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Declaration

This work is original and has not been submitted previously in support of a Degree qualification.

List of Tables

High intensity interval training versus continuous training for weight loss.

Systematic review of the efficacy of high intensity interval training versus continuous training for weight loss in overweight and obese individuals.

List of Abbreviations

AnT - anaerobic threshold
BMI - body mass index
CABG - coronary artery bypass grafting
CAD - coronary artery disease
c/down - cool down
CHO – carbohydrate
Cm - centimetre
CONT – continuous
DoH – Department of Health
DEXA - dual-energy X-ray absorptiometry
EPOC - excess post exercise oxygen consumption
FFM - fat free mass
HIIT - high intensity interval training
Kg – kilograms
kg/m^2 – kilograms per metre squared
Kcal – kilocalories
MHR - maximum heart rate
MJ – megajoules
mins – minutes
mm – millimetres
n - number
O_2 – oxygen
PA - physical activity
PICO - population, indicator, comparator, outcome
QRS – quality rating score
RER – respiratory exchange ratio
RI - recovery interval
secs – seconds
$\dot{V}O_2$ max – maximum oxygen consumption
VO_2 peak - peak value of oxygen uptake
WI - work interval
W/H ratio - waist to hip ratio
w/up - warm up
1RM - one repetition maximum
< - less than
> - greater than

Abstract

Regular exercise and physical activity are often prescribed as a means to prevent metabolic diseases and to aid with weight loss. Traditional exercise prescriptions to improve health and incur weight loss have largely focused on aerobic continuous (CONT) training performed at low to moderate exercise intensities. More recently high intensity interval training (HIIT) has been suggested as an alternative and more time efficient exercise prescription to CONT training. HIIT typically involves short periods of high intensity exercise interspersed with lower intensity recovery periods. The proposed benefits of HIIT compared to CONT training include an increased ability to oxidize fat and spare muscle glycogen during subsequent exercise sessions, a greater overall energy expenditure compared to lower intensity CONT exercise when the two training methods are performed for the same duration, and an increase in the excess post exercise oxygen consumption. In terms of actual weight loss, one of the main suggested benefits of HIIT is that it can achieve comparable or superior results to CONT training in much less time making it a more efficient form of exercise. The evidence to substantiate these purported benefits of HIIT over CONT training is however, equivocal with some studies showing greater benefits of HIIT on anthropometric outcomes whilst others support the use of CONT training. Whilst this suggests that both protocols can be effective for achieving weight loss and favourably altering body composition even in individuals classified as being of normal weight by the body mass index (BMI), the findings are confounded by numerous methodological issues. Discrepancies in study durations, wide variability in HITT and CONT training protocols across studies, and the problems associated

with dietary intake and controlling for exercise and physical activity outside of the intervention makes it difficult to draw firm conclusions as to the superiority of one exercise protocol over the other. This is further exacerbated in those studies that have not included a control group for comparison to the exercise intervention groups. Whilst it may be surmised that in normal weight individuals both HIIT and CONT can be effective for achieving favourable changes in anthropometric outcomes it is not known which exercise protocol is more beneficial for those individuals who are classified as overweight and obese.

Contents

1.0 Introduction

Regular exercise and physical activity are often prescribed as a means to prevent metabolic diseases and to aid with weight loss. Epidemiological data obtained from cross-sectional and longitudinal studies have demonstrated the protective effects of regular exercise and physical activity on conditions such as heart disease, impaired glucose tolerance, type II diabetes, hypertension and adiposity (Nybo et.al., 2010). To help prevent against hypokinetic disease conditions the Department of Health (DoH, 2011) recommend that adults should accumulate 150 minutes of moderate physical activity per week in bouts of 10 minutes or more, or alternatively perform 75 minutes of vigorous activity per week. A key recommendation to achieve the guidelines is to be active for 30 minutes a day five days a week (DoH, 2011). These recommendations are flexible in that they allow the choice for individuals to perform exercise in one continuous bout or in shorter bouts that can be accumulated throughout the day. The guidelines also infer that similar health benefits may be achievable in half the time if exercise is performed more vigorously compared to longer but lower intensity exercise sessions. This has led to attempts being made to establish which approach is the most effective exercise prescription to accrue the protective health benefits from participating in regular exercise.

1.1 Continuous and high intensity interval training

Traditional exercise prescriptions to improve health and incur weight loss have largely focused on "steady state" aerobic exercise also known as continuous (CONT) training. This method of training is performed at a sustained, low-moderate exercise intensity typically below 85% of the maximum heart rate (MHR) for a minimum duration of 30 minutes (Seiler & Tonnessen, 2009). In contrast to CONT exercise, high intensity interval training (HIIT) is not performed at one intensity but rather, involves periods of high intensity exercise followed by periods of lower intensity exercise or rest to allow for adequate recovery before repeating the next work interval. Work intervals are typically performed at intensities that elicit 85-100% of MHR whilst recovery intervals are typically performed at 60-70% MHR (Gaesser & Angadi, 2011). The work intervals in HIIT may vary considerably ranging from as little 8 seconds to 4 minutes whilst the active recovery intervals are usually of longer duration (Gaesser & Angadi, 2011). If rest intervals as opposed to recovery intervals are used between work intervals then no exercise is performed until the start of the next work interval. The work and recovery/rest intervals are repeated for the desired number of times to achieve the total workout time which is generally no longer than 20-25 minutes inclusive of both the work and rest/recovery intervals (Gibala & McGee (2008). Table 1 provides examples of two different HIIT protocols.

Table 1. Example protocols for high intensity interval training.

Variable	HITT example 1	HITT example 2
Duration	Work intervals = 30 seconds Recovery intervals = 4.5 minutes Repeat sequence 4 times	Work intervals = 60 seconds Recovery intervals = 60 seconds Repeat sequence 10 times
Workload	Work interval = 90% MHR Recovery interval = 65% MHR	Work interval = 90% MHR Recovery interval = 65% MHR
Total workout time	20 minutes	20 minutes

Adapted from Burgomaster *et al.* (2008) and Gibala, Little, MacDonald & Hawley, (2012).

1.2 Bioenergetics of continuous and high intensity interval training

The bioenergetics of CONT training and HIIT differ markedly during exercise primarily due to the inherent variation in the prescribed intensity and duration of the two modes of training. The traditional recommendation that exercise to target weight and fat loss should be performed at low sustained intensities for prolonged duration is partly based on the premise that during such activity intramuscular triacylglycerol and plasma free fatty acids released from adipose tissue help provide the largest percentage contribution to the energy pool (Bouchard, Despres & Tremblay, 1993). Thus, repeated bouts of such exercise should help promote the use of triacyglycerol and therefore aid with fat loss from adipocytes. Conversely, because of the increased workloads necessitated during HIIT there is more reliance on carbohydrate (CHO) in the form of muscle glycogen to provide energy during exercise with a smaller percentage contribution derived from fat (Carey, 2009). This is largely due to the anaerobic nature of the work intervals and the inability of the body to burn fat under highly intense anaerobic conditions. However, it has been shown that an adaptive response to HIIT training is an increased ability to oxidize fat during subsequent exercise sessions (Burgomaster et al., 2008).

Talanian, Galloway, Heiganhauser, Bonen and Spriet (2006) using eight recreationally active young women demonstrated that in just two weeks, 13 sessions of HIIT cycling involving ten 4 minute work intervals performed at 90% VO_{2peak} interspersed with 2 minute recovery intervals (recovery intensity not specified) increased fat oxidation by 36% in the post training cycling trial performed at 60% VO_{2peak}. Additionally, exercise net glycogen usage was reduced by 12% in the post training cycling trial indicating a CHO sparing effect of HIIT. Whilst it is worth noting that the HIIT protocol in this study required participants to exercise for a total of 40 minutes at 90% VO_{2peak} with a total exercise time of 60 minutes it appears

HIIT has the capacity to increase fat oxidation and reduce muscle glycogen utilisation in subsequent lower intensity exercise bouts.

Irrespective of the actual substrate use during exercise, HIIT uses more energy overall compared to lower intensity CONT exercise when the two training methods are performed for the same duration (Cambell, Wallman & Green, 2010). However, a lack of time may be a perceived barrier to regular exercise participation and for this reason HIIT may be seen as a more time efficient method of attaining weight loss when compared to CONT training (Kessler, Sisson & Short, 2012).

1.3 Excess post exercise oxygen consumption.

As well as an increased overall energy expenditure per given unit of time from HIIT compared to CONT training when exercise time is equated, an additional proposed benefit of HITT in aiding fat loss is an increase in the excess post-exercise oxygen consumption (EPOC). The EPOC can be defined as the increased oxygen (O_2) utilisation that continues after the cessation of exercise (Hazell, Dylan, Hamilton & Lemon (2012).

One of the proposed reasons for an increase in the EPOC as a consequence to HIIT is the observed elevation in catecholamines as a result of highly intense exercise. Trapp, Chisholm and Boutcher (2007) demonstrated that a cycling HIIT protocol comprising interval periods of 8 seconds work and 12 seconds recovery and 12 seconds work and 24 seconds recovery elicited a significant increase ($P< .05$) in the release of adrenaline and noreadrenaline in both trained and untrained females. A marked elevation in catecholamine levels has been shown to increase lipolysis in both subcutaneous fat and intramuscular fat (Boutcher, 2011). This release of stored fat as a potential source of energy induced by the hormonal response to HIIT may enhance fat oxidation subsequent to the exercise session and result in a greater EPOC compared to CONT exercise (King, Broeder, Browder & Panton, 2002; Trapp, Chisholm & Boutcher, 2007). However, Warren, Howden, Williams, Fell and Johnson (2009) using a crossover design demonstrated that when energy expenditure, intensity and total workout time were matched there was no significant difference ($P > .05$) in the respiratory exchange ratio (RER) and subsequent fat oxidation during CONT versus HIIT cycling in seven recreationally active females. In the CONT bout participants exercised for 90 minutes at 50% $\dot{V}O_2$ max whereas the HIIT bout was performed for the same duration using work intervals of 60 seconds at 85% $\dot{V}O_2$ max with recovery intervals of 120 seconds at 30% $\dot{V}O_2$ max. In the same study the authors did show there was a significant difference ($P < .01$) in the EPOC and fat oxidation comparing high versus low intensity cycling when energy expenditure was matched. Participants in the low intensity group exercised for 30 minutes at 50% $\dot{V}O_2$ max whilst in the high intensity protocol cycling was performed (continuously) at 85% $\dot{V}O_2$ max for approximately 12-15 minutes to equate energy expenditure between the two protocols.

The results of this study indicate that increasing "intensity" as opposed to "manipulating" work and recovery intervals is a key factor to elicit an increase in the EPOC and subsequent fat oxidation. However, Warren and colleagues acknowledged that despite the furore of interest in the EPOC in response to HIIT, any energy expenditure subsequent to the exercise performed may be inconsequential compared to the energy expended during the actual exercise session. Indeed, Laforgia, Withers and Gore (2006) have demonstrated that the EPOC arising from varying aerobic exercise intensities constituted between just 6-15% of the total net oxygen uptake during exercise.

1.4 Continuous training, high intensity interval training and weight loss.

It appears reasonable to suggest that HIIT may be a more efficient way to promote weight loss if utilising HIIT protocols incur similar or superior benefits than traditional CONT training in less time. A number of studies comparing HIIT to CONT training have included anthropometric data on weight loss, fat loss and body mass index (BMI) though more often than not these variables have not been the primary focus of such studies. Nonetheless, they provide insight into the effects of the two training modes on weight loss and body composition parameters.

In one of the early studies into the effects of exercise intensity on body fat and skeletal muscle metabolism Tremblay, Simoneau and Bouchard (1994) compared the effects of 20 weeks of CONT cycling (n = 8 men and 9 women) to 15 weeks of HIIT cycling (n = 5 men and 5 women) in young but sedentary adults of normal weight. CONT training consisted of 30 minutes at 60% MHR progressing over the intervention to 45 minutes at 85% MHR on 4-5 days per week. The HIIT programme initially consisted of 25 separate sessions each consisting of 30 minute cycling performed in continuous fashion at 70% MHR for the first 5 weeks of the intervention. HIIT participants subsequently performed 19 short (10-15 work intervals of 15-30 second duration) progressing to16 long (4-5 work intervals of 60-90 second duration) for the remaining 10 weeks. The initial short interval bouts were performed at 60% of the individual's predetermined maximal power output whilst the long interval bouts were performed at 70% maximal power output. These initial intensities were progressed by 5% every 3 weeks.

Data revealed that although the energy expended in the CONT protocol was twice as high compared to HIIT, the change in the sum of six skinfolds from pre to post training was significantly lowered (P< .01) in HIIT compared to CONT (94.2 ± 37.7mm vs 80.3 ± 36.mm and 79.2 ± 35.1mm vs 74.7 ± 34.2mm for HIIT and CONT respectively). In contrast to subcutaneous measures of adiposity, bodyweight data revealed no significant difference pre to post intervention both within and between groups (63.9 ± 11kg vs 63.8 ± 11.5kg and 60.6 ± 13.4kg vs 60.1 ± 12.1kg for HIIT and CONT respectively).

The authors concluded that HIIT resulted in greater fat loss than CONT training with a much lower overall energy cost. They further proposed that exercise intensity rather than volume is an important determinant of subsequent lipid oxidation which may enhance further weight loss. There are however, potential problems when interpreting the findings of this study. Firstly, the sample size is small whilst the standard deviation is large regards the sum of skinfolds for both HIIT and CONT groups indicating wide variability within each sample. Additionally, there is a lack of homogeneity between the HIIT and CONT samples indicated by the large difference in pre skinfold measurements. The authors did not clarify if participants were randomly assigned which may account for these observed differences. Furthermore, whilst skinfold assessment is a practical method for estimating overall body fat, there is a standard error of estimation of 3% (Ball, Swan & Altena, 2006). The results may also have been confounded by the fact that the HIIT group actually first performed 5 weeks of CONT training as part of the study design so it is difficult to ascertain what effect this training had on the results as opposed to the subsequent HIIT protocol that followed. What is clear is that neither intervention actually caused a reduction in bodyweight indicating that the previously sedentary participants may have been compensating for energy expended during exercise with subsequent additional dietary intake. No reference was made as to whether dietary guidance was provided or food intake controlled for during the intervention.

Warburton et al., (2005) investigated the effects of 16 weeks of either CONT training or HIIT on cardiovascular fitness in 14 male coronary artery disease patients. Participants were randomly assigned to either a CONT (n = 7) or HIIT (n = 7) group. Warm up and cool down protocols were matched between groups (10 minutes for each). The CONT group performed 30 minutes of aerobic exercise at 65% MHR whereas the HIIT group performed work intervals of 2 minutes at 90% MHR followed by 2 minutes recovery intervals at 40% MHR. Both groups performed a total workout time of 30 minutes on 2 days a week for 16 weeks. Exercise sessions consisted of 10 minutes each on a treadmill, stair-climber and a combined leg and arm cycle ergometer. Whilst the primary focus of the study was cardiovascular fitness, body mass data revealed significant ($p < .05$) group mean weight losses pre to post training of 4.2kg and 3.0kg for CONT and HIIT respectively. No significant difference between groups was indicated.

Caution is advised when interpreting the body mass results of this study due to the fact that resistance training was also part of the exercise prescription. Whilst this was standardised between groups, dietary intake may enhance or impair the adaptive response to resistance exercise. The authors did not indicate if dietary intake was controlled for or if participants were simply instructed to follow their normal eating patterns. Furthermore, actual body composition was not measured so it is not possible to determine if the observed weight loss was due to a reduction in lean or fat tissue and if this was significantly different between the two groups. Finally, participants were instructed to engage in three additional days of 30 minutes physical activity per week and whilst compliance rates of 98.5% ± 2% for both groups was reported for completion of independent physical activity, the authors did not clarify how the compliance rates were verified or how intensity was controlled for.

A 15 week intervention into the effects of HIIT on fat loss and the insulin levels of young women was conducted by Trapp, Chisolm, Freund and Boutcher (2008). Forty-five normal weight but inactive female participants were randomly assigned to one of three groups (HITT *n* = 15, CONT *n* = 15 or Control *n* = 15). The HITT group performed stationary cycling three times per week consisting of 8 second sprints with 12 second recovery intervals which was repeated 60 times for a total workout time of 20 minutes. Initially only 5 minutes total workout time was performed but this was gradually increased over the first two weeks as fitness levels improved so that by the end of the second week all participants were capable of achieving the full 20 minute workout (Trapp et al., 2008). Similarly, an initial resistance of 0.5kg for the work intervals was progressively increased as the HITT participants adapted. The CONT training protocol consisted of 40 minutes cycling 3 times per week at a predetermined intensity of 60% VO_{2peak}. The CONT group began the intervention performing 10-20 minutes and subsequently progressed to a total workout time of 40 minutes. Similar to the HITT protocol, resistance was increased from the initial 0.5kg as fitness improved. The Control group were instructed to perform their normal physical activity and dietary habits throughout the 15 week intervention. Total exercise energy expenditure was purposely matched between the HIIT and CONT groups.

Results presented in Table 2, revealed a significantly greater ($P < .05$) overall weight loss comparing HIIT to both CONT and Control groups as well as significant reductions ($P < .05$) in total fat mass and percentage body fat.

Table 2. Changes in body mass, fat mass and percentage fat after 15 weeks training.

Variable	Control		CONT training		HITT	
	Before	After	Before	After	Before	After
Body mass (kg)	65.1 ± 2.4	66.5 ± 4.4	59.8 ± 2.4	59.7 ± 2.3	63.3.3 ± 3.8	61.8 ±3.6 [a,b]
Fat mass (kg)	22.6 ± 3.3	22.9 ± 3.0	18.4 ± 2.2	18.8 ± 2.1	22.2 ± 3.0	19.7 ± 2.6 [a,b]
Fat (%)	35.6 ± 2.8	35.7 ± 2.6	31.7 ± 3.0	32.3 ± 2.9	35.1 ± 2.7	32.4 ± 2.3 [a,b]

Data is shown as mean ± **SD**

[a] Significantly different pre to post intervention. [b] Significantly different than Control and CONT ($p < .05$)

(Adapted from Trapp, Chisolm & Boutcher, 2008).

Data also revealed significant regional fat changes as assessed by dual-energy X-ray absorptiometry (DEXA). Of note was a significant reduction ($p < .05$) in central abdominal fat comparing HIIT to both CONT and Control groups both of which experienced an increase in abdominal fat.

Whilst the results of this study indicate that HIIT was more effective than CONT training for inducing weight and fat loss it is worth noting that the overall weight loss was just 1.5kg in the HITT group whilst the CONT group actually gained 0.1kg. This is somewhat surprising over a 15 week intervention where the HIIT group had a total calorie expenditure of 41.5 ± 0.81 Megajoules (MJ) whilst the CONT group expended a total of 36.3 ± 3.4MJ. All participants were instructed to maintain their normal dietary habits throughout the intervention and Trapp and colleagues reported no pre to post differences in energy intake within or between groups. Therefore, energy expended during the intervention for the CONT group (36.3 MJ) equated to 8670kcal. Based on the premise that 3,500 calories equates to 0.45kg of fat this should have approximated an observed weight loss of 1.12 kg (8670kcal / 3500kcal) in the CONT group. Such calculations do not take into account responders and none responders to exercise but nonetheless, it is conceivable that dietary factors may have had a confounding effect on the results as was acknowledged by the authors.

Burgomaster et al., (2008) investigated the metabolic adaptations to a 6 week cycling intervention comparing HIIT to CONT training with a focus on skeletal muscle CHO and lipid oxidation pre and post intervention. Twenty participants were assigned to a HIIT or CONT exercise group (*n=5* men and 5 women in each group). The HIIT protocol consisted of four to six repeated 30 second maximal efforts interspersed with 4.5 minute recovery intervals on 3 days per week. CONT training was performed at a predetermined 65% $\dot{V}O_{2\,peak}$ for 40-60 minutes on 5 days per week. The study design was purposely structured so that energy expenditure was not matched with the authors reporting that exercise volume was 90% lower in the HIIT group so that there was a three-fold greater time commitment required in the CONT group compared to HIIT (4.5 vs 1.5 hours per week respectively). Results revealed that values for whole body CHO and lipid oxidation significantly decreased and increased respectively ($p < .05$) pre to post testing for both HIIT and CONT with no significant difference between groups. The authors concluded that HIIT compared to CONT training achieved similar favourable metabolic adaptations despite a significantly lower time commitment required for HIIT.

Whilst weight loss was not discussed by Burgomaster et al., (2008) data revealed that mean pre and post values for HIIT were 69 ± 3kg and 68 ± 3kg respectively whilst prior to the intervention mean weight for the CONT training group was 75 ± 4kg and had not altered post intervention. There were no significant differences observed within or between groups. Body composition was not assessed so inferences of whether there was any favourable changes in adiposity without any significant weight loss cannot be made. Furthermore, participants were described as “active” but “untrained” though how this was determined and what level of physical activity constituted “active” was not elucidated. Finally, the authors described there being large differences in weekly training time (1.5 hours vs 4.5 hours for CONT and HIIT respectively) and weekly volume (225 kilojoules per week vs 2250 kilojoules for CONT and HIIT respectively) so that there was a stated 90% difference in overall volume between groups. However, they later described actual exercise time as being only 10 minutes in the HIIT group compared to 4.5 hours in the CONT group but this appears to not take into account the six 4.5 minute recovery intervals the HIIT group performed where they continued to cycle at 50 revolutions per minute at 30 watts power output between the 30 second maximal effort work intervals.

Nybo et al., (2010) compared the effects of 12 weeks CONT training, HIIT, strength training or a continuation of lifestyle behaviours on a number of metabolic indices of fitness in 36 untrained males. Examining the CONT and HIIT protocols only, CONT training consisted of

1 hour of running at 80% MHR. In contrast, HIIT consisted of a 5 minute warm up followed by 5 repeated 2 minute bouts at 95% of MHR interspersed with 1 minute recovery intervals. Total exercise time for HIIT inclusive of warm up was 20 minutes. Both groups achieved mean weekly workout frequencies of 2.0 ± 0.1and 2.5 ± 0.2 for HIIT and CONT respectively for the 12 week intervention period. Pre and post intervention anthropometric data are presented in Table 3 for CONT training and HIIT. Data for strength and control groups are not shown.

Table 3. Body mass and fat percentage before and after 12 week intervention for CONT training and HITT.

Variable	CONT training		HITT	
	Before	After	Before	After
Body mass (kg)	85.8 ± 5.5	84.8 ± 5.3 [a]	96.3 ± 3.8	94.9 ± 4.2
Fat (%)	24.3 ± 1.6	22.6± 1.7 [a]	24.7 ± 1.5	24.2 ± 1.7

Data is shown as mean ± **SD**

[a] Significantly lower than pre-training value (p< .05).

Adapted from Nybo et al., (2010).

The results revealed no significant pre to post difference in the HIIT group for body mass or body fat. In contrast, CONT training elicited a significant (P< .05) decrease in both body mass and body fat pre to post intervention. Whilst this data would indicate that CONT training is more effective than HIIT for reducing body mass and body fat the study exclusion criteria precluded anyone who had participated in regular physical activity for the previous 2 years. How this was quantified was not explained but it is questionable that “untrained” males could sustain 60 minutes of running at 80% MHR as required by the CONT protocol without previous regular participation in exercise.

1.5 Conclusion

The findings presented here comparing CONT training and HIIT protocols with regard to weight loss and body composition changes are equivocal and drawing definitive conclusions is confounded by numerous factors. Most studies to date involving CONT training and HIIT have utilised short but differing intervention periods making it difficult to know what, if any, long term differences may result between the two protocols. Additionally, some studies have not used control groups for comparison with the intervention groups. Whilst some interventions have attempted to match energy expenditure in order to account for this as a confounding variable, other researchers have purposely utilised a study design where the HIIT protocol is of much lower energy expenditure than the CONT protocol in an attempt to show HIIT can achieve similar or greater benefits to CONT training but in much less time. Furthermore, there have been differences in the prescribed exercise intensities and durations across studies which makes it difficult to make direct comparisons or inferences about what intensity, work/recovery ratios and duration of exercise may be the most effective exercise prescription.

One of the key limitations of the research to date is that dietary intake has been assessed using self-report measures. Whilst the use of food records as a way to estimate nutritional and energy intake is considered a practical and feasible method for research (Burke & Deakin, 2012) an early review by Block (1982) of dietary assessment methods proposed that the very fact an individual completes a food diary or record may alter their typical eating habits thereby influencing the information obtained. In most studies conducted to date on HIIT and CONT training self-report measures for dietary intake have only been completed pre and post intervention which does not allow for analysis of any shift in dietary intakes during the intervention. Braakhuis, Meredith, Cox, Hopkins and Burke (2003) recommend that to attain an acceptable degree of precision interim periods of recording are needed. Participants have, in most interventions been advised to continue with their normal dietary patterns but this approach may not account for any compensatory eating or indeed suppression of appetite that may occur as a result of previously untrained or sedentary individuals commencing a new exercise programme. A further confounding variable relates to the inability to control for physical activity behaviour beyond any supervised exercise sessions which may influence energy balance and subsequent weight loss or gain.

Many of the studies comparing CONT training and HIIT carried out thus far have used "normal" weight participants. Thus, the potential for weight loss in such individuals may be minimal which may mask the potential effectiveness of either protocol for inducing significant weight loss and reducing levels of adiposity. However, with the increasing trend of people becoming overweight and obese there has been a developing interest in whether HIIT as opposed to traditional CONT training is a more time efficient and effective way to achieve weight loss in such a population.

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Systematic review of the efficacy of high intensity interval training versus continuous training for weight loss in overweight and obese individuals.

Research paper submitted in accordance with the requirements of the University of Chester for the degree of Master of Science.

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Rationale for proposed journal publication

It is proposed this systematic review is appropriate for submission for publication to the International Journal of Obesity. The main focus of the review is the comparison of two methods of exercise prescription for individuals who are overweight or obese and the resultant outcomes on weight loss and other anthropometric measures. The named journal's purpose is to further knowledge of effective treatments for dealing with obesity and one such treatment is exercise. Therefore, attempting to determine if one exercise prescription is more effective than another for incurring weight loss in overweight and obese adults will help contribute to the existing knowledge base.

Abstract

The increasing prevalence of individuals being overweight and obese in conjunction with the associated co-morbidities continues to be a major public health concern. The traditional exercise prescription to accomplish weight loss in such a population has been to perform sustained low to moderate intensity aerobic exercise termed "continuous (CONT) training." More recently high intensity interval training (HIIT) has been suggested as a more effective alternative for weight loss. HIIT involves short periods of high intensity efforts interspersed with recovery periods of lower intensity. The rationale for such an approach is that individuals can achieve similar results to longer CONT type training but in less time. The purpose of this systematic review is to compare the effects of HIIT and CONT training on weight loss and other anthropometric measures in overweight and obese adults when both training protocols are matched for energy expenditure. A total of nine studies met the selection criteria for inclusion in the review. Four studies included only overweight participants. Of these four, one showed that both CONT training and HIIT were similarly effective for reducing body mass, BMI, body fat, FFM and waist circumference, whilst one

concluded that CONT training rather than HIIT was more effective at reducing total body fat and android fat. The remaining two found neither CONT nor HIIT to be effective at reducing overall body mass. Three studies used only obese participants. One found both CONT and HIIT to be equally effective in reducing measures of body mass, BMI and body fat. One found CONT training and HIIT were both equally effective in reducing body mass, fat mass, and gynoid fat mass when combined with a strict calorie controlled diet. The third found neither exercise protocol to be successful for weight or regional fat loss despite the inclusion of dietary guidance as part of the intervention. Of the two studies that included both overweight and obese participants one revealed that both CONT training and HIIT were equally effective in favourably altering body mass, BMI and waist circumference whilst the second showed that both protocols were equally effective at reducing body fat and waist circumference. This review does not support the premise that HIIT is superior to CONT training for weight and fat loss in overweight and obese adults when both exercise protocols are isocalorific in terms of energy expended. Rather, both approaches appear to be similarly effective for inducing favourable anthropometric changes and a combination of the two may be considered as a means to achieving weight loss in overweight and obese adults based on individual preference.

Contents

1.0 Introduction

1.1. Overview.

The increasing prevalence of individuals being overweight and obese in conjunction with the associated co-morbidities continues to be a major public health concern. Being overweight is classified as having a body mass index (BMI) of 25-29.9kg/m^2, whilst obesity is classified has having a BMI >30kg/m^2 (James, Rigby & Leach, 2004). The exponential rise in people becoming overweight and obese has led to research investigating the optimal exercise prescription to aid weight loss in this population group (Warren, Howden, Williams, Fell & Johnson, 2009). The traditional exercise prescription to achieve weight loss in overweight or obese individuals has been to perform sustained low to moderate intensity aerobic exercise (Tremblay, Despres, Maheux, Pouliot & Nadeau, 1991). This type of exercise is known as continuous (CONT) training. The rationale behind such an approach is that the percentage of lipid oxidized when considering the total substrate mix during low intensity exercise is greater than during a high intensity effort (Bouchard, Despres & Trembley, 1993). More recently however, high intensity interval training (HIIT) has been used as an alternative method to target weight and fat loss in overweight and obese adults. HIIT typically involves brief, repeated bouts of high intensity anaerobic exercise, termed work intervals, interspersed with recovery intervals or rest periods (Trapp, Chisholm, Freund & Boutcher, 2008). One of the suggested benefits of HIIT is that it can achieve similar or superior metabolic effects to CONT training in less time (Wisloff *et al;* 2007; Hazell, Olver, Hamilton, & Lemon, 2012; Kessler, Sisson, & Short, 2012). However, whilst it is well established that regular exercise can help maintain a normal weight and possibly induce favourable changes in body composition, it is not universally agreed whether HIIT is more effective than traditional CONT training to incur such changes in overweight and obese adults. Furthermore, it remains to be determined which method of training is more effective for weight loss when energy expenditure is matched between the two protocols.

1.2. Rationale and aims of the Systematic Review.

A number of studies have compared CONT training and HIIT both directly and indirectly in relation to weight loss and body compositional changes in overweight and obese adults. The aim of this systematic review is to determine if there a significant difference between CONT training and HIIT in relation to weight loss and body composition changes when energy expenditure is equated between the two approaches.

2.0 Method

2.1. The Search Strategy.

This section serves to outline how the research papers were searched for and selected for inclusion in the systematic review. Initially, the PICO acronym (population, indicator, comparator and outcome) was used so a clearly defined population group could be targeted and an indicator specified to assess against a comparator group to allow specified outcomes to be measured (Glasziou, Irwig, Bain & Colditz, 2001). The PICO variables and key search terms are presented in Table 1.

Table 1. PICO variables and related key search terms.

Variable	Key search term
Population	Obese and overweight
Indicator	High intensity interval training (HIIT)
Comparator	Continuous (CONT) training
Outcome	Weight loss, fat loss, Body mass index (BMI), waist/hip ratio, waist circumference

The PICO key search terms identified in Table 1 were input into relevant search engines, journal databases and selected journal titles. The use of specific journal titles was incorporated into the search strategy to refine the general approach using the named search engines and journal databases. A list of the search engines, journal databases and the combination of terms used are presented in Table 2.

Table 2. General search engines, journal databases and combination terms.

Search engine and journal databases	Combination terms
Blackwell Synergy Cochrane Library Google Scholar Ovid Medline PubMed Central Sport Discus Science Direct	Interval training and continuous training. High intensity interval training and continuous training. HIIT and continuous training. Continuous training and interval and weight loss and fat loss. High intensity interval training and continuous training and overweight and obese.

The final two search strategies were to: firstly use the related articles link in PubMed to access further articles deemed to be of relevance; secondly, individual reference lists were reviewed from all initially identified journal articles. This included the reference lists of journal articles both included, and those that were read, but subsequently excluded from the systematic review.

2.2 Selection criteria.

Articles selected for inclusion in the systematic review had to meet the following requirements:

- All participants had to be classed as adults (aged 18 years or older)
- All participants had to be classified as overweight or obese (determined by the BMI).
- The exercise intervention had to include a CONT arm and a HIIT arm for comparison.
- The frequency, intensity, time and type of the exercise protocol as well as the duration of the intervention had to be described.
- The two training methods had to be described as isocalorific in terms of energy expenditure.
- Pre and post intervention measures of anthropometric data had to be provided including body mass and/or BMI, body fat measures, waist to hip ratio and waist circumference.
- Participants had to be randomly assigned.

The above selection criteria were set because weight loss or body compositional changes were not the primary research focus of some of the studies included in the review and therefore there had to be sufficient and relevant data and appropriate study design to ensure that a feasible and fair comparison could be made between the two training methods. Following the search strategy outlined above a total of 41 research papers were sourced as being of possible relevance. After applying the selection criteria a total of nine studies were included in the systematic review.

2.3. Quality assessment of the research papers.

Each research paper selected for inclusion in the systematic review was subsequently quality assessed using adapted versions of the Jadad scale (1996) and the Consolidated Standards of Reporting Trials checklist (Consort, 2010). The Jadad scale was incorporated as an evaluation tool as it is an accepted means to assess the methodological quality of randomised controlled trials (Berger & Alperson, 2009). The difficulty of blinding exercise interventions is recognised as a limitation of the Jadad scale and thus is the justification for adapting the scale for use in this systematic review to remove the points assigned for blinding. The Consort checklist was used as it is a well-recognised guide for the initial design and analysis of research studies. Therefore, whilst it is not meant to rate the actual quality of studies it does provide a list of items that would be expected in well-designed clinical trials (Moher, *et al;* 2010). Used in conjunction with the validated method of the Jadad scale and Consort checklist, further quality assessment criteria specific to the focus of the systematic review were included to provide an overall quality rating score (QRS) out of eight. For the purpose of this systematic review a QRS of 0-2 was considered a "low" quality study, a QRS of 3-5 was considered a "moderate" quality study and a QRS of 6-8 was deemed a "high" quality study. These QRS bandings were used to help identify those studies that had incorporated sound methodological study design and reporting procedures as well as making attempts to control for possible confounding variables. The next section outlines how points were assigned to determine the overall QRS.

One point was assigned if participants in the study were randomly assigned into groups at the start and a further point was awarded if the randomisation procedure was adequately described. A third point was assigned if the number of withdrawals were identified and explanations for the withdrawals were adequately explained. A fourth point was awarded if it was shown how the sample size was calculated and how this related to effect sizes and levels of significance. A fifth point was assigned if the study design included a control group for comparison to the intervention groups. A sixth point was awarded if all exercise sessions were conducted in a controlled supervised setting to avoid having to rely on self-report data of independently performed unsupervised exercise sessions. The final two points were awarded based on attempts to control for possible confounding variables outside of the actual study interventions. A point was awarded if participants were instructed to not perform any additional physical activity or exercise other than the prescribed exercise of the intervention. A final point was awarded if participants had been instructed to maintain their normal eating habits for the duration of the study. If dietary intervention was an intended part of the study then zero was awarded to this criteria as a significant change in eating habits could have confounded the findings. The QRS checklist is presented in Table 3 for each study included in the systematic review.

Table 3. Quality rating score for each individual study.

Quality statement	1. The study was described as randomized.	2.The method of randomization described was appropriate.	3. Any withdrawals were identified and explanations provided.	4. How the sample size was determined was explained.	5. A control group was used.	6. Exercise sessions were supervised.	7. Instruction to perform "no" additional exercise outside of the intervention was provided.	8. Instruction to maintain normal eating habits throughout the intervention was provided.	Overall QRS
Rognmo et al. (2004)	1	1	1	0	0	1	1	0	**5/8**
Scherve et al. (2008)	1	0	1	0	0	1	0	1	**4/8**
Moreira et al. (2008)	1	0	0	0	1	0	0	1	**3/8**
Tjonna et al. (2008)	1	0	1	0	1	1	0	0	**4/8**
Wallman et al. (2008)	1	1	1	0	0	1	0	0*	**4/8**
Moholdt et al. (2009)	1	1	1	1	0	0	1	0	**5/8**
Campbell et al. (2010)	1	1	1	1	0	0	1	0**	**5/8**
Keating et al. (2014)	1	1	1	0	1	1	1	1	**7/8**
Kemmler et al. (2014)	1	1	1	1	1	1	0	0	***6/8***

For "yes" assign 1 point. For "no" assign 0 points.

Adapted from Jadad *et al;* (1996) (points 1-3) and the Consort checklist (2010) (points 4-8).

* Part of the study design was a 1 hour pre intervention dietary seminar on desirable level of calorie intake and healthy eating choices.

** Part of the study design was adherence to a strict calorie controlled diet.

3.0 Results

3.1. Overview and outcomes of systematic review.

The results presented in this section have been assimilated from original peer-reviewed studies whilst information from meta-analytical reviews have not been included. This was to ensure that the original studies could be reviewed fully to verify they met the selection criteria. The studies included in the review are presented in three separate tables for discussion purposes. Studies that only utilised participants who were classified by the BMI as being overweight are presented first in Table 4. These are followed by the studies that only included participants who were classified by the BMI as being obese presented in Table 5. Finally, studies that included a mix of the two aforementioned BMI categories are presented in Table 6.

Table 4. Summary of anthropometric outcomes from studies comparing continuous training to high intensity interval training in overweight participants.

Study	QRS	Participant characteristics	Sample size	Study design	CONT and HIIT protocol	Changes in anthropometric measurement(s)	Supervision and advice	Outcome(s)
Rognmo et al., (2004)	5/8	CAD patients (3 females, 14 males). Age (years) CONT 61.2 HIIT 62.9 BMI: overweight	21 (with 4 withdrawn) 8 CONT 9 HIIT	Uphill treadmill walking. 3 x per week for 10 weeks. Energy expenditure equated between groups.	CONT: 41 mins at 50-60% $VO_{2\ peak.}$ HIIT: 33 mins inc w/up and c/down. WI = 4x4 mins at 85-95% $VO_{2\ peak.}$ RI = 3mins at 50-60% $VO_{2\ peak.}$	**Body mass (kg)** CONT = -0.8 HIIT = -0.1	Exercise sessions supervised. Participants advised not to add additional leisure time PA outside of the intervention. Dietary advice not specified.	No pre-to-post significant difference ($p > .05$) for body mass within or between groups.
Moirera et al., (2008)	3/8	Sedentary participants. (8 male, 14 female). Age (years) CONT and HIIT 40. BMI: >25kg/m^2 overweight	30 (with 8 withdrawn) Equally split between CONT, HIIT and Control* groups.	Cycle ergometer 3 x per week for 12 weeks. Energy expenditure equated between groups.	CONT: 20 mins building to 60 mins by week 4 at 10% below AnT HIIT: 20 mins building to 60 mins by week 4 WI = 2 mins at 20% above AnT RI = 1 min. RI was complete rest.	**Body mass (kg)** CONT = -1.3 [a] HIIT = -1.2 [a] **BMI (kg/m^2)** CONT = -0.4 [a] HIIT = -0.4 [a] **Body fat (%)** CONT = -0.9 [a] HIIT = -0.6 [a] **FFM (%)** CONT = +0.9 [a] HIIT = +0.7 [a] **W/H ratio (cm)** CONT = -0.1 [a] HIIT = -0.2 [a, b] **Waist (cm)** CONT = -1.6 [a] HIIT = -0.72 [a]	Not stated whether exercise sessions were supervised or not. No advice about not to add additional leisure time PA outside of the intervention. Participants advised to maintain normal eating habits.	Pre-to-post significant difference ($p < .05$) for body mass, BMI, body fat, FFM W/H ratio and waist circumference within groups. Pre-to-post significant difference ($p < .05$) for W/H ratio between groups comparing HIIT to CONT.

Study	QRS	Participant characteristics	Sample size	Study design	CONT and HIIT protocol	Changes in anthropometric measurement(s)	Supervision and advice	Outcome(s)
Moholdt et al., (2009)	5/8	CABG patients (11 females, 48 males). Age (years) CONT 62 HIIT 60 BMI: Overweight	59 (with 11 withdrawn) 36 CONT 33 HIIT	Treadmill walking 5 x per week for 4 weeks. Home based exercise 3-4 x per week for 6 months. Energy expenditure equated between groups.	CONT: 46 mins at 70% MHR. HIIT: 38 mins including 8 min w/up and 5 mins c/down. WI = 4x4mins at 90% MHR. RI = 3 mins at 70% MHR.	**Body mass (kg)** CONT = +0.2 HIIT = +0.7	Exercise sessions supervised for first 4 weeks. Home based training 3-4x per week was part of the intervention post 4 weeks. Dietary advice not specified.	No pre-to-post significant difference ($p > .05$) for body mass within or between groups.
Keating et al., (2014)	7/8	Inactive participants exercising <3 days per week (31 females, 7 males). Age (years) 18-55 BMI 25-29.9 kg/m^2	38 (with 5 withdrawn) 13 CONT 13 HIIT 12 Placebo*	CONT and HIIT: Cycle ergometer 3 x per week for 12 weeks. Energy expenditure equated between groups. Placebo group: stretching, self-massage and fitball exercises plus 5 mins cycling 3 x per week.	CONT: 30 mins at 50% $VO_{2\,peak}$. Progressed to 45 mins at 65% $VO_{2\,peak}$ at 3 weeks. HIIT: 20 mins including 6 mins w/up and c/down. WI = 4x30-45 secs at 120% VO_2 peak RI = 2-3 mins at 30 watts. WI progressed to 6x1min at 120% VO_2 peak by week 5.	**Body mass (kg)** CONT = -0.8 HIIT = +0.2 **Body fat (%)** CONT = -2.6 [a, b] HIIT = -0.3 **FFM (kg)** CONT = -0.6 HIIT = -0.6 **Android fat mass (%)** CONT = -2.7 [a, b] HIIT = +0.8 **Gynoid fat mass (kg)** CONT = -0.1 HIIT = -0.1 **Waist (cm)** CONT = -3.6 HIIT = -1.8	Exercise sessions supervised. Participants advised to maintain normal additional leisure PA. Participants advised to maintain normal eating habits.	No pre-to-post significant difference ($p > .05$) for body mass, FFM, gynoid fat mass and waist circumference within and between groups. Pre-to-post significant difference ($p < .05$) for body fat % and android fat percentage comparing CONT to HIIT.

Age is presented as means for each group. *No pre to post significant difference within group (data not shown). a. Significant difference pre to post within groups ($p < .05$). b. Significant difference pre to post between groups ($p < .05$).

AnT = anaerobic threshold; **BMI** = body mass index; **CABG** = coronary artery bypass grafting; **CAD** = coronary artery disease; **c/down** = cool down; **CONT** = continuous; **FFM** = fat free mass; **HIIT** = high intensity interval training; **MHR** = maximum heart rate; **mins** = minutes; **PA** = physical activity; **RI** = recovery interval; **secs** = seconds **$VO_{2\,peak}$** = peak value of oxygen uptake; **WI** = work interval; **W/H ratio** = waist to hip ratio; **w/up** = warm up.

Table 5. Summary of anthropometric outcomes from studies comparing continuous training to high intensity interval training in obese participants.

Study	QRS	Participant characteristics	Sample size	Study design	CONT and HIIT protocol	Changes in anthropometric measurement(s)	Supervision and advice	Outcome(s)
Schjerve et al., (2008)	4/8	Obese participants (32 females, 8 males). Age (years) CONT 44.4 HIIT 46.9 Strength 46.2 BMI: >30kg/m^2	40 13 CONT 14 HIIT 13 Strength*	CONT and HIIT: Walking/running 3 x per week for 12 weeks. 2 treadmill, 1 outside. Energy expenditure equated between groups. Strength group: 4 sets x 5 repetitions at 90% of 1RM.	CONT: 47 mins at 60-70% MHR HIIT: 40 mins inc w/up and c/down. WI = 4x4 mins at 85-95% MHR RI = 3 mins at 50-60% MHR	**Body mass (%)** CONT = -3 [a] HIIT = -2 [a] **BMI (kg/m^2)** CONT = -1.1 [a] HIIT = -0.6 [a] **Body fat (%)** CONT = -2.5 [a] HIIT = -2.2 [a]	2 exercise sessions supervised 1 unsupervised. No advice about not to add additional leisure time PA outside of the intervention. Participants advised to maintain normal eating habits.	Pre-to-post significant difference ($p< .05$) for body mass, BMI and body fat within groups but not between groups.
Wallman et al., (2008)	4/8	Sedentary participants (18 females, 6 males). Age (years) CONT 44.8 HIIT 40.9 Diet 40.3 BMI: >30kg/m^2 Obese.	24 (with 3 withdrawn) 6 CONT 7 HIIT 8 Diet int. only.	Cycle ergometer 4 x per week for 8 weeks. Energy expenditure equated between groups.	CONT: 50% $VO_{2\ peak.}$ until same energy expended as matched pair in HIIT. HIIT: 30 mins. WI = 10x1min at 90% $VO_{2\ peak..}$ RI = 2 mins at 30% $VO_{2\ peak.}$ WI progressed to 105% $VO_{2\ peak.}$ RI progressed to 45%. $VO_{2\ peak}$ over 8 weeks.	**Body mass (kg)** CONT = +0.6 HIIT = -0.5 Diet = +0.2 **Android fat mass (kg)** CONT = -0.1 HIIT = -0.3 Diet = -0.1 **Gynoid fat mass (kg)** CONT = -0.2 HIIT = -0.3 Diet = -0.5	Exercise sessions supervised. No advice about not to add additional leisure time PA outside of the intervention. 1 hour nutritional seminar provided pre exercise intervention on desirable level of calorie intake and healthy food choices.	No pre-to-post significant difference ($p> .05$) for body mass, android fat mass and gynoid fat mass within or between groups.

Study	QRS	Participant characteristics	Sample size	Study design	CONT and HIIT protocol	Changes in anthropometric measurement(s)	Supervision and advice	Outcome(s)
Campbell et al., (2010)	5/8	Obese participants (20 females, 6 males). Age (years) CONT 44.4 HIIT 43.8 BMI: >30kg/m^2	44 (with 18 withdrawn) 14 CONT 12 HIIT	Home based walking 5 x per week for 12 weeks. Energy expenditure equated between groups.	CONT: 2 daily sessions of 15 mins at 50% $VO_{2\ peak}$ progressed to 55% $VO_{2\ peak}$ at 6 weeks. HIIT 2 daily sessions of 15 mins. WI = 5x1 min at 70% $VO_{2\ peak}$. RI = 2 mins at 40% $VO_{2\ peak}$. WI and RI progressed to 45% and 75% $VO_{2\ peak}$ respectively at week 6	**Body mass (kg)** CONT = -7.7 [b] HIIT = -8.5 [b] **Fat mass (kg)** CONT = -0.7 [b] HIIT = -0.9 [b] **FFM (kg)** CONT = -0.2 HIIT = No change **Android fat mass (kg)** CONT = -0.8 HIIT = -1.0 **Gynoid fat mass (kg)** CONT = -1.3 [b] HIIT = -1.4 [b]	Exercise sessions not supervised. Participants advised not to add additional leisure time PA outside of the intervention. Strict calorie controlled diet was part of the intervention.	Pre-to-post significant difference ($p < .001$) for body mass, fat mass and gynoid fat mass within groups but not between groups. No pre-to-post significant difference ($p > .05$) for FFM and android fat mass within or between groups.

Age is presented as means for each group. *No pre to post significant difference within group (data not shown). a. Significant difference pre to post within groups ($p < .05$). b. Significant difference pre to post within groups ($p < .001$).

BMI = body mass index; **CABG** = coronary artery bypass grafting; **CAD** = coronary artery disease; **c/down** = cool down; **CONT** = continuous; **FFM** = fat free mass; **HIIT** = high intensity interval training; **MHR** = maximum heart rate; **mins** = minutes; **PA** = physical activity; **1RM** = one repetition maximum; **RI** = recovery interval; **$VO_{2\ peak}$** = peak value of oxygen uptake; **WI** = work interval; **w/up** = warm up.

Table 6. Summary of anthropometric outcomes from studies comparing continuous training to high intensity interval training in both overweight and obese participants.

Study	QRS	Participant characteristics	Sample size	Study design	CONT and HIIT protocol	Changes in anthropometric measurement(s)	Supervision and advice	Outcome
Tjonna et al., (2008)	4/8	Patients with the metabolic syndrome, (15 females, 13 males). Age (years) CONT 52 HIIT 55.3 Control 49.6 BMI: Overweight and obese	32 (with 4 withdrawn) 10 CONT 12 HIIT 10 Control*	Treadmill uphill walking/running 3 x per week for 16 weeks. Energy expenditure equated between groups.	CONT: 47 mins at 70% MHR. HIIT: 40 mins including 10 mins w/up and 5 mins c/down. WI = 4x4 mins at 90% MHR. RI = 3 mins at 70% MHR.	**Body mass (kg)** CONT = -3.6 [a] HIIT = -2.3 [a] **BMI (kg/m^2)** CONT = -1.2 [a] HIIT = -0.7 [a] **W/H ratio (cm)** CONT = -0.4 HIIT = No change **Waist (cm)** CONT = -6 [a] HIIT = -5 [a]	Exercise sessions supervised. No advice about not to add additional leisure time PA outside of the intervention. Dietary advice not specified.	Pre-to-post significant difference ($p < .05$) for body mass, BMI and waist circumference within groups but not between groups. No pre-to-post significant difference for W/H ratio ($p > .05$) within or between groups.
Kemmler et al., (2014)	6/8	Untrained males exercising <2 days per week. Age (years) 30-50 CONT 42.9 years HIIT 43.9 years BMI: >25kg/m^2 but <35 kg/m^2	81 (with 16 withdrawn) 41 CONT 40 HIIT	Treadmill running 2 x per week for 8 weeks 3-4 x per week from 9-16 weeks. Energy expenditure equated between groups.	CONT: Progressed from 35 to 90 mins at 70-82.5% MHR over 16 weeks. HIIT: WI = 90 secs–12 mins at 85-97.5% MHR. RI = 1-3 mins at 65-70% MHR. HIIT protocol also included running sessions ranging from 25-45 mins at 85% MHR.	**Body mass (kg)** CONT = -2.5 [b, c] HIIT = -1.3 [a] **Body fat mass (%)** CONT = -9.5 [b] HIIT = -4.9 [a] **Waist (cm)** CONT = -2.6 [a] HIIT = -2.3 [a] **FFM (kg)** CONT = -1.1 [a] HIIT = -0.4	2 exercise sessions supervised. No advice about not to add additional leisure time PA outside of the intervention. Dietary advice not specified.	Pre-to-post significant difference for body mass ($p < .001$, $p < .05$) for CONT and HIIT respectively. Pre-to-post significant difference ($p < .05$) for body mass comparing CONT to HIIT. Pre-to-post significant difference for body fat mass ($p < .001$, $p < .05$) for CONT and HIIT respectively and waist circumference ($p < .05$) within groups but not between groups. Pre-to-post significant reduction ($p < .05$) for FFM in CONT but not HIIT.

Age is presented as means for each group. *No pre to post significant difference within group (data not shown). a. Significant difference pre to post within groups ($p < .05$). b. Significant difference pre to post within groups ($p < .001$). c. Significant difference pre to post between groups ($p < .05$).
BMI = body mass index; **c/down** = cool down; **CONT** = continuous; **FFM** = fat free mass; **HIIT** = high intensity interval training; **MHR** = maximum heart rate; **mins** = minutes; **PA** = physical activity; **RI** = recovery interval; **secs** = seconds; **WI** = work interval; **W/H ratio** = waist to hip ratio; **w/up** = warm up.

4.0 Discussion

4.1. Overview of the studies.

Nine studies formed the basis of this systematic review examining the effects of CONT training compared to HIIT on anthropometric measures in overweight and/or obese adults. Anthropometric measures included body mass, BMI, total body fat, android fat mass, gynoid fat mass, fat free mass, waist circumference and waist to hip ratio. Only studies that had attempted to equate energy expenditure between the CONT and HIIT protocols were included in the review.

4.2. Studies using overweight participants.

Four studies; Rognmo, Hetland, Helgerud, Hoff, and Slordahl, (2004); Moreira, de Souza, Schwingel, de Sa, and Zoppi (2008); Moholdt et al., (2009) and Keating et al., (2014) used overweight participants as classified by the BMI. The findings of these four studies are summarised in Table 4. Rognmo et al., (2004) used a total of 17 male and female CAD patients who completed 10 weeks of supervised uphill treadmill walking three times per week using either a CONT or HIIT protocol. The primary variable of interest was aerobic capacity but anthropometric data revealed no change in body mass for either group during the 10 week intervention. Although all exercise sessions were supervised a compliance of just 70% was set as criteria for completing the intervention and no actual compliance data was provided by the authors. Additionally, although weight loss was not the main outcome variable of this study, the lack of any observed reduction in body mass may have been due to the fact that no information was provided to maintain normal eating habits throughout the intervention. Therefore, participants may have been unintentionally or otherwise consuming additional calories to compensate for the energy cost of exercise. This cannot be verified as no pre and post dietary analysis was performed by Rognmo and colleagues.

Moirera et al., (2008) compared the effects of CONT training or HIIT on 22 previously sedentary male and female participants to examine changes in cardiac risk variables. Participants performed exercise on a cycle ergometer three times per week for 12 weeks. In relation to anthropometric data, results revealed significant reductions in body mass, BMI, body fat percentage and waist circumference with a significant increase in FFM for both CONT and HIIT protocols. There were no observed differences between groups for these variables. There was a statistically significant difference in the waist to hip ratio comparing HIIT to CONT although the actual reduction in HIIT was just 0.2cm compared to 0.1cm in the CONT group.

The researchers specified that participants were instructed to maintain normal dietary habits throughout the intervention yet no pre and post analysis of energy intake was performed to verify that this was the case. This makes it difficult to draw firm conclusions as to whether the favourable changes observed were due to the two exercise protocols, variability in dietary intake or a combination of these two factors. Furthermore, the total sample size was thirty participants including a control group, but eight participants withdrew equating to a 27% drop out rate. Whilst this number of withdrawals is considerable no reasons were provided, nor was it identified from which group(s) the withdrawals were from.

Moholdt et al., (2009) randomised 59 male and female CABG patients to either CONT or HIIT treadmill walking five times per week for 4 weeks to examine cardiovascular outcomes and improvements in quality of life. All sessions were supervised within the initial 4 week period before participants independently continued the intervention via home based exercise 3-4 times per week for a further 6 months. Testing at 4 weeks revealed that the CONT group had reduced body mass by a non-significant 0.8kg whereas the HIIT group had increased body mass by 0.1kg at this time point. However, both groups had experienced non-significant increases in body mass by 6 months.

This 6 month exercise intervention resulted in increased body mass in both groups; this is somewhat surprising. The results may in part be accounted for by the fact that the majority of the exercise intervention (5 months) was unsupervised and adherence was monitored by self-report training logs. There was also considerable variability in the reported weekly frequency and intensity of completed exercise sessions both within and between groups. As no control group was used for comparison and no dietary intake analysis was performed pre-and post-intervention, it makes it difficult to rule out nutritional intake as a confounding variable that may have negated any influence of exercise on body mass.

Keating et al., (2014) used 38 participants who were classed as inactive (exercising <3 days per week) to compare the effects of CONT training, HIIT or placebo on body composition parameters. The exercise intervention involved cycling on a stationary bike three times per week for 12 weeks. The placebo group performed stretching, fitball exercises and had massage. There were no significant changes in any group for measures of body mass, FFM, gynoid fat mass and waist circumference. Keating and colleagues did report pre to post significant differences for body fat percentage and android fat percentage comparing CONT training to HIIT. Body fat was reduced by 2.6% in the CONT group compared to a reduction of 0.3% in HIIT whilst android fat in the CONT group was reduced by 2.7% whereas there was an increase of 0.8% in the HITT participants.

Whilst these results indicate that CONT training rather than HIIT is more effective for reducing body fat and android fat in overweight adults a number of points are worth noting. Firstly, there was considerable heterogeneity within the sample with ages ranging from 18-55 years. Secondly, the sample was comprised of 31 females and just 7 males. Therefore, whilst group means are useful to indicate statistical differences, the authors did not examine whether age or gender was an influential factor in the observed differences between groups for body fat and android fat changes.

4.3. Studies using obese participants.

Three studies; Schjerve et al., (2008); Wallman, Plant and Rakimov (2008) and Cambell, Wallman and Green (2010) used only obese participants as classified by the BMI to study the effects of CONT training and HIIT on a number of physiological variables including anthropometric outcomes. These three studies were summarised in Table 5. Schjerve et al., (2008) recruited 40 male and female obese participants and randomised them to either CONT training, HIIT or a strength training group (data for strength training not discussed) to measure improvements in cardiovascular health. The exercise intervention consisted of walking/running three times per week for 12 weeks. Two supervised sessions were performed on a treadmill whilst the third session was performed as outdoor uphill walking. In relation to anthropometric changes results revealed significant reductions in body mass, BMI and body fat for both the CONT and HIIT groups with no observed statistical difference between the two protocols. Whilst not reaching significance, the CONT protocol did show more favourable reductions in body mass, BMI and body fat compared to HIIT (refer to Table 5). However, this observation should be viewed with caution as the acceptable compliance criteria was set at 70% which meant that 11 out of the total 36 sessions could be missed and participant data still included for analysis yet no information of compliance rates within or between each group was provided. Additionally, one exercise session was performed outdoors and unsupervised as uphill walking. During this session participants were subjectively asked to rate intensity via rating of perceived exertion to match the intensity of the indoor laboratory based supervised sessions. This is problematic as outdoor walking, especially uphill walking, is difficult to standardise and is often not comparable to treadmill walking. As participants did not wear heart rate monitors for outdoor sessions no data was collected on the energy expenditure so it is not known if the unsupervised outdoor sessions were indeed isocalorific between the two groups. Furthermore, whilst participants were advised to maintain normal eating habits no pre to post dietary analysis was conducted which again makes drawing conclusions about the superior effects of one exercise protocol over another difficult.

Wallman, Plant and Rakimov (2008) used 24 male and female obese participants who were classed as sedentary to investigate changes in aerobic fitness and fat mass as a result of performing either CONT training or HIIT. The exercise protocol involved cycle ergometry performed four times per week for 8 weeks where the intensity of the HIIT protocol was progressively increased over the 8 weeks and the CONT protocol time was extended to ensure energy expenditure was matched between groups. Both exercise groups had a one hour diet education workshop on healthy eating choices and desirable level of calorie intake (Wallman, Plant & Rakimov, 2008). A third group (DIET) performed no exercise but received the same diet education workshop. Findings revealed no pre to post significant differences for body mass, android fat mass and gynoid fat mass within or between groups. Body mass actually increased in both the CONT and DIET groups (0.6kg and 0.2kg respectively) whilst body mass in the HIIT group was reduced by just 0.5kg. Though not reaching significance the DIET group lost the most gynoid fat mass compared to the CONT and HIIT groups (0.5kg, 0.2kg and 0.3kg for DIET, CONT and HIIT respectively). In contrast the HIIT group lost the most android fat mass compared to the CONT and DIET groups (0.3kg, 0.1kg and 0.1kg respectively).

Whilst no reduction in body mass in both exercise groups is surprising, especially considering that guidance on healthy eating was provided, the authors acknowledged limitations of the study including a short intervention period, a small sample size which had mixed gender (18 females, 6 males) and a large age range (18-64 years). Interpretation of the findings is further compounded when changes in regional fat is influenced by both gender and hormonal factors (Wallman, Plant & Rakimov, 2008). Finally, whilst this study differed from the previously presented studies in that specific dietary guidance was provided as part of the intervention, dietary analysis was by self-report and only assessed pre and post exercise intervention. Though no significant differences were reported between groups for energy intake, Braakhuis, Meredith, Cox, Hopkins and Burke (2003) recommend that to attain an acceptable degree of precision, interim periods of recording are needed.

Cambell, Wallman and Green (2010) reported the outcomes on various physiological measures for 44 obese participants who completed home based walking five times per week for 12 weeks as either CONT training or HIIT. Anthropometric measures revealed pre to post significant reductions for body mass, fat mass, FFM, android fat mass and gynoid fat mass for both CONT and HIIT groups. There were no significant differences between groups for these measures.

The results of this study indicate that both CONT and HIIT protocols are equally effective in reducing overall body mass and body fat. Whilst this is promising in terms of favourably altering the body composition of obese adults, part of the intervention involved a strict calorie controlled diet where individual daily energy intake requirements were calculated based on participants current body weight. The authors stated that daily energy intakes were then set at approximately 1200-1400 calories. However, any subsequent weight loss during the intervention could have been influenced by how many calories individuals were consuming before the intervention. For example, some individuals may have had to reduce calorie intake by 2000 calories a day to attain a daily intake of 1200 whereas others may have only had to reduce intake by say 1500 calories. A more severe calorie restriction in some individuals may have had more of an effect on weight loss than any actual influence of the two exercise protocols. Regardless of this conjecture, the considerable reduction in body mass (7.7kg and 8.5kg for CONT and HIIT respectively) provides evidence that combining dietary restriction with exercise is much more effective than exercise alone as a weight loss strategy. The use of a diet only group for comparison would have helped clarify this observation further. A final point to note is that 18 of the 44 participants withdrew from the study. Whilst the authors reasoned that there were still sufficient numbers in each group to detect an effect at an alpha of .05 with an 80% confidence level (Cohen, 1988) it is perhaps just as important to acknowledge the problems of continued adherence to a new exercise regime combined with a significant reduction in energy intake in obese adults. The high withdrawal rate may also be accounted for by the fact that all exercise was performed unsupervised in a home based setting.

4.4. Studies using both overweight and obese participants.

Two studies; Tjonna et al., (2008) and Kemmler, Scharf and Lell (2014) used a mix of both overweight and obese participants to compare the effects of CONT training and HIIT on risk factors associated with the metabolic syndrome. The metabolic syndrome is defined as a cluster of cardiovascular risk factors that is manifested by dyslipidemia, impaired glycemic control, hypertension and abdominal obesity (Grundy, Brewer, Cleeman, Smith & Lenfant, 2004). The results of these two studies are summarised in Table 6.

Tjonna et al., (2008) recruited 32 overweight and obese male and female patients randomised into either a CONT or HIIT group who subsequently performed treadmill uphill walking and/

or running three times per week for 16 weeks. Anthropometric data revealed statistically significant reductions for body mass, BMI, W/H ratio and waist circumference in both groups with no significant difference between CONT training or HIIT. Whilst not reaching significance, the CONT protocol did show more favourable reductions in all anthropometric outcomes assessed. Beyond the 16 week intervention, such reductions may become more prominent especially with reference to body mass where there was a more favourable reduction of 3.6kg in the CONT group compared to 1.3kg in the HIIT group. If this trend continued over the long term this may translate into more marked improvements in an individual's health.

Kemmler, Scharf and Lell (2014) recruited 81 untrained males aged between 30-50 years to the Running Study and Heart (RUSH) trial to investigate the effects of moderate or high intensity running on cardiometabolic risk factors. Participants were randomly assigned to a CONT or HIIT training protocol that involved treadmill running two times per week for 8 weeks. The CONT participants served as their own waiting control group and commenced the 16 week exercise intervention after the HIIT group had completed the study. Exercise frequency was progressed to 3-4 times weekly from 9-16 weeks whilst maintaining isocalorific conditions between the two protocols.

Findings revealed a pre to post significant reduction for body mass in both groups with the CONT training group showing a significantly greater reduction compared to HIIT (2.5kg and 1.3kg for CONT and HIIT respectively). There was also a pre-to-post significant reduction in body fat mass and waist circumference within groups but not between groups. However, there was an observed significant decrease for FFM in the CONT group but not HIIT.

These results suggest that CONT training rather than HIIT is more effective at reducing overall body mass but at the expense of losing more FFM. However, this study is confounded by a number of factors. Most importantly the HIIT group, in addition to the HIIT exercise protocol also performed CONT bouts of exercise for 25-45 minutes at 85% MHR. Additionally, the actual HIIT protocol used ranged from work intervals of 90 seconds to 12 minutes duration. Performing HIIT for 12 minutes duration is not typical of a HIIT prescription and might actually be considered a form of CONT training. Thus, the performance of a considerable amount of CONT type training in the HIIT group makes it difficult to infer conclusions even under isocalorific conditions. The CONT group initially performed 35 minutes of treadmill exercise and this progressed to 90 minutes by the end of the intervention to match energy expenditure to the HIIT group. Such long duration raises the questions of practicality and exercise adherence in the long term. Perhaps a related point is that withdrawal rates were high with 16 participants (20%) withdrawn and a significant number of these reported orthopaedic problems as the reason (4 CONT and 3 HIIT).

Further confounding variables relate to the fact that only two sessions per week were actually supervised and heart rate data was only randomly collected in 50% of participants during these sessions. It is therefore questionable that participants were maintaining the correct intensity and that isocalorific conditions were actually similar between the two groups. Kemmler and colleagues recognised that seasonal change in dietary habits may have influenced the findings as the CONT group commenced the exercise intervention in January after acting as their own waiting controls for 16 weeks whilst the HIIT group began the intervention in the previous September. Finally, the authors stated that 73% of the CONT participants and 78% of HIIT participants were classified as overweight (25-29.9kg/m^2) by the BMI with an exclusion criteria set at >35kg/m^2 yet it is not made clear if the other participants were of normal BMI or if they had a BMI of 30kg/m^2 but below 35kg/m^2. This is further confounded as the authors do not provide the standard deviation for BMI, however, there is large standard deviations observed for body mass (12.3kg and 14kg for CONT and

HIIT respectively) indicating some participants would have been classified as obese as classified by the BMI. This distinction is important as such heterogeneity may influence the amount of weight loss and indeed other body compositional changes.

4.5. Summarising the evidence.

In relation to the four studies that included only overweight participants, the study by Moirera et al., (2008) has shown that both CONT training and HIIT similarly but significantly reduced actual body mass, BMI, body fat, FFM and waist circumference whilst there was a significant difference for W/H ratio between groups favouring HIIT to CONT. Keating et al., (2014) did not observe any significant reductions in body mass, FFM, gynoid fat mass or waist circumference in either group but identified that CONT training rather than HIIT was more effective at reducing total body fat and android fat. The studies by Rognmo et al., (2004) and Moholdt et al., (2009) found neither CONT nor HIIT to be effective at reducing overall body mass.

In summarising the three studies that included only obese participants Schjerve et al., (2008) found both CONT training and HIIT to be equally and significantly effective in reducing measures of body mass, BMI and body fat whilst Wallman, Plant and Rakimov (2008) found neither exercise protocol to be successful for weight or regional fat loss despite the inclusion of dietary guidance as part of the intervention. In direct contrast, Cambell, Wallman and Green (2010) demonstrated that CONT training and HIIT were both equally and significantly effective in reducing body mass, fat mass, and gynoid fat mass when combined with a strict calorie controlled diet though neither exercise intervention was effective at reducing android fat mass or increasing FFM.

Of the two studies that used both overweight and obese participants the findings by Tjonna et al., (2008) indicate that both CONT training and HIIT are equally and significantly effective in favourably altering body mass, BMI and waist circumference though there was no significant change in the W/H ratio in either group. The main findings of Kemmler, Scharf and Lell (2014) suggest that both protocols are equally and significantly effective at reducing body fat and waist circumference whilst CONT training was significantly more effective than HIIT for reducing overall body mass but this could have been at the expense of an observed reduction in FFM in the CONT group only.

In this review a quality rating score (QRS) was assigned to each study to provide an indication of the robustness of the study design. QRS's ranged from 3-7 indicating studies of moderate to high quality in relation to the methods used and attempts to control for confounding variables. It is difficult to ascertain any discernible pattern with regard to the QRS elements and actual study outcomes. Of note however, is that only three of the nine studies reviewed (Moirera et al., 2008, Keating et al., 2014, and Kemmler et al., 2014) show an actual significant difference comparing CONT training and HIIT on certain anthropometric measures but not on all. The study by Moirera et al., (2008) however, had the lowest QRS (3/8) of all the nine studies. In contrast, the study by Keating et al., (2014) with the highest QRS (7/8) of all the nine studies did not detect any significant difference within and between groups for any anthropometric outcome other than body fat and android fat percentage. Kemmler et al., (2014) also achieved a high QRS (6/8) but in contrast to the Keating study found both significant within and between group differences on various anthropometric outcomes. In comparing these two higher quality studies it is worth noting that in the Keating study participants were advised to not perform additional PA outside of the intervention and to adhere to their normal eating habits whereas no QRS points were assigned to these possible confounding variables in the Kemmler study.

4.6. Limitations and future directions.

Drawing definitive conclusions comparing CONT training and HIIT protocols with regard to weight loss and body composition changes in overweight and obese adults is confounded by numerous factors. The studies included in this review utilised relatively short but differing intervention periods ranging from 8-16 weeks duration. The studies by Rognmo et al., (2004) and Wallman et al., (2008) shown no significant changes in anthropometric measures and were of the shortest duration (10 weeks and 8 weeks respectively) inferring that longer interventions may be needed beyond these time frames to induce changes and to draw comparisons between CONT training and HIIT. There is therefore, a need to conduct long term interventions beyond 3-4 months.

The use of larger sample sizes would help increase the statistical power of any findings as participant total numbers ranged from 41-81in individual studies though there were significant withdrawals in a number of the studies. A further problem is the heterogeneity of samples as some studies included disproportionate numbers of females and males and very large age ranges. This is problematic when reporting data as group means as it does not infer if a particular exercise protocol was more or less effective in gender and age sub-groups. There have also been marked differences in the prescribed exercise intensities and duration of intervals across studies which makes it difficult to make direct comparisons or inferences about what intensity, work/recovery ratios and total duration of exercise may be the most effective exercise prescription. A comparative review of those studies that have utilised similar exercise protocols and homogenous groups may help clarify which are the most effective for weight loss in overweight and obese sub-groups.

One of the key limitations of the research to date is that dietary intake when reported, has been assessed using self-report measures and only at pre and post intervention. More frequent monitoring of dietary intake during any future exercise interventions is recommended as this may provide a better understanding of whether participants alter their dietary habits as a result of performing regular exercise. As well as difficulties in accurately monitoring food intake, a further confounding variable relates to the inability to fully control for physical activity behaviour beyond any supervised exercise sessions which may also influence energy balance and subsequent weight loss or gain. Finally, five of the eight studies included in this review did not use control groups which makes it impossible to draw comparisons to the exercise intervention groups. Future studies in this area should, for this reason, include a control group.

A limitation of this systematic review is that it focused only on anthropometric measures comparing CONT training and HIIT. It therefore makes no inference as to the superiority of either protocol on other outcome measures that may improve the health profile of overweight and obese individuals such as blood pressure, cholesterol, glucose control and aerobic capacity.

5.0. Conclusion

This systematic review examined the evidence that compared the use of CONT training and HIIT on anthropometric outcomes in overweight and obese adults where attempts had been made to match energy expenditure. The findings are equivocal as three studies found both exercise protocols to be ineffective in inducing weight or fat loss whilst the remaining six show both protocols to be beneficial on various anthropometric outcomes with some variation across the individual studies. Of note is that in the one study (Campbell et al., 2010) where the CONT and HIIT exercise protocols were combined with a strict calorie controlled diet there was a marked reduction in anthropometric variables beyond the results achieved by exercise alone in the other studies. This highlights the importance of combining calorie restriction with exercise for effective weight loss.

The evidence appears to show that HIIT can achieve similar results to CONT training though in less time which may make it a time efficient means to achieve weight loss. However, this review does not support the claims that HIIT is any more effective for weight loss than traditional CONT training in overweight and obese adults. Moreover, HIIT does require a greater effort and an increase in exercise intensity may not be well tolerated by all overweight and obese adults. In practical terms, if HIIT is performed unsupervised outside of the clinic setting then there may be an increased risk of injury in overweight and obese individuals due to the higher impact loading if the exercise prescription involves running. This however, remains to be established. Rather than attempting to determine which protocol is best, it is perhaps more important for practitioners to emphasise that overweight and obese adults should engage in forms of physical activity and exercise that are safe, enjoyable and something that they can adhere to in the long term so as to favourably impact health status. Therefore, the exercise prescription for overweight and obese adults may well include a mixture of both CONT training and HIIT because whilst the statistical significance is equivocal as to whether one protocol is superior to another, the evidence included in this review suggests that both can be effective for inducing weight and fat loss.

6.0. References

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