heart rate, fasted glucose, body mass, height and body composition (percentage body fat and percentage muscle mass) were also taken. Heart rate was measured through a Polar H7 or H10 monitor (Polar, 2016), Body composition was measured using a body composition analyser (MC-980 Bioelectrical Impedance Analyser, Tanita, Tokyo, Japan) (Tanita., 2010) and blood glucose was measured using the Accu-Check Performa Nano with Accu-Check glucose strips (Accu-Check, 2020).

Cardiopulmonary exercise testing (CPET)

CPET testing took place on a treadmill (Lode Valiant 2 CPET) and online gas analysis was measured through Metasoft, using the Cortex Metalyzer 3B on-line gas analyser (Cortex, Leipzig, Germany). Gas analysis was observed to measure the individuals respiratory exchange ratio (RER), maximal oxygen uptake (VO_2 max), breathing frequency, rate of elimination of carbon dioxide (VCO_2), energy expenditure and to calculate predicted VO_2 max. During the CPET test, the individual's effort and exertion, breathlessness and fatigue was measured every 2 minutes using the Borg Scale (Rating of Perceived Exertion, 6-20). Speed at VT1 and VT2 were also recorded throughout all CPET sessions.

The CPET began with a 3-minute unloaded phase on the treadmill (4km/h with a 0% incline). After the 3-minute unloaded phase, there was a 0.5km per minute increase in incline (increasing by 0.1% every 12 seconds) (RAMP test). This incline changed to 1% at the end of this 3-minute period and remained at 1%. During the test athletes were asked to run when they felt comfortable to do so. The CPET test terminated when the athlete had worked to a standardised limit of 95% heart rate reserve (based on the Karvonen calculator). Heart rate was recorded throughout the test via Metasoft using a polar heart rate monitor. CPET testing was completed in the laboratory prior to SST, post-SST and post interval training. During the CPET, VT1 and VT2 were assessed allowing us to delineate the exact locations of the exercise intensity domains.

Training programme sessions

Individual SST sessions took place for 12 weeks followed by 12 weeks of HIIT. SST sessions consisted of SST within the heavy intensity domain and were completed twice weekly. Between 20-40 minutes of SST was performed between VT1 and VT2 during each session. HIIT sessions were also completed twice weekly (work-matched to the SST intensity exercise), however this was split into small bouts (e.g. 3-6 intervals per session) of exercise alternating between the moderate (for 3 minutes) and severe domains (for 3 minutes). 10-minute warm up and cool down periods were included in all training sessions and the relative challenge was consistent between participants throughout.

Statistical Analysis

Data was statistically analysed via SPSS through a 3-way repeated measures ANOVA with pairwise comparisons ($F(df_{condition}, df_{error})$ = F value, p= p value). Mauchly's test for Sphericity was used and the Greenhouse-Geisser corrected any violations of the assumptions. The Bonferroni correction was used for all post hoc analysis and to adjust probability. Statistical significance was set at $P \leq 0.05$ and all data means and graph error bars were reported as ±SEM.

Results

Systolic Blood Pressure (n=7)

SBP data did not provide a statistically significant main effect of condition throughout the tests of within-subject effects ($F(2, 12)=0.606$, $p=0.562$). Post hoc tests found no statistically significant difference in SBP between conditions (baseline:114.7±4.0, post-SST:120±13.3, post-HIIT:116.5±10.9mmHg; p>0.05). Participants with baseline SBP measurements over 120mmHg found the largest decrease in BP post-HIIT training, however this sample size was too small to reliably statistically analyse (n=2). The SBP response for each individual participant has been displayed in figure 1.

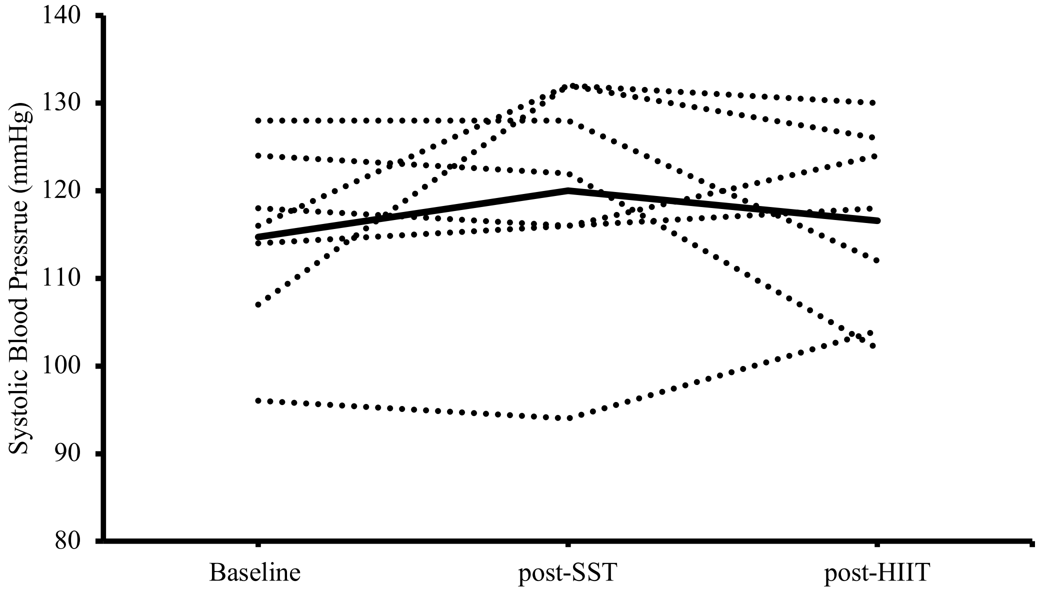

Figure 1: Dotted lines signify individual participant data for SBP measurements and bold line indicates group mean for all condition measurements. No main effect of condition was observed between conditions (p>0.05).

Diastolic Blood Pressure (n=7)

Diastolic BP (DBP) results did not provide a statistically significant main effect of condition throughout the tests of within subject effects ($F(2, 12)=0.213$, $p=0.811$). Post hoc analysis did not find a statistically significant difference in DBP between conditions (baseline:72.3±7.8, post-SST:72.3±9.6, post-HIIT:74±7.8mmHg; p>0.05). The DBP response for each individual participant has been displayed in figure 2.

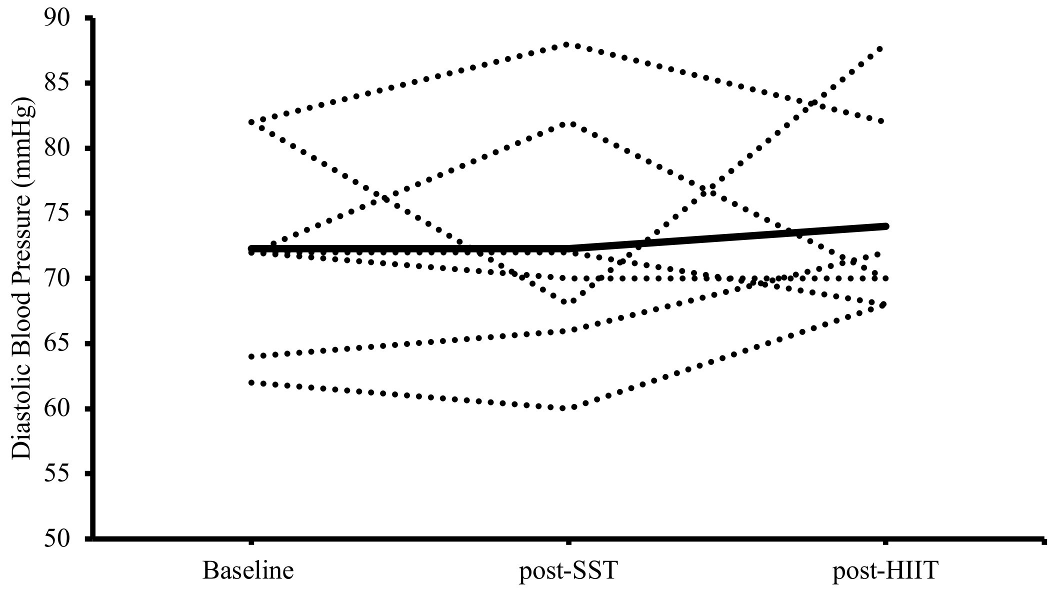

Figure 2: Dotted lines signify individual participant data for DBP measurements and bold line indicates group mean across the three conditions. No main effect of condition was observed between conditions (p>0.05).

Total Cholesterol level (n=7)

Throughout the tests of within-subject effects, no main effect of condition was observed throughout total cholesterol level data ($F(2, 12)=0.849$, p=0.452). Post hoc tests also did not find a significant difference in total cholesterol level pairwise comparisons between conditions (baseline:3.9±0.9, post-SST:3.8±0.6, post-HIIT:4.1±0.4mmol/L; p>0.05). The mean total cholesterol level response for each condition has been displayed in figure 3.

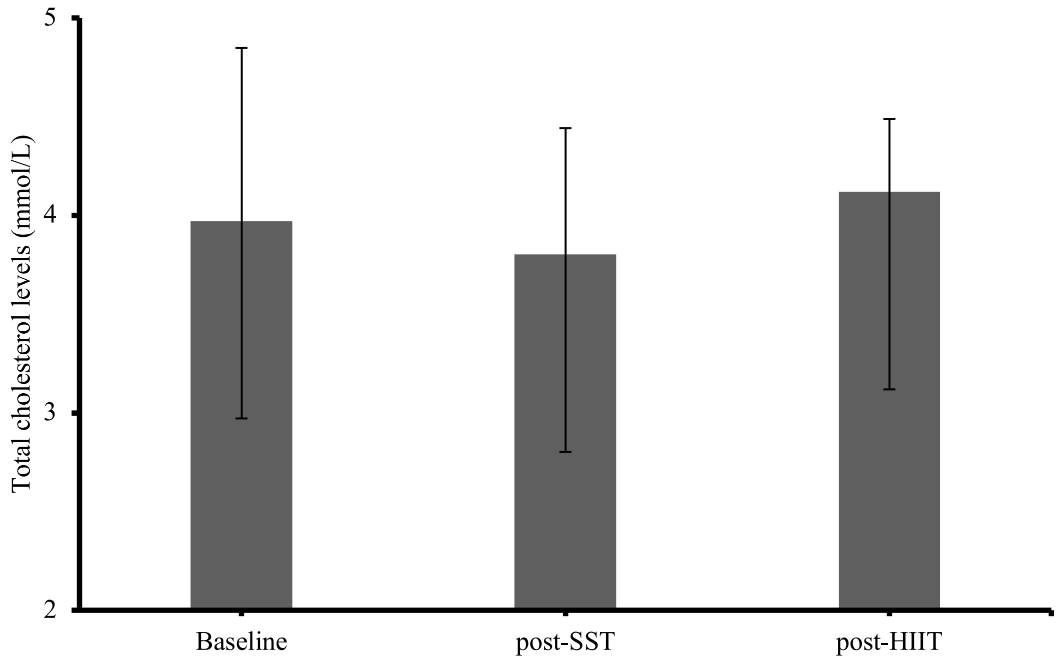

Figure 3: Mean data for total cholesterol measurements across the three conditions.

High-density lipoproteins (n=6)

Tests of within-subject effects statistical analysis did not find a significant main effect of condition throughout HDL data ($F(1.032, 5.160)=0.648$, $p=0.461$). Mauchly's test of sphericity was significant ($p=0.004$) and therefore the violated assumptions were corrected with the Greenhouse-Giesser. Post hoc analysis found no significance observed throughout pairwise comparisons between conditions (baseline:1.5±0.4, post-SST:1.6±0.3 and post-HIIT:1.6±0.1mmol/L; $p>0.05$). The mean HDL response for each condition has been displayed in figure 4.

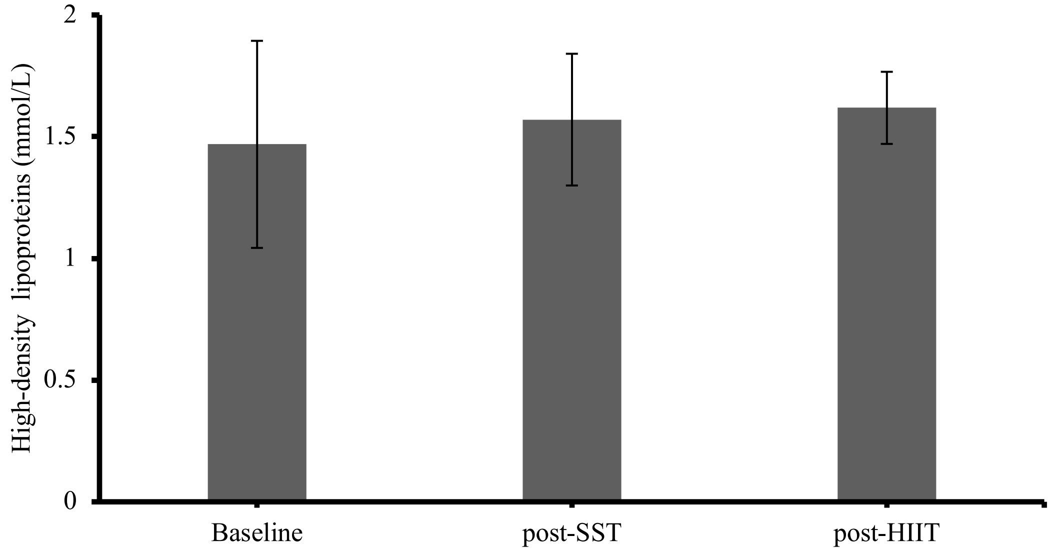

Figure 4: Mean data for the HDL concentration response across the three conditions.

Low-density lipoproteins (n=6)

Tests of within-subject effects statistical analysis did not find a significant main effect of condition throughout the LDL data ($F(2, 10)=0.937$, $p=0.424$). No statistical significance was found between conditions throughout post hoc data (baseline:2.7±0.6, post-SST:2.4±0.5, post-HIIT:2.6±0.2mmol/L; $p>0.05$). The mean LDL response for each condition has been presented in figure 5.

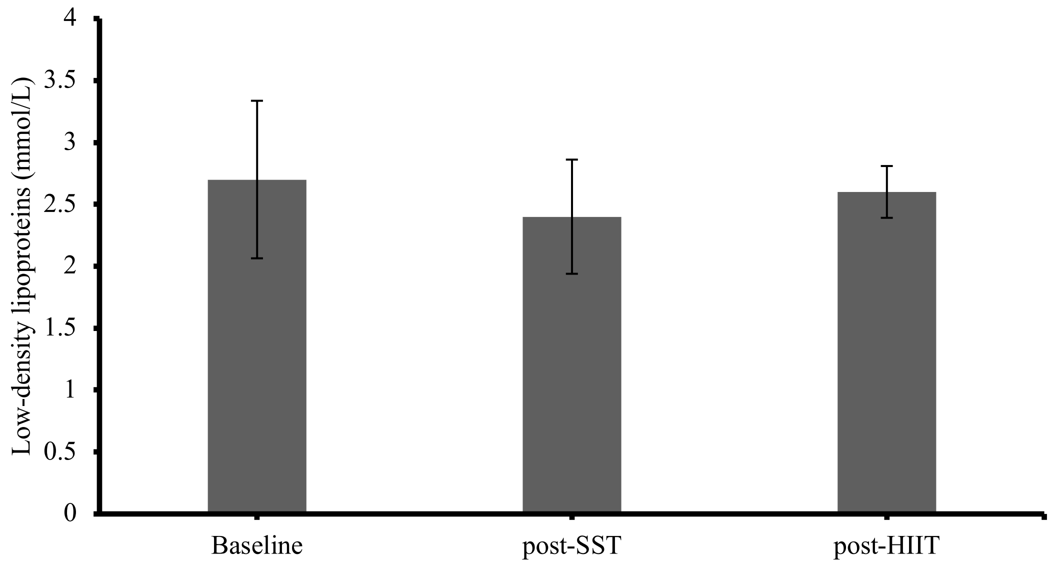

Figure 5: Mean data for the LDL concentration response across the three conditions.

Blood glucose (n=7)

Statistical analysis did not find a statistically significant condition effect throughout the blood glucose tests of within-subject ($F(2, 12)=3.223$, $p=0.76$) and no significance was observed throughout post hoc tests (baseline:5.9±0.4, post-SST:5.6±0.4 and post-HIIT:5.3±0.3mmol/L; $p>0.05$). The mean blood glucose response for each condition has been displayed in figure 6.

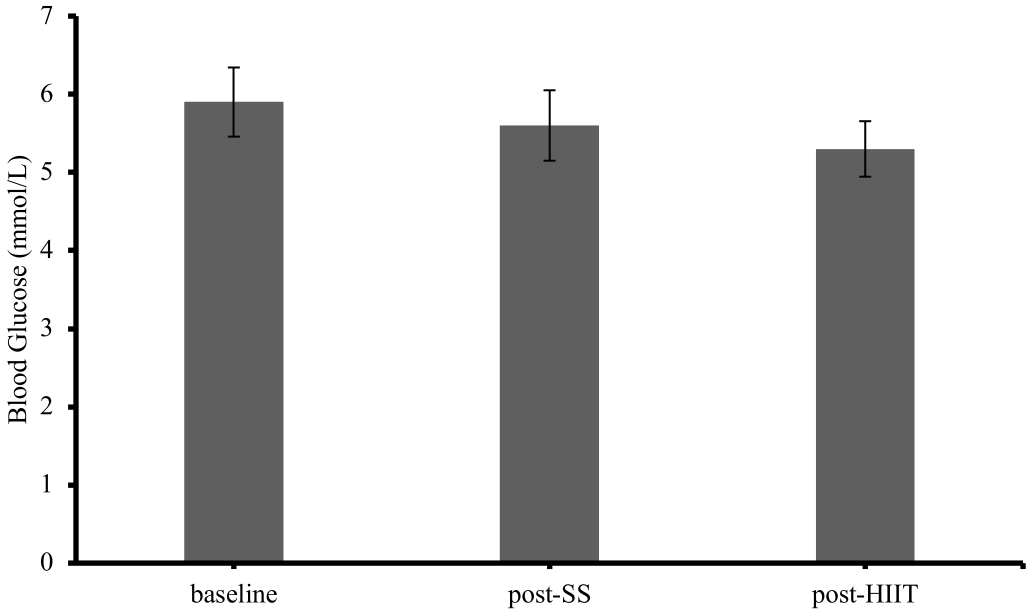

Figure 6: Mean data for the blood glucose concentration response across the three conditions.

Body Composition (n=13)

Tests of within-subject effects did not find a significant effect of condition throughout body fat percentage data ($F(2, 24)=2.896$, $p=0.075$). Despite this, a post hoc test found a significant increase in body fat percentage between post-SST training and post-HIIT (baseline:21.9±6.6, post-SST:21.9±7.2, and post-HIIT:22.7±7.4%, $p= 0.033$). Estimated effect size calculations found this to be a small, non-important effect ($\eta^2=0.194$). There was no significant difference between baseline and post-SST or baseline and post-HIIT ($p>0.05$). The mean body fat percentage response for each condition has been displayed in figure 7.

No statistically significant differences between conditions were observed throughout body mass data (baseline:73.6±12.7, post-SST:74.2±11.1, post-HIIT:74.5±11.3kg) and muscle mass data (mean= baseline:55.7±9.3, post-SST:55.2±9, post-HIIT:54.8±9.3%) analysis ($p>0.05$). The mean muscle mass percentage response for each condition has been displayed in figure 8.

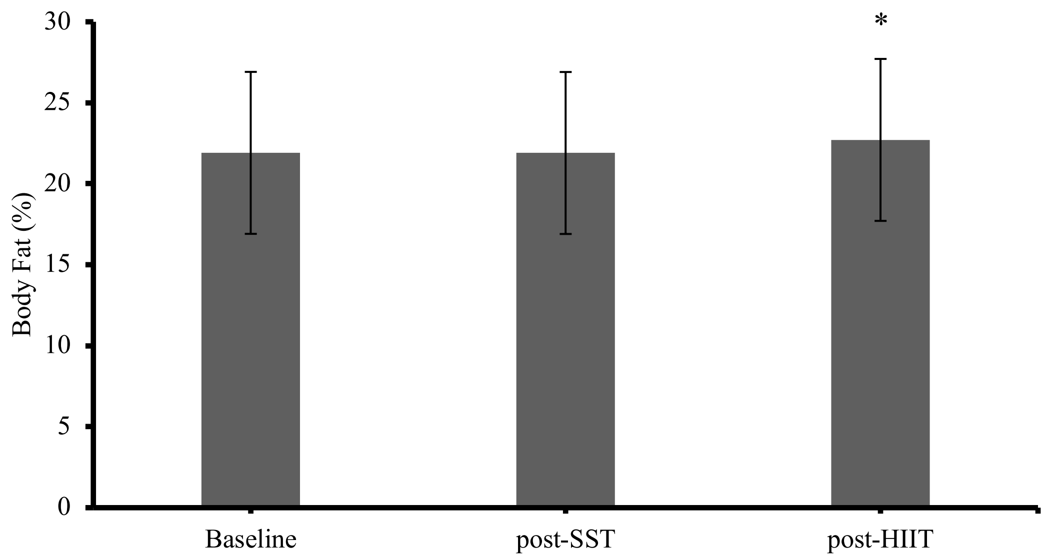

Figure 7: Mean body fat percentage data across the three conditions. * = Statistically significant difference between post-SST and post-HIIT ($p=0.033$), small effect size ($\eta^2=0.194$).

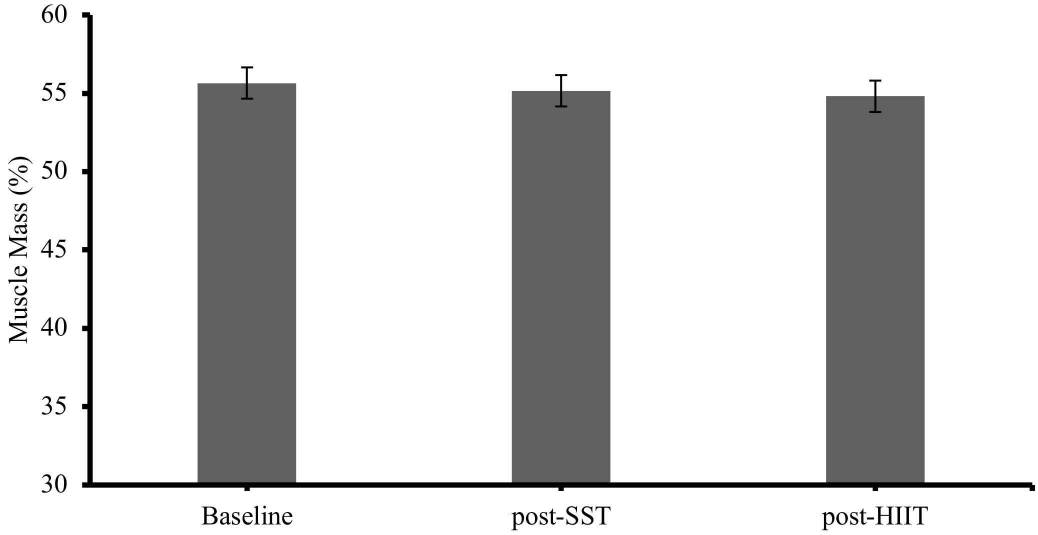

Figure 8: Mean muscle mass percentage data across the three conditions.

Predicted VO_2 max (n=13)

Predicted VO_2 max results provided a statistically significant effect of condition through the tests of within-subject effects ($F(2, 24)=9.907$, $p=0.01$). Post hoc analysis found a significant difference in predicted VO_2 max between baseline and post-HIIT ($p=0.001$) (baseline:37.5±5.5, post-SST:39±4.9 and post-HIIT:41.4±7.2mL/kg/min). For this significant result, average participant predicted VO_2 max raised ~10% from 37.5mL/kg/min at baseline to 41.4mL/kg/min at post-HIIT. Estimated effect size calculations found a medium effect size ($\eta^2=0.452$). Pairwise comparisons did not find a significant difference between baseline and SST or SST and HIIT. The mean predicted VO_2 max response for each condition has been displayed in figure 9.

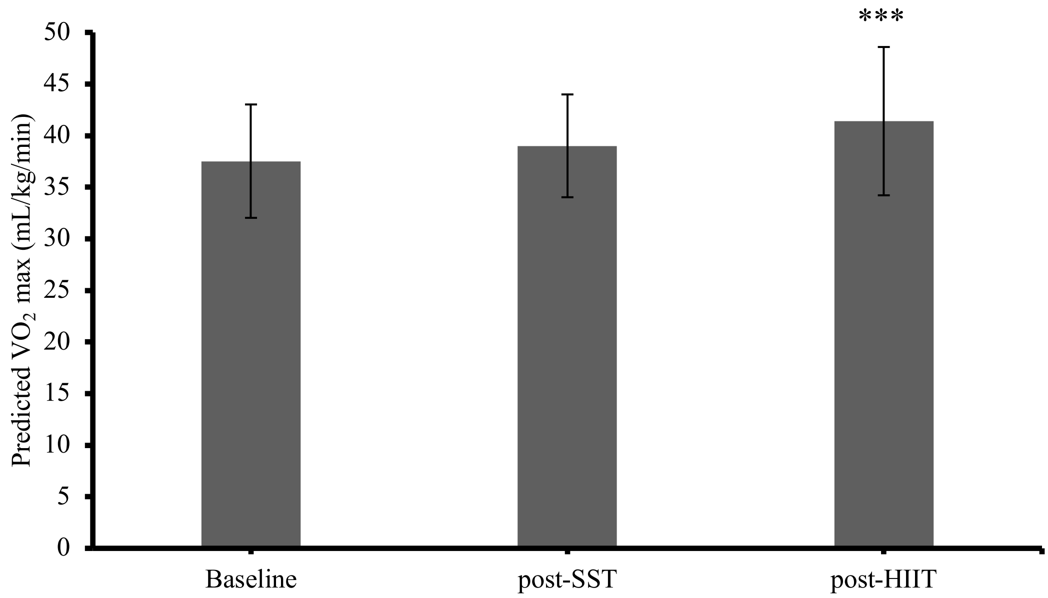

Figure 9: Mean predicted VO_2 max data across the three conditions. *** = Statistically significant difference between baseline and post-HIIT (p=0.001).

VO_2 and Speed at VT1 (n=13)

Statistical analysis did not provide a statistically significant main effect of condition throughout the tests of within-subject effects for VO_2 at VT1 data ($F(2, 24)=3.373$, p=0.051) or speed at VT1 ($F(2, 24)=2.592$, p=0.118) and the Greenhouse-Geisser was used to correct any violated assumptions. Post hoc tests found no statistically significant difference in VO_2 at VT1 and speed at VT1 throughout all conditions.

VO_2 and Speed at VT2 (n=5)

Statistical analysis did not provide a statistically significant main effect of condition throughout the tests of within-subject effects for VO_2 at VT2 data ($F(2, 8)=2.250$, p=0.168) or speed at VT2 ($F(2, 8)=1.514$, p=0.277). Post hoc analysis found no statistically significant difference in VO_2 at VT2 and speed at VT2 throughout all conditions. A slight trend (~10% increase from post-SST to post-

HIIT) suggested that HIIT may have improved VO_2 at VT2 results, however due to the small sample size (n=5) statistical significance was not apparent. The mean VO_2 response at VT1 and VT2 has been displayed in figure 10.

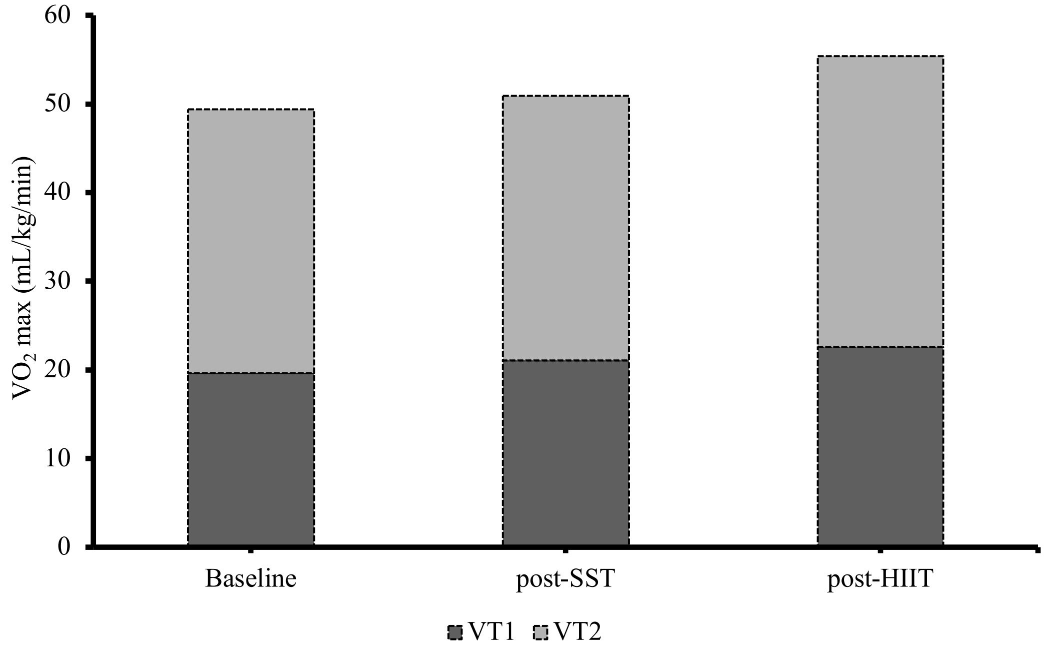

Figure 10: Mean data at baseline, post-SST and post-HIIT for VO_2 at VT1 (baseline:19.6±4.5, post-SST:21.1±4.27, post-HIIT:22.6±5.1mL/kg/min) and VT2 (baseline:29.8±4.1, post-SST:29.8±4.4, post-HIIT:32.8±4.3mL/kg/min).

Discussion

The primary aim of this study was to determine whether a 12-week work-matched HIIT programme was as effective as SST for CVRF improvements in middle-aged low risk adults. The principle finding of this study, supporting our hypothesis, found that HIIT may be an appropriate alternative to SST, maintaining and in some cases further increasing the CVRF improvements obtained by SST. This study also found that HIIT had superior effects on cardiorespiratory fitness when compared to SST.

Both systolic and DBP data provided no statistical difference between post-SST and post-HIIT training, however a very slight decrease in SBP was observed in those with baseline SBP over 120mmHg (baseline to post-SST: -0.8%, post-SST to post-HIIT: -14.4%). Despite this suggestion, the sample size of this group was too small to analyse and therefore future research on a more varied, larger sample size is needed to validate this finding. There was no trend observed throughout DBP data analysis. This is supported by Olea et al (2017) who did not find a significant reduction in DBP (84.9±3.9 to 85.8±17.6mmHg) after HIIT, however did find a significant reduction in SBP (145.4±9.0 to 118.3±15.6mm Hg: $p<0.05$). Olea's study design was different to ours as just over half of the participants were hypertensive (n=22). This larger hypertensive sample size may have been what our study needed in order to provide the statistically significant reduction in SBP in those with SBP within the higher range of normal. Similar to our study, they also completed 24 exercise sessions, however completed them over a shorter period of time (3 sessions per week).

Despite no statistical significance observed throughout cholesterol data analysis, a very slight trend was observed throughout LDL and total cholesterol data. This data presented that SST may have had a superior effect on LDL and total cholesterol levels when compared to HIIT, similar to the current literature. Throughout LDL data there was a 12.6% decrease from baseline to post-SST, and a 9.4% increase from post-SST to post-HIIT. There was also a 4.3% decrease from baseline to post-SST in total cholesterol level data, followed by another increase of 7.6% from post-SST to post-HIIT. These values may have not presented as statistically significant due to a small sample size, therefore in future a larger scale study should be performed to validate this trend. Kessler, Sisson and Short (2012) also found a similar trend throughout their meta-analysis of 24 studies. They found that none of the included studies reported improvements in total cholesterol and LDL levels after HIIT training. They did however find improvements in HDL levels post a minimum of 8 weeks HIIT training. This contrasting finding may be due to the volume of work not being consistent throughout both SST and HIIT meaning that differing volumes of work may have been completed. Unlike the current literature, our study provided a very similar volume of work throughout both HIIT and SS training. Another study supporting our finding found that total cholesterol levels reduced by 12.9% post-SST, but only 9.2% after HIIT training (Fisher et al, 2015). They also found that LDL also increased significantly more during SST (7.8%) compared to HIIT training (4.8%). Similar to our study they did not find a significant difference between post-SST and post-HIIT for HDL levels. This study had a differing structure to our study, completing 3 exercise sessions per week with the programme lasting only 6 weeks in total (Fisher et al, 2015). Mann, Beedie and Jimenez (2013) found that during continuous effort, the improvement in cholesterol levels became more consistent which suggests SST may be more beneficial with regards to cholesterol levels due to the consistently raised HR, rather than waves of HR fluctuation as seen in HIIT.

Although non-significant there was also a slight trend throughout blood glucose data, with HIIT providing to be better at blood sugar control. There was a 0.3mmol/L decrease from baseline to post-SST, and a following 0.3mmol/L decrease from post-SST to post-HIIT (6mmol/L decrease overall). This suggests that although SST exercise helps to decrease blood sugar levels, HIIT is need for the extra, further gain and improvement in blood sugar control. The current literature provides clear evidence that HIIT improves blood sugar control in those with type 2 diabetes however there is less evidence that HIIT improves blood sugar control in those with normal blood glucose levels (Francois and Little, 2015). A study on 8 patients with type 2 diabetes found that after 2 weeks of HIIT training 3 times per week, average blood sugar levels dropped by 6.6mmol/L (Little et al, 2011), similar to the 6mmol/L decrease from baseline to post-HIIT observed in our study. This suggests that the initial baseline blood glucose value does not affect the magnitude of improvement. This study is different to ours as it consists of 3 HIIT sessions per week and implemented 24hr continuous glucose monitoring. 24hr glucose monitoring may have been a more accurate way for us to measure the magnitude of improvement, yet something our study was unable to do due to participants spending short duration, limited periods of time within the clinic itself.

Body fat analysis provided a statistically significant increase in body fat percentage between post-SST and post-HIIT (1% increase), however the effect size appeared very small counting the significance as non-important. Any slight increases in body fat percentage may be due to daily variance in nutritional factors and activity levels. A meta-analysis from 2019 found that interval training and continuous intensity training both reduced body fat percentage, with interval training providing a 28.5% greater reduction in absolute fat mass compared to SST (Viana et al, 2019). A meta-analysis by Maillard, Pereira and Boisseau (2017) also found HIIT to be an efficient form of exercise to reduce total ($p=0.003$), abdominal ($p=0.007$) and visceral ($p=0.018$) fat mass. They also found that running was the most effective form of exercise in reducing total and visceral fat mass, as performed in our study. Similar to our study the high intensity training was also performed at above 90% HRR at minimum. Throughout our study we also did not see any significant changes throughout other body composition measurements such as body mass and muscle mass percentage. This finding also supports our statement that body fat percentage changed very acutely as these measurements did not change. As stated, our study presented various contrasting results to the current literature. This may have been due to some, if not all of the participants in our study already partaking in regular physical activity and therefore the initial reductions and improvements in body composition may have already taken place, with HIIT being an adequate form of exercise to maintain these levels. We are also unable to control adherence levels outside of the clinic, which may have had an impact on the results if levels of adherence were not consistent throughout all participants (those who work harder, will likely achieve better results).

Throughout our study, HIIT presented to be good at increasing overall VO_2 and performance measurements. Predicted VO_2 max significantly increased on average 9.4% from baseline to post-HIIT (37.5±5.5 to 41.4±7.2mL/kg/min) suggesting that SST caused the initial increase, however HIIT was needed to enhance the improvements significantly further. Our finding was supported by Astorino et al, (2012), who found that cardiovascular fitness (VO_2 max, O_2 pulse and power output) was increased after HIIT training. HIIT significantly increased VO_2 max by an average of 6.4±5.4%, which is slightly lower than in our study. This difference may have been because Astorino's study was performed on younger adults (25.3±4.5 years) whereas our study was performed on middle-aged adults which may have presented different outcomes due to physiological and age-related factors. Their study also consisted of a different form of intensity training (Wingate tests) over a 3-week period. Astorino's study also included a control group of 9 men who completed testing but did not partake in HIIT. This may have been useful in our study to allow us to eliminate and isolate differing variables, however, was not feasible for our study. Throughout our study there was no statistically significant difference apparent throughout VO_2 at VT1 and VT2 data. Despite this, a slight trend was seen in the VO_2 at VT2 data, providing an increase in VO_2 from post-SST to post-HIIT of 9.1%. Despite this finding, only 5 participants achieved a VT2 making reliable statistical analysis impractical. Small sample size has displayed as an ongoing limitation to this study and in order to determine the true validity of these suggested trends larger and more varied sample sizes would be needed in future studies.

Conclusion

In conclusion, data suggests that HIIT is an appropriate alternative to SST for the maintenance or improvement of CVRF's and may elicit superior improvements on Cardiovascular fitness when compared to SST. HIIT may be considered high-risk for the very poorly, but for fitter and healthier populations is considered a low-risk, appropriate and more time-efficient alternative form of exercise. Due to this study confirming the safety and applicability of HIIT in healthy low-risk populations, future research could potentially be conducted on those at higher risk of cardiovascular events, to see the true effect of HIIT in clinical populations. Larger sample sizes and between sex analysis would extend this research further.

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