

**BE@Work (Brief Exercise at Work): The development and
evaluation of a novel high-intensity interval training
intervention in the workplace on markers of physical fitness,
cardiometabolic and mental health.**

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Abstract

Cardiovascular disease is a leading cause of morbidity and mortality, with a multitude of modifiable risk factors including poor physical fitness, cardiometabolic and mental health. Exercise training is an effective strategy that can improve important cardiometabolic and mental health outcomes. High-intensity interval training (HIT) is a form of exercise training that can elicit physiological and psychological adaptations similar to traditional prescriptions of moderate intensity exercise; however the majority of research to date has been confined to laboratory environments, and as such the effectiveness of HIT outside of the laboratory is unclear. One setting in which the effectiveness of HIT is beginning to be explored is the workplace. Accordingly, this thesis describes a mixed methods programme of work with the overall aim of exploring the effects of workplace-based HIT on markers of physical fitness, cardiometabolic and mental health in employees.

Firstly, a systematic review is presented aiming to quantify the effects of workplace exercise interventions on cardiorespiratory fitness. Here, random effects meta-analysis demonstrated meaningful improvements in cardiorespiratory fitness, post-intervention. Subsequently, a qualitative formative evaluation explored the feasibility and acceptability of a proposed workplace-based HIT trial named Brief Exercise at Work (BE@Work), with data used to further develop the BE@Work protocol. Accordingly, the acute physiological and psychological responses to novel HIT modes selected by formative evaluation participants were explored in a randomised cross-over trial. As the novel modes of HIT elicited physiological responses indicative of high-intensity exercise, they were incorporated into a controlled feasibility trial of an 8-week workplace-based HIT intervention.

The BE@Work trial was advertised in two workplaces where ~400 individuals were employed. Seventy-seven individuals responded to recruitment attempts (global emails, presentations in meetings and taster sessions) and were assessed for eligibility. Fifty four participants completed baseline testing. Outcome measures were cardiorespiratory fitness (Chester step test); leg extensor muscle power (Nottingham Leg Rig); hand grip strength (hand dynamometer); blood pressure (automatic monitor); blood lipids and glucose (finger-prick point-of-care testing), body mass index, waist circumference and questionnaire assessed health-related quality of life, psychological wellbeing and perceived stress. All outcome measures were assessed in the workplace. With the exception of the Nottingham Leg Rig, the assessment

methods were found to be feasible and acceptable for data collection in a workplace. The Nottingham Leg Rig, is heavy and cumbersome which caused difficulty during transportation of the equipment, and noise from the device disturbed the working environment.

During the BE@Work trial 20 (± 3) out of 24 possible workplace HIT sessions were attended (range: 14 to 24 sessions). Post-intervention, meaningful improvements were observed in cardiorespiratory fitness, two domains of health-related quality of life and perceived stress, compared with control. There were no meaningful effects on markers of muscular fitness, anthropometry, blood pressure, blood lipids and glucose or psychological wellbeing. The findings of this thesis demonstrate that novel modes of HIT can be feasibly incorporated into a workplace-based exercise intervention capable of eliciting improvements in important markers of physical fitness and mental health. However, it is acknowledged that the BE@Work trial was exploratory in nature and used a predictive assessment of cardiorespiratory fitness and therefore the implementation of a definitive multi-site RCT is warranted before stronger conclusions can be made about the feasibility and effectiveness of workplace-based HIT.

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Abbreviations

1-RM	one repetition maximum
AIT	aerobic interval training
AU	arbitrary unit
BE@Work	Brief Exercise at Work
BMI	body mass index
BPM	beats per minute
Ca ²⁺	calcium ion
CI	confidence interval
CHD	coronary heart disease
CPET	cardiopulmonary exercise test
CVD	cardiovascular disease
DBP	diastolic blood pressure
HIT	high-intensity interval training
HR-QoL	health-related quality of life
HR _{max}	maximal heart rate
HRR	heart rate reserve
MET	metabolic equivalent
MICT	moderate intensity continuous training
PACES	Physical Activity Enjoyment Scale
PANAS	Positive and Negative Affect Scale
PGC-1 α	peroxisome proliferator activated receptor gamma coactivator 1 alpha
PSS	Perceived Stress Scale
RCT	randomised controlled trial
REHIT	reduced exertion high-intensity interval training
RPE	rating of perceived exertion
SBP	systolic blood pressure
SD	standard deviation
SERCA	sarcoendoplasmic reticulum calcium transport ATPase
SF-36	Medical Outcomes Survey Short Form Health Survey
SIT	sprint interval training
UK	United Kingdom
US	United States
VO ₂	oxygen consumption
VO _{2max}	maximal oxygen consumption
VO _{2peak}	peak oxygen consumption
WEMWS	Warwick Edinburgh Mental Wellbeing Scale
%1RM	percentage of one repetition maximum
%HR _{max}	percentage of maximal heart rate
%VO _{2max}	Percentage of maximal oxygen consumption

Scientific outputs

Conference communications

1. **Burn, N.**, Weston, M., Maguire, N., Atkinson, G., Weston, K. “The Brief Exercise at Work (BE@Work) intervention: the feasibility and effects of a workplace high-intensity interval training intervention on markers of physical fitness, cardiometabolic and mental health”. Oral presentation at the European Congress of Sports Science, Prague, Czech Republic, July 2019. Shortlisted for the Young Investigator Award.
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Publications

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Chapter 1: Introduction

Cardiovascular disease (CVD) is the name given to a group of disorders of the heart and blood vessels, including coronary heart disease (CHD); cerebrovascular disease; peripheral artery disease; aortic atherosclerosis and thoracic or abdominal aortic aneurysm (Nabel, 2003). Cardiovascular disease accounts for 45% of deaths in Europe each year (Wilkins et al., 2017). Between 1990 and 2015, the prevalence of CVD in Europe increased by 34% in males and 29% in females (Wilkins et al., 2017). In the United Kingdom (UK), the healthcare costs associated with CVD have been estimated at approximately £10 million per annum (Wilkins et al., 2017). It is, therefore, unsurprising that notable public health agencies (including the National Institute for Health and Care Excellence and the European Society of Cardiology) have called for increased focus on the prevention of CVD, as opposed to a treatment focused model (National Institute for Health and Care Excellence, 2018; Piepoli et al., 2016), to reduce the associated burden of disease.

The development of CVD is associated with a number of risk factors including low cardiorespiratory fitness (CRF) (Lee et al., 2010); poor muscular fitness (Silventoinen et al., 2009); hypertension (Stanaway et al., 2018); dyslipidaemia (Miller, 2009); diabetes and/or hyperglycaemia (Lupsa & Inzucchi, 2018) and abdominal obesity (Klein et al., 2007). The clustering of cardiometabolic risk factors (e.g. hypertension, dyslipidaemia, hyperglycaemia, and abdominal obesity) can confer additional risk beyond that of each of the individual risk factors alone (Marrachelli et al., 2016). Furthermore, individuals with low CRF levels (defined as $<35.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in women and $<44.2 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in men) are estimated to be five and eight times, respectively, more likely to display cardiometabolic risk factor clustering than those with high CRF levels (≥ 40.8 and $\geq 50.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in women and men, respectively) (Aspenes et al., 2011).

It is therefore concerning that a number of CVD risk factors are notably poor in adult populations (Joseph et al., 2017; Mokdad et al., 2014). More specifically, CRF levels (often measured as maximal oxygen consumption ($\text{VO}_{2\text{max}}$)) are estimated to have declined by 1.6% per decade globally since 1967 (Lamoureux et al., 2019) and hypertension prevalence has increased globally by 5.2% since 2000 (Mills et al., 2016). Fasting blood glucose has increased by $0.07 \text{ mmol}\cdot\text{L}^{-1}$ in men and $0.09 \text{ mmol}\cdot\text{L}^{-1}$ in women per decade since 1980 (Danaei et al., 2011) and in England

average waist circumference (a marker of abdominal adiposity) increased by 8cm in men and women between 1985 and 2009 (Hulmán et al., 2014). Furthermore, 63.3% of the UK population is estimated to have elevated total cholesterol (Wilkins et al., 2017), and 20% of the European population have been estimated to have abnormal triglyceride and high-density lipoprotein cholesterol (HDL-C) levels (Halcox et al., 2017).

Given the concerning trends in a number of important CVD risk factors, coupled with increasing CVD prevalence and the associated health care costs; novel interventions aiming to improve CVD risk factors in adult populations are vital. Physical activity or exercise training are interventions which have been associated with improvements in a range of cardiometabolic health outcomes including improvements in CRF, lipid profiles and markers of glycaemic control (Lin et al., 2015), markers of abdominal adiposity (Vissers et al., 2013) and reduced blood pressure (Cornelissen & Smart, 2013). Given the inverse association between CRF and CVD risk factor clustering (Aspenes et al., 2011), the promotion of CRF is a critical adaptation that can occur via physical activity or exercise training. Notwithstanding the physical health and fitness benefits associated with physical activity or exercise training, a more holistic view of health encompasses both physical and mental health (World Health Organization, 2017). This is particularly important as one in four adults are expected to experience mental ill health during their lifetime (World Health Organization, 2001), which can significantly reduce an individual's functional and social capacity (Keyes, 2005). Furthermore, a consistent negative association between low levels of physical activity defined as ≤ 150 minutes per week of moderate to vigorous intensity physical activity and negative mental health has been reported (Schuch et al., 2018), as has a consistent positive association between adequate physical activity levels defined as ≥ 150 minutes per week of moderate to vigorous intensity physical activity and positive mental health outcomes such as wellbeing (Mason & Kearns, 2013) and health-related quality of life (HR-QoL) (Bize et al., 2007). These findings suggest that physical activity or exercise training could prevent the development of mental ill health or improve perceptions of positive mental health.

In light of the range of morphological, metabolic and psychological adaptations that can be promoted by physical activity or exercise training, notable public health agencies have published physical activity guidelines detailing the dose of physical activity or exercise training recommended to promote health (Department of Health, 2011; US Department of Health and Human Services, 2008; World Health

Organization, 2010). Historically, public health physical activity guidelines have focused on prescriptions of 150 minutes of moderate, or 75 minutes of vigorous intensity activity, or a combination thereof per week. However, in the most recent iteration of the UK (Department of Health and Social Care, 2019) and United States (US) physical activity guidelines (2018 Physical Activity Guidelines Advisory Committee, 2018), the use of high-intensity interval training as a means of improving health and fitness outcomes in adults has been included for the first time (Campbell et al., 2019).

High-intensity interval training (HIT) is a form of exercise characterised by brief intermittent bursts of exercise performed at high-intensity, interspersed with periods of rest or active recovery (Fox et al., 1973). The inclusion of HIT in the latest iteration of the US and UK public health physical activity guidelines is based on accumulating evidence demonstrating that forms of HIT can elicit favourable adaptations in a range of physical fitness and cardiometabolic health variables such as CRF (Bacon et al., 2013; Milanovic et al., 2015; Weston et al., 2014b); blood pressure (Costa et al., 2018); lipid profiles and markers of glycaemic control (Campbell et al., 2019; Jelleyman et al., 2015); and body composition (Maillard et al., 2018; Viana et al., 2019). Part of the appeal of HIT is that the intermittent nature can allow participants to maintain high-intensity exercise for longer periods of time in comparison to continuous exercise (Guiraud et al., 2012), thus eliciting a training stimulus while permitting reduced exercise time (Milanovic et al., 2015). This could be particularly valuable given that 'lack of time' is a commonly cited barrier to physical activity and exercise training participation (Justine et al., 2013; Reichert et al., 2007; Trost et al., 2002). However, it has been argued that the 'lack of time' barrier to physical activity participation, actually reflects other psychological processes such as values (Biddle & Batterham, 2015). For example, when an individual states that they 'do not have time to exercise', they are assigning a specific value to that activity and are therefore indicating that they do not value the activity of exercise (Biddle & Batterham, 2015). If this is the case, it has been suggested that a focus on the enjoyment, value attached to the outcome of the activity or the affective response to the activity, may enhance participation more than ensuring an activity is time efficient (Biddle & Batterham, 2015). Indeed, while the 'time efficient' nature of HIT is often described as a benefit of this form of training (Gibala et al., 2012), the true time efficiency has been contested because total session length in some HIT protocols including warm-up, cool down and rest breaks is similar to traditional prescriptions of moderate intensity continuous training (MICT) (~30 minutes) (Hardcastle et al., 2014). This criticism may only apply

to certain HIT models, however, and despite the on-going debate, the evidence demonstrating the potential for HIT to elicit favourable adaptations in important cardiometabolic risk factors supports the promotion of HIT as a viable alternative, or perhaps adjunct to, traditional prescriptions of physical activity included in public health guidelines (2018 Physical Activity Guidelines Advisory Committee, 2018). This is especially important because objectively measured compliance with physical activity guidelines remains low (5% to 47%) (Colley et al., 2011; Marsaux et al., 2016; Troiano et al., 2008), which could indicate that traditional physical activity prescriptions may not be perceived as feasible, acceptable or engaging for some individuals (Ball et al., 2004; Berry et al., 2010).

Despite the inclusion of HIT in public health physical activity guidelines, the potential for HIT to promote population wide health and fitness adaptations remains contentious (Biddle & Batterham, 2015; Hardcastle et al., 2014). Opponents of HIT do not contest the utility of HIT for eliciting improvements in health and fitness variables in tightly controlled laboratory environments (Biddle & Batterham, 2015) (i.e. the *efficacy* of HIT (Courneya, 2010)). Rather, there is dispute surrounding the potential *effectiveness* of HIT in non-laboratory settings, under 'real-life' conditions, with minimal supervision and exercise equipment (Biddle & Batterham, 2015). These assertions are based on the foundation that HIT could elicit negative affective responses given the high-intensity nature of the exercise (Ekkekakis et al., 2011) and requires specialist equipment (such as cycle ergometers) which would lead to poor adoption and maintenance of the behaviour (Biddle & Batterham, 2015). The former standpoint has been challenged in light of accumulating evidence that HIT can elicit positive psychological responses similar to MICT prescriptions (Stork et al., 2017). However, to address concerns regarding the effectiveness of HIT, interventions are required in settings outside the laboratory (often described as 'real-world' settings), using modalities that do not require access to specialist equipment (Biddle & Batterham, 2015; Gray et al., 2016).

One real-world setting in which the effectiveness of HIT in adults has recently begun to be examined is the workplace (Allison et al., 2017; Shepherd et al., 2015). Workplaces are relatively controlled environments that provide access to a considerable proportion of the adult population, within natural social networks (Dishman et al., 1998). For these reasons, the workplace has been identified as a priority setting for health promotion initiatives (National Institute for Health and Care Excellence, 2008; World Health Organization, 2007). From an organisational

perspective, a desire to reduce healthcare or absenteeism costs and enhance employee health and productivity could provide a rationale for organisations to implement such strategies (Pescud et al., 2015), particularly since low physical activity levels have been associated with sickness absence (Virtanen et al., 2018). Although the provision of facilities to support physical activity in the workplace, such as structured exercise programmes, have been associated with a greater likelihood of achieving public health physical activity guidelines (Hipp et al., 2017; Knox et al., 2017), such interventions may overlook the prevailing notion that 'lack of time' is a commonly cited barrier to physical activity participation both within (Fletcher et al., 2008; Hunter et al., 2018) and outside (Justine et al., 2013) the workplace. Therefore, time efficient exercise strategies such as HIT have potential to overcome such barriers and may therefore represent a feasible alternative to traditional prescriptions of MICT, which are commonly utilised in workplace physical activity interventions (Conn et al., 2009).

The effects of workplace-based HIT have been investigated in two published studies to date (Allison et al., 2017; Shepherd et al., 2015). Shepherd et al., (2015) compared a prescription of cycle ergometer based HIT, involving ≤ 25 minutes of repeated 15-60 sec high-intensity bouts, at $\geq 90\%$ maximal heart rate (HR_{max}) thrice weekly, with five sessions per week of cycle ergometer MICT involving 30-45 mins at $\sim 70\%$ HR_{max} , in 99 healthy but inactive employees in an English university gym setting. Allison et al., (2017) examined the effects of two stair climbing HIT protocols involving a 3x 20sec protocol and a 3x 60sec protocol conducted thrice weekly for six weeks, in 31 healthy but inactive women from a Canadian university. Post-intervention, both trials reported improvements in CRF of between 2.1 to 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$. Shepherd et al., (2015) also reported improvements in cholesterol ($-0.3 \text{ mmol} \cdot L^{-1}$), HDL-C ($+0.04 \text{ mmol} \cdot L^{-1}$), triglycerides ($-0.13 \text{ mmol} \cdot L^{-1}$) and fat mass (-0.8 kg), which were not statistically significantly different from the MICT group. Conversely, Allison et al., (2015) reported no substantial changes from baseline in cardiometabolic health markers including blood pressure, blood glucose and body composition.

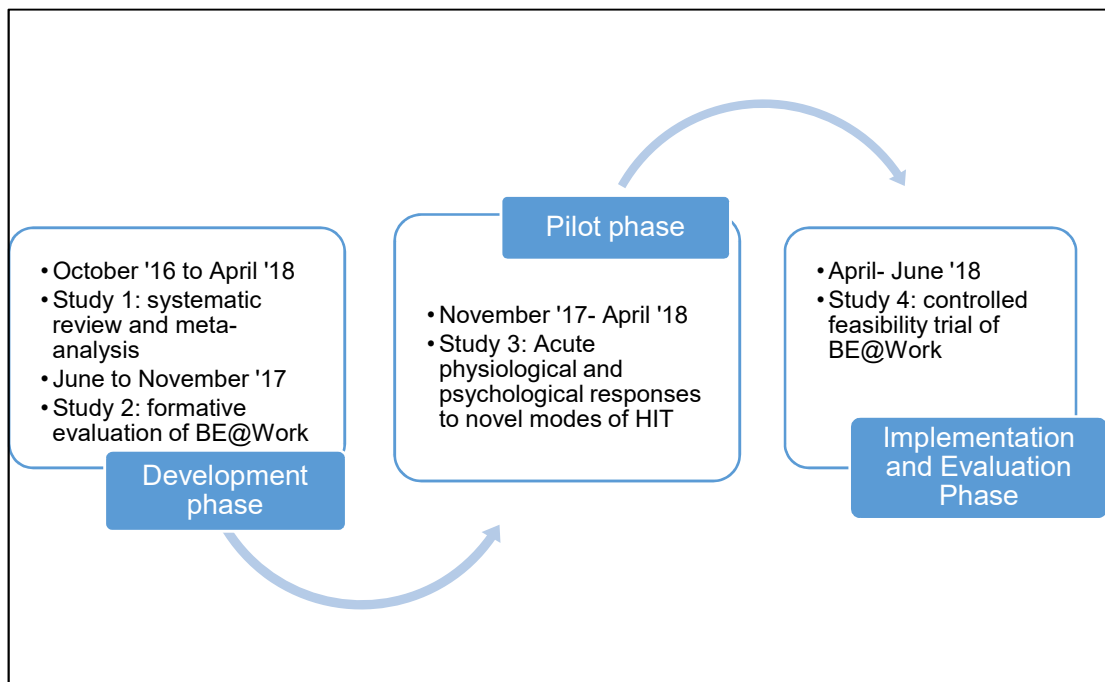
Although the above preliminary findings indicate the potential feasibility of implementing HIT into a workplace environment, a number of limitations exist in the current evidence base which will be discussed in more detail in the subsequent chapter of this thesis. Briefly, a lack of a no-exercise control group limits the confidence with which the findings can be interpreted, given the substantial biases that arise with non-controlled designs (Hariton & Locascio, 2018). Both trials were

conducted in a university setting, which limits the generalisability of the current evidence base. With the exception of two mental health variables (affect and perceptions of health) assessed by Shepherd et al., (2015), the investigation of the effects of workplace HIT on a wider variety of mental health variables is lacking. Lastly, it is questionable if cycle ergometer exercise would be feasible in some organisations given the cost and space requirements associated with this form of exercise. Although stair climbing is arguably more accessible than cycle ergometers, access to a large tower block could be required, which could be problematic in some organisations. ‘Variety’ has been identified as a facilitator to exercise intervention adherence (Morgan et al., 2016) therefore the use of a single exercise modality across an entire intervention, as was the case with both previous workplace HIT trials, may not facilitate adherence or compliance in some individuals. To begin to address these gaps in the literature, controlled workplace HIT trials are needed in settings other than university environments, with consideration of a more holistic battery of outcome variables and using a range of creative and accessible exercise modalities.

1.1 Programme framework and aims

In the chapters of this PhD thesis, the development, implementation and evaluation of a workplace HIT intervention are described, with the overall aim of exploring the effects of workplace-based HIT on markers of physical fitness, cardiometabolic and mental health outcomes in adult employees. The programme of work involved an iterative mixed methods approach, culminating in the evaluation of the Brief Exercise at Work trial (referred to herein as BE@Work). In line with the Medical Research Council (MRC) framework for the development and evaluation of complex interventions (Craig et al., 2008), the development of BE@Work was based on a phased approach, where the findings of earlier studies informed the research questions and methods of subsequent work.

Figure 1 the iterative development of the BE@Work intervention.



The development and implementation of the BE@Work trial is shown in Figure 1. The first stage of work is the development phase, where the evidence base is explored using systematic review methods and primary research with relevant stakeholders. As such, following this introduction, Chapter Two consists of a literature review aiming to provide an in-depth background and scientific rationale for the BE@Work trial. This is followed by a systematic review and meta-analysis quantifying the effects of workplace-based exercise interventions on CRF (Chapter Three). In Chapter Four a formative evaluation of the BE@Work programme is described involving qualitative focus groups and one-to-one interviews. The second phase of the MRC framework involves piloting and feasibility testing of the intervention. Accordingly, in Chapter Five a randomised cross over trial examining the acute physiological and psychological responses to three novel modes of HIT is reported. The final phases of the MRC framework involve the implementation and evaluation of the intervention. In Chapter Six the implementation and evaluation of a controlled feasibility trial of the BE@Work trial is presented. Finally, the thesis concludes with a synthesis of all presented findings and discussion of the research and practical implications (Chapter Seven). The individual aims of the research studies presented in this thesis are shown in Table 1.

Table 1 Aims of the research studies presented in the thesis

Chapter	Study title	Aim	Objective
Three	Study One. Effects of workplace-based exercise interventions on cardiorespiratory fitness: a systematic review and meta-analysis of controlled trials.	To synthesise and evaluate the current literature on workplace exercise interventions.	1.) To use random effects meta-analysis to quantify the effects of workplace exercise interventions consisting of at least moderate intensity activity on VO_{2max} . 2.) To explore the modifying effects of study and participant characteristics.
Four	Study Two. A formative evaluation of a workplace-based high-intensity interval training intervention: the development of the Brief Exercise at Work (BE@Work) trial	To explore the acceptability and feasibility of workplace-based HIT.	1.) To use qualitative focus group and interview data to formatively evaluate a proposed workplace HIT trial in workplaces in the Teesside area of North East England. 2.) To use the findings of the formative evaluation to further develop BE@Work trial protocol.
Five	Study Three. Acute physiological and perceptual responses to three novel modes of high-intensity interval training.	To explore whether novel modes of HIT could elicit a high-intensity exercise response (e.g. $\geq 85\% HR_{max}$) and to assess the psychological responses to these modes of HIT	1.) To use a randomised cross-over trial to assess the acute physiological (heart rate and blood pressure) and psychological (rating of perceived exertion, mood and enjoyment) responses to prototype HIT protocols in adults based on stair climbing, stepping and boxing 2.) To explore whether these outcomes substantially differed across HIT modes.
Six	Study Four. Brief Exercise at Work (BE@Work): a controlled feasibility trial of a high-intensity interval training intervention delivered in the workplace	To explore the feasibility and effects of a HIT intervention delivered in the workplace	1.) To implement a controlled feasibility trial of an 8-week multi-activity workplace-based HIT intervention 2.) To explore the feasibility and effects of a workplace-based HIT intervention on markers of physical fitness, cardiometabolic and mental health and in employees.

Chapter 2: Review of the literature

2.1 Overview

As a diagnostic category, cardiovascular disease (CVD) includes four main conditions: coronary heart disease (CHD) (including myocardial infarction, angina pectoris, heart failure and coronary death); cerebrovascular disease (stroke and transient ischemic attack); peripheral artery disease; aortic atherosclerosis and thoracic or abdominal aortic aneurysm (Nabel, 2003). In 2010, CHD and stroke accounted for one in four deaths worldwide, compared with one in five in 1990 (Lozano et al., 2012). Data from the World Health Organization mortality database (World Health Organization, 2018) indicates that CVD accounts for more than 45% of total deaths in Europe (Wilkins et al., 2017). Between 1990 and 2015 CVD prevalence increased by 34% in males (30.8 million to 41 million cases) and 29% in females (34 million to 44 million cases) in Europe and by 10% (2.3 million to 2.6 million cases) in the UK, although data were not stratified by sex for UK data (Wilkins et al., 2017).

Health has been defined as a state of complete physical, mental and social wellbeing, not merely the absence of disease (World Health Organization, 2017). This definition is important with regard to health promotion, as one in four adults are estimated to experience mental ill health within their lifetime (World Health Organization, 2001). Aside from the psychological impact of the conditions themselves, mental illnesses have also been associated with various physical health complications. For example, individuals suffering from depression are twice as likely to develop Type II Diabetes Mellitus (T2DM), and the prevalence of CVD is three to five fold higher than in individuals without depression (Fenton & Stover, 2006).

In 2018, the Department of Health and Social Care within the UK Government highlighted a commitment to a 'prevention focused' model of health and social care policy (Department of Health and Social Care, 2018). Prevention was defined as a process of "*helping people stay healthy, happy and independent for as long as possible. This means reducing the chances of problems from arising in the first place*" (Department of Health and Social Care, 2018, p5.). This policy highlights the importance of the prevention of chronic physical and mental health conditions, as opposed to a treatment focused model. In light of this, the work presented in this thesis will focus on the use of exercise to elicit improvements in modifiable risk factors

for CVD and mental health conditions, as opposed to exercise for the treatment of such conditions.

There are a range of modifiable risk factors for CVD including low CRF (Lee et al., 2010), poor muscular fitness (Silventoinen et al., 2009), hypertension (Stanaway et al., 2018), dyslipidaemia (Miller, 2009), diabetes and/or hyperglycaemia (Lupsa & Inzucchi, 2018), and abdominal obesity (Klein et al., 2007) as well as behavioural risk factors such as smoking, poor diet and physical inactivity (Castelli, 1984). Although there is also undeniably heritability associated with CVD risk (Kathiresan & Srivastava, 2012), the focus of this PhD thesis is on the application of exercise training; therefore, the following literature review will focus on the CVD risk factors that could feasibly be altered with exercise training (Swift et al., 2013).

This thesis will use the definitions of “physical activity” and “exercise” described by Caspersen et al., (1985). Here, physical activity is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” (Caspersen et al., 1985, p126). This definition encompasses a broad range of activities (e.g., active commuting and occupational physical activity), whereas “exercise” is defined as a subset of physical activity that is “planned, structured, and repetitive and has as a final or an intermediate objective of the improvement or maintenance of physical fitness” (Caspersen et al., 1985, p128). Notwithstanding the substantial body of evidence demonstrating the strong inverse relationship between habitual physical activity and all-cause mortality and CVD risk (Kannel, 1967; Lee et al., 2012), the focus of this thesis is the application of a form of exercise training (HIT). Unless otherwise stated, this literature review will focus on the application and effects of structured exercise training with a limited discussion of more broadly defined physical activity where necessary.

The aim of this literature review chapter is to provide an in-depth background for the chapters that will be presented subsequently in the thesis. The physical fitness, cardiometabolic and mental health variables relevant to this thesis will be examined, followed by discussion of the workplace as a setting for the promotion of physical activity or exercise training. The effects of HIT on each of the variables relevant to the thesis will then be discussed in turn. The literature review will culminate with discussion of the workplace-based HIT trials published to date.

2.2 Risk Factors

2.2.1 Cardiorespiratory fitness

2.2.1.1 Cardiorespiratory fitness: definition

Cardiorespiratory fitness is defined as “the ability of the circulatory, respiratory, and muscular systems to supply oxygen during sustained physical activity” (Lee et al., 2010), usually expressed as maximal oxygen consumption (VO_{2max}). Maximal oxygen consumption is commonly used in clinical and research practice as a measure of the functional capacity of the cardiorespiratory system; and is the product of cardiac output ($L \cdot min^{-1}$) and maximal arteriovenous oxygen difference (Garber et al., 2011; Swain, 2013). Age, sex and fitness level can cause variations in VO_{2max} , which result largely from differences in cardiac output (Swain, 2013). For this reason the primary determinant of VO_{2max} is thought to be the functional capacity of the heart (Bassett Jr & Howley, 2000).

The terms VO_{2max} and peak oxygen consumption (VO_{2peak}) are often used interchangeably in the literature yet there is a distinction between the values. Peak oxygen consumption represents the highest measured value of oxygen consumption on a specific test, whereas VO_{2max} is the true maximal oxygen consumption of the individual. Although VO_{2peak} describes the highest value attained during a maximal oxygen consumption test, it does not necessarily define the highest value attainable by the participant (Poole & Jones, 2017; Poole et al., 2008). As such, this thesis will use the term VO_{2max} throughout.

2.2.1.2 Cardiorespiratory fitness: link to health

An inverse association between CRF and CVD and all-cause mortality has been reported in a number of epidemiological studies. In a meta-analysis of 33 observational cohort studies ($n=102,980$), Kodama and colleagues (2009) reported that every 1 metabolic equivalent of task (MET) (equivalent to $3.5 mL \cdot kg^{-1} \cdot min^{-1}$) increase in CRF is associated with a 15% and 13% reduction in relative risk of CVD/CHD and all-cause mortality, respectively. However, this does not consider the impact of changes in CRF on mortality risk. In a longitudinal follow-up study of 579 men (aged 42-60 years), Laukkanen et al., (2016) reported that a $1 mL \cdot kg^{-1} \cdot min^{-1}$ improvement in CRF (over a median follow up period of 13.3 years) was associated with a 9% relative risk reduction in all-cause mortality. Furthermore, individuals with low CRF (defined as $\leq 35.1 mL \cdot kg^{-1} \cdot min^{-1}$ in women and $\leq 44.2 mL \cdot kg^{-1} \cdot min^{-1}$ in men)

were estimated to be five and eight times, respectively, more likely to have a cluster of CVD risk factors (including hypertension, dyslipidaemia, hyperglycaemia, and abdominal obesity) than those with high CRF ($\geq 40.8 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in women and $\geq 50.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in men) (Aspenes et al., 2011). It is particularly concerning then, that a recent meta-analysis including data from 2,525,827 men and women from eight countries in North America, Asia and Europe reported that CRF levels declined by 7.7% (95% CI: -8.4 to -7.0%) between 1967 and 2016 (Lamoureux et al., 2019). In light of this concerning trend in CRF, the promotion of this outcome is vital.

2.2.1.3 *Cardiorespiratory fitness: measurement*

The gold standard $\text{VO}_{2\text{max}}$ test is a maximal cardiopulmonary exercise test (CPET) until exhaustion, on either a cycle ergometer or treadmill (Shephard, 1968). During a CPET, pulmonary ventilation and expired volumes of oxygen and carbon dioxide are measured using open-circuit spirometry which requires the participant to breathe through a mask covering the nose and mouth (Riebe, 2018; Swain, 2013). Although CPET gives the most thorough quantification of $\text{VO}_{2\text{max}}$, it is a cost and labour-intensive test (Garber et al., 2011). As CPET requires participants to exercise to the point of volitional exhaustion, this requires not only high participant motivation, but may require medical supervision in high risk individuals (Riebe, 2018). For these reasons maximal CPET measurement of $\text{VO}_{2\text{max}}$ is generally reserved for use in clinical or laboratory-based research settings (Garber et al., 2011; Swain, 2013). Maximal oxygen consumption can also be predicted using a range of submaximal exercise tests (Swain, 2013).

There are several assumptions underpinning the submaximal prediction of $\text{VO}_{2\text{max}}$ (Garber et al., 2011; Riebe, 2018; Swain, 2013). The first assumption is that in healthy non-medicated participants (i.e. those not prescribed a β -blocking agent), maximal heart rate (HR_{max}) can be predicted as a function of age. Maximal heart rate is influenced by age and age-related neural influences, such as reduced sensitivity to sympathetic stimuli that compromises myocardial contractility and pumping ability (Fletcher et al., 2013; Tanaka et al., 2001). For one commonly used equation ($\text{HR}_{\text{max}} = 220 - \text{age}$ in years) (Robergs & Landwehr, 2002) between subject variability is ± 12 beats per minute (BPM) (Fletcher et al., 2013). Whereas an alternative prediction equation was developed by Tanaka et al., (2001) ($208 - 0.7 \cdot \text{age}$ in years). Here, true HR_{max} was determined via CPET and stepwise regression analysis revealed that age explained $\sim 80\%$ of the individual variance in HR_{max} (Tanaka et al., 2001). Although true HR_{max} was inversely related to age ($r = -0.90$) between-subject variation in true

HR_{max} was evident with standard deviations ranging from 7 to 11 BPM (Tanaka et al., 2001). The second assumption in the submaximal prediction of VO_{2max} is that a linear relationship exists between oxygen consumption (VO_2) and heart rate at a given work rate (Swain, 2013). However, at higher intensities VO_2 , heart rate and power output do not always follow a linear relationship, as a deflection between VO_2 and heart rate can occur (Billat & Lopes, 2006; Zoladz et al., 1998). This deflection causes errors in the estimation of VO_{2max} of $\pm 15\%$ (Sartor et al., 2013). Thirdly, it is assumed that the heart rate of separate work rates can be plotted on a regression line, as the heart rate- VO_2 relationship and extrapolated to the estimated HR_{max} , enabling the prediction of VO_{2max} (Sykes & Roberts, 2004). The error associated with the prediction of VO_{2max} using this method is typically accepted as ± 1.96 standard error of the estimate (Sartor et al., 2013). Although caution is warranted when interpreting VO_{2max} from submaximal prediction tests, they are commonly utilised in both clinical and research settings when a maximal exercise test is not feasibly possible (due to lack of space, equipment or expertise) or not advisable (elderly or cardiac patients) (Sartor et al., 2013). Such tests include (but are not limited to) the Astrand submaximal cycle ergometer protocol (Astrand, 1960), the YMCA submaximal cycle ergometer protocol (Golding et al., 1989) and the Ebbeling single-stage submaximal treadmill walking test (Ebbeling et al., 1991). Although these tests appear to provide an appropriate estimate of VO_{2max} in comparison to directly measured VO_{2max} , given that these tests require access to specialist exercise equipment they are unlikely to be feasible in field-based research settings. Because the focus of this thesis is on the implementation of exercise testing and an exercise intervention in the workplace, it is pertinent to consider alternative tests requiring limited equipment and space to estimate VO_{2max} .

Step tests are a mode of CRF assessment that may represent a feasible alternative to CPET (Bennett et al., 2016). These tests typically require the participant to repeatedly step on to and off a portable step at a set cadence for a required time period, with heart rate monitored throughout the test (Bennett et al., 2016). There are a range of step tests available including (but not limited to) the Queens College Step Test (McArdle et al., 1972) and the YMCA modified 3 minute step test (Santo & Golding, 2003); however, the Chester Step Test (Sykes, 1998) has been recommended above other available step tests for use in field-based research (Bennett et al., 2016).

The Chester step test is a multistage test which involves stepping on to and off a 15, 20, 25 or 30-cm step. Step height is dependent on age and habitual physical activity level and cadence is set by a metronome beat. The initial step rate is 15 steps per minute and every 2 minutes the cadence increases by 5 steps per minute, for a maximum of 10 minutes. Participants continue stepping until 80% of age predicted HR_{max} is reached, they report ratings of perceived exertion of ≥ 15 (hard) on the Borg 7-20 scale (Borg, 1982), or they complete all five stages of the test (Sykes, 1998; Sykes & Roberts, 2004).

The validity of the Chester Step Test for the prediction of VO_{2max} was first assessed in 7 male and 6 female (22.4 ± 4.6 years) physically active university students (Buckley et al., 2004). Directly measured VO_{2max} was established with a CPET, and the Chester step test was undertaken twice, within 5-7 days. In both trials, the Chester step test underestimated true VO_{2max} . The bias $\pm 95\%$ limits of agreement between the Chester step test predicted VO_{2max} and the actual VO_{2max} for trials one and two, were -2.8 ± 6.1 $mL \cdot kg^{-1} \cdot min^{-1}$ and -1.9 ± 7.4 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively. In terms of reliability of the test, the bias $\pm 95\%$ limits of agreement of the Chester step test predicted VO_{2max} between each trial was 0.8 ± 3.7 $mL \cdot kg^{-1} \cdot min^{-1}$.

In a subsequent study, Sykes and Roberts (2004) compared Chester Step Test predicted VO_{2max} from two separate time points in 68 participants (age: 31 ± 10 years, of both sexes and varying fitness and activity levels) with CPET assessed VO_{2max} . Although the standard error of the estimate between the true and Chester step test predicted VO_{2max} was 3.9 $mL \cdot kg^{-1} \cdot min^{-1}$, the high correlation between true and predicted VO_{2max} ($r=0.92$) led the authors to conclude that the Chester step test is a valid predictor of VO_{2max} (Sykes & Roberts, 2004). In terms of reliability of the test in the sample, there was a mean difference between the two Chester Step tests of -0.7 $mL \cdot kg^{-1} \cdot min^{-1}$ (Sykes and Roberts, 2004). The limits of agreement analysis demonstrated a measurement repeated on a separate day was within 4.5 $mL \cdot kg^{-1} \cdot min^{-1}$ of the original predicted measurement (Sykes and Roberts, 2004). Other typically presented reliability statistics such as intra-class correlations were not reported in either of the studies examining the reliability of the Chester test (Buckley et al., 2004; Sykes & Roberts, 2004) and so they cannot be presented here. Nonetheless, the Chester step test has been recommended for use in intervention studies above other similar step tests (Bennet et al., 2016).

In reporting the above statistics for quantifying agreement between measurement methods and test-retest time points, it is important to acknowledge the different

analytical goals when making decisions about acceptable measurement (within-subjects) variability; these being either in the context of individual patient/person decisions (e.g. for the purpose of diagnosis or screening) or in the context of research on samples of participants (Atkinson and Nevill, 1996). The primary context of the present thesis is research. Specifically, the important question is whether test-retest variability of the employed measurement tool/protocol is small enough to detect a minimal clinically important difference (MCID) in a future study with a feasible sample size (Atkinson and Nevill, 1996). In this context, there is a link to sample size estimation (Batterham and Atkinson, 2005). Accordingly, limits of agreement statistics are relevant to the context of measurement error for individual participants (Atkinson & Nevill, 1996). Specifically, the 95% limits of agreement indicate the upper limits for test-retest variability expected, with coverage of 95% of cases in a sample, for a single participant. For example, if the 95% limits of agreement for test-retest measurements of VO_{2max} are $\pm 4.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, this indicates that the agreement between repeated measurements of VO_{2max} on a person drawn from the population would be unlikely to be worse than $\pm 4.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. This information can then be used to predict the implications of this agreement on the robustness of diagnostic decisions on individuals. Therefore, although the limits of agreement cited above ($\pm 4.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Sykes & Roberts, 2004) for the Chester step test may appear to be particularly large, this statistic should not be applied directly to research purposes where the aim is to detect a clinically relevant mean change with a feasible sample size. Measurement error statistics can then be used to inform a sample size estimation for future research. For example, the above limits of agreement can be converted to the standard deviation of differences (a term in the denominator of a paired t-test) and inputted into a sample size estimation designed to detect a MCID of $1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Laukkanen et al., 2016) in a future trial. For this purpose the expected standard deviation (SD) of differences can be calculated from the limits of agreement:

$$4.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1} / 1.96 = 2.3 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}.$$

Using a statistical power program such as GPOWER, it can be estimated from this test-retest SD that a future study would require 44 participants in a single arm pre-post trial to achieve a power of 80% and a level of significance of 5% (two sided), for detecting a mean difference of $1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; assuming the standard deviation of the differences to be $2.3 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Collectively, this information could be used to justify the use of the Chester step test as a sufficiently reliable tool for the detection of a MCID of $1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ with a sample size that would be feasible in an exercise

trial. It is, however, acknowledged that the validity of predictive CRF assessments, such as step tests, have been questioned (Grant et al., 1999). Specifically relevant to the present body of work, it is unclear whether the Chester step test is valid for detecting a change in CRF over time, despite the test appearing to be acceptably reliable on a test-retest basis.

2.2.1.4 Cardiorespiratory fitness: effects of exercise training

Exercise training can elicit both central and peripheral physiological adaptations that are associated with improved oxidative metabolism, which in turn lead to improvements in CRF (Egan & Zierath, 2013). An increase in cardiac output is the key central adaptation associated with training induced improvements in CRF, which is mediated by increased stroke volume as a result of increased left ventricular end-diastolic volume, blood volume and cardiac contractility (McArdle, Katch & Katch, 2015). The peripheral muscle fibre adaptations associated with exercise training are related to increased oxygen extraction and utilisation, which are mediated by increases in skeletal muscle mitochondrial content and function (Hawley et al., 2014). Improvements in CRF can be detected with four weeks of training (Saltin et al., 1977).

An established body of randomised controlled trial (RCT) evidence demonstrates that exercise training can improve CRF (Swift et al., 2013). In one of the earliest RCTs, Kraus et al., (2002) randomised 84 sedentary overweight participants (35 female, 52.3 ±7.8 years) into one of three aerobic exercise training prescriptions or a no-exercise control group for eight months. The high-amount/high-intensity prescription involved the caloric equivalent of jogging 32 km per week at 65-80% of VO_{2max} , the low-amount/high-intensity prescription involved the caloric equivalent of jogging 19 km per week at 65 to 80% VO_{2max} , and the low-amount/moderate-intensity prescription involved the caloric equivalent of walking approximately 19 km per week at 40 to 55% VO_{2max} . Post-intervention compared with the control group, only the high-amount-high-intensity and low-amount-high-intensity groups significantly ($p=0.01$) improved VO_{2max} (18% or 0.41 ±0.2 L.min⁻¹ and 17% or 0.43 ±0.14 L.min⁻¹, respectively). This finding suggests that the intensity of exercise is paramount for eliciting adaptations in CRF. A recent meta-analysis demonstrated the proliferation of research investigating the effect of exercise training on CRF (Lin et al., 2015). Here, the effects of 122 RCTs ($n=4792$) comparing structured aerobic exercise training of at least moderate intensity (defined as ≥75% HR_{max} including a wide range of modalities such as walking, running, small sided games, deep water running, cycle ergometer and broadly defined “aerobic or endurance exercise”), to control. The

meta-analysed effect on VO_{2max} was $3.9 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (95% CI 3.45 to $4.35 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) (Lin et al., 2015), compared with control. However, it was unclear from the study reporting if control groups in the individual studies were inactive comparators, which could impact on the magnitude of the intervention effect.

As first indicated by Kraus et al., (2002), it is now recognised that when compared on a matched work basis (e.g., energy expenditure is matched), vigorous intensity exercise ($\geq 77\% \text{ HR}_{max}$ or $\geq 64\% \text{ VO}_{2max}$) can elicit greater improvements in CRF when compared with moderate intensity continuous training (MICT) ($64\text{-}76\% \text{ HR}_{max}$ or $46\text{-}63\% \text{ VO}_{2max}$) (Garber et al., 2011). This assertion is reflected in public health physical activity guidelines where although 150 minutes of moderate intensity physical activity are recommended, only 75 minutes of vigorous intensity physical activity is suggested, or combination thereof per week (2018 Physical Activity Guidelines Advisory Committee, 2018; Department of Health, 2011; World Health Organization, 2010).

2.2.2 Muscular fitness

2.2.2.1 Muscular fitness: definition

Muscular fitness is a term that encompasses muscular strength and power (Garber et al., 2011). Muscular strength refers to the muscles ability to generate force (Hass et al., 2001), whereas muscular power, although related to strength, is a separate attribute defined as the ability of the neuromuscular system to produce the greatest amount of force as fast as possible (Reid & Fielding, 2012; Tiainen et al., 2009).

2.2.2.2 Muscular fitness: link to health

Poor muscular strength, as opposed to total muscle mass, is a strong and independent predictor of all-cause mortality (Newman et al., 2006). A recent meta-analysis of 36 prospective observational studies ($n=1,907,580$, aged 19 to 84.5 years, from 22 high and low income countries) demonstrated that higher muscular strength (quantified via grip strength assessments) is associated with a reduced risk of all-cause mortality (hazard ratio=0.69; 95% CI 0.64 to 0.74) (García-Hermoso et al., 2018). However, the usefulness of the findings are limited because the study authors did not provide the exact quantification for “high” and “low” grip strength.

Higher muscular power is associated with the performance of basic daily activities, which depend on the ability to produce force at high velocity, such as chair rising and

stair climbing (Bassey et al., 1992; Katula et al., 2008). Given the age-associated declines in muscular power that occur from middle-age onwards (Izquierdo et al., 1999); to maintain functional capacity with aging, it is vital to improve or maintain muscular power before the onset of old age (Straight et al., 2016) .

2.2.2.3 Muscular fitness: measurement

The gold standard muscular strength assessment is the highest amount of weight that an individual can lift once using correct technique (one repetition maximal strength [1RM]) (Fernandez, 2001; Hass et al., 2001). However, the utility of this form of testing with untrained populations and outside of the laboratory is questionable given the risk of injury and muscle soreness (Barnard et al., 1999). Maximal hand grip strength is an alternative and simple method for assessing general upper body muscle strength and function, measured using hydraulic hand dynamometers (Bohannon, 2008; Roberts et al., 2011). The most commonly used dynamometers are the Jamar and Baseline Evaluation Instruments dynamometers. The Jamar dynamometer has been shown have good ($r = 0.80$) test–retest reliability (Mathiowetz et al., 1984) and the Baseline Evaluation Instruments dynamometer has excellent test-retest reliability (intra class correlation= 0.99) and relative reliability when compared with Jamar dynamometer (intra class correlation= 0.90) (Mathiowetz et al., 2000). It is however essential that the adjustable hand piece is correctly sized to the participants hand (Mathiowetz et al., 2000), which requires researcher judgment and may compromise the inter-rater reliability of the instrument. However, reference protocols are available to ensure standardised testing procedures across participants (Perna et al., 2016). Given that grip strength permits a simple non-invasive quantification of upper body strength that requires limited space, time and participant exercise experience it has been included in a range of population based cohort studies (Perna et al., 2016; Shields et al., 2010).

Based on the definition of muscular power provided above, it should be distinguished from short-term power output (often called anaerobic capacity/ power) measured over longer periods such as 15-60secs in an ‘all-out’ effort on a cycle ergometer (Patton & Duggan, 1987; Sculthorpe et al., 2017). Lower body power can also be assessed by vertical two legged jumping onto a force plate (Harman et al., 1991); however, this assessment has been critiqued as it requires expensive equipment and may not be suitable in inactive or middle aged to older adults due to risk of injury and falls (Bassey & Short, 1990).

The Nottingham leg extensor power rig (henceforth referred to as “leg rig”) (Medical Engineering Unit, University of Nottingham, Nottingham, UK) is an alternative lower body muscular power assessment tool (Bassey & Short, 1990). Leg rig assessed lower limb muscular power has been shown to significantly correlate with both peak isokinetic dynamometer assessed power (Spearman’s rho (ρ) 0.82, $p=0.001$) and single leg force plate jump ($\rho=0.86$, $p=0.001$) (Bassey & Short, 1990). This suggests that similar muscular capabilities are being assessed, indicating the validity of the leg rig for estimates of lower limb power (Bassey & Short, 1990). The short (3 days) and long (12 week) term reliability of the leg rig has been investigated in 72 healthy middle-aged and older adults (mean age: 63 ± 9 years) (Hurst et al., 2018a). As the intraclass correlation coefficients were high following repeated tests for both short (0.88–0.96) and long-term reliability (0.94–0.96), the leg rig is established as a reliable tool for the assessment of lower limb muscular power (Hurst et al., 2018a).

2.2.2.4 Muscular fitness: effects of exercise training

Although aerobic exercise training is recommended for the development of CRF, resistance training is recommended to elicit adaptations in muscular fitness (Garber et al., 2011). Improvements in muscular strength and power are thought to be mediated by neural adaptations during the first few weeks of a training programme (Häkkinen et al., 1998a) which, in turn, are responsible for enhanced maximal motor unit firing rate (Kamen & Night, 2004), increased activation of agonist muscles and reduced co-activation of antagonist muscles (Häkkinen et al., 1998b). In addition to neural adaptations, morphological adaptations during strength and power training include an increase in muscle cross-sectional area and increases in both type I and type II muscle fibres (Folland & Williams, 2007). In a meta-analysis, Rhea et al., (2003) reported that resistance training (exercises that cause muscles to work against, move or overcome an applied force or weight (Garber et al., 2011)) can improve muscular strength such that in untrained individuals maximal strength gains were achieved at a training intensity of 60% of 1RM (effect size: 2.8), 3 days per week (effect size: 1.94), and with a mean training volume of 4 sets per muscle group (effect size: 2.28) (Rhea et al., 2003). However, as the focus of this thesis is not on the application of resistance training *per se*, it should be noted that any exercise training has the potential to challenge (and therefore elicit adaptations in) muscular fitness, albeit at different respective levels relative to the training content (Buchheit & Laursen, 2013b). Plyometric exercises involving rapid deceleration of the body followed immediately by rapid acceleration in the opposite direction (such

as squat jumps) have been recommended as an alternative or adjunct to resistance training for the promotion of muscular power (Fatouros et al., 2000). There is evidence to suggest that plyometric exercise training can improve markers of muscular power in athletic (Chelly et al., 2010; Váczki et al., 2013), and older adult populations (Vetrovsky et al., 2019). This suggests that body weight exercise could improve muscular power without the need for the specialist equipment or loaded machines typically required for resistance training.

2.2.3 Hypertension

2.2.3.1 Hypertension: definition

Blood pressure is dependent on output from the heart, blood vessel flexibility and resistance to blood flow, volume of blood and blood distribution to organs (Williams et al., 2018). Healthy blood pressure is defined as resting systolic blood pressure (SBP) of 120 mmHg and resting diastolic blood pressure (DBP) of 80 mmHg and hypertension is defined as resting SBP of ≥ 140 mmHg and DBP of ≥ 90 mmHg (Kannel et al., 1961; Mills et al., 2016).

2.2.3.2 Hypertension: link to health

Hypertension is the leading all-cause mortality risk factor, accounting for 10.4 million deaths globally, ahead of smoking, high blood glucose and high body mass index (Stanaway et al., 2018), and accounts for 54% of all strokes and 47% of all ischaemic heart disease events globally (Lawes et al., 2001). In 2010, the global prevalence of hypertension was 31.1% in adults aged ≥ 20 years, which is an increase of 5.2% since 2000 (Mills et al., 2016), with the prevalence in England estimated at 31% in men and 26% in women (Public Health England, 2016). In adults aged 50-59, it has been estimated that each 20mmHg lower usual SBP reduces stroke death rate by 62% (Lewington et al., 2002).

2.2.3.3 Hypertension: measurement

The mercury sphygmomanometer is the gold standard clinical blood pressure measurement technique (Coleman et al., 2005). However, the precision of this method can be compromised by various human errors including incorrect eye positioning when reading the scale and applying excessive stethoscope pressure on the brachial artery (Perloff et al., 1993). Automatic monitors are frequently used to assess blood pressure and should be validated based on their agreement with measurements taken using a mercury sphygmomanometer in accordance with the

European Society of Hypertension International protocol (O'Brien et al., 2010; Takahashi et al., 2010). The validation protocol requires that automated machines give at least 50% of readings within 5 mmHg and 75% within 10 mmHg with the two methods (O'Brien et al., 2010).

2.2.3.4 Hypertension: effects of exercise training

Exercise training has both acute and chronic effects on blood pressure. In both normotensive and hypotensive individuals, following an acute bout of exercise, blood pressure temporarily falls below pre-exercise levels due to exercise induced peripheral vasodilation, a phenomenon known as post-exercise hypotension (Pescatello et al., 2015). Following chronic training, a sustained decrease in blood pressure is thought to be mediated by improved endothelial function (Sabbahi et al., 2016). Peripheral vascular resistance is a key determinant of blood pressure and increased endothelial function is associated with, and may contribute to, lower peripheral vascular resistance (Sabbahi et al., 2016). Reductions in blood pressure have been observed in hypertensive individuals within eight to twelve weeks of exercise training (Dimeo et al., 2012).

Notable public health agencies, including the World Health Organization (World Health Organization, 2003), the European Society of Hypertension and Cardiology (Mancia et al., 2014), and the American College of Sports Medicine (Pescatello et al., 2015) advocate exercise training or increased physical activity as a first line intervention for the prevention and treatment of hypertension. Cornelissen & Smart (2013) meta-analysed the effects of 105 aerobic (35% to 95% of VO_{2max}), 34 resistance (10% to 100% of 1-RM) and 14 combined exercise training interventions from a total 5223 participants on resting blood pressure. Post-intervention, compared with control, exercise training reduced SBP by -3.5 mmHg (95% CI -4.6 to -2.3 mmHg) and DBP by -2.5 mmHg (95% CI -3.2 to -1.7 mmHg) (Cornelissen & Smart, 2013). Furthermore the reduction in blood pressure was greater in hypertensive individuals (SBP -8.3 mmHg [95% CI -10.7 to -6.0], DBP -5.2 mmHg [95% CI -6.8 to -3.4]) (Cornelissen and Smart, 2013). Similar reductions in blood pressure were observed in an earlier meta-analysis of 54 RCTs where aerobic exercise training (intensity not defined) elicited reductions of -3.8 mmHg (95% CI -5.0 to -2.8) and -2.6 mmHg (95% CI -3.4 to -1.8) in SBP and DBP, respectively, compared with control (Whelton et al., 2002).

2.2.4 Dyslipidaemia

2.2.4.1 *Dyslipidaemia: definition*

Dyslipidaemia is characterised by a clustering of abnormalities in blood lipids including elevated cholesterol and triglyceride and reduced high-density lipoprotein cholesterol (HDL-C) (Miller, 2009). Historically, clinical guidelines recommended the use of fasted lipid samples (≥ 8 hours) (National Cholesterol Education Programme, 2001) in order to reduce variability and achieve consistency in the metabolic states of participants (Warnick & Nakajima, 2008). However contemporary guidelines now recommend non-fasted samples (National Institute for Health and Care Excellence, 2014; Nordestgaard et al., 2016). When compared with fasting lipid profiles, mean changes 1 to 6 hours after habitual meals are small and not clinically significant (cholesterol -0.2 mmol.L⁻¹; triglycerides $+0.3$ mmol.L⁻¹) and fasting does not have an impact on HDL-C concentrations (Nordestgaard et al., 2016). It has also been suggested that abnormal postprandial triglyceride levels may better predict CVD risk than fasted levels (Harchaoui et al., 2009; Nordestgaard & Varbo, 2014). Non-fasted samples may be more feasible in field-based research by reducing participant burden and the inconveniences associated with fasting while also permitting data collection throughout the day, rather than just following an overnight fast. Threshold values for normal non-fasted lipids are ≤ 5 mmol.L⁻¹ for cholesterol, ≥ 1 mmol.L⁻¹ for HDL-C and ≤ 2 mmol.L⁻¹ for triglyceride (Nordestgaard et al., 2016).

2.2.4.2 *Dyslipidaemia: link to health*

Although non-fasted lipid values are recommended in contemporary guidelines, the vast majority of work examining the link between dyslipidaemia and CVD or all-cause mortality risk use fasted lipid values. For example, in a seminal study, data from the Framingham Heart study demonstrated that fasted cholesterol of ≥ 6.3 mmol.L⁻¹ was associated with three times the incidence of CHD when compared with fasted cholesterol of ≤ 5.4 mmol.L⁻¹ (Kannel et al., 1961). Subsequent observational studies have supported the positive association between elevated cholesterol (Chen et al., 1991; Lewington et al., 2007; Stamler et al., 1993) and triglyceride levels (Nordestgaard & Varbo, 2014) and CVD/ CHD mortality. Conversely, HDL-C has been shown to have a protective effect on CVD/CHD mortality such that higher HDL-C levels are associated with lower CVD/ CHD mortality risk (Cooney et al., 2009).

Twenty percent of European adults are estimated to have either triglyceride or HDL-C levels characteristic of dyslipidaemia (Halcox et al., 2017) and 63% of the UK

population is estimated to have elevated cholesterol ($\geq 5 \text{ mmol.L}^{-1}$) (Wilkins et al., 2017). Although there is data to suggest that population cholesterol levels have reduced in the UK since 1985 (median decrease of 22%) this is thought to be largely due to the widespread use of cholesterol lowering medication (Hulmán et al., 2014).

2.2.4.3 Dyslipidaemia: measurement

The gold standard blood lipid assessment technique is laboratory-based analysis using assay techniques with a venous blood sample (Jain et al., 2011). However, the collection, storage and transportation of blood for analysis in a laboratory may not be practically or ethically possible in field-based research, therefore an alternative is point-of-care testing. Point-of-care finger prick blood sampling using the Cholestech LDX analyser (Cholestech Corporation, Hayward, CA, USA) is currently used for the National Health Service Health Checks (Jain et al., 2011) and involves the collection of a small sample of blood from the finger which is analysed in minutes using a portable point-of-care testing analysis unit. Carey et al., (2006) reported correlations between the LDX analyser and traditional laboratory analysis of 0.92 and 0.93 for triglycerides and HDL-C, respectively. Parikh et al., (2009) reported similar correlations when compared with laboratory analysis of 0.91 for cholesterol, 0.77 for HDL-C and 0.93 for triglycerides. However in one study of hyperlipidaemic individuals aged over 70 years, the LDX analyser over estimated triglycerides by 1.6 mmol.L^{-1} and HDL-C by 0.08 mmol.L^{-1} (Stein et al., 2002).

2.2.4.4 Dyslipidaemia: effects of exercise training

Exercise training has been recommended as either an adjunct to medication or a stand-alone therapy for the prevention and treatment of dyslipidaemia (Wang & Xu, 2017). While it has been suggested that exercise induced weight-loss mediates improvements in lipid profiles (Stefanick, 1999), some studies have reported improvements in lipid profiles in the absence of weight loss (Durstine et al., 2001; Carroll & Dudfield 2004; Kraus et al., 2002). It has therefore been suggested that increases in skeletal muscle mass, reductions in intra-abdominal fat or improvements in cardiorespiratory fitness mediate the exercise induced improvements in lipid profiles (Ross et al., 2004). Furthermore, as exercise increases the ability of skeletal muscles to utilise lipids as opposed to glycogen, this may also reduce plasma lipid levels (Earnest et al., 2013).

In a meta-analysis of RCTs, comparing aerobic exercise training of at least moderate intensity ($\geq 75\% \text{ HR}_{\text{max}}$ including walking/running, small sided games and cycle ergometers) to control, exercise training resulted in decreases in cholesterol (-0.03

mmol.L⁻¹; 95%CI; -0.24 to 0.31, 68 studies) and triglycerides (-0.06 mmol.L⁻¹; 95% CI -0.12 to -0.01, 66 studies) and an increase in HDL-C (0.06 mmol.L⁻¹; 95% CI 0.03 to 0.10, 74 studies) (Lin et al., 2015). However, the wide confidence interval around the estimation of cholesterol indicates low precision in the estimate; therefore the finding should be interpreted with caution. Adaptations in lipid profiles have been detected with 6 to 24 weeks of exercise training (Mann et al., 2014).

2.2.5 Hyperglycaemia

2.2.5.1 Hyperglycaemia: definition

Hyperglycaemia is a state of elevated blood glucose and diabetes mellitus is defined as a chronic state of hyperglycaemia (Laakso & Kuusisto, 2014). There are two subtypes of diabetes mellitus; type 1 diabetes mellitus (T1DM) and T2DM. Type 1 diabetes mellitus results from the autoimmune destruction of the β cells in the pancreas, whereas the development of T2DM can be attributable to lifestyle related factors such as insufficient physical activity and poor nutrition (International Diabetes Federation, 2017).

Glycated haemoglobin (HbA_{1c}) is the result of the addition of glucose to amino groups of haemoglobin (Little & Sacks, 2009) and is the most widely accepted marker of glycaemic control in clinical practice (Bergenstal et al., 2013). The concentration of HbA_{1c} depends on the concentration of glucose in the blood and the lifespan of the red blood cell to which the haemoglobin is bound (Little & Sacks, 2009). Red blood cells have a lifespan of approximately 120 days; therefore HbA_{1c} represents the integrated blood glucose concentration over the preceding 8 to 12 weeks (Goldstein et al., 2004; Weykamp et al., 2008). The diagnostic criteria for diabetes mellitus is a HbA_{1c} of $\geq 6.5\%$ (48 mmol.mol⁻¹), fasting blood glucose level of ≥ 7.0 mmol.L⁻¹ or a random blood glucose level of ≥ 11.1 mmol.L⁻¹ (World Health Organization, 2006).

2.2.5.2 Hyperglycaemia: link to health

The high prevalence of CHD in individuals with T2DM has been recognised for more than a century (Joslin, 1924) and compared with healthy individuals; individuals with T2DM have a three to fourfold increased risk of CVD mortality (Laakso, 1999; Lupsa & Inzucchi, 2018). Non-diabetic hyperglycaemia has also been associated with subsequent development of CVD (Sarwar et al., 2010). Collectively this evidence suggests that hyperglycaemia is a key risk factor for the development of CVD and CVD mortality (Pistrosch et al., 2011). The prevalence of T2DM is estimated to be 10% in men and 9% in women which is an increase from 8% in both sexes since 1980

(Danaei et al., 2011). Furthermore, since 1980 the global age-standardised mean fasting blood glucose has increased by 0.07 mmol.L⁻¹ in men and 0.09 mmol.L⁻¹ in women per decade (Danaei et al., 2011).

2.2.5.3 Hyperglycaemia: measurement

The measurement of HbA_{1c} involves the collection of whole venous blood, which is analysed using laboratory-based assay techniques (Little & Sacks, 2009). The measurement of HbA_{1c} may not be pragmatically or ethically possible in field-based studies owing to the need for storage and transportation of whole blood samples. As both fasting blood glucose and HbA_{1c} are equally effective screening tools for the detection of T2DM, fasting blood glucose has been suggested as an alternative marker of glycaemic control (Bennett et al., 2007).

Although fasting blood glucose can be assessed in a similar manner to HbA_{1c} (Sacks et al., 2011), point-of-care testing procedures are a feasible alternative in field-based settings involving the collection of a sample of venous blood from the finger which is analysed in minutes using a portable point-of-care testing analysis unit (Jain et al., 2011). The Cholestech LDX analyser, used for the assessment of blood lipids described in section 2.2.4.3, can also be used to assess blood glucose. Shemesh et al., (2006) reported correlations between the LDX analyser and traditional laboratory analysis of (Cohens κ) 0.84 to 0.95 for blood glucose concentrations.

2.2.5.3 Hyperglycaemia: effects of exercise training

Exercise has both acute and chronic effects on glycaemic control. Glucose disposal is enhanced following an acute bout of exercise which may be due to increased translocation of the glucose transporter GLUT-4 into the sarcolemma and the T-tubules of the muscle (Kennedy et al., 1999). Similarly, increased expression of GLUT-4 protein in skeletal muscle (Houmard et al., 1993) and increased skeletal muscle mitochondrial content and function (Toledo et al., 2006) represent possible mechanisms underlying the effect of chronic exercise training on glycaemic control. Typically, chronic exercise induced adaptations in glycaemic control can be observed following 8-12 weeks of exercise training (Boulé et al., 2001).

The American Diabetes Association (Colberg et al., 2016) and the American College of Sports Medicine (Colberg et al., 2010) support the use of exercise training or increased physical activity for the management of glycaemic control. A meta-analysis

of 26 RCTs demonstrated that supervised exercise training improved HbA_{1c} in diabetic participants, resulting in reductions of -0.70% (95% CI: -1.02 to -0.38%), -0.62% (95% CI: -1.14 to -0.11%) and -0.47% (95% CI: -0.64 to -0.31%) for aerobic, resistance and combined exercise training, respectively (Umpierre et al., 2013). In non-diabetic participants a meta-analysis demonstrated that when compared with controls, exercise training resulted in a reduction in both HbA_{1c} (-0.28%: 95% CI: -0.42 to -0.14%, 19 studies) and fasting blood glucose (-0.07mmol.L⁻¹, 95%CI: -0.13 to 0.004, 49 studies) (Lin et al., 2015). Although purely speculative, the higher number of exercise trials reporting blood glucose (n=49) compared with HbA_{1c} (n=19) may indicate that blood glucose is the preferred measure of glycaemic control in exercise trials with non-diabetic populations.

2.2.6 Abdominal adiposity

2.2.6.1 Abdominal adiposity: definition

Body mass index (BMI) is an index of an individual's body mass, relative to their height and is defined as the body mass in kilograms divided by the square of the height in metres (kg/m²). Body mass index can be used to classify underweight (<18.5 kg/m²), normal weight (18.5-24.9 kg/m²), overweight (≥25.0 kg/m²) and obesity (≥30.0 kg/m²) in adults (World Health Organization, 2000). However it has been claimed that BMI is not an adequate metric for assessing overweight and obesity, and waist circumference has been suggested as an alternative assessment of abdominal adiposity (Bouchard, 2007). It is recommended that waist circumference does not exceed ≥102cm for men and ≥88cm for women, to minimise CVD risk (Janssen et al., 2002).

2.2.6.2 Abdominal adiposity: link to health

Overweight and obesity are associated with increased risks of mortality (Lewington et al., 2009), CVD (Van Gaal et al., 2006), diabetes and cancer (Gallagher & LeRoith, 2015) and reduced quality of life (Kolotkin & Andersen, 2017). Currently in England, 40% of adults are overweight and 31% are obese (NHS Digital, 2019). Although the proportion of the adult population who are overweight in England has remained stable since 2010 (NHS Digital, 2017) if current obesity trends continue, it is predicted that 60% of men and 50% of women will be obese by 2050 (Butland et al., 2007). In addition to general adiposity, an accumulation of adipose tissue specifically in the abdominal region (abdominal adiposity) has been associated with increased CVD (Britton et al., 2013) and all-cause mortality risk (Janssen et al., 2004; Pischon et al.,

2008). Among both men and women, each 1 cm increase in waist circumference has been associated with a 1.07 increase in the odds of the presence of at least two other CVD risk factors including hypertension and dyslipidaemia (Shields et al., 2012). Data from the Whitehall Longitudinal Study (n=10,308) suggests that in the UK, waist circumference increased by 8cm between 1985 and 2009 in both men and women (Hulmán et al., 2014).

2.2.6.3 Abdominal adiposity: measurement

The gold standard tool for the estimation of abdominal fat mass is magnetic resonance imaging (MRI) (Klein et al., 2007). However, given the high associated cost and impracticality of this measurement technique in field-based research, waist circumference is often used as an alternative indicator of abdominal fat mass (Klein et al., 2007). Waist circumference has been shown to correlate highly with MRI assessed total ($r=0.94$) and abdominal fat mass ($r=0.94$) in adults (Pouliot et al., 1994). Numerous protocols exist for the measurement of waist circumference which can lead to discrepant results and interpretations (Pettitt et al., 2012). The International Society for the Advancement of Kinanthropometry (ISAK) provides guidelines for the assessment of a range of anthropometric variables, including waist circumference (Marfell-Jones et al., 2012). Here it is recommended that waist circumference is measured at the narrowest point between the lower costal border (10th rib) and the top of the iliac crest, perpendicular to the long axis of the trunk using a non-elastic Gulick tape measure with a tension device. In a review of cross-sectional studies (n=9) intra-observer measurement errors in waist circumference measurements were reported between 0.7 to 9.2cm and inter-observer measurement errors were from 1.4 to 15cm (Verweij et al., 2013). Although these measurement errors are large, they may have been due to differences in measurement protocols used (Verweij et al., 2013). Five studies used measurements from midway between the lower rib and the iliac crest, one study at the narrowest point between the rib cage and the iliac crest, one study used the uppermost limit of the ileum, one study compared measurements taken at all three sites and one study did not specify how measurements were taken. Although one study reported a 12cm inter-observer measurement error when researchers untrained in anthropometric assessments measured waist circumference (Sebo et al., 2008), the training status of the researchers in the remaining studies were not disclosed. To reduce the measurement error associated with this assessment, ISAK recommend using the same trained researcher for all assessments and repeating the measurements twice at each data collection point (Marfell-Jones et al., 2012).

2.2.6.4 Abdominal adiposity: effects of exercise training

The role of physical activity and exercise training in the prevention and treatment of overweight and obesity is long established (Garrow, 1986). Exercise training results in increased caloric expenditure, resulting in a negative energy balance, if the expended energy is not compensated for with an increase in caloric intake, and the metabolism of endogenous energy stores (Williams et al. 2013).

In light of the association between abdominal adiposity and CVD risk (Janssen et al., 2004) increasing research efforts have explored the effect of exercise specifically on markers of abdominal adiposity (Vissers et al., 2013). During exercise it has been posited that lipid mobilisation is greatest in the abdominal region (Arner et al., 1990) which may explain why reductions in abdominal adiposity have been noted in response to exercise training (Vissers et al., 2013). Reductions in MRI estimated abdominal adiposity, have been observed following eight weeks of exercise training (Keating et al., 2015). Furthermore, in a meta-analysis, both aerobic and resistance training reduced MRI estimated abdominal adiposity in overweight participants (Hedge's $g = -0.5$ 95% CI: -0.7 to -0.3 , 12 studies) (Vissers et al., 2013), however it is unlikely that MRI would be available in field-based research settings. However there is RCT evidence to suggest that six months of aerobic exercise equivalent to 4, 8 and 12 kcal.kg.week⁻¹ can elicit reductions in waist circumference in the absence of weight loss (mean \pm SD; -3 ± 2 cm, -2.5 ± 2.5 cm and -3 ± 2.5 cm in 4, 8 and 12 kcal.kg.week⁻¹ groups respectively) (Church et al., 2009).

2.2.7 Mental health

2.2.7.1 Mental health: definition

Mental health encompasses the dimensions of positive and negative mental health. Positive mental health is a combination of positive subjective wellbeing and positive functioning (Huppert et al., 2005); allowing an individual to manage life, maximise their potential and contribute to society (Keyes, 2005). Negative mental health is an umbrella term for a range of mental health disorders, for example depression, which are characterised by long-lasting symptoms and reduced functional capacity (Keyes, 2005).

2.2.7.2 Mental health: link to health

It is estimated that one in four adults will experience mental ill health within their lifetime (World Health Organization, 2001). Although there are a range of potential antecedents of mental ill health, including family history and history of trauma (World Health Organization, 2001), psychological stress is one potentially modifiable antecedent (Cohen et al., 2016). Psychological stress occurs when an individual perceives that environmental demands tax or exceed their adaptive capacity (Cohen et al., 1995).

Exposure to chronic stress has been linked with the development of depression (Knoll & Carlezon, 2009) and CVD (Krantz & McCeney, 2002; McEwen, 1998). The link between chronic stress and disease progression has two hypothesised causal pathways. Firstly, behavioural changes such as increased smoking or substance abuse and decreased physical activity and sleep may occur as a result of an individual responding to stressors, which can influence disease progression (Cohen et al., 2007). Secondly, endocrine responses to stress include increased circulating cortisol and catecholamine levels, which affect both autonomic nervous system function and some metabolic pathways (Dimsdale, 2008). Disruption of these pathways can lead to the chronic inflammation which is associated with CVD (McEwen, 1998).

2.2.7.3 Mental health: measurement

A plethora of standardised outcome measures are available for the assessment of mental health in clinical and research settings (Mental Health Partnerships, 2013). Outcome measures range from clinically focused disease severity assessments such as the Beck Depression Inventory (Beck et al., 1988) to the assessment of general wellbeing concepts such as life satisfaction (Diener et al., 1985). As such, the selection of pertinent mental health assessment variables and tools in exercise trials can be problematic. Although guidelines exist for use in clinical settings (British Psychological Society, 2017), such guidelines may not be pertinent in exercise trials with non-clinical populations and may not encompass all potentially relevant outcome variables. The selection of outcomes and assessment methods in exercise trials could therefore be guided by previous exercise trials or consideration of pertinent outcomes to relevant stakeholders (Bauman & Nutbeam, 2013).

2.2.7.4 Mental health: effects of exercise training

The European Psychiatric Association recommend increased physical activity or exercise training as an adjunct to usual care for individuals with mental health disorders (Stubbs et al., 2018). It is therefore unsurprising that the majority of exercise training studies examining the effect of exercise on mental health are limited to clinical populations (Barbour et al., 2007; Lawlor & Hopker, 2001). Nonetheless in adults without known mental health issues at baseline, there is epidemiological evidence demonstrating positive associations between habitual physical activity and positive mental health outcomes such as wellbeing (Mason & Kearns, 2013) and health-related quality of life (HR-QoL) (Bize et al., 2007). Furthermore negative associations have been observed between physical activity and negative mental health outcomes such as risk of depression (Chekroud et al., 2018; Schuch et al., 2018).

Although the mechanisms underlying the effect of exercise on mental health are likely multifactorial, encompassing various biopsychosocial elements (Salmon, 2011), it has been posited that exercise may provide a distraction from negative thoughts and emotions (Pedersen & Saltin, 2015). Additionally, there is evidence to suggest that various hormonal changes that occur during or after exercise, such as increases in beta-endorphins and monoamine concentrations, may have a positive effect on mood (Mynors-Wallis et al., 2000). In clinical psychiatric populations, where the majority of controlled exercise trials examining changes in mental health have been conducted, changes in symptom severity or mood have been observed following 9 weeks of exercise training (Salmon, 2011).

2.3 Workplace physical activity and exercise training interventions

The wide ranging physical and mental health benefits associated with exercise training described in this literature review highlight the need for exercise interventions aiming to improve these outcomes. The workplace provides access to a considerable proportion of the adult population in a relatively controlled environment. Therefore, notable public health agencies have identified the workplace as a priority setting for the delivery of health promotion interventions (National Institute for Health and Care Excellence, 2008; World Health Organization, 2007). A desire to enhance employee health and productivity and reduce healthcare or absenteeism costs may present a strong rationale for organisations to implement such strategies (Pescud et al., 2015).

As lack of time, facilities or social support are commonly reported barriers to physical activity participation in adults (Justine et al., 2013; Reichert et al., 2007; Trost et al., 2002), delivering physical activity or exercise training in the workplace could reduce barriers by providing convenient access to physical activity or exercise opportunities. The onsite provision of facilities to support physical activity, such as structured exercise programmes, is associated with a greater likelihood of employees achieving physical activity guidelines (Hipp et al., 2017; Knox et al., 2017), indicating that such interventions could be perceived as acceptable to organisations and employees alike.

2.3.1 Physical fitness

Although previous systematic reviews and meta-analyses have demonstrated that workplace physical activity or exercise training interventions can increase employee physical activity levels (Abraham & Graham-Rowe, 2009; Dishman et al., 1998; Dudgeon et al., 2008; Proper et al., 2003; Reed et al., 2017; To et al., 2013), whether this translates into adaptations in markers of physical fitness is unclear.

The last meta-analysis examining the impact of workplace physical activity and exercise training programmes on CRF reported an increase of $3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (effect size= 0.57) in $\text{VO}_{2\text{max}}$ following broadly defined workplace physical activity programmes (n= 38,231 participants, number of studies reporting this outcome not stated) (Conn et al., 2009). Although encouraging, the meta-analysis included interventions where physical activity participation was promoted to employees with no further intervention applied, and interventions where exercise training was delivered to employees at their workplace. It is questionable whether such different intervention strategies should be grouped and meta-analysed together. The high between-study variability observed ($I^2=0.56$) further supports this suggestion (Higgins & Green, 2008). Furthermore, the meta-analysis by Conn et al., (2009) is now over a decade old, and an updated quantification of the effect of workplace exercise interventions on CRF is required.

In comparison to the effects on CRF, the effects of workplace-based exercise interventions on markers of muscular fitness are less well studied. In a recent meta-analysis, compared with no-exercise control, workplace-based exercise training interventions resulted in small improvements in muscle power (effect size: 0.29 [95% CI: 0.05 to 0.53], 5 studies), however there was no statistically significant change in markers of muscular strength compared with control (effect size: -0.04 [95% CI: -0.46

to 0.38], 16 studies) (Prieske et al., 2019). However, the wide confidence interval around the estimate of the intervention effect on muscle strength could be a reflection of the five different strength assessments used across the included studies.

2.3.2 Cardiometabolic health

Reed et al., (2017) meta-analysed the effects of workplace physical activity and exercise training interventions on cardiometabolic health outcomes and reported decreases in body mass (-0.83 kg; 95% CI -1.64 to -0.02, 7 studies), BMI (-0.35 kg/m²; 95% CI, -0.62 to -0.07, 6 studies) and blood glucose (-0.18 mmol.L⁻¹; 95% CI, -0.29 to -0.07, 2 studies) compared with control. However, given the low number of studies reporting each outcome, the findings should be interpreted with caution and further studies are needed to confirm the findings. Additionally, although the findings appear to be statistically significant, it is unclear if they are likely to be clinically meaningful.

2.3.3 Mental health

There is preliminary evidence to suggest that workplace exercise interventions can positively affect mental health (Abdin et al., 2018). In a narrative review, Abdin et al., (2018) identified five studies (n=3 RCTs and n=2 non-controlled trials) where structured exercise training was delivered to office-based employees in their workplace. Interventions included walking programmes (n=3), yoga (n=1), and a 'moderate volume, low intensity exercise programme' (n=1). A range of mental health outcomes were assessed using 10 different questionnaires, including stress, subjective vitality, HR-QoL, wellbeing, affect and perceived work limitations. Although the study authors concluded that workplace exercise training interventions can improve markers of mental health (Abdin et al., 2018), it is concluded here that given the small number of studies reporting each outcome and heterogeneity in the variables and assessment tools used, caution should be taken in the interpretation of the findings. Further work is needed to establish the effect of workplace exercise interventions on markers of mental health.

Although the effects of workplace physical activity and exercise interventions on physical fitness, cardiometabolic and mental health appear to vary and can only be considered preliminary in the case of some outcome variables, the number of individual studies conducted to date suggest that the workplace remains a popular setting for the implementation of health promotion programmes. Despite this,

participation rates have varied from 33-61% of eligible employees (Bull et al., 2003; Robroek et al., 2009) and loss to follow up of 4-40% (median: 27%) (Rongen et al., 2013). Poor reach and high attrition may indicate that some programmes are not feasible or acceptable in the settings in which they are implemented. In an attempt to overcome such issues, formative primary research with relevant stakeholders has been recommended during intervention planning (Bauman & Nutbeam, 2013; Craig et al., 2008). Furthermore, novel and time efficient exercise prescriptions could have the potential to engage employees who perceive 'lack of time' as a barrier to physical activity participation in the workplace (Hunter et al., 2018). One such exercise prescription is high-intensity interval training.

2.4 High-intensity interval training

High-intensity interval training (HIT) is a form of exercise characterised by brief intermittent bursts of relatively high-intensity exercise, interspersed with periods of rest or active recovery (Fox et al., 1973). The use of HIT to enhance physical fitness and promote performance in athletic populations has been commonplace for many decades (Billat, 2001; Buchheit & Laursen, 2013a). Interval training was first described by Reindell & Roskamm (1959) and was popularised by a range of athletes during this time including the Olympic long-distance runner Emil Zatopek. Zatopek repeated up to one hundred 400m repetitions at high running velocity per training day, interspersed with 200m of recovery running (Billat, 2001). Clearly the volume of interval training here would be extreme in untrained individuals; however, in the last decade there has been increased research interest into the effects of a range of different interval protocols on health and fitness variables in untrained populations (Gibala et al., 2012).

To illustrate, a search for "high-intensity interval training" and "adults" using the Scopus database returns 1094 search results (as of June 2019). Although the earliest result was from 1978, 95% of the search results were published since 2010, and 60% since 2015. While crude, this measure indicates the growth of research activity into the topic of HIT in the last decade. Notwithstanding the wealth of literature available examining the effects of HIT in populations such as clinical groups (Hannan et al., 2018; Harvey et al., 2019; Weston et al., 2014a), children and adolescents (e.g. Bond et al., 2017; Wewege et al., 2017) and athletic populations (Engel et al., 2018; Laursen, 2010; Laursen & Jenkins, 2002; Seiler & Tønnessen, 2009; Stöggl & Björklund, 2017), the volume of literature available coupled with the limited space

available within a PhD thesis necessitates that the following section of this literature review will discuss the effects of HIT only on outcomes, and in populations (i.e. healthy adults), that are relevant to the PhD thesis unless otherwise specified. Where available, the literature review will discuss the findings of systematic reviews and meta-analyses with consideration of a selection of pertinent primary research studies. Since the focus of this PhD thesis is on HIT interventions delivered outside the laboratory, the following literature review will primarily focus on HIT trials conducted in 'real-world' environments in adults. Here, real-world environments are defined as settings outside of the laboratory, in places where individuals might usually conduct their activities of daily living that therefore have high external validity (Roche et al., 2014), such as community parks, gyms, home-based settings or the workplace. The literature review will culminate with a discussion of the workplace HIT trials published to date.

2.4.1 The development of HIT protocols

Up to nine training variables can be manipulated within HIT protocols, including the exercise mode, intensity, interval and recovery period duration, number of repetitions and recovery periods, and the activity performed during recovery periods (Buchheit & Laursen, 2013a), which has led to the development of a wide range of HIT protocols (Weston et al., 2014a). Although to date a 'best practice' HIT protocol has not been identified (Gibala, 2018), for the purposes of clarity the protocols described in the literature will be categorised accordingly: aerobic interval training (AIT) describes protocols with high-intensity bouts lasting >60 secs; sprint interval training (SIT) describes protocols with high-intensity bouts lasting ≤ 30 secs; and low-volume HIT describes protocols with high-intensity bouts lasting between 30-60 secs.

A commonly applied AIT protocol originated from a Norwegian research group led by Professor Ulrik Wisløff and involves 4x 4 minute high-intensity bouts performed at 85-95% of maximal heart rate (HR_{max}), interspersed with 3 minutes of active recovery (Rognmo et al., 2004; Wisløff et al., 2007). In the first study examining the effects of AIT, 21 older adults ($n=3$ women, aged 63 years) with stable coronary artery disease were randomised to either an AIT group (uphill treadmill walking, 4x 4 min 80-90% VO_{2max} , 3 minutes of walking at 50-60% VO_{2max}), or a MICT group (41 min of continuous treadmill walking at 50-60% of VO_{2max}) (Rognmo et al., 2004). Post-intervention, VO_{2max} improved in both groups, but the 18% ($6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) increase in the AIT group was significantly greater ($p=0.011$) compared to the 8% ($2.7 \text{ mL}\cdot\text{kg}^{-1}$

$\cdot \text{min}^{-1}$) increase observed in the MICT group. There was no change in blood pressure or body mass in either group, post-intervention. Given that the exercise prescription in both groups was comparable on a matched-work basis, this study supports the notion that intensity of exercise, as opposed to duration, is of paramount importance for eliciting adaptations in CRF. This study was limited by a lack of no-exercise control group and the inclusion of only three women in the sample, therefore subsequently Wisloff et al., (2007) randomised 27 patients with stable heart failure ($n= 13$ women, age: 76 ± 11 years) to 12 weeks of thrice weekly AIT or MICT using the same protocols as previously described, or a no-exercise control group. Post-intervention, $\text{VO}_{2\text{max}}$ improved by 46% ($6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) in the AIT group and 14% ($1.9 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) in the MICT group compared with control. Lateral vastus levels of peroxisome proliferator activated receptor gamma coactivator 1 alpha (PGC-1 α), a regulator in the activation of genes responsible for substrate utilisation and mitochondrial biogenesis (Lira et al., 2010) increased by 47% in the AIT group ($p=0.01$) only. Maximal rate of calcium ion (Ca^{2+}) reuptake into sarcoplasmic reticulum by sarcoendoplasmic reticulum calcium transport ATPase (SERCA) in skeletal muscle increased by 60% ($p=0.01$) in the AIT group only (Wisloff et al., 2007). As such, this study was the first to attempt to elucidate the mechanisms behind AIT induced adaptations.

Early AIT studies were conducted in older adults with chronic health conditions; however, a model of HIT at the highest end of the intensity spectrum, SIT, was initially tested in young, recreationally active individuals. A commonly applied SIT protocol involves repeated Wingate sprints consisting of 4-6x 30sec high-intensity bouts and 4 minutes of recovery at supramaximal intensity ($\geq 100\% \text{VO}_{2\text{max}}$) (Burgomaster et al., 2005). This protocol was popularised by work from a Canadian research group led by Professor Martin Gibala. Using a non-randomised, controlled trial design, Burgomaster et al., (2005) assigned eight healthy participants (2 women; mean age 22 ± 1 years; baseline $\text{VO}_{2\text{max}}$ $45.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) to a SIT group (2 weeks, thrice weekly, Wingate sprints described above) and eight healthy men (mean age 25 ± 2 years) served as a no-exercise control group. Post-intervention cycle time to exhaustion improved from 26 ± 5 minutes at baseline to 51 ± 11 minutes post-intervention ($p= 0.05$) with no change in the control group. Although in comparison to control there were no changes in $\text{VO}_{2\text{max}}$ in the SIT group, muscle biopsy assessed maximal citrate synthase activity (a marker of the mitochondrial content of skeletal muscle) increased by 38% ($p=0.05$) and resting muscle glycogen concentration increased by 26% ($p=0.05$). Although preliminary in nature, given the small sample

and non-randomised study design, the improvements in markers of muscle metabolism and oxidative capacity observed here, begin to elucidate the mechanisms behind SIT induced improvements in CRF and exercise performance. However, as this study was conducted in a small sample of young and physically fit participants, it is unclear if such a demanding protocol would be feasible and acceptable in inactive or older participants. Subsequently, using a non-controlled study design Whyte et al., (2010) examined the effect of the same SIT protocol (2 weeks, 3 sessions per week) in overweight or obese men (n=10, mean age: 32.1 ± 8.7 years). Participants were able to complete the protocol without adverse events and post-intervention there was a $3.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ increase in $\text{VO}_{2\text{max}}$ ($p=0.015$). While these findings suggest that SIT can be conducted with overweight or obese participants, given the lack of control group it cannot be known if adaptations were induced by the exercise training. Although collectively these findings indicate that SIT may positively impact on physiological and metabolic markers, repeated 'all-out' Wingate sprints have been criticised as too demanding for inactive individuals (Hawley & Gibala, 2009).

Consequently, Gibala's research group sought to design a more 'practical' HIT protocol where the absolute intensity of the intervals and recovery time decreased but interval duration increased. This model of HIT incorporated 8 to 12x 60sec high-intensity bouts at $\geq 90\%$ of HR_{max} , interspersed with 75secs of rest (Little et al., 2010). In the first study examining this model of low-volume HIT, seven healthy recreationally active young men participated in 2 weeks of cycle ergometer HIT with 8-12x 60 second high-intensity bouts at a workload that corresponded to the peak power output achieved during a CPET, interspersed with 75 secs of low intensity cycling (Little et al., 2010). Post-intervention levels of PGC-1 α increased by $\sim 24\%$ ($p=0.02$), there was a 16% and 20% increase in the maximal activity and protein content of citrate synthase, respectively (both $p=0.01$) and protein content of GLUT4 (an insulin regulated glucose transporter) increased by 119% ($p=0.04$). Although $\text{VO}_{2\text{max}}$ was not quantified post-intervention, 50 kJ and 750 kJ cycle time trials improved by 11% ($p=0.04$) and 9% ($p=0.005$), respectively. Although preliminary in nature due to the non-controlled study design and small sample size, these findings demonstrate that low-volume HIT can improve markers of mitochondrial biogenesis, indicating the potential mechanisms behind the HIT induced muscle adaptations that may lead to increased exercise capacity. Although this protocol was termed 'practical' (Little et al., 2010), the true practicality of the model is questionable as it still requires a ~ 25 -minute time commitment including warm-up, rest breaks and cool down. Furthermore, it is unknown if the same adaptations would occur using other exercise modalities as the

protocol has been tested using only cycle ergometers with intervals conducted against a high breaking force.

There is an expanding body of literature examining HIT protocols with shorter high-intensity bout durations (≤ 20 secs). One protocol gaining traction has been termed reduced-exertion HIT (REHIT) which involves 10 minutes of low intensity cycling interspersed with one to two 10-20sec all-out sprints against a breaking force equivalent to 7.5% of body weight (Metcalf et al., 2012; Metcalf et al., 2015; Metcalf et al., 2016; Vollaard & Metcalf, 2017). Metcalf et al., (2012) randomly assigned 29 healthy but inactive young men ($n=13$) and women ($n=16$) to a REHIT intervention or a control group. The REHIT intervention consisted of six weeks of thrice weekly, low intensity cycle ergometer exercise (60W) for 10 minutes interspersed with one (1st session) or two (remaining sessions) 15-20 sec all-out cycle sprints against a braking force equivalent to 7.5% of body weight. Post-intervention VO_{2max} improved by 13% in the REHIT group (male: $5.3 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; female: $3.9 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, both $p<0.01$) with no substantial changes from baseline in the control group. Although in comparison to the control group there was no substantial changes in area under the curve for blood glucose, insulin sensitivity significantly improved by 28% in male participants ($p<0.05$), but not in females. Although it is unclear why these sex differences occurred, the limited sample size in this preliminary work limits the confidence with which conclusions to be made. In a subsequent non-controlled trial, Metcalf et al., (2016) examined the effects of six weeks of thrice weekly REHIT involving 10 minutes of unloaded cycle ergometer exercise with one or two 10-20 sec 'all-out' sprints against a resistance of 5% of body mass in 35 inactive participants (18 women, mean age men: 33 ± 9 years and women: 36 ± 9 years). Post-intervention VO_{2max} improved by 9.6% ($3.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, $p<0.001$) and both blood insulin and glucose area under the curve reduced by 8.3% and 4.1% respectively; however, this effect was not statistically significant ($p=0.096$ and $p=0.119$, respectively). Although, this preliminary body of work demonstrates that REHIT may elicit favourable adaptations in fitness and metabolic markers, the utility of this form of HIT outside of the laboratory is questionable, as a cycle ergometer is required with a specific breaking force applied. This exercise modality may not only be impractical for some individuals, correctly calculating and applying the breaking force may reduce the compliance with the protocol in field-based environments, thus attenuating the training response.

It is acknowledged that there are other novel SIT protocols incorporating a higher number of shorter duration high-intensity bouts (e.g. 60x 8 second cycle ergometer sprints (Trapp et al., 2008)). However, the findings of these studies will not be described in detail here. The purpose of this literature review is to provide a scientific rationale and background for a field-based HIT programme and it is questionable whether a protocol with such tight work/rest turnaround times would be feasible without the use of cycle ergometers or treadmills, which are likely to be unavailable for use in this programme of work. Therefore a focus will be given to protocols which are more likely to be feasible in a field-based intervention.

Despite the evolution of a range of HIT protocols, no 'best practice' HIT protocol has been identified (Gibala, 2018). Although this could be viewed as problematic when designing evidence based HIT protocols; it could also be viewed as an opportunity to design a range of HIT programmes that could be tailored to a range of settings, provided the intensity of the exercise is uniform and quantified (Taylor et al., 2015). Indeed a "one-size-fits-all" approach to exercise recommendations may not suit all individuals (Vollaard & Metcalfe, 2017) and therefore alternative or novel exercise options could engage a wider range of individuals. To provide an overview of the HIT literature as a whole, the following section of this literature review will describe the effect of HIT on the physical fitness, cardiometabolic and mental health outcomes relevant to the PhD programme. For the purposes of clarity, HIT will be used as an umbrella term describing all protocols, whereas AIT, SIT and low-volume HIT will be used where appropriate to describe distinctions between the protocols used in the individual studies.

2.4.2 Effects of HIT on markers of physical fitness

2.4.2.1 Effects of HIT: cardiorespiratory fitness

In comparison to traditional endurance training, HIT was originally perceived to have less of an impact on oxidative energy metabolism and endurance capacity (Gibala & McGee, 2008). Considerable research has since demonstrated that HIT can elicit improvements in VO_{2max} similar to those found with more traditional modes of endurance exercise. Exercise that elicits VO_{2max} or a very high percentage of VO_{2max} is thought to maximally stress the oxygen transport and utilisation systems and therefore stimulate adaptations in CRF (Laursen & Jenkins, 2002). Exercise at close to, or at, VO_{2max} allows for greater recruitment of large motor units (Martinez-Valdes et al., 2017) and attainment of close-to-maximal cardiac output (Astorino et al., 2017),

which over time could cause oxidative muscle fibre adaptation and cardiac enlargement, thus improving VO_{2max} . Part of the practical appeal of HIT, is that the intermittent nature may allow the maintenance of high-intensity exercise for longer periods of time, in comparison to continuous exercise (Guiraud et al., 2012), thus eliciting a training stimulus while permitting reduced exercise time. Table 2 outlines the six meta-analyses that have been conducted to date on this topic. Across these meta-analyses, the effect of HIT on VO_{2max} when compared with no exercise control varies in magnitude from moderate ($d=0.69$) (Gist et al., 2014) to likely large (7.8%, Vollaard et al., 2017) ($5.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Milanovic et al., 2015) improvements in VO_{2max} . The effect of HIT on VO_{2max} in comparison to MICT varies from unclear (Weston et al., 2014b); to trivial (Gist et al., 2014) and possibly small (Milanovic et al., 2015).

One potential explanation for the differences in the meta-analysed effects could be the definitions of HIT (or type of HIT protocols) used in each of the individual meta-analyses. For example, while Milanovic et al., (2015) included any HIT protocol, provided the exercise intensity was described as $\geq 90\% HR_{max}$, Weston et al., (2014b) defined low-volume HIT as interval durations between 30-60s, conducted at maximal or near maximal intensity. Although three of the meta-analyses included only SIT protocols, their definitions of SIT vary (Gist et al., 2014; Sloth et al., 2013; Vollaard et al., 2017). Gist et al., (2014) defined SIT as any interval duration between 30sec to 4 min where intensity was described as “maximal”, whereas both Sloth et al., (2013) and Vollaard et al., (2017) defined SIT as intervals lasting between 10-30sec at “maximal” or “all-out” intensity. The intensity of HIT defined by Bacon et al., (2013) was lower at $\geq 80-85\% VO_{2max}$, with work: rest ratio of $\geq 1:1$. Furthermore a range of different populations were included in the aforementioned reviews, for example Gist et al., (2014) included participants of all ages including children and older adults whereas the remaining reviews included healthy, untrained or recreationally active adults only.

Table 2 Meta-analyses of effects of HIT on CRF in healthy adults

Author date	Number of studies	Subjects	HIT definition	Comparison group	Δ VO_{2max} vs. non-exercise control	Δ VO_{2max} vs. MICT
Gist et al., (2014)	16	All ages	SIT: 30s-4 min interval duration, all out, supra maximal, maximal or $\geq 100\%$ vo_{2max}	Control: no exercise MICT: endurance	Cohens d= 0.69	Cohens d= 0.04
Weston et al., (2014)	32	Sedentary males, sedentary females, active non-athletic males, active non-athletic females, athletic males, over 18 years	Low volume HIT 30-60 second intervals, maximal/ near maximal	Control= non-exercise control Endurance= MICT group	Active non-athletic males: Likely moderate 6.2% 90%CL $\pm 3.4\%$ Sedentary males: possibly moderate 10.0% 90%CL $\pm 5.1\%$ Active non-athletic females: possibly moderate 3.6% 90%CL $\pm 4.3\%$ Sedentary females: likely small 7.3% 90%CL $\pm 4.8\%$ Athletic males: unclear	Unclear (-1.6% 90% \pm CL 4.3%)
Sloth et al., (2013)	19	Healthy sedentary, recreationally active young adults	SIT- 10-30 second intervals, maximal	Comparison group not defined by authors	Hedges g= 0.6, 95% CI 0.39 to 0.87 4.2-13.4% increases in VO_{2max} across studies	
Milanovic et al., (2015)	28	Healthy, untrained sedentary, recreational and non-recreational athletic adults aged 18-45 years	HIT: any interval protocol with intensity described as "all-out", "supramaximal", "maximal" or high (90-95% HR_{max})	Endurance= 60-85% HR_{max} Control: no exercise control	Likely large beneficial effect 5.5 $mL \cdot kg^{-1} \cdot min^{-1}$ 95%CL $\pm 1.2 mL \cdot kg^{-1} \cdot min^{-1}$	Possibly small beneficial effect for HIT 1.2 $mL \cdot kg^{-1} \cdot min^{-1}$ 95%CL $\pm 0.9 mL \cdot kg^{-1} \cdot min^{-1}$
Bacon et al., (2013)	37	Health, sedentary/ recreationally active adults, 18-45 years	HIT: $\geq 80-85\%$ VO_{2max} , interval duration not	Unclear from the study reporting	0.51 $L \cdot min^{-1}$ (95%CI 0.43 to 0.60 $L \cdot min^{-1}$)	

specified, work rest ratio ≥1:1						
Vollaard et al., (2017)	34	Healthy untrained (baseline $\text{VO}_{2\text{max}} \leq 55 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) adults aged over 18 years	SIT: all-out cycle sprints	Wingate	Controlled and non-controlled trials included	Likely large $\pm 4.0\%$ 7.8% 90% CL
Key: HIT= high-intensity interval training, SIT= sprint interval training, CL= confidence limit, $\text{VO}_{2\text{max}}$ =maximal oxygen consumption, HR_{max} = maximal heart rate						

Despite between-study differences in the findings, from the current evidence base it can be concluded that both HIT and MICT elicit substantial and similar improvements in VO_{2max} . However, the HIT induced improvements in VO_{2max} are attained following a lower training volume and time commitment. The vast majority of trials examining the effect of HIT on CRF are laboratory-based and therefore can only determine the efficacy of HIT under tightly controlled circumstances which limits the ecological validity of the findings. To address this limitation, effectiveness trials can be implemented to investigate intervention effects under 'real-life' conditions (Courneya, 2010). This is important because the magnitude of effects is thought to be attenuated and more variable under less tightly controlled conditions (Courneya, 2010). To illustrate, Blackwell et al., (2017) compared four weeks of supervised laboratory-based low-volume HIT (5x 60sec high-intensity bouts, 90sec rest) performed on cycle ergometers with a home-based low-volume HIT protocol using body weight exercises (e.g. star jumps). Post-intervention there was an 8% increase in VO_{2max} ($2.2 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; variability in change not reported) in the home group, whereas there was a 17% ($4.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ variability in change not reported) increase in the laboratory group. Despite reporting 100% session attendance in both groups, Blackwell et al., (2017) did not provide exercise intensity data, which is concerning given that the intervention was unsupervised. The lack of exercise data is also problematic as it precludes an intervention fidelity assessment for the home-based study arm; that is the extent to which the intervention was implemented as intended, in a comparable manner to all participants (Dumas et al., 2001). Although exercise trials frequently report session attendance, this does not give any indication as to whether the participants have complied with the prescribed exercise. Such an omission is problematic in HIT research where adhering to the required exercise intensity is paramount, as it is likely the intensity that drives the physiological adaptations (Taylor et al., 2015). Heart rate monitoring is one commonly used method of comprehensively assessing the intensity of exercise (Taylor et al., 2015). As Blackwell et al., (2017) observed a larger improvement in VO_{2max} in the laboratory group compared with the home group (17% vs. 8%, respectively); it is unclear if the exercise intensity was compromised in the home group. This may be particularly important as there is evidence to suggest that adherence and compliance is higher in supervised versus unsupervised exercise programmes (Fennell et al., 2016). In the most recently published study comparing unsupervised home-based HIT with a laboratory-based HIT protocol, participants ($n=32$, 13 males, mean age: 36 ± 3 years) self-selected into either a home group ($n=9$), a laboratory group ($n=10$) or a home MICT group ($n=13$) with twelve weeks of thrice weekly exercise sessions prescribed for all groups (Scott

et al., 2019). The home HIT protocol involved 4-8x 60 sec high-intensity bouts, with 60 secs of rest incorporating two different 30-sec bodyweight exercises such as jumping jacks or jogging on the spot while punching the air. The laboratory HIT protocol involved the same low-volume HIT protocol conducted on cycle ergometers at 100% of peak watts (W_{peak}) established during a CPET. The home-based MICT group performed 30-50 minutes of continuous moderate intensity exercise of their choosing (e.g. swimming, walking). High-intensity interval training participants wore heart rate monitors for every HIT session and the threshold for high-intensity exercise was $\geq 80\%$ HR_{max} , which is slightly lower than the commonly utilised threshold for HIT (Weston et al., 2014a). Nonetheless, the HIT criterion was achieved in 80-100% of completed sessions (Scott et al., 2019). Although it is unclear from the study reporting, it appears that the criterion was satisfied if participants achieved the target heart rate at any single time point over the course of the HIT protocol, as opposed to whether the criterion was satisfied during each high-intensity bout. As such it is unclear if participants were exercising at high-intensity for all of the HIT bouts, or for only one second at any time point during the HIT session. Despite this, post-intervention VO_{2max} increased by 16%, 20% and 12% in the home-HIT, laboratory HIT and home-MICT groups, respectively, with no statistically significant difference between groups (Table 3) (Scott et al., 2019). Collectively these findings demonstrate that HIT could feasibly be delivered and elicit improvements in CRF outside of the laboratory. However, inadequate exercise intensity reporting limits the confidence with which the findings can be interpreted.

The effects of HIT in adults have also begun to be explored in other 'real-world' settings including community gyms (Reljic et al., 2018), community parks (Lunt et al., 2014) and workplaces (Allison et al., 2017; Shepherd et al., 2015), however the findings of workplace HIT trials published to date will be discussed in depth later in this literature review. The effects of real-world HIT trials published to date on VO_{2max} are shown in Table 3 and vary widely from a reduction in VO_{2max} of 0.7% ($-0.2 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) (Roy et al., 2018) to an improvement of 25% ($7.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) (Reljic et al., 2018).

Table 3 Summary of real-world HIT trials in adults

Author, date	Setting	Participants (n= sample size, age= mean \pm standard deviation)	Group	Duration (weeks)	Frequency (per week)	Intensity	No. of HI bouts	HI bout: rest duration	Modality	VO _{2max} assessment method	VO _{2max} baseline (±SD) (mL·kg ⁻¹ ·min ⁻¹)	VO _{2max} follow up (±SD) (mL·kg ⁻¹ ·min ⁻¹)	Intensity quantification (mean \pm SD) %HR _{max} .
Reljic et al., (2018)	Gym	Sedentary n=34 (11 males) age: 30.5 \pm 7 years	I1: LV-HIT	8	2	85-95% HR _{max}	5	60 sec: 60sec	Cycle ergometer	Cycle erg. CPET	29.4 \pm 7.3	36.5 \pm 7.3 *	95 \pm 3
			I2: AIT	8	2	85-95% HR _{max}	2	2mins: 4 mins	Cycle ergometer	Cycle erg. CPET	30.3 \pm 9.1	35.3 \pm 6.6 *	91 \pm 4
			MICT	8	2	65-75% HR _{max}	1	33 mins	Cycle ergometer	Cycle erg. CPET	28.8 \pm 8.5	32.9 \pm 8.7 *	74 \pm 4
Scott et al., (2019)	Laboratory vs. at home	Sedentary obese n=32 (13 males) age: 36 \pm 3 years	I1: Home LV-HIT unsupervised	12	3	\geq 80% HR _{max}	4-8	60 sec: 60sec	Body weight exercises	Cycle erg. CPET	23.8 \pm 2.5	27.6 \pm 4.7	80-100% of sessions achieved \geq 80% HR _{max}
			I2: Laboratory LV-HIT supervised	12	3	\geq 80% HR _{max}	4-8	60 sec: 60sec	Cycle ergometer	Cycle erg. CPET	24.8 \pm 6.4	29.8 \pm 8.2	100% of sessions achieved \geq 80% HR _{max}
			I3: Home MICT	12	3	65% HR _{max}	1	30-50 mins	Participant choice	Cycle erg. CPET	24.9 \pm 6.8	28.0 \pm 8.1	100% of sessions achieved 65% HR _{max}
Blackwell et	Laboratory vs. at home	Inactive n=18 (5 male)	I1: Home	4	3	95-110% Watt _{max}	5	60s:90s	H-HIT: star jumps,	CPET	27.77 \pm 4.75	29.9 8	Not reported

al., (2017)		age: 52±5 years	LV-HIT unsupervised						squat thrusts, static sprints		±6.0 1					
			CON: Laboratory LV-HIT supervised	4	3	95-110% Watt _{max}	5	60s:90s	L-HIT: Cycling	CPET	26.50 ±6.31	31.00 ±6.69	Not reported			
Lunt et al., (2014)	Community park	Overweight and inactive n= 49 (13 men) age: 48 years	I1: AIT						Outdoor walking or jogging		24.2 ±4.8		25.6 ±4.8**	≥80% HR _{max} achieved in average 73.4% of sessions		
			I2: SIT						Outdoor incline walking or jogging		25.0±2.8		25.2 ±3.4	Maximum HR in week 6: 88.6% HR _{max} Maximum HR in week 10: 85.1% HR _{max}		
			MICT						Outdoor walking		26.5 ±5.3		25.2 ±3.6	65-75%HR _{max} achieved in 87.7% of sessions		
Roy et al., (2018)	Home unsupervised	Overweight/ obese adults n= 250 (95 male)	I1: HIT						Selected by participants		YMCA submaximal cycle ergometer test		29.1±6.6		28.9 ±5.4*	21-24 mins/week spent ≥80% HR _{max}

age: 44 years	CON: Public health prescription (MICT)	52 PA	“Most or all days of the week”	Moderate intensity	30 mins	Selected by participants	YMCA submaximal cycle ergometer test	28.9 ±7.3	28.6 ±6.5 *
<p>Key: I= intervention group, CON= control group, PA= physical activity, LV-HIT= low volume high-intensity interval training, HIT= high-intensity interval training, MICT= moderate intensity continuous training, SIT= sprint interval training, AIT= aerobic interval training *= significant difference pre- post at p=0.05, ** significant difference in change intervention vs. control, CPET= cardiopulmonary exercise test, erg= ergometer</p>									

One explanation for the variation could be the range of HIT protocols utilised in the individual trials. Reljic et al., (2018) examined the impact of a low-volume HIT protocol (5x 60sec with 60sec rest) and an AIT protocol (2x 4 min with 2 min rest) conducted on cycle ergometers in 34 sedentary participants (n= 11 males, age: 30.5 ±7 years) in a community gym setting. Post-intervention there were improvements in VO_{2max} of 25% (7.2 mL·kg⁻¹·min⁻¹) in the low-volume HIT group and 16% (5.0 mL·kg⁻¹·min⁻¹) in the AIT group. In contrast, Lunt et al., (2014) compared an AIT protocol (fast walking or jogging, 4x 4min, with 3 mins rest) with a SIT protocol (uphill jogging or walking, 3x 30s, with 4 mins rest) in 49 sedentary and overweight participants (men=13, mean age: 48 years). Post-intervention there was no substantial improvement in VO_{2max} in the SIT group (0.2 mL·kg⁻¹·min⁻¹), though a 6% (1.4 mL·kg⁻¹·min⁻¹) improvement in VO_{2max} was observed in the AIT group.

The previously described real-world HIT trials were relatively short in duration (between 4 to 12 weeks), so the long-term effect of HIT delivered in real-world settings is unclear. To address this limitation, in a twelve month trial Roy et al., (2018) randomised 250 (95 male) overweight and obese adults (mean age: 44 years) into either a 'physical activity guidelines' group, who were advised to participate in 150 minutes per week of moderate to vigorous intensity physical activity or a 'HIT' group. Participants in the HIT group self-selected their own HIT protocol, session frequency and duration based on a single education session where examples of HIT protocols were provided to participants. A broad range of activities were included in the 'HIT' prescription such as small sided games, group exercise classes and previously described SIT and low-volume HIT protocols (Burgomaster et al., 2005; Little et al., 2010). This decision is highly questionable for a number of reasons. Firstly, the authors could not promote the safety of their participants while they were participating in exercise modalities that were recommended. Furthermore, it cannot be known if or to what extent the intervention was standardised between participants, indeed it is likely that it was not. The intensity and modality of the small sided games and group exercise classes recommended to participants as 'HIT' had not been quantified pre-intervention. As the intensity of exercise is an important mediator in the adaptations promoted by chronic training (MacInnis & Gibala, 2017), this is a major study design flaw which could explain why the HIT intervention had limited effect on VO_{2max} (-0.3 mL·kg⁻¹·min⁻¹) (Roy et al., 2018). Indeed, given the lack of high-quality intervention fidelity monitoring procedures, it is unclear if the participants adhered to any form of HIT protocol for the duration of the intervention.

Although four of the five real-world HIT trials described in Table 3 undertook heart rate monitoring during the intervention, the data are equivocal. Only a single trial (Reljic et al., 2018) conducted heart rate monitoring in all exercise sessions and reported mean peak heart rates indicative of high-intensity exercise (i.e. $\geq 85\%HR_{max}$ (Weston et al., 2014a). However providing mean heart rate as the only quantification of intervention fidelity has been criticised (Taylor et al., 2015) because repeated exercise sessions performed across an intervention will give rise to between-subject and within-subject variability in exercise intensity, overestimating the true intervention fidelity (i.e. whether the intervention has been implemented as intended across all participants) (Dumas et al., 2001). Although Lunt et al., (2014) conducted heart rate monitoring in every session in the AIT and MICT groups, heart rate monitoring was only conducted in weeks 6 and 10 of the intervention for the SIT group; the study authors did not justify this decision (Lunt et al., 2014). Roy et al., (2018) conducted heart rate monitoring intermittently at month 0, 3, 6 and 12 of the intervention for one week each when participants were performing physical activity. At month 0, 82% of participants provided heart rate data whereas by month 12 only 29% of participants provided data. Nevertheless, the authors reported that HIT participants spent an average of 21 to 24 minutes per week with heart rates corresponding to $\geq 80\% HR_{max}$ (Roy et al., 2018) but given the limited number of participants providing this data, HIT adherence is unclear. All of the real-world HIT trials conducted to date lack a true no-exercise control group, which limits the confidence with which findings can be interpreted given the substantial biases that arise from non-controlled study designs (Hariton & Locascio, 2018). Although four of the five studies (Blackwell et al., 2017; Lunt et al., 2014; Reljic et al., 2018; Scott et al., 2019) quantified VO_{2max} using a CPET, a submaximal prediction of VO_{2max} (YMCA step test) was used by Roy et al., (2018) which may further explain the differences observed in the effects.

In summary, collectively the real-world HIT trials conducted to date with adults demonstrate that HIT conducted outside of the laboratory may elicit improvements in VO_{2max} , yet there are a number of limitations associated with the current evidence base. Controlled real-world HIT interventions with rigorous measurement and reporting of exercise intensity are required to address these limitations.

2.4.2.2 Effects of HIT: muscular fitness

In comparison to CRF, the effect of HIT on muscular fitness is less well studied. The effect of low-volume HIT on peak sprint power (a marker of short term muscular power) was assessed in a meta-analysis of 16 controlled and non-controlled trials (Weston et al., 2014b). In comparison to the selected minimal important difference of 1.7 watts (0.2 of the baseline standard deviation), the improvement of 2.2 watts (90% confidence limit ± 10.3 watts) observed in the HIT group was unclear given the large uncertainty in this estimate. The studies included only male participants (Weston et al., 2014b), which limits the generalisability of the findings. However, a subsequent study examined the effect of HIT on muscular fitness following a six week intervention where 28 recreationally active women (mean age: 25 years) were randomised into either a rowing HIT group or a multi-modal HIT group (MM-HIT) (Buckley et al., 2015). Both interventions followed the same thrice weekly low-volume HIT protocol (6x 60sec, interspersed with 3 minutes of rest), with different exercise modalities between groups. The rowing HIT group participated in six “all-out” rowing bouts on a rowing ergometer; whereas each 60sec MM-HIT bout was divided into three parts: a strength exercise for 4–6 repetitions, an accessory movement for 8–10 repetitions, and a “metabolic component” conducted at “all-out” intensity for the remainder of the 60sec. No further detail was provided for the MM-HIT exercise prescription, which limits the repeatability of this study. In accordance with the principles of training specificity (Gamble, 2006), as the MM-HIT group also included strength based exercises it is unsurprising that post-intervention there was a statistically significant ($p \leq 0.05$) improvement in (mean change \pm SD; percentage change) squat (18kg \pm 15kg; 39%), shoulder press (10kg \pm 4kg; 27%) and dead lift (12kg \pm 18kg; 18%) 1RM. In comparison, in the rowing HIT group the changes in squat (1kg \pm 14kg; 2%), shoulder press (1kg \pm 9kg; 4%) and dead lift 1RM (2kg \pm 27; 3%) did not reach statistical significance. Due to the inclusion of a dedicated strength training component in the MM-HIT group, it clearly does not constitute an exclusively “HIT” intervention, therefore when considering only the literature available for HIT, the study by Buckley et al., (2015) demonstrates that rowing HIT may not substantially effect muscular fitness in young women. Additionally, as muscular strength was assessed by 1RM tests, it is unclear if rowing-based HIT affects other markers of muscular fitness such as grip strength.

The effect of HIT on muscular fitness in middle aged and older adults was investigated in a recent RCT (Hurst et al., 2018b). Here, 36 adults (aged between 51-80 years) were randomly allocated to either a control group or 12 weeks of twice weekly

combined upper and lower body AIT (4x 4mins, with 4 mins recovery). Post-intervention, compared with control the intervention effect was a likely trivial effect for dominant hand grip strength (5.9%; 90% CI 0.5–11.5%) (Hurst et al., 2018b). As such more data is needed to assess the impact of this form of HIT on markers of muscle strength and power.

The studies examining the effects of HIT on muscular fitness have been confined to laboratories and muscular fitness variables have not been assessed in the real-world HIT trials that have been published to date. Furthermore, in the aforementioned studies (Buckley et al., 2015; Hurst et al., 2018b), although muscular strength and power were assessed, direct between-study comparisons are problematic due to differences in the assessment techniques. Given the short duration of the HIT trials that have assessed facets of muscular fitness (6-12 weeks), the impact of long-term HIT participation on markers of muscular fitness is unknown. Furthermore, between-study differences in exercise modalities and HIT protocols impede conclusions regarding the optimal HIT prescriptions that may elicit adaptations in muscular fitness variables. As such, the evidence examining the effect of HIT on markers of muscular fitness can be considered preliminary at best. Further controlled trials are needed in a wider range of populations, examining a range of muscular fitness variables to further elucidate the effect of HIT on markers of muscular fitness.

2.4.3 Effects of HIT on cardiometabolic health outcomes

2.4.3.1 Effects of HIT: blood pressure

A meta-analysis of seven RCTs examined the effect of HIT (intensity $\geq 80\%$ HR_{max}) in comparison to MICT on resting blood pressure in individuals with pre to established hypertension (Costa et al., 2018). Both HIT and MICT elicited similar reductions in resting blood pressure (SBP -6.3 mmHg and -5.8 mmHg in HIT and MICT groups respectively; DBP -3.8 mmHg and -3.5 mmHg in HIT and MICT groups respectively). However, the participants in the included studies had a range of other co-morbidities including metabolic syndrome (n=3 studies), prediabetes (n=1 study), heart failure (n=3 studies), coronary artery disease (n=1 study) and abdominal adiposity (n=1 study) and so these findings may not be generalisable to healthy participants. Furthermore, there were differences across the studies in the measurement techniques used for the assessment of blood pressure. For example, two studies used supine and seated measurement, one study used 24-hour ambulatory monitoring and four studies did not report measurement technique details (Costa et

al., 2018). Although current guidelines suggest that blood pressure can be measured in either the supine or sitting position (Pickering et al., 2005), it has been documented that both SBP and DBP can be 2-3 mmHg higher if measured in the sitting position compared with supine measurement (Jamieson et al., 1990) and so direct comparison of between-study effects is problematic. Given that the majority of participants from the studies included in the meta-analysis by Costa et al., (2018) were clinical populations, it is unsurprising that all studies were conducted in laboratory settings. However the effect of HIT on blood pressure has been assessed in a limited number of field-based studies (Table 4).

Table 4 Effects of real-world HIT trials on blood pressure

Author, date	Group	Systolic BP (mmHg)				Diastolic (mmHg)			
		Pre (mean \pm SD)	Post (mean \pm SD)	Δ (mmHg)	Δ (%)	Pre (mean \pm SD)	Post (mean \pm SD)	Δ (mmHg)	Δ (%)
Reljic et al., (2018)	I1: LV-HIT	119 \pm 21	120 \pm 19	+1	+0.8	80 \pm 10	81 \pm 10	+1	+1.3
	I2: AIT	115 \pm 7	112 \pm 9	-3	-2.6	79 \pm 7	80 \pm 6	+1	+1.3
	MICT	122 \pm 15	118 \pm 14	-4	-3.3	89 \pm 13	81 \pm 15	-8	-9.0
Blackwe ll et al., (2017)#	I1: Home-based LV-HIT	129 \pm 15	124 \pm 8	-5	-3.9	81 \pm 12	75 \pm 5	-6	+2.4
	CON: Lab based LV-HIT	127 \pm 15	124 \pm 15	-3	-2.4	84 \pm 2	86 \pm 11	+2	-7.4
Lunt et al., (2014)	I1: AIT	119 \pm 14	116 \pm 12	-3	-2.5	75 \pm 8	74 \pm 7	-1	-1.3
	I2: SIT	129 \pm 14	123 \pm 10	-6	-4.7	81 \pm 11	75 \pm 7	-6	-7.4
	MICT	133 \pm 20	127 \pm 21	-6	-4.5	85 \pm 9	83 \pm 14	-2	-2.4
Roy et al., (2018)	HIT	124 \pm 16	120 \pm 14	-4	-9.0	78 \pm 10	76 \pm 9	-2	-2.6
	MICT	125 \pm 15	121 \pm 14	-4	-9.0	79 \pm 10	76 \pm 10	-3	-3.8

Key: I= intervention group, lab= laboratory, LV-HIT= low volume high-intensity interval training, HIT= high-intensity interval training, MICT= moderate intensity continuous training, SIT= sprint interval training, AIT= aerobic interval training *= significant difference pre- post at p=0.05, ** significant difference in change intervention vs. control, # data extracted from graph using software programme

With the exception of Reljic et al., (2018) who reported a 1 mmHg increase in SBP following an unsupervised 12 month HIT intervention, the real-world HIT studies published to date reported a reduction in SBP of between 3-5 mmHg, with a similar trend for DBP (-6 mmHg to +1 mmHg). Although these findings did not reach statistical significance, MICT has been shown to reduce blood pressure to a similar extend (-3-5 mmHg) (Cornelissen & Smart, 2013). Furthermore, these findings may be clinically meaningful because a 6 mmHg and 3 mmHg reduction in SBP and DBP, respectively, have been shown to reduce the risk of CHD by 14% and stroke by 18%, (Salam et al., 2019). As previously discussed, the between-study variation in the

effects of real-world HIT trials on blood pressure could be due to a number of factors including differences in HIT protocols or intervention fidelity. Additionally, the average baseline blood pressure was not notably high, and so substantial changes in blood pressure may not be expected or necessary. Although the current evidence base suggests HIT could elicit clinically important improvements in blood pressure in both normotensive and hypertensive individuals, it can be considered preliminary at best given the limited number of trials that have assessed this outcome.

2.4.3.2 Effects of HIT: blood lipids

The earliest systematic review examining the effect of HIT on blood lipids was published by Kessler et al., (2012). A qualitative synthesis of 24 studies concluded that HIT (any HIT protocol $\geq 80\%$ HR_{max}) had no significant effect on cholesterol or triglyceride levels (Kessler et al., 2012). However, the mean baseline values for both outcomes were within normal parameters in all included studies, which could explain the lack of effect. Although Kessler et al. (2012) concluded that HIT interventions of less than eight weeks in duration did not significantly affect HDL-C, one RCT conducted in healthy young men demonstrated an 18% improvement ($+0.2 \text{ mmol.L}^{-1}$, variation in change not reported) in HDL-C compared with no-exercise control following 8 weeks of thrice weekly HIT (4x 800m treadmill running intervals, with 1:1 work to rest ratio) (Musa et al., 2009). Despite the apparent limited effect of HIT on blood lipids in these early studies, it should be noted that in studies comparing HIT with MICT, there was also no effect on any of the blood lipid markers in MICT groups (Kessler et al., 2012). This may be explained by the short duration of the majority of studies (<12 weeks), as modifications in blood lipids are generally not expected in under 12 weeks (Robson, 2008). However, in a more recent meta-analysis examining the effect of any HIT protocol ($\geq 85\%$ HR_{max}) compared with MICT on blood lipids in overweight and obese adults, similar changes in all blood lipid outcomes were reported in both HIT and MICT groups (Su et al., 2019). Although the effect of HIT and MICT on cholesterol was statistically significantly different from baseline (HIT $-0.01 \text{ mmol.L}^{-1}$; 95% CI 0.004 to 0.023; MICT $-0.01 \text{ mmol.L}^{-1}$; 95% CI 0.004 to 0.020, 12 studies, $p \leq 0.05$), this does not consider whether a reduction of this magnitude is clinically meaningful so the finding should be interpreted with caution. Increases in HDL-C of $0.003 \text{ mmol.L}^{-1}$ (95%CI -0.005 to 0.01) in HIT groups and $0.008 \text{ mmol.L}^{-1}$ (95%CI -0.007 to 0.009) in MICT groups from 19 studies were not statistically significant. An increase in triglycerides of $0.003 \text{ mmol.L}^{-1}$ (95%CI -0.002 to 0.01) in HIT and $0.002 \text{ mmol.L}^{-1}$ (95%CI -0.004 to 0.008) in MICT groups from 12 studies was also not statistically significant. Su et al., (2019) did not report, or differentiate

between, fasted or non-fasted blood lipid measurement techniques, which may explain the low precision in the effect estimates, as indicated by wide confidence intervals. With the exception of one study (Lunt et al., 2014), all of the studies included in the meta-analysis by Su et al., (2019) were conducted in laboratory environments. As demonstrated in Table 5, blood lipids have been assessed in three real-world HIT trials to date.

Collectively there is a trend for small reductions in cholesterol levels from baseline. However, with the exception of Lunt et al., (2014) where a decrease in cholesterol of -0.1 mmol.L^{-1} in the SIT group and no change in the AIT group, was significantly ($p=0.045$ and $p=0.004$, respectively) different from the MICT group, the findings of the other studies did not reach statistical significance. The effect of real-world HIT interventions on HDL-C is unclear, with non-statistically significant effects ranging from a reduction of -0.1 mmol.L^{-1} (Lunt et al., 2014) to an increase of 0.1 mmol.L^{-1} (Reljic et al., 2018). Similarly, the effect of real-world HIT interventions on triglycerides is varied, with effects ranging from -0.2 mmol.L^{-1} (Roy et al., 2018) to $+0.5 \text{ mmol.L}^{-1}$ (Reljic et al., 2018); however these results did not reach statistical significance. The range in effects on triglycerides is most clearly represented in an eight week community gym-based HIT trial (Reljic et al., 2018) where AIT resulted in a reduction in triglycerides of -0.2 mmol.L^{-1} whereas low-volume HIT resulted in an increase of 0.5 mmol.L^{-1} .

Between-study variation may be partially explained by the different assessment techniques used. Fasting venous samples were used by Lunt et al. (2014) whereas two studies used non-fasting samples (Roy et al., 2018, Reljic et al., 2018). Furthermore, short intervention duration (12 weeks) may also explain the lack of effect (Robson, 2008), as previously described. It should be noted here that participants from one real-world HIT trial (Roy et al., 2018) were recruited from a concurrent trial investigating the impact of various dietary weight loss strategies; therefore, the effect of HIT on blood lipids cannot be elucidated from the impact of the dietary intervention.

Collectively the evidence from meta-analyses and a limited number of real-world HIT trials demonstrate varying effects of HIT on blood lipids. Although favourable adaptations comparable to MICT may be possible in some blood lipid markers, further consideration of the clinical importance of the magnitude of such adaptations is warranted.

Table 5 Effect of real-world HIT interventions on blood lipids

Author, date	Fasted or nonfasted	Group	Cholesterol				HDL-C				Triglyceride			
			Pre (mean ±SD)	Post (mean ±SD)	Δ (mmol.L ⁻¹)	Δ (%)	Pre (mean ±SD)	Post (mean ±SD)	Δ (mmol.L ⁻¹)	Δ (%)	Pre (mean ±SD)	Post (mean ±SD)	Δ (mmol.L ⁻¹)	Δ (%)
Reljic et al., (2018)	Non-fasted ear-lobe prick sample	I1: LV-HIT	4.2 ±0.7	4.0 ±0.5	-0.2	-4.8	1.3 ±0.2	1.3 ±0.3	0	0	1.3 ±0.5	1.8 ±1.0	+0.5	+38.5
		I2: AIT	4.3 ±0.8	4.0 ±0.6	-0.3	-7.0	1.4 ±0.2	1.5 ±0.2	+0.1	+7.1	1.4 ±0.4	1.2 ±0.5	-0.2	-14.3
		MICT	4.7 ±0.5	4.6 ±0.4	-0.1	-2.1	1.2 ±0.2	1.3 ±0.2	+0.1	+8.3	1.5 ±0.4	1.7 ±0.8	+0.2	+13.3
Lunt et al., (2014) ^a	Fasted venous sample	I1: AIT	5.4 ±1.1	5.4 ±0.8	0	0**	1.3 ±0.3	1.2 ±0.3	-0.1	-7.7	0.8 ±0.6	0.7 ±0.4	-0.1	-12.5
		I2: SIT	6.0 ±1.5	5.9 ±1.3	-0.1	-1.6**	1.3 ±0.4	1.3 ±0.4	0	0	0.8 ±0.3	0.9 ±0.4	+0.1	+12.5
		MICT	5.4 ±0.9	4.9 ±1.0	-0.5	-9.3	1.2 ±0.2	1.2 ±0.2	0	0	0.8 ±0.4	0.7 ±0.2	-0.1	-12.5
Roy et al., (2018)	Non-fasted finger prick sample	HIT	5.5 ±1.0	5.2 ±1.0	-0.3	-5.5	1.3 ±0.3	1.3 ±0.4	0	0	1.4 ±0.5	1.2 ±0.5	-0.2	-14.3
		MICT	5.4 ±0.9	5.3 ±1.0	-0.1	-1.9	1.3 ±0.3	1.4 ±0.4	+0.1	+7.7	1.3 ±0.6	1.3 ±0.4	0	0

Key: I= intervention group, LV-HIT= low volume high-intensity interval training, HIT= high-intensity interval training, MICT= moderate intensity continuous training, SIT= sprint interval training, AIT= aerobic interval training *= significant difference pre- post at p=0.05, ** significant difference in change intervention vs. control, ^a= converted from mg/dL.

2.4.3.3 Effects of HIT: blood glucose

Low-volume HIT has been shown to elicit adaptations in markers of muscle metabolism and mitochondrial biogenesis in healthy adults, including increases in PGC-1 α , maximal activity and protein content of citrate synthase and protein content of GLUT4 (Little et al., 2010). As reduced content and activity of mitochondria are implicated in the development of T2DM (Cheng & Almeida, 2014), Little et al., (2011) sought to investigate the effects of this model in a diabetic population (n=8; mean age: 63 \pm 8 years). Following six sessions of low volume HIT (10x 60 secs cycling at 90% HR_{max}, 60 secs rest) over two weeks, mean 24 hour blood glucose concentration was significantly reduced (baseline: 7.6 \pm 1.0 mmol.L⁻¹, post-intervention: 6.6 \pm 0.7 mmol.L⁻¹, p \leq 0.05). Furthermore, citrate synthase maximal activity (20%) and GLUT4 protein content (369%) (all p \leq 0.05) increased indicating improvements in muscle mitochondrial capacity. Although the findings should be interpreted with caution given the small sample and non-controlled trial design, this preliminary work led to increased interest into the effect of HIT on markers of glycaemic control.

Jelleyman et al., (2015) conducted a meta-analysis of 18 controlled trials examining the effects of HIT on blood glucose. In healthy participants a reduction of 0.13 mmol.L⁻¹ (95% CI -0.19 to -0.07 mmol.L⁻¹) from baseline was not statistically significantly different to control (effect size -0.17, 95% CI -0.34 to 0.01) (Jelleyman et al., 2015). However, in those with metabolic syndrome or T2DM, there was a reduction in blood glucose of 0.92 mmol.L⁻¹ (95% CI -1.22 to -0.63) following HIT compared to no-exercise control (Jelleyman et al., 2015). A subsequent meta-analysis of controlled and non-controlled trials reported that HIT (any protocol) reduced fasting glucose in overweight and obese populations (effect size -0.35, 95% CI -0.62 to -0.09) (Batacan et al., 2017). However, this result should be interpreted with caution as the inclusion of non-controlled trials could inflate effect estimates (Higgins & Green, 2008). Although it appears that HIT may improve blood glucose levels in those with elevated levels at baseline or in overweight or obese populations, it was not intended in this body of work to specifically target these populations. More relevant to this thesis, following a previously described community gym HIT intervention (Table 3), Reljic et al., (2018) observed a non-significant reduction in non-fasting blood glucose of -0.1 mmol.L⁻¹ and -0.2 mmol.L⁻¹ in the HIT and AIT groups, respectively, but no change from baseline in the MICT group. Given that the mean blood glucose levels of the participants were not outside normal parameters at baseline (mean \pm SD: 4.7 \pm 0.8 mmol.L⁻¹), this could further explain the lack of effect. Collectively, although there is meta-analytic evidence to suggest that HIT may elicit improvements in blood

glucose in those with elevated levels at baseline, further work is needed to examine the effect of HIT on blood glucose in settings outside of the laboratory.

2.4.3.4 Effects of HIT: abdominal adiposity

The earliest study to examine the effect of HIT on body composition in healthy but inactive participants was a non-randomised trial comparing the effects of 20 weeks of MICT (30-45 minutes of continuous cycle ergometer exercise 4-5 times per week at 60-85% heart rate reserve (HRR)) in 17 men and women with 15 weeks of HIT in 10 men and women (Tremblay et al., 1994). Post-intervention, the HIT group demonstrated larger reductions in trunk fat (as measured by the sum of suprailiac and abdominal skin fold measurements) compared with the MICT group (HIT: -8.7mm vs. MICT: -6.3 mm). The HIT prescription used by Tremblay et al., (1994) included a combination of both MICT and HIT such that over the intervention 'HIT' participants conducted 25 MICT sessions and 36 interval sessions (10-15x 15 to 30s or 4-5x 60 to 90sec high-intensity intervals). Therefore, although promising, the effects of HIT on body composition cannot be separated from the effects of MICT. Subsequently, Trapp et al., (2008) randomised 45 healthy but inactive young women to 15 weeks of SIT (60x 8sec "all-out" cycle ergometer sprints, 12sec rest), MICT (10-40 mins continuous cycling at 60% VO_{2max}) or a non-exercise control group. Post-intervention, there were significant reductions ($p \leq 0.05$) in dual-energy X-ray absorptiometry (DXA) assessed total body fat in the SIT group only (SIT: -2.5 ± 0.83 kg; MICT 0.44 ± 0.88 kg; control 0.33 ± 0.47 kg), as well as significant reductions in central abdominal fat in the SIT group only (SIT: -0.15 ± 0.07 kg; MICT: $+0.1 \pm 0.08$ kg; control: 0.03 ± 0.04 kg).

These early studies led to further investigation of the effects of HIT on various measures of body composition. Wewege et al., (2017) meta-analysed the effect of five HIT interventions (any interval duration ≤ 4 minutes, intensity $\geq 85\%$ HR_{max}) on waist circumference in overweight and obese adults. Both HIT and MICT elicited similar reductions in waist circumference (-3cm for both groups, no statistically significant difference between groups). Similarly the most recent meta-analysis examined the effect of HIT in comparison with MICT on total body fat in any population including athletic, healthy and inactive, and clinical populations from all age groups (36 studies) (Viana et al., 2019). Both HIT and MICT resulted in significant ($p \leq 0.01$) and similar improvements in total body fat percentage (HIT: -1.5% ; 95% CI -2.1 to -0.9 and MICT: -1.4% ; 95% CI -2.0 to -0.9). Although these findings are useful, the inclusion of studies with both trained and untrained participants in the analysis is

questionable given the effect that training is thought to have on fat metabolism during exercise (Hurley et al., 1986). In the trained state, greater utilisation of free-fatty acids at higher exercise intensities is thought to be driven by increased lipolysis of muscle triglycerides compared with the untrained state (Martin et al., 1993) which could impact on the chronic effects of high-intensity exercise on body composition. Notwithstanding this, between-study comparisons are problematic given the range of assessment techniques and reporting methods used across the meta-analyses and primary trials, although waist circumference is a commonly used measure of abdominal adiposity in real-world HIT trial (Table 3).

As demonstrated in Table 6, real-world HIT trials resulted in reductions in waist circumference ranging from -1.3 to -3.5cm, but the only statistically significant change from baseline was observed by Reljic et al., (2018) (-2.1cm). The reductions in waist circumference following HIT appear to be similar to the reductions in the MICT groups which ranged from -1.3 to -3.6 cm (Table 6). As previously discussed, participants in one study (Roy et al., 2018) were recruited from a concurrent weight loss trial, so it is unknown if the adaptations are HIT induced. From the current evidence base it can be concluded that HIT can elicit similar or greater reductions in markers of abdominal adiposity to MICT, however the evidence from real-world HIT trials is preliminary and further studies are needed to confirm or refute the current findings.

Table 6 Effect of real-world HIT interventions on waist circumference

Author, date	Group	Waist circumference			
		Pre (cm, mean \pm SD)	Post (cm, mean \pm SD)	Δ (cm)	Δ (%)
Reljic et al., (2018)	I1: LV-HIT	82.3 \pm 10.5	80.2 \pm 9.2	-2.1*	-2.5
	I2: AIT	83.1 \pm 14.9	81.8 \pm 13.6	-1.3	-1.6
	MICT	90.4 \pm 19.5	89.1 \pm 20.6	-1.3	-1.4
Lunt et al., (2014)	I1: AIT	103.5 \pm 10.4	100.0 \pm 9.9	-3.5	-3.4
	I2: SIT	100.4 \pm 11.7	98.6 \pm 12.5	-1.8	-1.8
	MICT	105.9 \pm 11.2	102.3 \pm 10.7	-3.6	-3.4
Roy et al., (2018)	HIT	101.3 \pm 13.1	98.2 \pm 12.2	-3.1	-3.1
	MICT	101.6 \pm 12.0	98.6 \pm 12.1	-3.0	-3.0

Key: I= intervention group, LV-HIT= low volume high-intensity interval training, HIT= high-intensity interval training, MICT= moderate intensity continuous training, SIT= sprint interval training, AIT= aerobic interval training *= significant difference pre- post at p=0.05.

2.4.4 Effects of HIT on psychological outcomes

As health is defined as not merely the absence of disease, but complete physical, mental and social wellbeing (World Health Organization, 2017) it is pertinent to consider the effect of HIT on both physical and mental health outcomes. Despite the

accumulating body of evidence demonstrating the efficacy of HIT to improve physical fitness and cardiometabolic health and the inclusion of HIT in public health physical activity guidelines (2018 Physical Activity Guidelines Advisory Committee, 2018; Department of Health and Social Care, 2019), the promotion of HIT for public health improvement remains a contentious topic (Biddle & Batterham, 2015; Hardcastle et al., 2014). In a seminal debate paper (Biddle & Batterham, 2015) the opponent of HIT, Professor Biddle, questioned the potential effectiveness of HIT outside the laboratory, based on the foundation that HIT would elicit negative affective responses, which would lead to poor adoption, maintenance and adherence to HIT protocols (Biddle & Batterham 2015). This assertion was based on Dual Mode Theory of affective responses to exercise which finds that affective responses during exercise become more negative as the intensity of exercise approaches an individual's functional limits (Ekkekakis, 2003). These assertions are based on data from continuous vigorous intensity exercise (Acevedo et al., 1994; Hardy & Rejeski, 1989; Parfitt et al., 1996; Parfitt et al., 1994) and, as Professor Batterham refuted, was prematurely generalised to HIT. Indeed, Jung et al., (2014) randomised 44 inactive participants (n=16 men, mean age men 31 ±13 years and women 36 ±17 years) to the order they would complete single sessions of a.) low-volume HIT (10x 60s at ~100% W_{peak} and 60 second rest), b.) MICT (40 minutes at ~40% W_{peak}) and c.) continuous vigorous intensity exercise (20 minutes at ~80% W_{peak}). All exercise was conducted in the laboratory on cycle ergometers and affective responses were measured before, during and after each session and enjoyment after each session. Affect immediately post-exercise was significantly ($p<0.01$) less positive in the HIT and continuous vigorous intensity condition compared to the MICT (mean affect scores (\pm SD) were 1.1 arbitrary units (AU) (\pm 2.5), 0.6 AU (\pm 2.5), and 2.7 AU (\pm 1.6) for HIT, continuous vigorous, and MICT conditions, respectively). Although affect improved 20 minutes following all of the conditions, a significant difference remained between the continuous vigorous and MICT ($p=0.01$). While there was no significant difference between the HIT and MICT at 20-minutes post-exercise ($p=0.11$), twenty minutes post-exercise mean affect scores (\pm SD) were 3.6 AU (\pm 0.2), 3.3 AU (\pm 0.2) and 2.8 AU (\pm 0.3) for HIT, MICT, and continuous vigorous intensity exercise conditions, respectively. Therefore, although participants may have experienced more negative affect immediately following HIT and continuous vigorous intensity exercise than MICT, affect was similar in HIT and MICT 20 minutes post-exercise. These preliminary findings suggest that affective responses to continuous vigorous intensity exercise are different from, and should not be generalised to, HIT. Furthermore, mean (\pm SD) enjoyment scores for the HIT condition (80 ± 5 AU out of a

possible 126) were significantly higher than continuous vigorous intensity exercise (70 ± 6 AU, $p=0.01$) (Jung et al., 2014). The mean enjoyment score following the HIT condition (75 ± 3 AU) was not statistically different ($p=0.08$) to the MICT enjoyment score.

These initial findings challenge the assertion that HIT elicits aversive psychological responses, compared with exercise at lower intensity (Biddle & Batterham, 2015) and there is now a growing body of evidence demonstrating that HIT may elicit positive psychological responses. A scoping review identified 42 studies examining the effects of HIT on psychological outcomes in a range of populations (e.g., healthy, clinical, active and inactive) (Stork et al., 2017). A qualitative synthesis reported that while affect was generally more negative during exercise, post-exercise affect improved such that there were no significant differences between post-exercise affect in HIT and MICT (Stork et al., 2017). Collectively enjoyment was reported to be similar or greater between HIT protocols and continuous moderate or vigorous intensity protocols (Stork et al., 2017). Although this review concluded that positive psychological responses to HIT are possible, the majority of studies included in the review were conducted in laboratory settings, using cycle ergometers and therefore the acute affective responses to HIT conducted outside the laboratory using novel HIT modes remain to be explored.

2.4.4.1 Effects of HIT: wellbeing

As previously discussed, a broad array of assessment tools are available to evaluate various mental health facets (Mental Health Partnerships, 2013). 'Wellbeing' is an umbrella term which includes a range of psychological states such as positive emotion (e.g. feelings of happiness), psychological resources of self-esteem and mastery, and resilience which is the capacity to cope with adversity (Tennant et al., 2007). As wellbeing appears to include a broad range of mental health facets it may provide an indication of an individual's overall mental health (Tennant et al., 2007). However, a recent scoping review aiming to identify all studies examining psychological responses to HIT did not identify any training studies including wellbeing as a distinct outcome measure (Stork et al., 2017) and therefore the chronic effect of HIT on wellbeing is unknown. As there is evidence to suggest that HIT can acutely improve positive mood state post-exercise (Stork et al., 2017), it seems plausible to suggest that consistent improvements in acute mood could chronically impact on perceptions of wellbeing. Although this hypothesis is conjecture at this time, given that no studies have examined the effect of HIT on wellbeing in adults. There

is, however, preliminary evidence to suggest that HIT could result in small improvements in mental wellbeing in adolescents (effect size: 0.34) (Costigan et al., 2016).

2.4.4.2 Effects of HIT: health-related quality of life

Health-related quality of life (HR-QoL) is a multi-dimensional construct relating to the impact of health status on quality of life and includes domains of physical, mental, emotional and social functioning (Karimi & Brazier, 2016). HR-QoL is often used as an outcome measure to evaluate the patient perceived impact of disease states or treatment effects in clinical research studies (Karimi & Brazier, 2016). There is epidemiological evidence to suggest that higher habitual physical activity is associated with better HR-QoL (Anokye et al., 2012). Furthermore, although meta-analyses have demonstrated that HIT can result in improvements in HR-QoL in various clinical populations (Beauchamp et al., 2010; Gomes Neto et al., 2018; Jaureguizar et al., 2016), these findings may not be generalisable to non-clinical populations. The effect of HIT on HR-QoL in non-clinical populations is less well studied.

Lunt et al., (2014) assessed three domains of HR-QoL using the Medical Outcomes Study 36-Item Short Form Health Survey (SF-36) (Ware & Sherbourne, 1992; Ware et al., 2002) in 49 overweight and inactive but otherwise healthy adults following three, 12 week outdoor community based programmes of either SIT, AIT or MICT (Table 3). Post-intervention, compared with MICT, participants in the SIT group improved perceptions of physical (3.6 AU; 95% CI -5.9 to 13.0) and mental health (2.3 AU; 95% CI -4.8 to 9.4). The AIT group did not improve perceptions of mental health (-0.8 AU; 95% CI -7.9 to 6.3) compared to MICT, but improvements in both perceptions of physical health (4.9 AU; 95%CI -4.5 to 14.3) and bodily pain (4.1 AU; 95% CI -11.6 to 19.5) were observed. However, bodily pain increased in the SIT group which was indicated by a reduction in the score (-8.9 AU; 95%CI -24.3 to 6.5). Although these changes did not reach statistical significance, a change of 3 to 5 points on HR-QoL scales has been established as the threshold for clinical meaningfulness (Samsa et al., 1999). Therefore the improvements in perceptions of physical health in both the SIT and AIT groups, and the increase in bodily pain in the SIT group could represent a meaningful change in HR-QoL for the participants, and therefore warrants further investigation. In summary, although there is evidence to suggest that HIT can positively impact on HR-QoL in clinical populations, further work is needed to

establish the effect of HIT on HR-QoL in non-clinical populations especially in real-world settings.

2.4.4.3 Effects of HIT: perceived stress

The effect of HIT on perceived stress has begun to be examined in a limited number of studies. In a non-controlled trial, 30 inactive participants with high stress levels (defined by the authors as a perceived stress scale (Cohen et al., 1995) score of $\geq 14/40$) completed four weeks of thrice weekly trampoline based HIT (Bhosle et al., 2018). This criterion for “high stress” is questionable given that the authors cite a reference defining “high stress” levels as a PSS score of ≥ 20 , (Peluso & Guerra de Andrade, 2005) it is unclear why a criterion of ≥ 14 was selected. Nevertheless, the HIT protocol involved trampoline jumping for 1-2 minute high-intensity bouts interspersed with 1-2 minutes of rest; no further details regarding the number of high-intensity bouts was provided. Although a 58% reduction in perceived stress was observed post-intervention (-11 AU, variability of change not reported) (Bhosle et al., 2018) exercise intensity was not monitored and therefore it is unclear if the exercise prescription can be classified as HIT. Furthermore a lack of control group limits the confidence with which conclusions can be drawn given the significant biases that can arise with uncontrolled designs and therefore it cannot be known without a control group if adaptations would have occurred without the presence of an intervention (Hariton & Locascio, 2018). In a previously described community gym based HIT intervention (Table 3) Reljic et al., (2018) observed a 1.5% reduction (-0.6 AU) in perceived stress scores in the low-volume HIT group, whereas there was a 1% (+1.4 AU) and 11% (+4.3 AU) increase in perceived stress scores in the AIT and MICT groups, respectively, assessed using the Perceived Stress Questionnaire (Fliege et al., 2005). Although the changes in perceived stress scores in the aforementioned studies (Bhosle et al., 2018; Reljic et al., 2018) did not reach statistical significance, the authors also did not comment on the clinical significance of the findings. The current evidence base exploring the effect of HIT on stress is preliminary at best and further controlled trials, with adequate exercise intensity monitoring are needed.

2.5 Workplace HIT interventions

To date, two published studies have examined the effects of HIT delivered in the workplace (Allison et al., 2017; Shepherd et al., 2015). Shepherd et al., (2015) examined the effects of 10 weeks of thrice weekly cycle ergometer HIT consisting of ≤ 25 minutes of repeated 15-60 sec high-intensity bouts, at $\geq 90\%$ maximal heart rate

(HR_{max}) and MICT (30-45 mins, at ~70% HR_{max}, 5 sessions per week) in 99 healthy and inactive employees in an English university gym setting (56 males, mean age: 42 ±11 years). Post-intervention VO_{2max} increased by 2.8 mL·kg⁻¹·min⁻¹ (95% CI: 2.0 to 3.6) and 2.4 mL·kg⁻¹·min⁻¹ (95% CI: 1.7 to 3.3), in HIT and MICT groups, respectively (equivalent to a 9% and 8% increase in VO_{2max}, respectively) (Shepherd et al., 2015). Both HIT and MICT resulted in improvements in other cardiometabolic risk factors including cholesterol (HIT: -0.3 mmol.L⁻¹, 95% CI; -0.7 to -0.1, MICT: -0.4 mmol.L⁻¹, 95% CI; -0.7 to -0.1), HDL-C (HIT: 0.04 mmol.L⁻¹, 95% CI; 0.06 to 0.16, MICT: 0.14 mmol.L⁻¹ 95% CI; 0.03 to 0.25), triglycerides (HIT: -0.13 mmol.L⁻¹, 95% CI; -0.25 to -0.01, MICT: -0.05, 95% CI; -0.17 to 0.08) and fat mass (HIT: -0.8 kg, 95%CI: -1.5 to -0.1, MICT: -1.0 kg 95% CI: -1.7 to -0.3) (Shepherd et al., 2015). There were no significant differences between the changes in the aforementioned outcomes between the HIT and MICT groups, despite a substantially lower exercise time commitment in the HIT compared with MICT group (~75 mins.week⁻¹ vs. 150-225 mins.week⁻¹, respectively) (Shepherd et al., 2015). Exercise intensity was quantified using heart rate monitors, and mean peak heart rate over the intervention corresponded to 91 ±6 %HR_{max}, indicating that the exercise elicited a high-intensity response (Weston et al., 2014a). However as previously described, reporting mean and standard deviation of the peak heart rates across exercise sessions as the only quantification of exercise intensity could overestimate true intervention fidelity (Dumas, 2001). Shepherd et al., (2015) also assessed mood using the Positive and Negative Affect Scale (PANAS) (Watson et al., 1988) (Watson et al., 1988). Positive affect scores increased by a similar magnitude in both groups (HIT: 0.48 AU, MICT: 0.47AU, measure of variability not reported) and negative affect scores reduced by a similar magnitude (HIT: -0.13AU, MICT: -0.12AU measure of variability not reported) in both groups, post-intervention. Although encouraging, it is unclear if the magnitude of such changes in positive and negative affect are likely to be clinically meaningful. Lastly, Shepherd et al., (2015) used one item from the SF-36 (Ware & Sherbourne, 1992) to assess one of the eight domains of HR-QoL (perceptions of general health). Perceptions of general health improved by 16% and 12% in the HIT and MICT groups, respectively, with no statistically significant difference between groups. However this result should be interpreted with caution given the questionable validity of selecting a single measure from a validated questionnaire, as this is not specifically recommended by the questionnaire developers (Ware et al., 2002). Although these findings are encouraging, a lack of no-exercise control group further limits the confidence with which the findings can be interpreted.

A process evaluation was also conducted as part of the evaluation of the workplace HIT trial conducted by Shepherd et al., (2015). Here the participant experiences of the intervention were explored in focus groups with 12 of the 46 HIT group participants (Kinnafick et al., 2018). Although the findings of this process evaluation will be discussed in more detail in the subsequent chapters of this thesis, briefly the participants reported that HIT was perceived as novel and interesting and they were attracted to the reduced time commitment associated with the HIT intervention compared with MICT (Kinnafick et al., 2018). Although these findings indicate that HIT may be perceived as an acceptable and feasible form of workplace-based exercise, the participants included in the focus groups all adhered to the prescribed protocol ($\geq 80\%$ session attendance), so the findings may have been different in those with lower session attendance.

The most recently published workplace HIT intervention was a non-controlled trial examining the effect of two stair climbing HIT protocols (3x 20 second and 3x 60 second high-intensity bouts with 2 mins of rest) conducted thrice weekly for 6 weeks, in 31 healthy but inactive women from a Canadian university (Allison et al., 2017). Post-intervention, VO_{2max} increased by $3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and $2.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, in the 3x 20 second and 3x 60 second groups respectively (measure of variability not reported). Although other cardiometabolic health variables were assessed (blood pressure, fasting blood glucose and measures of body composition), no significant changes from baseline were observed. However this lack of effect may have been because the cardiometabolic health variables were not outside of normal parameters at baseline.

High session attendance in both studies (83% Shepherd et al., 2015; 99% Allison et al., 2017) provides an indication that HIT could be a feasible and acceptable form of exercise within the workplace. Although it has been suggested that HIT is “unlikely to be taken up by the majority of the sedentary population” (Hardcastle et al., 2014, p1), given that both workplace HIT trials to date specifically recruited inactive participants, this suggests that HIT could be perceived as feasible and acceptable in physically inactive individuals.

Nevertheless, there are several limitations associated with the current workplace HIT evidence base. As previously described the psychological responses to this novel form of exercise are often the focus of debate (Biddle & Batterham, 2015; Jung et al., 2016; Stork et al., 2017) and assessment of psychological wellbeing variables in

workplace HIT trials to date is limited, with only one trial examining changes in affect and one facet of HR-QoL (Shepherd et al., 2015). There is a clear need to consider a more holistic view of health, with the inclusion of a wider range of psychological health variables, alongside physical fitness and cardiometabolic health variables. Both of the workplace HIT trials published to date have been conducted within a university workplace, which is perhaps unsurprising given the potential ease of access academics may have for the recruitment of university employees. This could limit the external validity of the current workplace HIT evidence base, because university environments may not be representative of a wider range of working environments. A lack of no-exercise control groups limits the confidence with which conclusions can be drawn due to the substantial biases that may arise from non-controlled study designs, including confounding and regression to the mean (Hariton & Locascio, 2018). Although the sample size recruited by Shepherd et al., (2015) (n=99) is larger than the sample recruited by Allison et al., (2017) (n=31), both are relatively small samples which could lead to overestimation of effect sizes and low reproducibility of findings (Button et al., 2013). Given the cost and space requirements associated with cycle ergometers the use of this exercise mode by Shepherd et al., (2015) reduces the scalability and external validity of the trial. Although stair climbing is arguably more accessible than cycle ergometers, some organisations may not be located in large tower blocks or have sufficient access to stair cases to permit exercise to be conducted without disrupting the working environment. It is therefore important to assess the requirements and facilities available within participating organisations during intervention planning. Lastly, both workplace HIT trials published to date have utilised only a single exercise modality across the intervention. As ‘variety’ has been identified as a key facilitator to exercise intervention adherence (Morgan et al., 2016), the use of a single exercise modality within a HIT trial may not facilitate adherence or compliance in some individuals. Potential participants could be consulted during intervention development to establish acceptable and feasible exercise modalities (Bauman & Nutbeam, 2013).

2.6 Clinical versus statistical significance

In the majority of literature presented throughout this literature review, the interpretation of findings are underpinned by the concept of “statistical significance”, typically assessed with an index called the p-value. In null hypothesis significance testing, a research hypothesis (e.g. variable A influences variable B) and a null hypothesis (e.g. variable A does not influence variable B) are stated and the

probability of the latter being true is tested (Winter et al., 2014). The smaller the p-value, the greater the statistical incompatibility of the data with the null hypothesis which can be interpreted as providing evidence against the null hypothesis. Typically, the threshold for a “statistically significant” p-value is less than or equal to 0.05. The American Statistical Society has advised against the use of this arbitrary threshold as the sole basis for the declaration of scientific findings (Wasserstein & Lazar, 2016). This is based on the foundation that p-values are typically impacted by sample size and that smaller p-values do not necessarily imply the presence of larger or more important effects, and conversely larger p-values do not imply a lack of effect (Wasserstein & Lazar, 2016). Indeed, “statistically significant” findings could have little practical or clinical relevance and similarly findings that are declared “not statistically significant” could be practically or clinically meaningful (Winter et al., 2014).

For these reasons, alternative statistical methods to evaluate the effects of interventions have been proposed. Cohen (1988) proposed that effects sizes are derived, which expresses a difference between groups or change within groups as a fraction of the variability between participants which is usually the standard deviation. Effect sizes are then interpreted as follows; trivial <0.2, small 0.2- to 0.3, moderate 0.4 to 0.8, and large >0.8 (Cohen, 1992). Alternatively, the uncertainty in the estimates can be expressed using confidence intervals and evaluated on the basis of the inclusion of zero (i.e. no effect) (Cumming & Finch, 2001). Although typically 95% confidence intervals are expressed, 90% confidence intervals have been recommended as a way of discouraging readers from interpreting the outcome as significant or non-significant at the 5% level (i.e. $p \leq 0.05$). A magnitude based inferences framework proposes that effects are evaluated based on where a confidence interval lies in relation to threshold values for a substantial effect or a minimal clinically important difference (MCID) (Hopkins et al., 2009). In controlled trial studies, the MCID is defined as the smallest difference in an outcome measure that must occur for the intervention to be considered effective (Winter et al., 2014). Many notable journals in the area of sport and exercise science now require the presentation of metrics such as effect sizes, confidence intervals and MCIDs and will not accept manuscripts where the outcomes are evaluated solely on the basis of statistical significance (Wasserstein and Lazar, 2016).

2.7 Literature review summary

Cardiovascular disease is a leading cause of mortality worldwide (Murray et al., 2012). Low CRF (Lee et al., 2010), poor muscular fitness (Silventoinen et al., 2009), hypertension (Stanaway et al., 2018), dyslipidaemia (Miller, 2009), hyperglycaemia (Lupsa & Inzucchi, 2018) and abdominal obesity (Klein et al., 2007) are modifiable CVD risk factors. However a more holistic view of health encompasses both physical and mental health facets. Given that a number of CVD risk factors are notably poor in adult populations (Joseph et al., 2017) and it is estimated that one in four adults experience poor mental health within their lifetime (World Health Organization, 2001), interventions aiming to improve physical and mental health indicators are vital. Physical activity or exercise training can improve physical fitness (Garber et al., 2011; Lin et al., 2015), cardiometabolic (Swift et al., 2013) and mental health (Mason & Kearns, 2013; Schuch et al., 2018). Historically public health physical activity guidelines have promoted ≥ 150 minutes of moderate to vigorous intensity physical activity per week (Department of Health, 2011). However, HIT has recently been included in contemporary physical activity guidelines (2018 Physical Activity Guidelines Advisory Committee, 2018; Department of Health and Social Care, 2019). This is based on accumulating evidence demonstrating the efficacy of HIT to elicit improvements in physical fitness and cardiometabolic health. High-intensity interval training can elicit substantial improvements in VO_{2max} (Weston et al., 2014b), with a lower time commitment than traditional moderate intensity exercise prescriptions. Furthermore, HIT can elicit improvements in markers of cardiometabolic health including blood pressure (Costa et al., 2018), blood glucose (Jelleyman et al., 2015) and abdominal adiposity (Wewege et al., 2017). Although in its infancy, there is evidence to suggest that HIT can elicit improvements in markers of mental health including HR-QoL (Shepherd et al., 2015) and perceived stress (Bhosle et al., 2018), though more work is needed to confirm these preliminary findings. Despite the demonstrated efficacy of HIT in laboratory-based settings, there is debate surrounding the potential effectiveness of HIT for public health improvement in settings outside of the laboratory (Biddle & Batterham, 2015; Hardcastle et al., 2014). Opponents of HIT express concerns relating to negative affective responses elicited by high-intensity exercise, and requirements for expensive equipment or extensive exercise knowledge which could lead to poor adoption and maintenance of the behaviour (Biddle & Batterham 2015). However this standpoint has been challenged in light of accumulating evidence suggesting that HIT can elicit positive post-exercise affective responses (Stork et al., 2017) and a limited number of real-world HIT trials in settings outside the laboratory such as community gyms (Reljic et al., 2018),

community parks (Lunt et al., 2014) and home-based settings (Blackwell et al., 2017; Scott et al., 2019). Although the workplace has been identified as a priority setting for health promotion, the evidence examining the effects of workplace-based exercise training interventions on CRF specifically is dated (Conn et al., 2009). Despite this, the workplace has been used as a setting in which the effectiveness of HIT has begun to be explored (Shepherd et al., 2015; Allison et al., 2017). As such, the following chapter of this thesis presents a systematic review and meta-analysis examining the effect of workplace-based exercise interventions on CRF.

Chapter 3: Study One. Effects of workplace-based exercise interventions on cardiorespiratory fitness: a systematic review and meta-analysis of controlled trials

A version of this chapter has been published in *Sports Medicine* (Burn et al., 2019), with minor amendments made to the version presented herein.

3.1 Introduction

Cardiorespiratory fitness (CRF) is strongly associated with cardiovascular disease (CVD) and all-cause mortality (Kodama et al., 2009) and is perhaps a stronger correlate than total physical activity (Lee et al., 2011), hypertension, diabetes mellitus, smoking and obesity (Lee et al., 2010). Recent analyses of population based longitudinal datasets have emphasised the importance of maintaining good CRF, such that a $1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ increase in maximal oxygen consumption ($\text{VO}_{2\text{max}}$) is associated with a 9% relative risk reduction in all-cause mortality (Laukkanen et al., 2016). Nevertheless, it has also been reported that CRF levels have declined by 1.6% per decade internationally since 1967 (Lamoureux et al., 2019). Despite this, Lee et al. (2010) maintain that CRF is often overlooked as an outcome measure for intervention strategies aiming to promote or deliver physical activity and exercise training compared with other risk factors such as total physical activity and other cardiometabolic health outcomes.

Evidence from randomised controlled trials (RCTs) suggests that exercise of at least moderate intensity can maintain or improve CRF (Lin et al., 2015). However, objectively measured compliance with public health physical activity guidelines in adults' remains low (5 to 47%) (Colley et al., 2011; Marsaux et al., 2016; Troiano et al., 2008). As described in Chapter Two, the workplace has been identified as a priority setting for the implementation of health promotion interventions (National Institute for Health and Care Excellence, 2008), which could include the promotion of CRF through increased physical activity or exercise training. The relationship between CRF and important workplace outcomes has been explored, albeit cross-sectionally in a limited number of studies. Although higher CRF has been associated with higher productivity (Pronk et al., 2004), subsequent studies have found no significant relationships between CRF and productivity or sickness absence (Bernaards et al., 2007) and sickness presenteeism (Christensen et al., 2015). Despite these conflicting outcomes, higher levels of CRF have been linked to higher

HR-QoL (Sloan et al., 2009) and lower risk of depressive symptoms (Sui et al., 2009), burnout and stress (Gerber et al., 2013) which may be important outcomes from an organisational perspective.

Although previous systematic reviews support the use of workplace physical activity interventions to increase physical activity levels (Abraham & Graham-Rowe, 2009; Dishman et al., 1998; Duggill et al., 2008; Proper et al., 2003; Reed et al., 2017; To et al., 2013), whether this consistently translates into improvements in CRF is unclear. The last meta-analysis examining the effects of workplace physical activity and exercise training interventions on CRF reported an increase of $3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in $\text{VO}_{2\text{max}}$ (Conn et al., 2009). Though encouraging, this finding must be treated with caution due to the inclusion of both controlled and non-controlled trials in their analysis. Due to a lack of a comparison group, non-controlled trials can be susceptible to confounding or regression to the mean (Higgins & Green, 2008). Moreover, very broad eligibility criteria led to the inclusion of various intervention designs, including those where increasing physical activity was the primary outcome (e.g. behaviour change interventions such as the provision of leaflets on the benefits of physical activity), those where the effect of exercise on a primary outcome was examined (e.g. where exercise is delivered in the workplace to impact on a health outcome) and those where physical activity or exercise was part of a multicomponent intervention. As these designs and subsequent intervention outcomes are distinctly different, it is questionable whether the effects of such different strategies should be grouped and meta-analysed together (Courneya, 2010). Finally, the meta-analysis by Conn et al. (2009) was conducted a decade ago, therefore new and relevant literature is likely to be available (Garner et al., 2016) and an update on the effect of workplace-based exercise interventions on CRF is needed. Accordingly, the aim of this study was to use random effects meta-analysis to quantify the effect of workplace-based exercise interventions consisting of at least moderate intensity exercise on CRF, and explore the modifying effects of study and participant characteristics.

3.2 Methods

This review was carried out in accordance with the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) guidelines (Liberati et al., 2009). The review methodology was prospectively registered with PROSPERO (registration number: 42017057498).

3.2.1 Eligibility criteria

This study sought to identify peer reviewed journal articles describing workplace exercise interventions; defined as interventions where exercise was both prescribed and delivered to employees at (or commencing from) their workplace. The inclusion criteria were as follows:

- A. Population: working adults (aged 16+ years).
- B. Intervention: interventions where exercise of at least moderate intensity (e.g. $\geq 64\%$ of maximal heart rate (HR_{max}) or $\geq 43\%$ VO_{2max} , as defined by Garber et al., (2011)) was prescribed and delivered to employees in the workplace (e.g. group exercise classes held at the workplace) or commenced from the workplace (in the case of workplace walking interventions).
- C. Comparator: no-treatment control groups (e.g. usual activity), or non-active comparators (e.g. leaflets on the health benefits of physical activity).
- D. Outcome: CRF, measured by actual or predicted VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$).
- E. Study design: randomised and non-randomised controlled trials.

Exclusion criteria were as follows:

- F. Studies including patient groups, retirees or unemployed persons.
- G. General physical activity promotion or environmental change interventions where exercise was not specifically delivered in the workplace.
- H. Interventions designed solely to decrease sedentary behaviour.
- I. Multicomponent interventions (e.g. interventions with concurrent exercise and dietary components), unless one group received only the exercise intervention and data could be extracted for only this group.
- J. Articles not in English.
- K. Articles were excluded if each of the FITT components (frequency of exercise, target intensity, time spent and type of exercise) (Heyward, 2010) were not adequately described.

3.2.2 Deviations from the pre-registered review protocol

During the systematic review process, it was necessary to deviate from the protocol initially registered on PROSPERO on occasion. Justification for these deviations is provided herein. Following initial protocol registration, it became apparent that the facilities and funding to permit the translation of non-English language papers were not available. As such, 'Articles not in English' was added to the exclusion criteria (criteria J). Due to the substantial biases that can arise in uncontrolled study designs (Hariton & Locascio, 2018), only controlled trials were included in the review (reflected in criteria C and E), thus excluding single arm studies. During the early phases of the

review screening process, it became apparent that the term ‘physical activity’ and ‘exercise’ are operationalised in very different ways across sport and exercise medicine literature. Accordingly, it was necessary to provide a clear definition of what exercise constituted for inclusion in the review (e.g. the definition from Garber et al., (2011) described in criteria B). Due to poor reporting of what workplace-based exercise interventions actually comprised, the exclusion criteria were updated such that articles where the interventions were not adequately described (e.g. the frequency of exercise sessions, target intensity, time spent performing exercise and type of exercise (Heyward, 2010)) would not be included in the review (criteria K). Upon initial protocol registration, the intention was to meta-analyse a range of physical fitness, cardiometabolic and mental health outcomes where possible. Due to an insufficient number of studies reporting each of the other outcomes and significant heterogeneity in the assessment methods used across different outcomes which precluded meta-analysis (Jackson & Turner, 2017), outcome variable selection was reduced to CRF only (criteria D). For transparency, Table 7 shows the range of other physical fitness and cardiometabolic health outcomes and the number of studies reporting each of these outcomes. Finally, although the protocol specified that risk of bias would be assessed, the specific assessment tool was not specified *a priori* (PEDro risk of bias tool (Maher et al., 2003)).

Table 7 Workplace exercise interventions reporting other physical fitness and cardiometabolic health outcomes

Outcome	Number of studies reporting outcome
Grip strength	3
Blood pressure (automatic monitor)	5
Blood pressure (mercury sphygmomanometer)	2
Blood pressure (ambulatory monitoring)	2
Body fat percentage (bioelectrical impedance)	3
Body fat percentage (skin folds)	5
Cholesterol (fasting)	3
Cholesterol (non-fasting)	3
LDL cholesterol (fasting)	3
LDL cholesterol (non-fasting)	2
HDL cholesterol (fasting)	3
HDL cholesterol (non-fasting)	3
Triglycerides	5
Blood glucose	1

3.2.3 Information Sources

An electronic search of seven databases (MEDLINE, PubMed, PsycINFO, SPORTDiscus, CINAHL, EMBASE and Scopus) was conducted from the beginning

of coverage dates for each individual database (exact coverage detailed below) to 3rd September 2018; MEDLINE (1966 to September 2018), PubMed (1997 to September 2018), PsycINFO (1597 to September 2018), SPORTDiscus (1892 to September 2018), CINAHL (1937 to September 2018), EMBASE (1947 to September 2018) and Scopus (1970 to September 2018).

3.2.4 Literature Search

The complete search strategy is presented in Table 8 and the strategy was modified according to the indexing systems of each database. Reference lists of all included papers were hand searched for relevant papers by the thesis author.

Table 8 Search Strategy

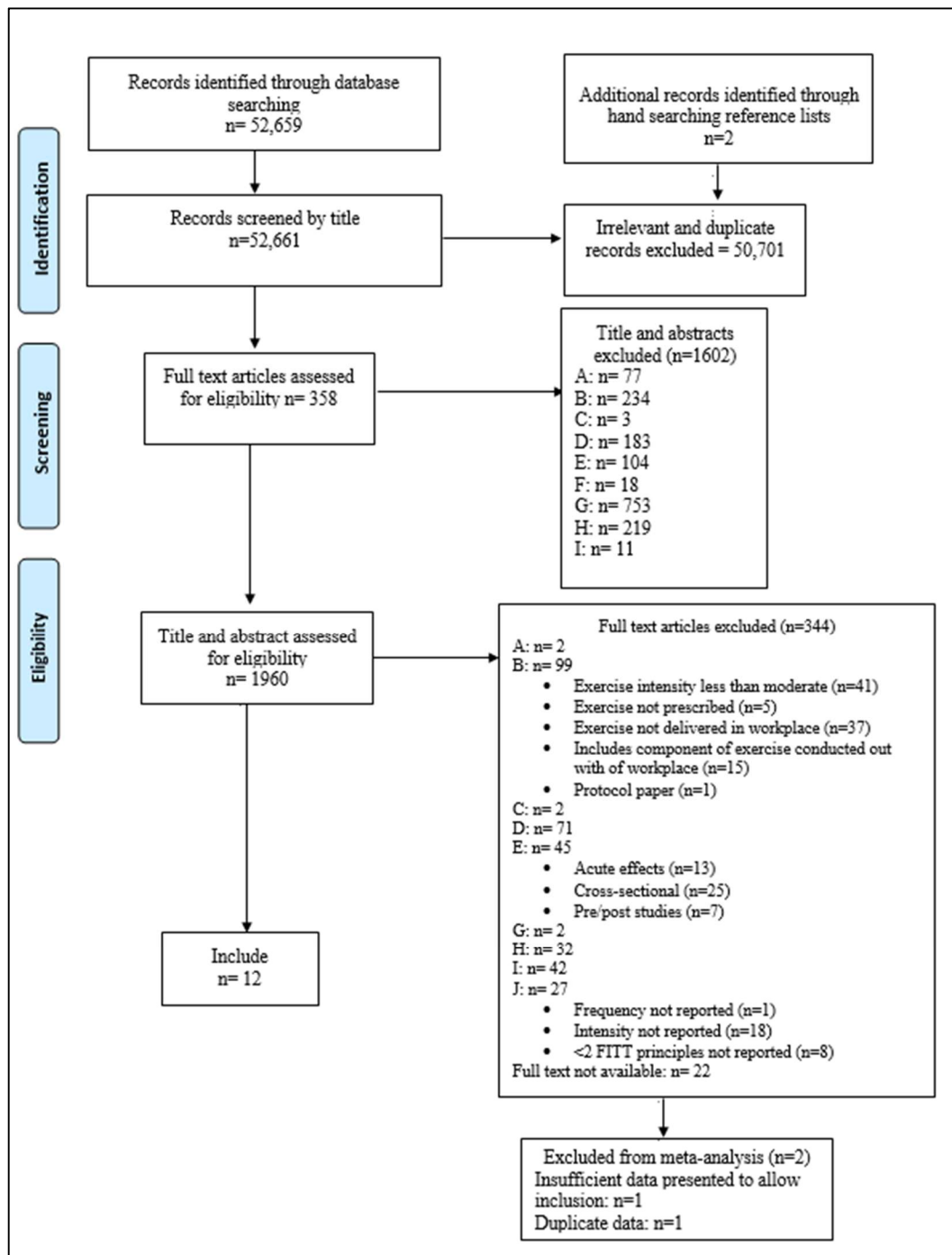
Category	Search terms
1. Workplace terms	TI ABS KEY (workplace OR worksite OR "work place" OR "work site" OR "working place" OR "work setting" OR "working environment" OR worker OR workforce OR employe* OR industr* OR corporate)
2. Exercise terms	TI ABS KEY (exercise OR "physical activity" OR fitness OR sport OR "aerobic training" OR "stair climbing" OR "stair use" OR "resistance training" OR "strength training" OR walk*)
3. Intervention terms	TI ABS KEY (intervention OR program* OR evaluation OR trial OR randomi* OR promotion OR effect*)
1 AND 2 AND 3	

3.2.5 Study Selection

Search results were imported from individual databases to reference management software (Mendeley Desktop v1.17.10) and duplicates deleted. The details of each study (authors, date of publication, title, journal title, volume, issue, page numbers and reference type) were then imported into a spreadsheet. Search results were screened for relevance and all irrelevant articles were removed at this stage. Title and abstracts were retrieved and independently screened against inclusion criteria by the thesis author and a graduate student researcher. Full text articles were screened by inclusion and exclusion criteria by both researchers. In accordance with systematic review protocol guidance (Higgins & Green, 2008), the study selection process was completed independently by the thesis author and the graduate student researcher and any disputes were settled by a third researcher. As demonstrated in Figure 1, after evaluation of full texts there were 12 papers that met the inclusion criteria and

were included in the meta-analysis. Two studies were excluded during data extraction, one because insufficient data was presented in the paper to allow for inclusion, and no response was received from study authors upon request for further information and one because it presented follow up data from another included study.

Figure 1 PRISMA diagram showing flow of studies through the review



Key: Inclusion/ exclusion criteria:

Inclusion: A. population: working adults (aged 16+ years), B. intervention: exercise of \geq moderate intensity is prescribed and delivered in the workplace. C. comparator: no intervention control groups, or non-active comparators. D. outcome: Cardiorespiratory fitness (actual or predicted VO_{2peak}). E. study design: RCTs or controlled trials. Exclusion: F. Population: specific patient groups, disabled populations, retirees or unemployed. G. Physical activity promotion/ environmental change/ sedentary behaviour interventions when exercise was not specifically prescribed and delivered in the workplace. H. multi-component interventions (e.g. interventions with concurrent exercise and dietary components). I. Not in English J: All FITT (frequency, intensity, time and type of exercise) principles adequately reported.

3.2.6 Data extraction

Data was extracted from all included studies using a specifically developed spreadsheet by the thesis author. Accuracy of all data extraction was confirmed via intra- and inter-individual reassessments of data extraction by the thesis author and a graduate student researcher. The researchers were not blinded to the authors or journals during data extraction. Details of the exercise intervention extracted included the exercise modality, session frequency, duration, intensity, intervention length and location. The age, sex, job role and sample sizes for intervention and control groups were also recorded. The primary outcome data taken and used in the analyses included the intervention effect (intervention minus control) on CRF as measured by relative VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$). In the case where a study included two intervention groups and one control group, the outcome data from the two intervention groups were combined to create a single pair-wise comparison (Higgins & Green, 2008).

3.2.7 Risk of bias assessment of individual studies

Risk of bias was assessed using the PEDro scale (Maher et al., 2003) independently by the thesis author and a graduate student researcher. In case of disagreement, consensus was achieved by discussion and disputes settled by a third researcher. Items in the PEDro scale include; specified eligibility criteria (external validity); demonstrated random allocation; allocation concealment; similar groups at baseline, blinding of participants, facilitators and assessors; follow up of $\geq 85\%$ of participants; intervention received as intended or intention to treat analysis and reporting of between-group statistical comparisons, point measures and measure of variability. The maximum score for the PEDro scale is 10 points (low scores indicate higher risk of bias), because item 1 (specified eligibility criteria) is not included in the calculation of the total score.

A range of tools are available for the assessment of risk of bias (Higgins & Green, 2008). In the present study, the PEDro scale was selected with the intention of using the score as a moderator variable in the meta-regression. This was based on recent work demonstrating a relationship between group mean and risk of bias assessed using the PEDro scale (Franklin et al., 2018). The Cochrane Collaborations tool for risk of bias is another commonly used risk of bias assessment tool, however this tool does not provide a score and therefore the exploration of the relationship between risk of bias and treatment effect would not have been possible.

3.2.8 Small study bias

Small study bias was assessed using visual inspection of the funnel plot and Egger's test to evaluate asymmetry (Egger et al., 1997).

3.2.9 Data synthesis

A random effects meta-analysis was conducted using the Comprehensive Meta-analysis Software Package, Version 3 for Windows (Biostat Company, Englewood, NJ, USA). The primary outcome was the intervention effect (intervention minus control) on mean outcome measures. Confidence intervals (CI), between study variation (τ) and prediction intervals were calculated.

3.2.10 Outcome statistics

Uncertainty in the estimates of effects on VO_{2max} was expressed as 90% CI and in relation to a threshold value for clinical relevance. The smallest clinically relevant effect on VO_{2max} was taken from recent epidemiological evidence suggesting that a $1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ increase in VO_{2max} is associated with a 9% relative risk reduction in all-cause mortality (Laukkanen et al., 2016). This criterion was applied post initial protocol registration. Between study heterogeneity was indicated by tau-squared which is the recommended statistic for quantifying heterogeneity in meta-analyses, and preferred to the relative index of heterogeneity known as 'I-squared' (Rucker et al., 2008).

Meta-regressions were conducted to explore the influence of putative moderator variables on the intervention effect. Study (intervention length and PEDro risk of bias score) and participant characteristics (age, baseline VO_{2max} and sex) were selected given that they could reasonably influence the overall effect of exercise on VO_{2max} . To explore the effect of intervention characteristics on heterogeneity of the effect, a single intervention characteristic was selected (intervention length). Intervention length was selected in place of other intervention characteristics such as exercise intensity, mode or frequency due to the multicollinearity that may exist between these variables and the heterogeneity in the way other variables were reported across the studies, both of which may violate the assumptions of meta-regression (Jackson and Turner, 2017).

The modifying effects of these five variables were calculated as the effect of two standard deviations (SD) (i.e. the difference between a typically low and a typically high value) (Hopkins et al., 2009). Meta-regression was performed only when there were ≥ 10 data sets (Higgins & Green, 2008). A 95% prediction interval (IntHout et al., 2016) was derived which provides a plausible range for the expected pooled mean effect (intervention minus control) on VO_{2max} in a future workplace exercise intervention conducted in similar settings.

3.3 Results

3.3.1 Study and participant characteristics

The final dataset for changes in VO_{2max} consisted of 25 estimates from 12 studies. Study and participant characteristics from the eligible studies are shown in Table 10. VO_{2max} estimates from a total of 733 participants were included in the meta-analysis. Participants in the individual studies were aged 25 to 67 years (mean: 41 years) and were from a range of both sedentary office based and manual labour intensive occupations including office workers (n=3), “insurance company workers” (n=2), “Westinghouse corporation workers” (n=1), “Ford Motor Company workers” (n=1), pharmaceutical company workers (n=1), construction workers (n=1), care workers (n=1), cleaners (n=1), and poultry processing workers (n=1). Studies were conducted in Denmark (n=4), United Kingdom (n=2), Sweden, (n=1), Norway (n=1), Netherlands (n=1), Turkey (n=1), Canada (n=1) and the United States of America (n=1). The length of interventions ranged from 8 to 52 weeks (median: 12 weeks). Four studies prescribed exercise twice per week; six studies prescribed exercise thrice weekly and two studies prescribed exercise five times per week. Exercise session length was variable and ranged from ~4 minutes to up to 60 minutes. The majority of exercise interventions involved aerobic exercise (n=8), however some studies prescribed resistance training (n=2) and multi-component exercise training (e.g. a combination of aerobic and resistance training in one intervention group) (n=2).

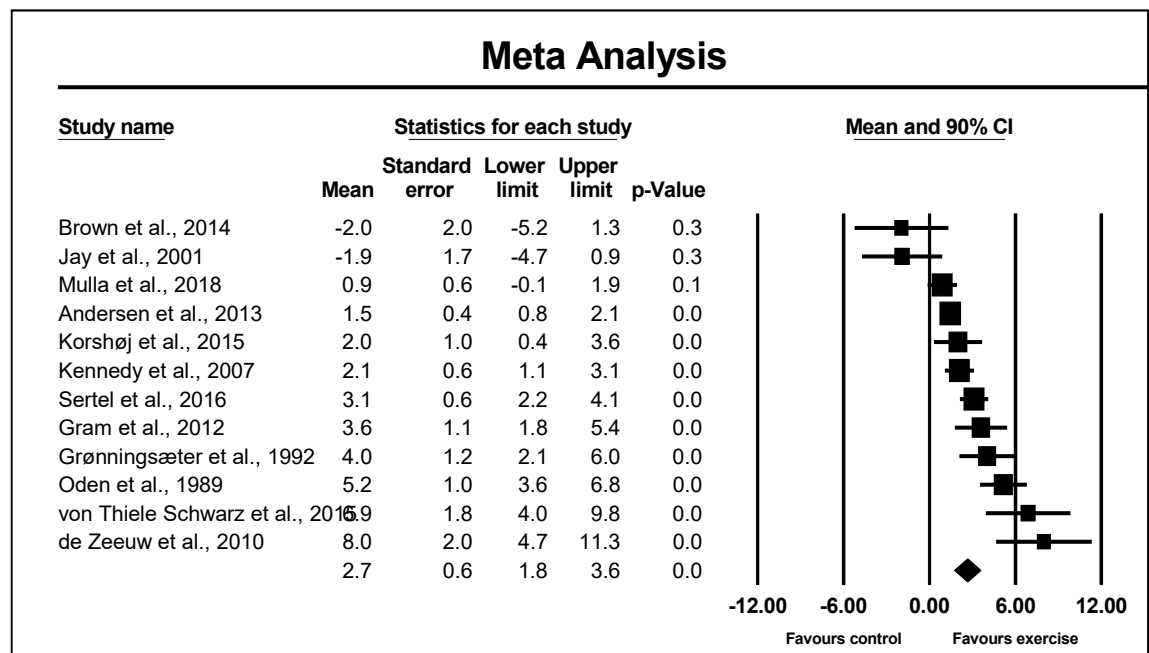
3.3.2 Risk of bias assessment

The risk of bias assessment of all included studies is presented in Table 9. The highest risks of bias were for blinding of participants, facilitators and assessors.

3.3.3 Effect of workplace exercise training interventions on VO_{2max}

Random effects meta-analysis demonstrated that when compared with controls, workplace exercise training interventions resulted in a beneficial improvement in VO_{2max} (2.7 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; 90% CI 1.6 to 3.8 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; 733 participants; 12 studies; Figure 2).

Figure 2 Forrest plot of the effect of workplace exercise training interventions on VO_{2max} .



Between-study heterogeneity (τ) was $\pm 1.6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (90% CI 1.1 to 2.7 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). The 95% prediction interval was -1.1 to 6.5 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Egger's coefficient was 1.51 (95% CI -1.40 to 4.41; $p= 0.28$). The non-significant Eggers test coupled with the balanced nature of the funnel plot presented in Figure 3, suggest there is no evidence of small study bias.

Table 9 PEDro Risk of Bias Assessment

Author, date	1) Specified eligibility criteria	2) Demonstrated random allocation	3) Concealed allocation	4) Similar groups at baseline	5) Subjects blinded	6) Facilitators blinded	7) Assessors blinded	8) >85% followed up	9) Intervention received as intended/ ITT analysis	10) Results of between-group statistical comparisons reported for at least one outcome	11) point measures and measures of variability for at least one outcome	Total/10
Brown et al., 2014	Y	+	+	+	-	-	-	-	-	+	+	5
Jay et al., 2011	Y	+	+	+	-	-	+	+	+	+	+	8
Mulla et al., 2018	Y	+	+	+	-	-	+	+	+	+	+	8
Andersen et al., 2013	Y	+	+	+	-	-	+	+	+	+	+	8
Korshøj et al., 2015	Y	+	+	+	-	-	+	-	+	+	+	7
Kennedy et al., 2007	Y	+	-	+	-	-	-	+	-	-	+	4
Sertel et al., 2016	Y	+	-	+	-	-	-	-	-	+	+	4
Gram et al., 2012	Y	+	+	+	-	-	-	+	+	+	+	7
Grønningsæter et al., 1992	Y	+	-	-	-	-	-	+	-	+	+	4
Oden et al., 1989	N	+	-	+	-	-	-	-	-	+	+	4
von Thiele Schwarz & Lindfors, 2015	N	-	-	-	-	-	-	+	-	+	+	3
de Zeeuw et al., 2010	Y	+	+	+	-	-	-	+	-	+	+	6
	Total/12	11	7	10	0	0	4	8	5	11	12	
<p>Key: Y= yes, N=no. += demonstrated evidence, - = no demonstrated evidence, ITT= intention to treat. Scores of ≥6 considered at low risk of bias, scores of <6 considered at high risk of bias.</p>												

Table 10 Study characteristics

Author, date	Design	Location	Population, sample size (n), % female, age (year) (mean unless otherwise stated)	Group	Duration (weeks)	Frequency (per week)	Length (mins)	Mode	Intensity	Attendance	Dose Quantification	VO _{2max} measurement technique	Baseline VO _{2max} (mL·kg ⁻¹ ·min ⁻¹)	% Δ VO _{2max} (mL·kg ⁻¹ ·min ⁻¹)
Brown et al., (2014)	RCT	UK	Office workers n=32 (15.6% female, 46y)	I1	8	2	20	Aerobic (walking-nature walk)	2km walk in 20 mins	Twice weekly session attendance achieved by 42% of participants	Average increase in steps/ day: 745 steps (target step increase: 600 steps/ day)	Chester step test*	39.0	+0.8
			Office workers n=33 (27.3% female, 39y)	I2	8	2	20	Aerobic (walking-built environment walk)	2km walk in 20 mins	Twice weekly session attendance achieved by 43% of participants	Average increase in steps/ day: 374 steps (target step increase: 600 steps/ day)	Chester step test*	39.8	0.0
			Office workers n=29 (20.6% female, 40y)	C				Wait list control				Chester step test*	39.6	+5.3
Jay et al., (2011)	RCT	Denmark	Pharmaceutical company workers n=20 (85% female, 44y)	I	8	3	20	Resistance (kettlebells)	Four increasingly difficult kettlebell exercises. Progression when each exercise could be completed at the highest level of intensity.	70% average session attendance	Average two-handed kettle bell swing weight and number of sets increase from 8.3kg for 23.2 sets in week 1-2 to 12.4kg for 22.1 sets in week 7 and 8.	Submaximal cycle ergometer Astrand protocol*	37.0	+7.8
			Pharmaceutical company	C				Inactive control				Submaximal cycle	39.0	+12.3

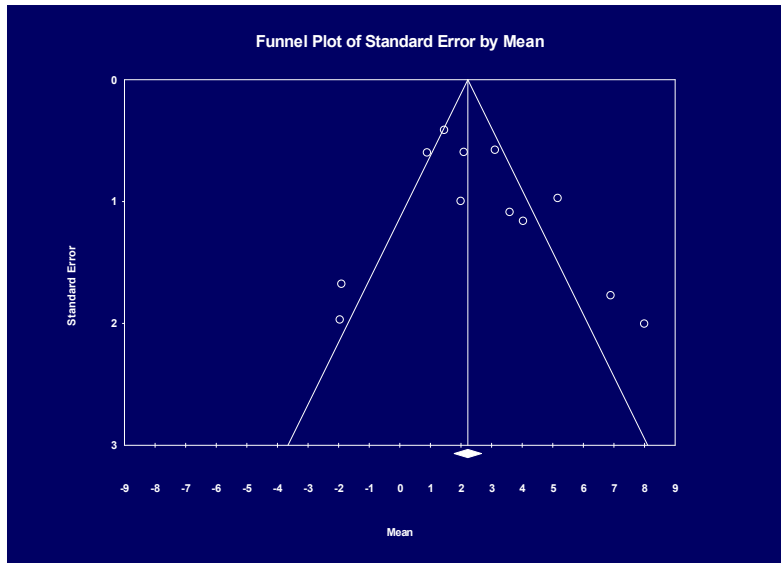
			workers n=20 (85% female, 43y)										ergometer Astrand protocol*		
Mulla et al., (2018)	RCT	Canada	Ford motor company workers n=21 (57% female, 44y)	I	12	3	45	Resistance (lower body strengtheni ng)	RPE= 5-7 on 10 point RPE scale	Mean session attendanc e: 2.3 per week	Not reported	Ebbling Single stage treadmill walking test*	34.9	+2.9	
			Ford motor company workers n=21 (68% female, 43y)	C				Wait list control				Ebbling Single stage treadmill walking test*	34.6	+0.3	
Andersen et al., (2013)	RCT	Denmark	Office workers n=106 (79.2% female, 42y)	I	10	5	10	Aerobic (Stair climbing)	90% HRR (measured retrospectiv ely)	Mean session attendanc e: 3.3/ week.	Mean heart rate recorded during one session: 90% HRR	Maximal cycle ergometer	36.0	+6.4	
			Office workers n=54 (75.9% female, 43y)	C				Inactive control				Maximal cycle ergometer	38.0	+2.3	
Korshøj et al., (2015)	Cluster RCT	Denmark	Cleaners n= 57 (75.4 % female, 45y)	I	16	2	30	Aerobic exercise (more specific details not reported)	≥60% VO _{2max}	Mean session attendanc e: 51%	Mean heart rate recorded every fourth week: 67% HRR	Step test*	24.8	+7.1	
			Cleaners n=59 (76.3% female, 50y)	C				Health lectures				Step test*	25.0	-1.0	
Kennedy et al., (2007)	RCT	United Kingdom	Office workers n= 35 (43% female, 44y)	I	8	5	1- 3 climbs / sessio ns (4 mins averag e)	Aerobic (stair climbing)	8 flights of stairs at 75 steps/ min	Mean session attendanc e: 88%	Not reported	Submaximal cycle ergometer YMCA protocol*	27.8	+9.4	
			Office workers n=17 (65% female, 39y)	C				Inactive control				Submaximal cycle ergometer YMCA protocol*	27.1	+1.9	

Sertel et al., (2016)	RCT	Turkey	Poultry processing workers n=31 (100% female, 31y)	I	8	3	30	Resistance (Theraband exercises)	50-85% MVC	Session attendance not reported	Not reported	Queens college step test*	38.5	+6.8
			Poultry processing workers n=30 (100% female, 33y)	I	8	3	30	Aerobic (walking/running)	40-80% VO _{2max}	Session attendance not reported	Not reported	Queens college step test*	38.3	+9.4
			Control n=30 (100% female, 35y)	C				Inactive control				Queens college step test*	35.5	0.0
Gram et al., (2012)	RCT	Denmark	Construction workers n=35 (100% male, 44y)	I	12	3	20	Multicomponent cycling/rowing and resistance training	≥70% VO _{2max} or 60% 1RM	Mean session attendance: 68%	Not reported	Submaximal cycle ergometer Astrand protocol*	27.1	+14.4
			Construction workers n=32 (100% male, 43y)	C				Health lectures				Submaximal cycle ergometer Astrand protocol*	26.5	+1.1
Grønningsæter et al., (1992)	RCT	Norway	Insurance company workers n=30 (43% female, 25-67y [range as mean age not provided])	I	10	3	55	Aerobic (rhythmic aerobics)	70-80% HR _{Max}	Mean session attendance: 76% (men), 80% (women)	Not reported	Submaximal cycle ergometer Astrand protocol*	39.8	+7.0
			Insurance company workers n=31 (48% female, 25-67y)	C				Waitlist control				Submaximal cycle ergometer Astrand protocol*	37.8	-3.3
Oden et al., (1989)	RCT	USA	Westinghouse corporation workers n=23 (80%	I	24	3	30	Aerobic (walking, jogging, cycling)	60-80% HRR	Not reported	Not reported	Maximal treadmill Bruce protocol	30.0	+17.9

			female, 29y.)													
			Westinghouse corporation workers n=22 (80% female, 29y)	C					Inactive control				Maximal treadmill Bruce protocol	29.9	+0.6	
Von Thiele Schwarz & Lindfors (2015)	CT	Sweden	Care workers n=15 (100% female, 42y)	I	52	2	60	Aerobic (aerobics, Nordic walking, cross training)	“Middle to high- intensity”	Not reported	Not reported	Submaximal cycle ergometer Astrand protocol*	35.8	+11.5		
			Care workers n=13 (100% female, 44y)	C				Inactive control				Submaximal cycle ergometer Astrand protocol*	29.5	-9.5		
de Zeeuw et al., (2010)	RCT	Netherlands	Insurance company workers n= 15 (40% female, 41y)	I	10	2	40-60	Aerobic (cycling, jogging, stair stepping)	80% HR _{Max}	Mean session attendance: 85.6%	Not reported	Submaximal cycle ergometer Astrand protocol*	29.7	+24.9		
			Insurance company workers n=15 (53% female, 41y)	C				Inactive control				Submaximal cycle ergometer Astrand protocol*	32.3	-1.9		

Key: CT: controlled trial, RCT: randomised controlled trial, y: years, I: intervention group, C: control group, HR_{max}: maximum heart rate, HRR: heart rate reserve, VO_{2max}: maximal oxygen consumption, MVC: maximum voluntary contraction, 1RM: one repetition maximum, RPE: Rating of Perceived Exertion, *submaximal prediction of VO_{2max}.

Figure 3 Funnel Plot of standard error by mean



Meta-regressions were undertaken with intervention length, PEDro risk of bias score, mean baseline VO_{2max} , mean age and sex as selected predictors (Table 11). The relevant scatter plots with fitted meta-regression slopes are shown in Figures 4-8. Meta-regression analysis revealed an additional effect for typically longer interventions ($3.2 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; 90% CI 1.3 to $5.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), and lesser effects for studies with a lower risk of bias ($-2.5 \text{ mL}\cdot\text{kg}\cdot\text{min}^{-1}$; 90% CI -4.0 to $-1.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), greater baseline VO_{2max} ($-1.6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; 90% CI -3.6 to $0.4 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and older participants ($-1.4 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; 90% CI -3.2 to $0.3 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). Percentage female (sex) had an additive effect on VO_{2max} ($0.4 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; 90% CI -1.6 to $2.4 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$).

Table 11 Meta-regression

Model	Coefficient (90% CI)	τ^2	R^2 (%)	I^2 (%)	p-value
Intervention length (weeks)	0.17 (1.3 to 5.1)	1.79	26	73	0.01
PEDro risk of bias score	-0.66 (-4.0 to -1.0)	1.74	28	78	0.01
Baseline VO_{2max} ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	-0.16 (-3.6 to 0.4)	2.49	0	78	0.18
Age (years)	-0.15 (-3.2 to 0.3)	2.42	14	74	0.16
Sex (% Female)	0.01 (-1.6 to 2.4)	2.77	0	80	0.73

Figure 4 Scatter plot of meta-regression of intervention length

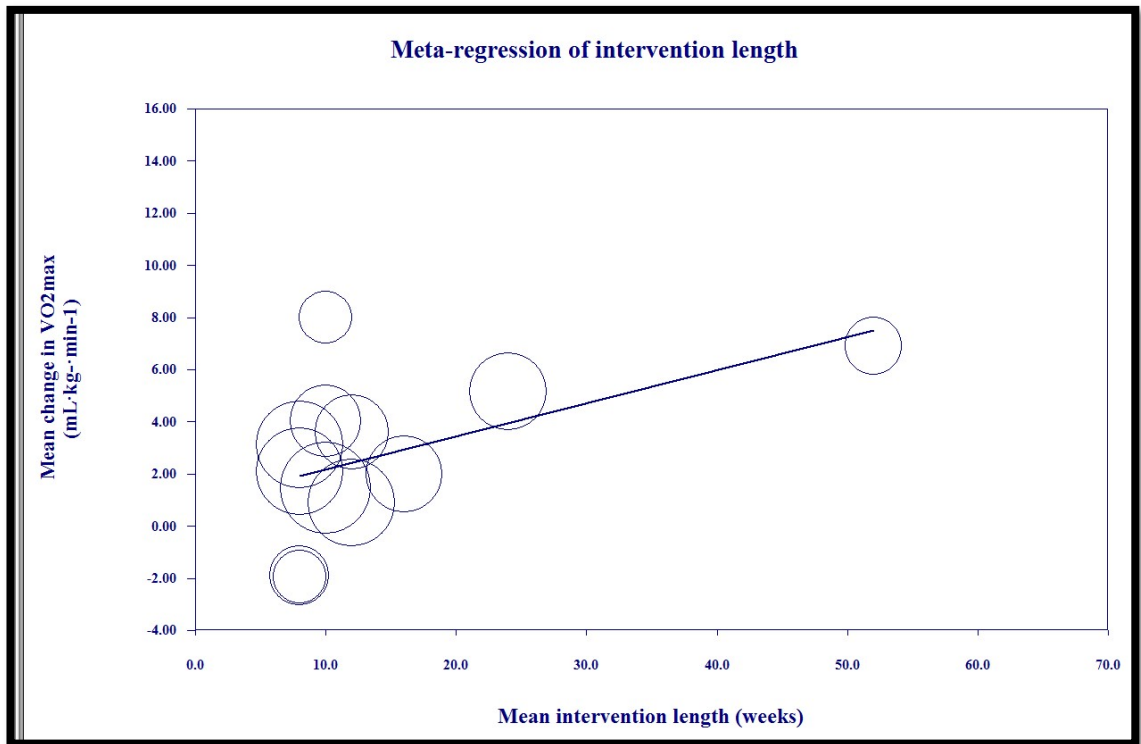


Figure 5 Scatter plot of meta-regression of PEDro risk of bias score

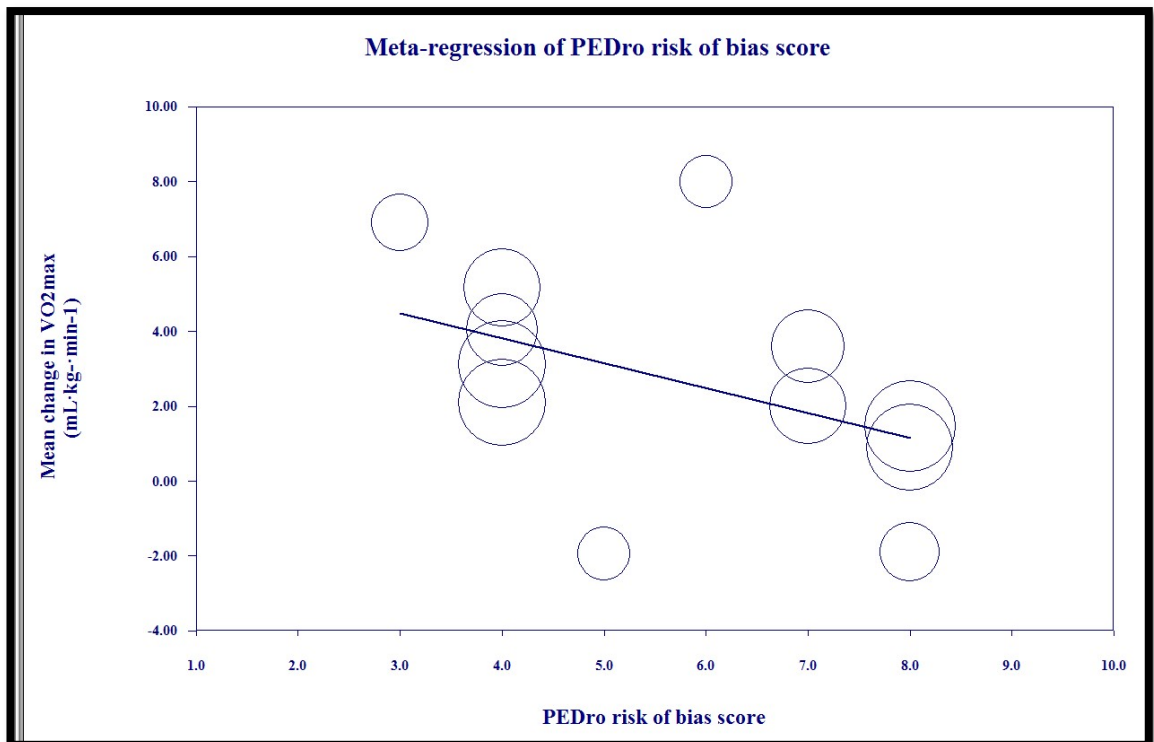


Figure 6 Scatter plot of meta-regression of baseline VO₂max.

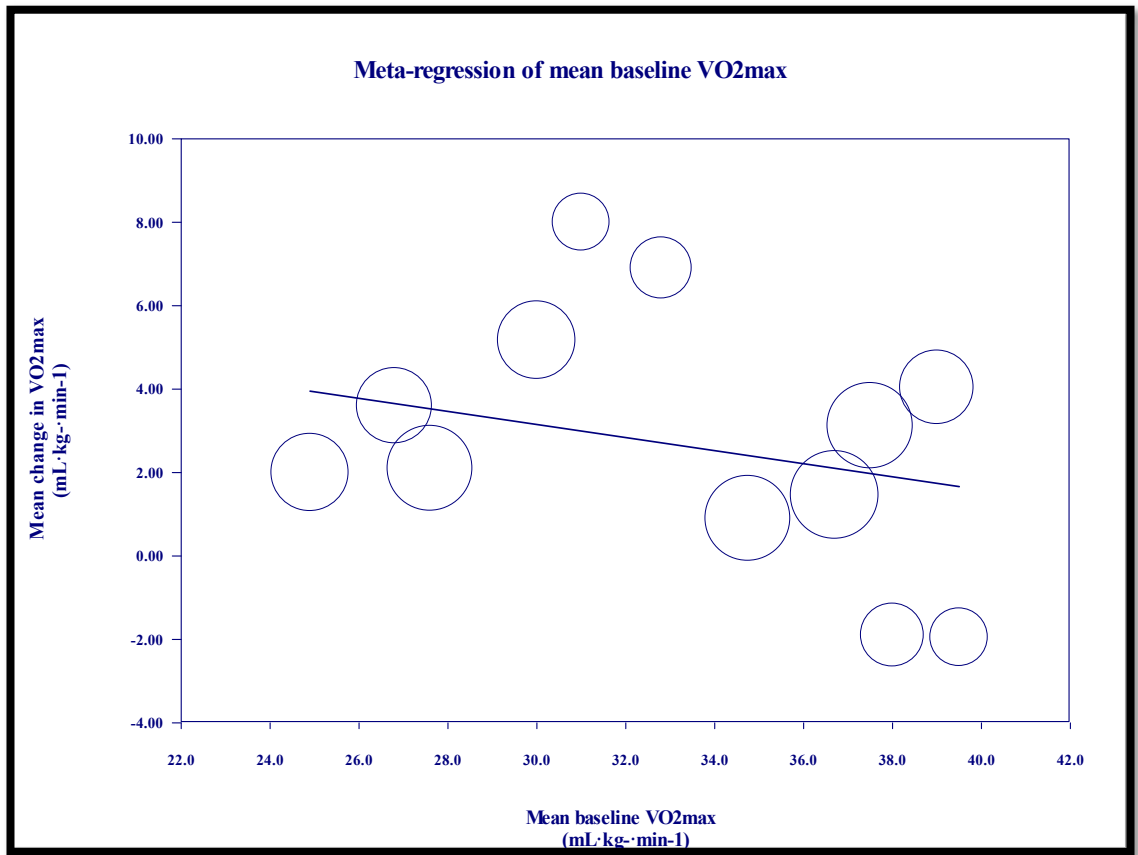


Figure 7 Scatter plot of meta-regression of mean age.

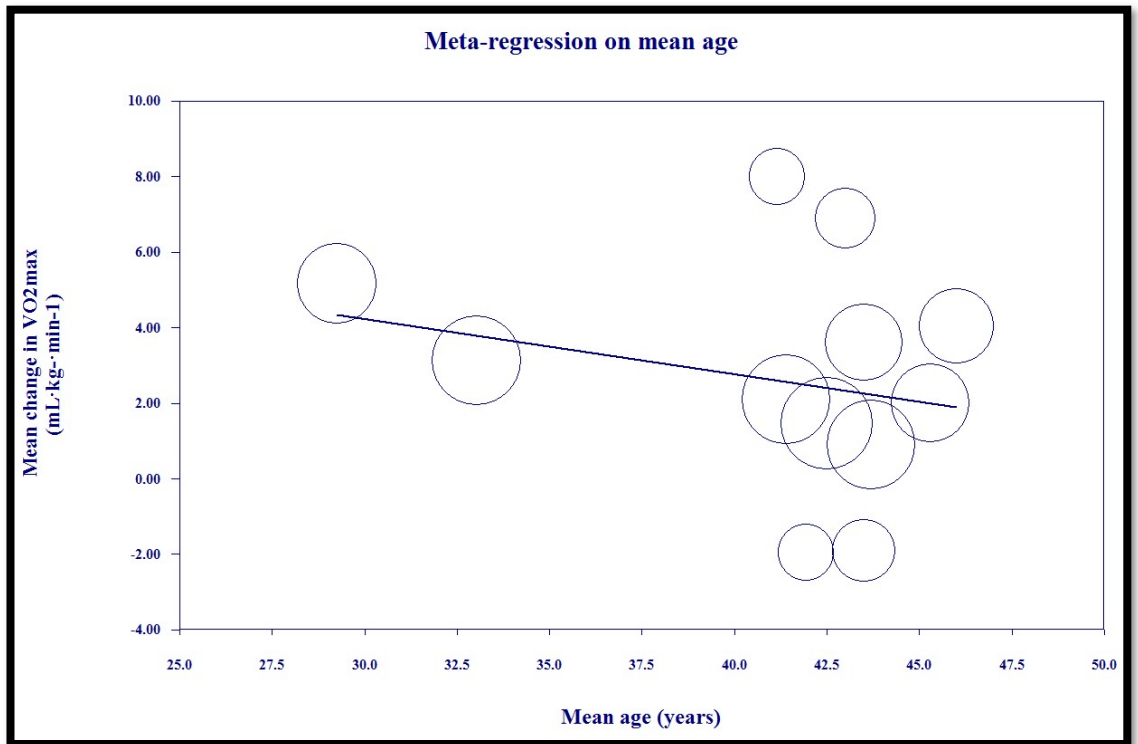
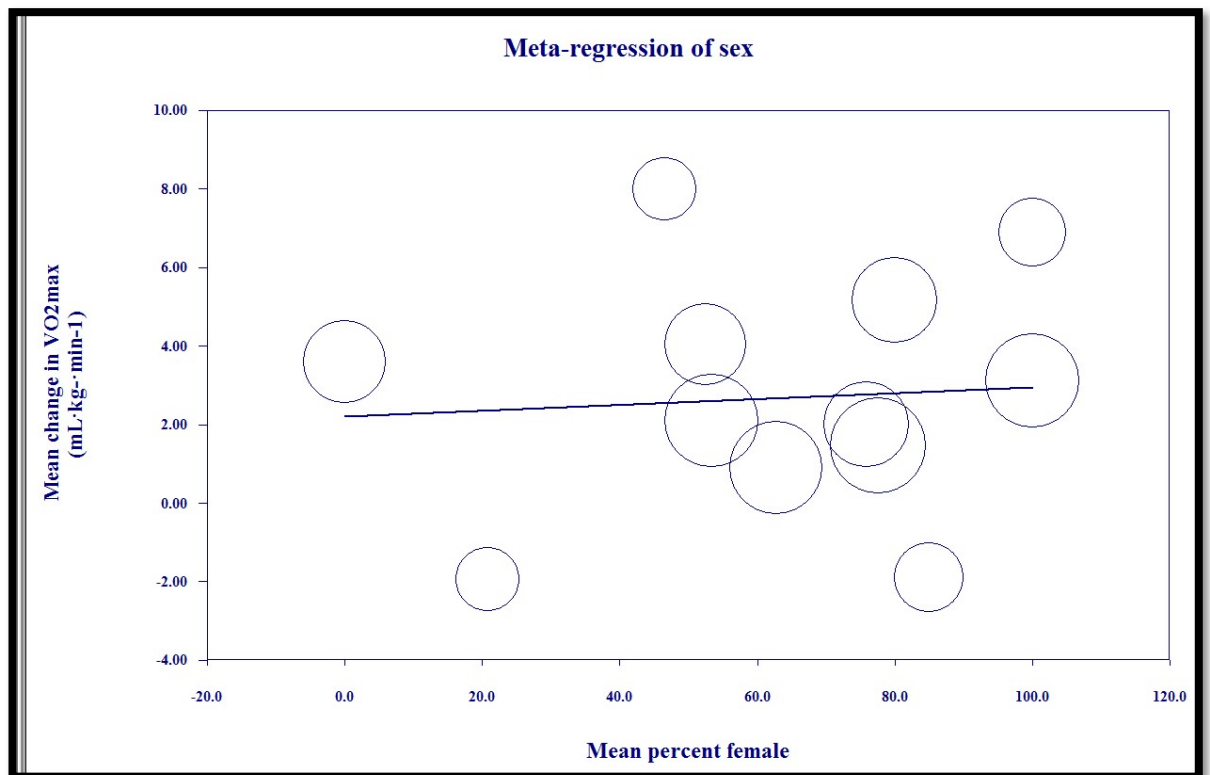


Figure 8 Scatter plot of meta-regression of sex (percentage female participants).



3.4 Discussion

This study presents a quantitative evaluation of the effects of workplace-based exercise interventions on CRF in healthy employees. Establishing the effectiveness of workplace-based exercise interventions on CRF is particularly timely in light of recent evidence suggesting that CRF levels have declined by 10.8% ($-4.2 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) in working populations in the last two decades (Ekblom-Bak et al., 2018). The results of the random effects meta-analysis showed that when compared to controls, workplace exercise interventions result in an improvement in $\text{VO}_{2\text{max}}$ of $2.7 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Given that a $1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ increase in $\text{VO}_{2\text{max}}$ has been associated with a 9% relative risk reduction in all-cause mortality (Laukkanen et al., 2016); the magnitude of improvements in $\text{VO}_{2\text{max}}$ induced by workplace-based exercise interventions may be clinically meaningful. The prediction interval, which describes a plausible range of mean treatment effects in a hypothetical future workplace exercise intervention in similar settings, ranged from a reduction in $\text{VO}_{2\text{max}}$ of -1.1 to an improvement of $6.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. It is possible that this range in plausible effects is explained by the broad range of exercise prescriptions included in the review (Table 10).

The results of this meta-analysis are lower than those reported in a previous meta-analysis (Conn et al., 2009) where an increase of $3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ was found following more broadly defined workplace physical activity interventions (including the promotion of general physical activity). However their results should be interpreted with caution, due to the inclusion of non-controlled trials and a broad range of intervention formats in the meta-analysis.

Despite observing a beneficial improvement in $\text{VO}_{2\text{max}}$ in this meta-analysis, there was also heterogeneity in the effect ($\tau = 1.6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), indicating variation in the intervention effect between studies. To explore this variation further, meta-regression was conducted using intervention (intervention length and PEDro risk of bias score) and participant (age, sex and baseline $\text{VO}_{2\text{max}}$) characteristics. Study characteristics (intervention length and PEDro risk of bias score) explained some of the heterogeneity of the effect ($r^2 = 26\%$ and 28% , respectively, Table 11). Although there was an additional improvement in $\text{VO}_{2\text{max}}$ for typically longer interventions, one study with a long intervention length and large intervention effect (Figure 4) was an outlier and may have impacted on the slope of the meta-regression. Therefore, this result should be interpreted with caution. There was a lesser effect for studies with a low risk of bias. This result was not unexpected given that methodological characteristics of studies are thought to have a substantial impact on treatment effect estimates in meta-analysis (Verhagen et al., 2001). Given that the modifying effect of participant characteristics explained only a very limited proportion of the heterogeneity of the effect ($r^2 = 0\%$ for baseline $\text{VO}_{2\text{max}}$, 14% for age and 0% for sex), a conservative approach has been taken in the interpretation of this result. Given the data available from the studies included in this meta-analysis, it can be concluded that no single group (e.g. older or less fit individuals) can be definitively identified as standing to benefit more from workplace exercise interventions at this stage. Further work is needed to quantify the impact of participant characteristics on the effects of workplace exercise interventions on CRF.

One other possible explanation for the heterogeneity in the effect could be the measurement error associated with the submaximal prediction of $\text{VO}_{2\text{max}}$. All but two (Andersen et al., 2013; Oden et al., 1989) of the included studies used submaximal estimates of $\text{VO}_{2\text{max}}$ (either via step tests, submaximal cycle ergometer tests, or treadmill walking tests, Table 10). This is unsurprising given the limited feasibility of performing maximal oxygen consumption tests in the workplace. Alternatively, the

heterogeneity may be attributed to the range of exercise prescriptions used and/ or the extent to which the fidelity of the intervention was upheld (e.g. whether the intervention was implemented as intended across all participants (Dumas et al., 2001; Taylor et al., 2015)). However, these variables could not be included in a meta-regression due to inconsistencies in reporting practices in the individual studies. Another possible explanation for the heterogeneity in the effect could be the various study designs used in the included studies (e.g. controlled trials vs. RCTs vs. cluster RCTs). In a cluster RCT, randomisation is likely to occur at the workplace rather than individual level, whereby one workplace would act as an intervention group and a separate workplace would act as the comparator. A cluster RCT design may avoid contamination in the control group, which can be an issue in exercise trials which arises when control participants modify their behaviour despite requests to maintain their usual activity pattern (Steins Bisschop et al., 2015). The issue of contamination was discussed by the authors of one of the studies included in this meta-analysis (Brown et al., 2014) who employed a traditional RCT design. Here, although participants were blinded to their group allocation at baseline, all were recruited from the same workplace and may therefore have established their group allocation through informal discussions with colleagues.

As demonstrated in Table 10, a range of occupations were recruited in the included studies. Although five of the twelve included studies recruited desk-based employees, the remaining studies included a range of manual labour based workers such as construction workers and cleaners. This suggests that workplace-based exercise interventions could be implemented in a range of occupational environments. All of the studies included in this meta-analysis were from high or upper-middle income countries, with the majority of the included studies from European countries and the remaining from North America. It is likely that the implementation of such programmes are highly context dependent (Craig et al., 2008) due to a variety of factors such as workplace cultural norms or climate. Therefore the generalisability of individual workplace-based exercise interventions to diverse geographical locations may be limited at this time.

It is important to acknowledge that this study is not without limitations. It was initially intended to meta-analyse a broad range of physical fitness, cardiometabolic and mental health outcomes. However due to significant heterogeneity in outcome measures reported in individual studies and low numbers of studies reporting some outcomes, this was not possible. Given that such heterogeneity could violate the

assumptions of a meta-analysis (Jackson & Turner, 2017); a cautious approach was taken in outcome variable selection. A more comprehensive assessment of health, fitness and psychological variables in future intervention studies would assist further in evidence-based programming decisions. To be eligible for inclusion in this meta-analysis exercise sessions had to be delivered, or at least begin, from the participants' workplace (i.e. in the case of walking interventions). This led to the exclusion of studies where participants were recruited from their workplace, but exercise was conducted elsewhere. The decision was made to exclude such studies because one rationale for delivering exercise in the workplace is that there is potential to reduce commonly cited barriers to exercise participation, such as lack of time and access to facilities (Hunter et al., 2018). If participants are required to travel to an external location to participate in 'workplace' exercise, it was deemed that this was no longer a workplace exercise intervention because this could result in further exacerbation of such barriers. Only interventions prescribing exercise of at least moderate intensity were included in this meta-analysis; which led to the exclusion of studies delivering exercise of lower intensities. There is evidence to suggest that exercise training of at least moderate intensity can elicit adaptations in various markers of physical fitness, including CRF (Lin et al., 2015). Therefore exercise prescriptions of less than moderate intensity may not be expected to have an impact on CRF in healthy populations.

The use of the PEDro scale to assess the risk of bias in the included studies could also be considered a limitation of this review. The use of summary scales to assess risk of bias have previously been described as misleading because not all scale elements may be relevant in all contexts, but are still weighted equally (Armijo-Olivo et al., 2015). Nonetheless, the PEDro scale is a useful tool which permitted the exploration of the linear negative association between risk of bias and size of treatment effect, which has been conducted in a similar way in a previous meta-analysis (Franklin et al., 2019).

Given the limitations in the evidence base discussed above, several recommendations for future workplace-based exercise interventions will now be presented, which in turn could aid further systematic reviews and meta-analyses on the topic. A cautious approach was taken in outcome variable selection due to significant heterogeneity in outcome assessment and reporting methods in the individual studies. Future intervention studies should consider the assessment of a wide range of physical fitness, cardiometabolic and mental health outcomes, with

consideration of pertinent outcomes for participating organisations. For this to be possible it has been suggested that stakeholders (in this case employees and senior management teams) are consulted during the design and implementation phases of such programmes wherever possible (Bauman & Nutbeam, 2013). This could be done in the form of a formative evaluation, which is a process thought to facilitate the development of acceptable and feasible interventions and in turn increase adherence and compliance (Bauman & Nutbeam, 2013). Furthermore, a detailed description of the exercise prescription (frequency, intensity, time and type) had to be presented for studies to be included in this review. Poor reporting of the exercise prescription resulted in the exclusion of a number of studies. This was possibly not surprising, given that inadequate reporting of intervention trials remains commonplace in the exercise literature (Taylor et al., 2015). As such, this meta-analysis supports calls for standardised reporting of exercise prescriptions and intervention fidelity or compliance quantification (Hurst et al., 2018b; Nielsen et al., 2019; Straight et al., 2016; Taylor et al., 2015; Weston et al., 2014b). This should include the presentation of exercise training programming variables (e.g. frequency, intensity, time and type of exercise) as well as information about the extent to which the fidelity of the intervention was upheld. Adherence to reporting checklists such as the Template for Intervention Description and Replication (TIDieR) checklist (Hoffmann et al., 2014) or Consensus on Exercise Reporting Template (CERT) guidelines (Slade et al., 2016) are also recommended. From a more practical standpoint thorough intervention reporting is particularly important when recruiting organisations to workplace-based exercise programmes. Senior management teams will require in depth information regarding the exercise prescription involved in a programme, before they can allow their employees to participate. Lastly, the average weekly exercise time commitment in the included studies was ~80 minutes. Given that “lack of time” has been reported as a barrier to workplace exercise participation (Hunter et al., 2018), more time efficient exercise prescriptions may be well received by organisations and employees alike. One such time efficient strategy is high-intensity interval training (HIT), however the acceptability and feasibility of prescribing and delivering this form of exercise in the workplace is understudied (Kinnafick et al., 2018).

3.5 Conclusion

This meta-analysis has demonstrated that exercise that is delivered in the workplace can result in improvements in VO_{2max} of $2.7 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, when compared to controls. The prediction interval, which describes a plausible range of effects in a hypothetical

future workplace exercise intervention in similar settings ranged from a reduction in VO_{2max} of -1.1 to an improvement of 6.5 $mL \cdot kg^{-1} \cdot min^{-1}$. The effect was moderated by PEDro risk of bias score and intervention length such that studies with higher risk of bias and longer intervention length demonstrated larger intervention effects. However the impact of intervention length should be interpreted with caution due to the presence of an outlier. At this time the modifying effects of age, sex and baseline fitness of participants are not definitive, and further work is needed to fully elucidate the impact of these characteristics. Given the data available at the present time, no specific group of employees (e.g. older or less fit) can be definitively identified as standing to gain more or less from workplace exercise interventions aimed at improving CRF. Future research should explore the effect of workplace exercise on outcomes beyond simply CRF, whilst also ensuring that precise and in-depth reporting of the exercise prescription and implementation is provided. More time efficient exercise prescriptions may be well received by employees and organisations alike, however little is known regarding the acceptability and feasibility of delivering such interventions in the workplace. As such, the study presented in the following chapter aims to assess employee and management perceptions of these issues, via a formative evaluation of a proposed workplace HIT intervention.

Chapter 4: Study Two. A formative evaluation of a workplace-based high-intensity interval training intervention: the development of the Brief Exercise at Work (BE@Work) trial

4.1 Introduction

The meta-analysis presented in Chapter Three and the review of the workplace-based physical activity and exercise literature presented in Chapter Two demonstrated that workplace-based exercise training interventions can elicit meaningful adaptations in CRF, markers of cardiometabolic health (Reed et al., 2017) and wellbeing (Abdin et al., 2018). Despite these findings, evidence from systematic reviews suggest that participation rates in workplace health promotion programmes vary widely from 10 to 64% (median: 33%) of eligible employees (Robroek et al., 2009) and loss to follow-up has been reported to range from 4 to 40% (median: 27%) (Rongen et al., 2013). In an attempt to address low participation and high attrition rates during intervention implementation, the Medical Research Council recommended formative research with relevant stakeholders at the planning stage of a complex intervention (Craig et al., 2008).

Formative evaluation can be defined as a form of primary research undertaken before an intervention is implemented to obtain detailed information about the people for whom, and the context in which interventions will be implemented (Gittelsohn et al., 1999). Formative evaluation is distinct from process evaluation as the former occurs prior to intervention implementation, whereas process evaluations are a set of activities conducted after an intervention is implemented to assess the implementation process and further refine an intervention (Bauman & Nutbeam, 2013). Formative evaluation can facilitate an understanding of the circumstances, needs and assets of the target population, assess the types of solutions to barriers that the target population would support (Bauman & Nutbeam, 2013) and facilitate relationships between researchers and target populations (Gittelsohn et al., 1998; Gittelsohn et al., 1999; Kumanyika et al., 2003). These activities can facilitate the development of acceptable and feasible interventions which could promote recruitment, adherence and compliance (National Institute for Health and Care Excellence, 2008).

A range of methods can assist in the formative evaluation of prospective health promotion programmes (Bauman & Nutbeam, 2013). Commonly utilised qualitative data collection methods include telephone interviews, semi-structured face-to-face interviews and focus group discussions; whereas surveys and questionnaires are commonly employed quantitative data collection methods in formative evaluations (Gittelsohn et al., 2006). Although surveys or questionnaires could permit the recruitment of a larger sample size (Langdridge & Hagger-Johnson, 2009), this may be at the expense of the depth of information collected (Bauman & Nutbeam, 2013). Furthermore, as part of the rationale for conducting formative evaluation is to build relationships with key stakeholders and potential intervention participants, face-to-face focus groups or semi-structured interviews are considered a more appropriate data collection technique for this purpose (Bauman and Nutbeam, 2013).

A range of data collection methods have previously been used to explore participant perspectives of workplace exercise. In focus groups conducted with 42 hospital-based employees, participants expressed an interest in a range of workplace physical activity programmes including walking groups, team-based competitions, health and exercise classes and access to personal trainers (Phipps et al., 2010). Similarly, in a cross-sectional survey of 252 university employees, personal training and group exercise classes were selected as the preferred exercise modalities that could be included in a workplace exercise programme (Hunter et al., 2018). Although there are clearly similarities in the preferences expressed by participants in these two studies, the wide range of preferred modalities may indicate that a single standard exercise prescription would not be feasible and acceptable for all employees in a range of workplaces. While these studies demonstrate that workplace physical activity or exercise programmes may be viewed favourably by employees, they were not conducted to inform the development of a specific intervention; rather they were standalone studies and so the findings do not indicate how programmes could be tailored and implemented into workplace settings. In one-to-one interviews conducted as part of a process evaluation of a workplace resistance training programme, employees reported inflexible work conditions, high job demands and “feeling guilty for leaving the workplace to exercise” were barriers to participation (Bredahl et al., 2015). With poor adherence to the two prescriptions of resistance training included in the intervention (18 to 39% session attendance), the authors concluded that prior investigation of these barriers during intervention development could have allowed consideration of such barriers, resulting in a more feasible and acceptable intervention (Bredahl et al., 2015). This finding further highlights the importance of

including key stakeholders and potential participants before an intervention is implemented.

The aforementioned studies focused on employee opinions toward a range of physical activity and exercise prescriptions or promotion strategies, yet research into the acceptability of delivering HIT in the workplace is in its infancy. Only one study to date has investigated participant perceptions of a HIT intervention delivered in the workplace. Here, Kinnafick et al., (2018) conducted a process evaluation using focus group interviews with 12 participants following a workplace HIT intervention which has been described in detail in Chapter Two (section 2.5) (Shepherd et al., 2015). The time efficient nature of HIT was perceived positively by participants, and HIT was described as a novel exercise modality that initially attracted participants to the intervention. The proximity of the exercise facility to the workplace, and the availability of multiple exercise sessions across a week were discussed as facilitators for attendance (Kinnafick et al., 2018). Although preliminary, these findings indicate that HIT may be a viable training strategy that can be integrated into a workplace-based programme. However, the 12 participants included in the focus groups were all classified as 'adherers' to the intervention (i.e., attended $\geq 80\%$ of HIT sessions), and so their views may not necessarily be representative of other intervention participants, particularly those who did not adhere to the intervention. Focus groups were conducted post-intervention and so stakeholder opinions were not considered during intervention development. As formative evaluation is an integral part of intervention development (Bauman & Nutbeam, 2013; Craig et al., 2008), it is critical to assess the acceptability and feasibility in the setting in which it will likely be implemented, with key stakeholders and potential participants alike, before the intervention is fully designed and implemented. The aim of this study is to explore the acceptability and feasibility of workplace-based HIT. The study objectives are to a.) use qualitative focus group and interview data to formatively evaluate a proposed workplace HIT trial (BE@Work) in workplaces in the Teesside area of North East England, and b.) to use the findings of the formative evaluation to further develop the BE@Work trial protocol.

4.2 Method

The reporting of this study adheres to the consolidated criteria for reporting qualitative research (COREQ) (Tong et al., 2007). Ethical approval was granted by the School of Health and Social Care Research Governance and Ethics Sub-committee from

Teesside University, study number 053/17. Participation in the study was voluntary and all participants provided written informed consent prior to data collection.

4.2.1 Study Design

This study utilised a qualitative study design where focus groups with employees and one-to-one interviews with management representatives were conducted. Following guidance on the reporting of qualitative research (Tong et al., 2007), brief details regarding the researchers involved in this project will be provided here, to provide insights into the perspectives they may bring to the work. The thesis author was the lead researcher and was a female postgraduate student with lived experience of HIT. The thesis author had 2 years of previous qualitative research methods experience, had received appropriate training in qualitative research methods and conducted all interviews and data analysis. A second male graduate research student, with expertise in the prescription and delivery of HIT, conducted peer-debriefing during theme development.

4.2.2 Recruitment and participants

The study was conducted in two of the five local authorities in the Tees Valley region of North East England (Redcar & Cleveland and Stockton-on-Tees). Data from the most recent health profiles from both regions indicate that overall health is poorer than the English average (Public Health England, 2017). For example, life expectancy is between 1.4 and 1.7 years lower for residents of these regions than the English average (Public Health England, 2017). Additionally, CVD mortality in both regions is considerably worse than the English average (85.1 and 94.5 per 100,000 deaths in Stockton-on-Tees and Redcar and Cleveland respectively, English average 73.5 per 100,000 deaths) (Public Health England, 2017). In addition, the Index of Multiple Deprivation indicates that Redcar & Cleveland and Stockton-on-Tees are within the 10-20% most deprived regions in England (Office of National Statistics, 2015). Furthermore, although the Health Survey for England found that 66% of men and 58% of women met current physical activity guidelines in England overall, compliance was much lower in areas of high deprivation (NatCen Social Research, 2017). As residents of Redcar & Cleveland and Stockton-on-Tees have lower life expectancies, higher CVD mortality rates and are likely to participate in less physical activity than residents in other areas of England, the implementation of cardioprotective health promotion programmes in the Tees Valley region is vital. Furthermore, although it could not be known at the time of planning the present study exactly which organisations would participate in the proposed BE@Work trial, these areas were

targeted for recruitment because it was envisaged that the proposed intervention would be implemented in an organisation within this geographical area.

The thesis author contacted Local Authority Health Leads within the Teesside area, with preliminary study information. The Local Authority Health Leads acted as gatekeepers and distributed this information to organisations they had established contacts with in the area. After initially expressing interest to the Local Authority Health Leads, Workplace Health Leads from interested organisations were sent information packs including participant information sheets (Appendices A and B) to be distributed to employees by their Workplace Health Leads.

Participant inclusion criteria was any employee of the participating organisations aged over 18 years. Employees were defined as any paid member of staff from the organisations involved in the study. To understand all working conditions in the organisations involved, no restrictions were placed on length of employment or employment status (e.g. part time/ full time/ casual employment).

It was also necessary to explore organisational perspectives of the proposed intervention, so management representatives were approached separately for recruitment. Management representatives were defined as any employee in a senior management position within the organisation. Employees and management representatives were separated for the purpose of data collection to prevent participants feeling unable to discuss their opinions in the presence of staff of differing levels of seniority.

Exclusion criteria were inability to speak fluent English and inability to provide informed consent. Interested employees registered their interest over email and/or phone call with the thesis author. A focus group or interview was then scheduled at the workplace of the participants during their normal work hours. Across six organisations from the Teesside area of North East England, 42 participants were recruited, using convenience sampling (Robinson, 2014). Organisation and participant characteristics are presented in Table 12.

Table 12 Organisation and participant characteristics

Study Site Number	Type of organisation	Total number of employees	Number of focus groups (n=participants)	Management interview	Mean age (\pm SD)	% female
1	Charitable organisation	45	1 (n=3)	n=1	48 (\pm 7)	100
2	Charitable organisation	10	1 (n=5)	No response	43 (\pm 9)	80
3	Charitable organisation	12	1 (n=4)	n=1	32 (\pm 10)	100
4	Local authority	500*	3 (n=12)	No response	40 (\pm 5)	50
5	Tertiary institution (support staff)	130	1 (n=7)	n=1	52 (\pm 5)	100
6	Tertiary institution (one school within institution (academic staff))	222	1 (n=7)	n=1	44 (\pm 14)	30
* within the main office site						

4.2.3 Procedure

Data collection was conducted between June and November 2017. Participant characteristic information was collected prior to the focus group or interview. Eight focus groups were conducted with 38 employees, with 3 to 7 participants per focus group (see Table 12). The focus groups provided an opportunity to elicit opinions via group discussion rather than individual reflection. Focus groups were conducted by the thesis author and a second researcher was present as a secondary moderator for the first focus group, but it was not logistically possible to have a secondary moderator at the subsequent focus groups. Focus groups were between 34 to 64 minutes in length and were audio-recorded and transcribed verbatim. This resulted in 140 pages of focus group transcriptions (Arial, font size 12, 1.5 line spacing).

Focus groups were proposed with management representatives but due to time commitments the organisations requested one-to-one interviews, where one member of the management team could speak on behalf of their organisation. A management representative from four of the organisations involved in the study participated in a one-to-one interview. Management representatives from the remaining two

organisations (study sites 2 and 4) did not respond to recruitment attempts. Management interviews were between 21 to 33 minutes in length and were audio-recorded and transcribed verbatim. This resulted in 35 pages of interview transcriptions (Arial, font size 12, 1.5 line spacing).

4.2.4 Instrument

The focus group interviews explored the acceptability of HIT as an exercise modality conducted in the workplace and the feasibility of the proposed workplace HIT trial. The employee focus group schedule can be found in Appendix C. Management representative interviews focused on the organisational perspectives of the acceptability and feasibility of the proposed workplace HIT trial and the interview schedule can be found in Appendix D.

Semi-structured focus group and interview schedules were developed and piloted on a group of employees from a university prior to data collection. Slight changes were made (the questions were reordered) to improve the flow of the focus group or interview. Due to limited time availability with senior management representatives, questions pertaining to the acceptability of HIT in the workplace were removed, so that management interviews could focus on the feasibility and logistics of the proposed programme.

4.2.5 Definition of HIT

Participants were provided with the following definition of HIT:

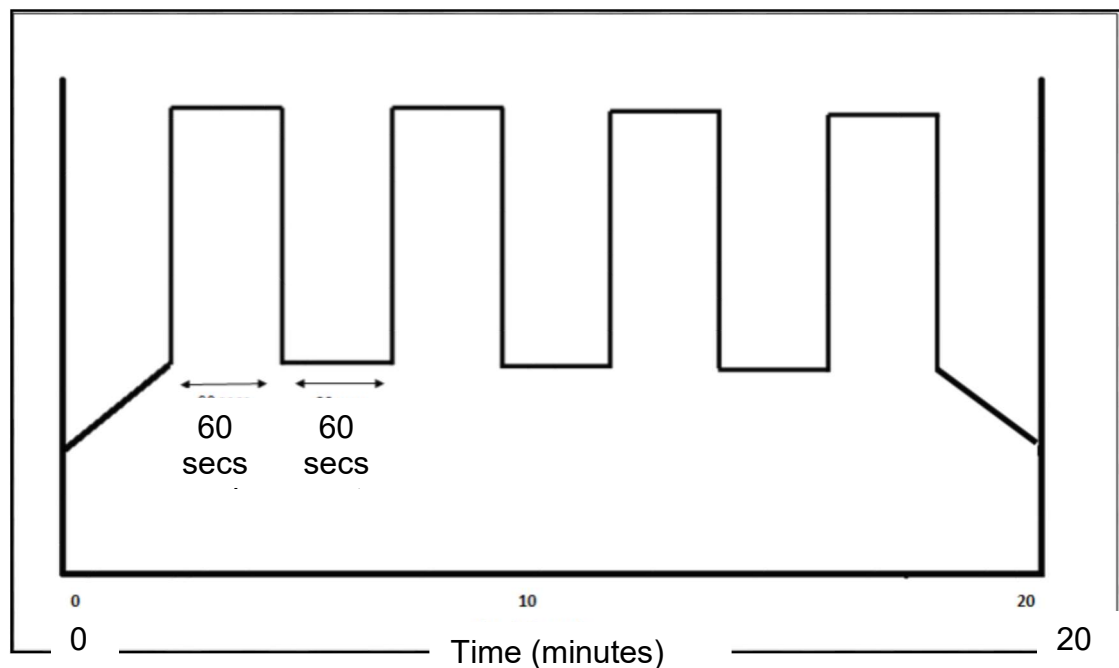
“HIT is a type of exercise where you do bursts of exercise, always followed by a rest break, repeatedly. During the bursts of exercise, you work as hard as you can, and you always get a break afterwards. In the bursts of exercise your heart rate would increase, you would feel out of breath and you wouldn’t be able to speak in full sentences. By the end of each burst you would need a rest break to catch your breath and be able to speak in full sentences.

HIT will look different in different people. For example, for some people “working as hard as they can” is walking as fast as possible, and for others it is running as fast as possible. Both people would be working at high-intensity, it is just that the intensity “looks” different depending on their fitness levels and ability.”

This definition of HIT was developed with several considerations in mind. Firstly, the generally accepted definitions of HIT (Fox et al., 1973; Gillen & Gibala, 2014) were

used to describe the intermittent nature of the exercise. Secondly, the criterion for high-intensity exercise in HIT protocols is generally accepted as $\geq 85\%HR_{max}$ (Weston et al., 2014a); therefore, it was explained to participants that their heart rate would substantially increase during the high-intensity bouts. The “talk test” is a subjective assessment of exercise intensity that has been used as a surrogate marker of high-intensity exercise (Goode et al., 1998). It was explained to participants that they would be out of breath and unable to speak in full sentences by the end of each high-intensity bout. The final paragraph of the HIT definition describes that the intensity of HIT is relative to the fitness of the participant and HIT can be enacted differently depending on an individual's fitness level (Biddle & Batterham, 2015). The definition of HIT was accompanied by Figure 9, demonstrating the HIT protocol that would likely be used in the BE@Work trial. This model constitutes four 60-second-high-intensity bouts interspersed with 60 seconds of rest. Including a 5-minute warm up and 2-minute cool down this model takes 15 minutes to complete. The rationale for this HIT protocol will be described subsequently.

Figure 9 Schematic of an example HIT protocol



4.2.6 *The proposed BE@Work trial*

The proposed BE@Work trial described to participants was a HIT intervention where three 20 to 30 minute exercise sessions would be delivered in or close by to the workplace for a duration of 6 to 10 weeks, based on the length of previously published workplace HIT interventions shown to improve CRF (Allison et al., 2017; Shepherd et al., 2015).

As previously described in Chapter Two, to date no “best practice” HIT protocol has been identified (Gibala et al., 2012). When designing HIT programmes, researchers could base their protocol selection on a multitude of factors (Buchheit & Laursen, 2013a). Given that the purpose of this PhD programme was to implement a HIT trial into workplaces with a multitude of time constraints, the time efficiency of the protocol to be used was of paramount importance. When considering the future scalability of a workplace HIT intervention, it is likely that funding for exercise equipment would be limited, and therefore exercise modality choice was a limiting factor in this programme of work. With these constraints in mind, a commonly utilised HIT protocol is a Wingate style protocol which involves 4 to 6, 30 second bouts of supramaximal cycling (Burgomaster et al., 2005). Wingate style protocols are extremely demanding and require long rest periods, which increase the total exercise session length. Additionally, they may not be practical or tolerable in untrained populations (Gibala et al., 2012). Given that the exercise modalities (described subsequently) proposed for the present study could not be manipulated in the same manner as a cycle ergometer to elicit a supramaximal stimulus, a longer duration high-intensity bout may be required to elicit a high-intensity response (e.g. $\geq 85\%$ of age predicted HR_{max}). Based on a low volume HIT protocol utilised by Little et al., (2010), the length of the high-intensity bouts was set at 60 seconds, with 60 seconds of rest. The number of high-intensity repetitions described in the HIT model in Figure 9 was based on a low-volume HIT protocol that was successfully implemented into a school-based HIT intervention (Weston et al., 2016a). The high-intensity protocol was preceded by a standardised 5-minute warm-up and was followed by a 2-minute cool down. The total exercise session time for the proposed HIT protocol including warm-up, cool down and recovery periods was 13 minutes.

Exercise modality examples provided to participants were walking, jogging, running, skipping, non-contact boxing (hence forth called boxing), stair stepping, stair climbing and dance. This exercise modality selection provided to participants in the present study was based on previous workplace exercise interventions in the case of walking,

jogging and running (Brown et al., 2014; Sertel et al., 2016), a previous multi-activity HIT programme in the case of boxing and dance (Weston et al., 2016a), a previous workplace HIT programme in the case of stair climbing (Allison et al., 2017) and a previous vigorous intensity workplace exercise programme in the case of stair stepping (Mair et al., 2016). Furthermore, exercise modalities were required to be scalable to various fitness levels and previous exercise participation, as well as requiring limited equipment. It was explained to participants that the modalities were examples and other modalities could be discussed.

The purpose and format of a randomised controlled trial (RCT) was described to participants, and participants were informed that various health and fitness variables would be measured both before and after the intervention. The outcome variables described to participants were cardiorespiratory fitness, muscular fitness, waist circumference, blood pressure, blood lipids and glucose. The purpose of this was to evaluate the acceptability and feasibility of assessing these outcome variables in a workplace setting, and to ascertain if additional outcome variables were perceived as relevant to employees or organisations.

4.2.7 Analysis

Analysis followed Braun and Clarke's (2006) six steps to thematic analysis, using the software package NVivo 10. This form of analysis has been used successfully in similar formative research undertaken during the development of a school-based HIT trial (Taylor, 2014). The first step in thematic analysis is familiarisation with the data which included both transcription and re-reading the transcripts by the thesis author. Secondly, transcripts were read line-by-line to generate initial codes. A deductive-inductive approach was used in the analysis of the data. Deductive thematic analysis refers to an analytical approach that is driven by either a theoretical framework or by predefined areas of interest (Braun and Clarke, 2006). Because the aim of this study was to develop an understanding of the feasibility and acceptability of various BE@Work programme elements, a predefined coding framework was developed in the first instance and focused on important intervention elements as demonstrated in Table 13. An inductive approach means that themes are developed from the data themselves, without the use of predefined analytical or theoretical frameworks (Braun and Clarke, 2006). The use of both inductive and deductive approaches allowed the logical organisation of large volumes of qualitative data in the first instance, followed by data-driven development of candidate themes. After codes were deductively organised, based on the pre-defined coding framework (Table 13), the third step of

searching for themes was conducted within these broad groupings. Codes were inductively clustered with similar codes into candidate themes. The thesis author discussed the coding process and rationale for the decisions with another researcher, providing confidence in the procedure (Smith & McGannon, 2018). In the fourth step, the thesis author conducted an iterative process of reviewing and refining the themes to ensure coherence within and differences between the themes. The thesis author then presented the thematic map to a second researcher who asked the thesis author to justify the rationale, rigour and consistency of the analysis in a process known as peer-debriefing (Smith and McGannon, 2018). In the fifth step, the thesis author then conducted an iterative process of defining and naming each theme. The themes were then presented with illustrative quotes (Braun & Clarke, 2006).

Table 13 Coding Framework

Code	Description
Barriers	Elements of participants working environment that are a barrier to an employee's ability to participate in exercise in the workplace
Facilitators	Elements of participants working environment that facilitate an employee's ability to participate in exercise in the workplace
Intervention structure: Frequency	Views and opinions on acceptability and feasibility of timing of frequency of exercise sessions in the workplace
Intervention structure: Time	Views and opinions on acceptability and feasibility of timing of exercise sessions in the workplace
Intervention structure: Length of exercise sessions	Views and opinions on acceptability and feasibility of length of exercise sessions in the workplace
Intervention structure: Length of the intervention	Views and opinions on an acceptable and feasible intervention length
Intensity: before definition	Views and opinions of HIT before definition of HIT was provided
Intensity: after definition	Views and opinions of HIT after definition of HIT provided
Exercise modalities	Views and opinions on acceptability and feasibility of different modalities of HIT in the workplace

Overall programme considerations: Group based vs. individual exercise	Views and opinions on the acceptability and feasibility of group based exercise or individual exercise sessions in the workplace
Overall programme considerations: Location of exercise	Views and opinions on the feasible exercise locations within/ nearby to the workplace
Overall programme considerations: Outcome measures	Views and opinions on acceptability and feasibility of suggested outcome measures
Overall programme considerations: Programme promotion	Views and opinions on how to promote a workplace exercise programme within the workplace

4.3 Results

Descriptions of the main themes from the employee focus groups are presented in the following section, with direct participant quotes relating to each theme presented in the corresponding tables.

4.3.1 Employee Focus Groups: Barriers and facilitators

Participant quotes relating to the themes barriers and facilitators are shown in Table 14. The most commonly reported barrier to workplace exercise participation was 'lack of time'. Workload commitments were perceived as high and participants reported that their work took priority over other activities during the working day. Family or caring commitments were reported as barriers which would prohibit them from participating in exercise either before or after work. A lack of shower facilities within the workplace was another commonly reported barrier. Participants reported that a culture of long working hours within their workplace could make individuals feel unable to participate in exercise during work hours.

The most commonly reported facilitator for workplace exercise participation was flexible working conditions and autonomous workload planning. All but one of the participating organisations operated flexible working policies where employees were permitted to arrange their own working schedule between 7am and 7pm. Social support was also a facilitator for workplace exercise. Participants reported that if they were familiar with other people in a group-based exercise session, they would be more likely to attend and social support was perceived as particularly important for inactive individuals. Lastly, participants reported that a workplace exercise programme should be enjoyable.

Table 14 Participant quotes relating barriers and facilitators

Theme	Quotes
Barriers	<p>Lack of time: <i>"I can't remember the last time I had a lunch break. Or not sat at my desk eating"</i>. Male, study site 4.</p> <p>Family commitments: <i>"I was going to start rowing. But I can't get child care to cover when the rowing classes are. So, I can't do that"</i>. Female, study site 4.</p> <p>Lack of shower facilities: <i>"Cos we've got like an exercise bike now ...but they don't get used really. Mainly because we have got no showers I would say"</i>. Female, study site 1.</p> <p>Culture of long working hours: <i>"...the culture of working such long hours as well. I know we have these arbitrary cut points but sometimes I mean I have worked 70-100 hour weeks. And that at one point became kind of the norm. And when you are working those kind of hours fitting anything else in that isn't eat and sleep is actually really difficult"</i>. Female, study site 6.</p>
Facilitators	<p>Flexible working hours or autonomous workload planning: <i>"In this sector we are actually very autonomous in our time management and we all manage our diaries independently. We have some fixed commitments, where we have to be at certain places at certain times... And I have the luxury of being able to be flexible with that, that's why I can be here this afternoon. I don't have to go and ask if I can come to this [focus group]. So I think within this sector there is some flexibility built into it. In other sectors people have to ask to leave the workplace, ask to get permission if it's something unusual to leave the workplace maybe for a lunch break"</i>. Male, study site 6.</p> <p>Senior management encouragement: <i>"I think it needs to be officially sanctioned by the senior management of this organisation. In response to one of the staff surveys, one of the top things in their action plan was going to the gym more so if there are going to be these supervised group or class sessions I think the invitation for them to go out should come from a senior management representative. This is them saying you have my permission as the senior manager of this organisation to go and do this. Rather than 'oh try and fit it in as best as you can'. Yeah? So basically put their money where their mouth is"</i>. Male, study site 6.</p> <p>Social support and enjoyment: <i>"Sometimes like you become a really good friend with the colleagues and you know that they will never go for a run for whatever reason. But if you make it more fun and actually get them to... encourage them to come along and have a go. And if they try it and like it, they might continue"</i>. Female, study site 4.</p>

4.3.2 Employee Focus Groups: Intervention structure

Participant quotes relating to intervention structure themes are shown in Table 15.

4.3.2.1 Frequency

Although the majority of focus group participants agreed that thrice weekly exercise sessions would be acceptable, participants from one study site reported that twice

weekly would be more acceptable initially, with the possibility of increasing frequency to three sessions per week after a number of weeks.

4.3.2.2 Timing of exercise sessions

As previously mentioned, many of the participating organisations operated flexible working policies. Although participants said this may facilitate individual workplace exercise capacity, they discussed that group-based exercise sessions at a single time point would likely be poorly attended. Participants suggested that multiple exercise sessions should be offered throughout the day, which was popular with many other participants when described by the thesis author in subsequent focus groups. Participants expressed a preference for exercise sessions before work, at lunch time and after work to avoid the intervention impeding on work commitments.

4.3.2.3 Length of exercise sessions

Participants across all groups explained that they were entitled to a 30-minute break in the middle of the day and so exercise sessions were required to fit within this timeframe. It was perceived that 60-minute exercise sessions would be too time consuming.

4.3.2.4 Length of the intervention

Most participants reported that the proposed intervention length of 6 to 10 weeks was acceptable; but there was no consensus between participants in terms of an exact preferred duration.

Table 15 Participant quotes relating to intervention structure

Theme	Quotes
Frequency	<i>"I don't know if it would be an ongoing thing after the trial type thing. But then maybe up it [increase the frequency of exercise sessions] later on to three. See how it's going first and then say right would you be interested in doing it three times per week".</i> Female, study site 5.
Timing of exercise sessions	Multiple facilitated sessions preferred rather than a single session: <i>"I think you have to factor in your workplace commitments. And the nature that your day can change from what you come into and what it becomes. I think the danger is if you offer one session a week, say on a Wednesday at 1 o'clock. People can make it but then something might happen and they drop off and might make some weeks and not others. I think it has to be sessions that you have the opportunity to drop in. It needs to be three sessions per week and you've got the opportunity to drop into a number of sessions over the week".</i> Male, study site 4.
Length of exercise sessions	60 minute session too long: <i>"I think an hour is a big commitment at the beginning or the end of the day".</i> Female, study site 1.

	No consensus on exact acceptable length:
	<i>“See I think that sounds too long, 10 weeks. I think 6 weeks, but that’s just me”.</i>
Length of the intervention	<i>“But we would just be getting fitter then [6 weeks]. We would just be starting to see the effects”.</i>
	<i>“Well what’s the magic 10, why not 7, why not 12?”</i>
	<i>“Yeah but we don’t know the research behind it. You might be able to achieve the same results in 6 weeks, you don’t know”.</i>
	-Females, study site 3.

4.3.3 Intensity: views and opinions of HIT

Participant quotes relating to the following theme are presented in Table 16. Before the definition of HIT was provided, participants were asked about their knowledge of activities that they perceived to be HIT. Although it was outside the scope of this study to ascertain the exact number of participants in each category, some participants were unaware of HIT, some were aware but had not participated in HIT, and others had previously or currently participated in HIT, thus demonstrating a broad range of experiences within the sample. Those who had some knowledge or had participated in HIT previously reported that they had initially heard about HIT via “celebrity” exercise videos or group exercise classes involving repeated high-intensity bouts of exercise on treadmills or cycle ergometers and circuit style exercise classes.

Participants felt that HIT was physically demanding and resulted in sweating, an increase in heart rate and feelings of breathlessness. Examples of exercise modalities that participants identified as HIT exercises were burpees, squat jumps or sprinting. Although infrequently discussed, some participants recognised the intermittent nature of HIT and that HIT could be completed in a shorter amount of time compared with traditional exercise modes. Participants perceived that HIT could elicit weight loss and “burnt calories” more effectively than traditional moderate intensity continuous “cardio” exercise modalities.

Some participants reported that HIT was not suitable for all individuals and one participant perceived that HIT conferred a risk of musculoskeletal injury. One participant expressed the view that HIT may not be appealing to all individuals based on his experience attending what he thought were HIT-type group exercise classes at his local gym where there was a high turnover of participants.

After participants were provided with the definition of HIT, discussion of the acceptability and feasibility of participating in HIT in the workplace continued. The

intermittent nature of HIT was received positively by participants because the rest breaks were reported as sufficient to permit recovery. Because of the intermittent nature of HIT, participants perceived the intensity to be more manageable than initially discussed. Participants felt that because intensity of HIT was relative to each individual, HIT would be manageable for less physically fit individuals, which was in contrast to their opinion before the definition was provided. Additionally, given the short duration of the HIT protocol that was provided, participants reported that HIT would be a feasible form of exercise given the limited time frame available in the workplace. One participant discussed that HIT has a “time/intensity trade off”, where although the exercise may be physically demanding, the lower time commitment required and positive feelings on completion of HIT may negate discomfort felt during exercise.

Of particular importance to workplace HIT interventions, personal hygiene was reported as a major barrier for participating in HIT in the workplace. Participants felt that exercise at high-intensity would result in sweating, so a change of clothes and shower would be required before they could return to work.

Table 16 Participant quotes relating to views and opinions of HIT

Theme	Quotes
Intensity: before definition	<p><i>“I don’t know jogging on the spot with your arms going up and down getting your heart rate up, warming your muscles up, getting your heart rate going”</i>. Female, study site 1.</p> <p><i>“So one minute is really fast, fast, race your heart rate and then rest for 30 seconds or another minute and then to do that again”</i>. Female, study site 4.</p> <p><i>“It’s better for condensing all of your time down and not spending two hours in the gym and getting as much out”</i>. Female, study site 2.</p> <p><i>“And I find that it is a good fat burner and it doesn’t last too long, it’s not prolonged”</i>. Female, study site 4.</p> <p><i>“...I would be very very concerned about trying to push it too far too fast, I would have to really work up to any sort of high-intensity work very slowly now. Because of the physical risks... I am aware that my knees are full of sand these days, so I don’t want to actually damage my knees...I don’t think I have actually got an injury I just don’t want to make whatever is happening, which is probably something to do with arthritis, to get any worse”</i>. Male, study site 6.</p> <p><i>“I’ve been doing my metafit classes for donks [a long time]... And I know if you see anyone start new and they don’t come back. It’s the same people... same 12 who have been going there for a couple of years every week, interspersed with people who come and go, come and go. I don’t think... it’s definitely not for everyone”</i>. Male, study site 4.</p>
Intensity: after definition	<p><i>“And then like you say you get a rest to get your breath back and your oxygen levels back up *laughs*. So that gets a tick”</i>. Female, study site 3.</p>

"It doesn't last long so you can give your all, flat out, knowing that you have got a recovery afterwards". Female, study site 4.

"The good thing about it is that you can tailor it so that if you have limitations... presumably you can develop bursts to be able to do something that you can manage. As long as it is something that you can do and you do it as hard as you can, doesn't it? That's the key to it isn't it?". Male, study site 4.

"I think people would do that. Because the trade-off is, it's not comfortable while you are doing it, but when you asked us why we didn't exercise we all said time. And the benefit of this is that you do feel quite good after it and you can do it... give up 10 minutes maybe to do it". Male, study site 6.

"Assuming you break a sweat you will need to have a shower, get changed into and out of the clothes that you would exercise in". Male, study site 5.

4.3.4 Exercise Modalities

4.3.4.1 Walk/ jog/ run

Participants discussed that walking, jogging and running would be feasible exercise modalities for a range of fitness levels. This perception was because most participants were aware of previous workplace walking or running initiatives either in their current or previous workplaces. Based on the definition of HIT provided by the thesis author, participants acknowledged that for some individuals, power walking would elicit a high-intensity response, whereas for others running would be required. Although this modality was perceived as simple to understand, one participant reported that not all individuals may enjoy running. It was also acknowledged by participants that this activity would require outdoor space and would only be feasible during fine weather.

4.3.4.2 Skipping

Many participants noted that skipping was an exercise they had frequently participated in as a child but had not tried for some time, although it was identified as a novel and fun exercise. Some participants noted that to elicit a high-intensity response, a level of skill would be required to continuously skip without tripping on the rope.

4.3.4.3 Boxing

Participants discussed that boxing was a novel and interesting form of exercise, which was a good "stress release" and would be fun because it required partner work. It was noted that limited space would be required to participate in boxing, which was perceived as important for workplace exercise. Participants felt that some individuals may not enjoy the technical or physical nature of boxing, especially with a partner they did not know or feel comfortable with. Another participant from the same focus

group reported that boxing might be an activity that people would enjoy after trying it once.

4.3.4.4 Stair stepping/stair climbing

Stair climbing or stair stepping were perceived as feasible exercise modalities because they were simple, required no prior exercise knowledge, and could be completed using the facilities available within the workplace. Although, some participants expressed concerns in relation to the safety of fast paced stair climbing.

4.3.4.5 Dance

Perceptions regarding the acceptability and feasibility of dance as an exercise modality were polarised. Although some participants reported that dance would be particularly enjoyable and also suitable for inactive individuals, others reported that if dance were included in an intervention they would decline to participate in the intervention as a whole. Most participants agreed that some level of dance knowledge or experience would be required to permit high-intensity dance exercise. Additionally, it was noted that dance would be difficult to facilitate in some workplaces due to the requirement for music which may disrupt the working environment.

4.3.4.6 Other activities

Yoga was discussed as a preferred exercise modality by some participants; however, it was explained by the thesis author that the intention was for the exercise to increase the heart rate which would not likely be possible with yoga. The participants did not express an interest in any other exercise modalities during the focus groups.

4.3.4.7 Choice and variety

Despite individual differences in opinions on the acceptability and feasibility of each of the previously reported exercise modalities, all participants agreed that a choice of modalities should be available both between and within sessions. Participants discussed that individual preferences should be taken into account to facilitate enjoyment for a range of individuals. A choice of a variety of exercise modalities between sessions was perceived to be more engaging. Lastly, many participants noted that some individuals may have physical limitations that prohibit participation in certain exercise modalities.

Table 17 Participant quotes relating to exercise modalities

Theme	Quotes
	<p>Walk/ jog/ run: <i>“Running and jogging would be easier to understand it [the exercise modality], but at the same time people may not like it because they don’t like to run.”</i> Female, study site 4.</p> <p>Skipping: <i>“You would need to be quite a skilled skipper to be able to go at full intensity for a minute wouldn’t you? So a lot of people wouldn’t be able to be to complete it”.</i> Male, study site 5.</p> <p>Boxing: <i>“The fact that you have got away from your desk and you have gone and punched the living daylights out of a punch bag, you’ll probably feel a whole lot better in the afternoon.”</i> Male, study site 5.</p> <p><i>“I’m not sure if it would be too technical. I just think some people might be a bit put off if they haven’t done that type of thing before. If you said you haven’t exercised for years you come here and we are going to do some non-contact boxing, get the pads on, get a partner. Some people wouldn’t want to do that.</i> Female, study site 4.</p> <p><i>“I think as well, it’s one of those things. I had never really done it before and my son goes to a kick boxing class. And one of the guys was there and he asked would I mind holding some pads for him, and then when you start hitting them you think ‘oh this is actually quite good you know’, and you work up a hell of a sweat doing it.</i> Male, study site 4.</p> <p>Stair stepping/stair climbing: <i>“I think everybody, even if they are not active at the moment, they would know what stair stepping is. You’re not being put off by ‘I can’t run’ or ‘I can’t box’ or anything like that. But everybody could do that one”.</i> Male, study site 5.</p>
Modality	<p><i>“The first thing I think of is the safety issues. Because stairs is fantastic totally, and even though we have the facilities, it’s not easy if you can run up. And the traffic of people as well. And also I don’t think that stairs is safe for me, anyway”.</i> Male, study site 4.</p> <p>Dance: <i>“I think though, if you are a beginner because that has been around for a while a lot of people, they know what it is... and they know what they are going to do. And I think they would be more inclined to go and do something like that than boxing. I’m just thinking about some of the ladies in my office that would probably go along to that because they know what to expect”.</i> Female, study site 4.</p> <p><i>“That is my idea of hell. I would never go anywhere near it... I have never been able to dance I have my own weird sense of dance and I cannot put steps to music at all”.</i> Male, study site 5.</p> <p><i>“It might be more, I’ll use the word disruptive because our conference rooms... you wouldn’t be able to accommodate that and obviously booking any bigger rooms would be difficult I guess. So the location of that one may be a problem”.</i> Female, study site 4.</p> <p>Choice and variety: <i>“So you say you’ve got your four, minute intervals... you can fill the four minutes with the things you like doing. You might one day choose to do three boxing things or one of each on one day, so you get variety. So for somebody who can’t skip very well yes they are not going to get much of a workout because you are forever faffing about with the rope. Whereas if you can skip proficiently you know, I still think a minute of skipping is hard work. Other people might disagree. Obviously running for a minute is hard work if you make it hard work, going up stairs, I’ve punched</i></p>

a punch bag for a minute that is crucifying. So it would all do the job. It's just having the choice of which one you want to do". Male, study site 5.

"If you sold it to me that we just did stair stepping 3 times a week for 8 weeks I would probably get bored. So I think it would be interesting to give different activities to do as part of a programme". Female, study site 4.

"But classically someone who has got a bit of a dodgy knee or dodgy hip could come to this and they know their body better than anybody else. They could say well I will do that one or that one because I'll be alright with it, but my knee won't let me do that one so I will leave it out [and] I will do the others. Male, study site 3.

4.3.5 Overall programme considerations

Participant quotes for the themes relating to overall programme considerations are shown in Table 18.

4.3.5.1 Group based vs. individual sessions

Overwhelmingly, group-based exercise was the preferred format for a workplace HIT programme because participants perceived that it would increase motivation and compliance and provide an opportunity for networking and team building. Many participants acknowledged that it would be important for some individuals to have the option to exercise individually, if preferred.

4.3.5.2 Location of exercise

It was important to participants that workplace exercise sessions were facilitated as close to their place of work as possible. Outdoor sessions were perceived positively because they would allow for a break from the indoor office environment but only if the weather was fine.

4.3.5.3 Outcome variables

The measurement of the various physical fitness and cardiometabolic health outcomes in the workplace was perceived as acceptable by participants and no negative opinions were expressed regarding any of the outcome variables described. Participants noted that the outcome variables were wide ranging and included important aspects of health and fitness. Many participants noted that a measure of mental health or wellbeing would be a pertinent measure that should also be included.

4.3.5.4 Promotion of a programme

Participants from study site 4 discussed offering “taster sessions” as a method of programme promotion. They suggested that during taster sessions potential participants could try a HIT session before they decided whether to participate in the full programme. This proposal was popular with participants in subsequent focus groups when described by the thesis author.

Table 18 Participant quotes relating to overall programme considerations

Theme	Quotes
Group based vs. individual exercise	<p>“I don't think I would find it particularly motivating myself to just pop over here and do something myself alone. I'd be probably, I would rather do it with a group. So that we are all together, that's my view”. Female, study site 1.</p> <p>“I mean in so many ways we hear about the sense of belonging in the organisation and the doing things together and all that kind of thing. And that (group based programme) could be something that helps facilitate that”. Female, study site 4.</p> <p>“[some people] may not want to do it with a bunch of other people. And I think that is the other thing when you look at things you can offer, is offering collective things [exercise sessions] but individual things [exercise sessions] as well”. Female, study site 4.</p>
Location of exercise	<p>“As close to work as possible...no travel required”. Female, study site 4.</p> <p>“We went to go out for one (a walk) didn't we once? We were going to go around here, and we got outside and it started pouring down with rain and everybody just did an about turn”. Female, study site 1.</p>
Outcome measures	<p>Mental health outcomes important: “I just want to go off how I felt. How I feel is most important to me....I used to really care about how I looked but at the minute it's just how I feel. If I feel more... if I have more energy, if I am enjoying work more, if I can go home after a shift and not feel like the walking dead. And still have energy to run after a baby, that's what is important”. Female, study site 3.</p>
Programme promotion	<p>Taster session: “Those who are familiar with exercise probably won't mind turning up to a class blind. But when you are introducing something new, they [people unfamiliar with exercise] need that bit of reassurance. Study site 4.</p> <p>“And it's hard to get people to sign up for like an 8 week programme from scratch.” Female, study site 4.</p>

4.3.6 Management Representative Interview Results

Descriptions of the main themes from the management interviews are presented in the following section, with direct participant quotes relating to each theme presented in the corresponding tables.

4.3.6.1 Barriers and Facilitators

Management representative quotes relating to the themes of barriers and facilitators are shown in Table 19.

Employees and management representatives discussed similar barriers to workplace exercise participation. In addition to the barriers discussed by employees, senior management representatives reported that despite their support for workplace exercise programmes, work commitments would always be prioritised over exercise participation. They also perceived that although they would support a potential workplace exercise programme, the support of middle management would be critical for the success of such a programme, as permitting staff to attend exercise sessions would be at the discretion of middle management staff.

In addition to the facilitators described by employees, senior management representatives felt it was important that they participate in workplace health programmes with their employees, to promote employee participation.

Table 19 Management representative quotes relating to barriers and facilitators

Theme	Quotes
Barriers	<i>“Possibly their manager letting them go, if it’s not within a lunch break or something like that. So that might be one thing. Workload... what work demand they have got on at the moment”</i> . Male, study site 6.
Facilitators	<i>“I took part when I could, when I was here, and I thought that was important that I took part [in previous workplace activity programme]. Because if I wasn’t willing to take part, then that just gave license to everyone else to say well if you aren’t even going to do it then why should we bother. So I made an effort to take part as much as I possibly could”</i> . Male, study site 3.

4.3.6.2 Intervention Structure

Management representative quotes relating to the theme ‘intervention structure’ are shown in Table 20. Daily exercise sessions were perceived as too time consuming, whereas once weekly sessions were also unacceptable due to the risk of individuals losing interest or being unable to attend one session and then missing a whole week of training. Thrice weekly sessions were identified as feasible. Management representatives were in agreement with employees in that offering only a single exercise session per day would be unlikely to suit the availability of all employees. To promote attendance, multiple sessions at different time points across the day were suggested by management staff. In agreement with employees, management

representatives suggested that exercise sessions should not exceed 30 minutes in length for them to be conducted within the usual midday break from work. Lastly, a short term intervention (6 to 10 week) was feasible and acceptable.

Table 20 Management representative quotes relating to intervention structure

Theme	Quotes
Frequency	<i>"I think if you make it every day I think it might be more difficult. If you only make it once per week people might lose enthusiasm"</i> . Female, Management representative, study site 1.
Timing of exercise sessions	<i>"We can't seem to find a solution for everyone. Because some people want them in the morning, some people want them during the work day, some people don't want them during the work day. Some people won't stay after work, they want to go home. "</i> . Female, Management representative, Study site 6.
Length of exercise sessions	<i>"So we do tend to run a lot of campaigns over lunch time. But then we have got to bear in mind that it eats into their lunch time. So the shorter the better. Because I think staff are more likely to come if it is a shorter session"</i> . Female, Management representative, Study site 6.
Length of intervention	<i>"I think if you make something so far into the future that it is something that they can't see an end to, they will drop out"</i> . Female, Management representative, study site 1.

4.3.6.2.1 Overall programme considerations

Management representative quotes relating to overall programme considerations are shown in Table 21.

4.3.6.2.2 Modality

Management representatives reported that they would be supportive of whichever modalities were preferred by the employees in their organisation. The management representatives expressed a preference for simple exercise modalities that did not require extensive exercise knowledge or experience for a potential programme to be inclusive of all fitness levels and abilities.

4.3.6.2.3 Group based vs. individual sessions

Senior management representatives expressed a preference for group-based exercise within a workplace exercise programme, with the view that this would facilitate camaraderie between colleagues and potentially increase attendance and compliance. It was also perceived that group exercise would provide an opportunity for staff to network with a wider range of employees than in their typical working routines. Management representatives also believed that some individuals may not

feel comfortable exercising with their colleagues and participants should have the option for individual sessions.

4.3.6.2.4 Location of exercise

Many of the management representatives acknowledged that an indoor location would be problematic for the facilitation of multiple exercise sessions across a day, because available space was limited in most of the participating organisations.

4.3.6.2.5 Outcome variables

The measurement of the various physical fitness and cardiometabolic health outcomes in the workplace was perceived as acceptable by management representatives. Additionally, they expressed a desire for the inclusion of a measure of psychological wellbeing and stress levels.

Table 21 Management representative quotes relating to overall programme considerations.

Theme	Quotes
Modalities	<i>“If you are trying to increase physical activity in the workplace we want something that will be suitable for everyone. So it’s trying to make it, for anyone that doesn’t do exercise going from nothing to something that is fairly active and physically exertive, they might think “no I definitely can’t do that”. But if you are only suggesting something that is quite simple to do, something that they can facilitate within their activities of daily living, I think you would get more engagement”.</i> Male, management representative, Study site 3.
Group based vs. individual exercise sessions	<i>“Because all of that builds up relationships in the organisation which is kind of good for networking and people knowing each other. I would really like to see people mix more and get to know people across the organisation”.</i> Female, Management representative, Study site 1. <i>“Personally I think it would be better in groups. But I supposed individual choice would come into it as well. So if somebody felt particularly uncomfortable doing some sort of exercise with fellas or with other people, then I just think it’s their choice at that point.</i> Male, management representative, Study site 5.
Location of exercise sessions	<i>“It’s just finding that location. We do have a real problem with finding room availability.”</i> Female, Management representative, Study site 6.
Outcome variables	<i>“Our biggest reason for absence in the last two years for our staff has been stress, or stress related.”</i> Female, Management representative, Study site 1.

4.4 Discussion

This study aimed to formatively evaluate a proposed workplace HIT intervention named BE@Work. The purpose of formative evaluation is to obtain in-depth information that can be used to guide intervention development (Zinn & Schofield, 2012) and has been described as an integral stage of the intervention development process (Gittelsohn et al., 2006). Formative evaluation has been used successfully in the development of previous workplace health promotion programmes (Ammendolia et al., 2016; Gates et al., 2006).

Firstly, it was necessary to establish employee and management perceptions of barriers and facilitators for workplace exercise. Commonly cited barriers were lack of time or competing work priorities, family or caring commitments, lack of facilities in the workplace and perceived negative workplace culture towards being active in the workplace. Senior management representatives also discussed that the support of middle managers could also be a barrier for employees, despite the support of senior management. Facilitators discussed by employees included flexible working conditions, senior management support to participate in a workplace exercise programme, as well as social support from colleagues. Senior management representatives echoed these facilitators, but also added that it was important that management staff participate in workplace health programmes to support employees. The barriers and facilitators reported by participants in this study are consistent with those reported in previous work exploring these factors in various organisational settings in organisations from both the public and private sectors, including office based organisations and hospitals (Brinkley et al., 2017; Jørgensen et al., 2016; Planchard et al., 2018). Although no new novel barriers to workplace exercise were identified during this study, as barriers and facilitators are likely to be highly context specific (Craig et al., 2008), it remains vital to assess these factors in the setting in which an intervention is to be implemented. The majority of research to date assesses barriers and facilitators to workplace exercise after intervention implementation, usually as part of a process evaluation (Bredahl et al., 2015; Brinkley et al., 2017; Kinnafick et al., 2018). Assessing these factors before an intervention is implemented allows the intervention to be tailored to reduce the impact of barriers and utilise facilitators where possible.

The proposed BE@Work trial was described to both employees and management representatives and the acceptability and feasibility of each intervention element was

discussed. The BE@Work trial will be facilitated by the thesis author, with assistance from a small number of other researchers for baseline and post-intervention data collection only. It became apparent that it would not be feasible to facilitate multiple exercise sessions across a working week at multiple organisations, if more than one participating organisation required exercise sessions at similar times of the day. Although it was not known at the commencement of this study if any of the participating organisations would be able or willing to participate in the BE@Work trial, following data collection the management representatives at Study Site 4 expressed strong interest in participating in the BE@Work intervention. For this reason, the practicalities of the intervention (timing of exercise sessions etc.) were tailored to the requirements of this study site where possible. The following section will describe the modifications that were made to the planned BE@Work trial based on the findings of the present study.

4.4.1 Programme structure

The frequency and length of exercise sessions (20 to 30 minutes, thrice weekly) were perceived as acceptable by the majority of participants and so no changes were planned for this element of the intervention. This is consistent with a process evaluation of a workplace resistance training intervention where participants reported that a similar time commitment was acceptable because it did not impact on work commitments (Bredhal et al., 2015).

Although one group of participants reported that twice weekly sessions would be more acceptable during the early weeks of an intervention, with the option to increase to thrice weekly after a number of weeks, a balance had to be sought between stakeholder requests and evidence-based programming decisions. Given that the majority of HIT trials published to date prescribe thrice weekly HIT (Weston et al., 2014b), as have the two previously published workplace HIT trials (Allison et al., 2017; Shepherd et al., 2015), the decision was made not to change the planned frequency of HIT sessions in the BE@Work trial in this instance.

Due to competing work and family commitments participants in the present study stressed that flexibility in exercise session attendance would be important and they proposed that several exercise sessions be made available throughout the week. Flexibility in structured exercise session attendance was also noted as a facilitator by participants in the process evaluations of both workplace resistance training (Brehdal et al., 2015) and HIT (Kinnafick et al., 2018) interventions. The BE@Work programme will therefore permit employees to self-select any three sessions from four exercise

sessions delivered every day from Monday to Thursday and two sessions delivered on a Friday. The sessions are planned to be conducted during the organisations “flexible hours” (i.e. early morning, lunch time and late afternoon), when work related events were not held, to allow participants to use their flexible working arrangements to attend HIT sessions.

4.4.2 Exercise Intensity: HIT

Views on the acceptability and feasibility of delivering HIT in the workplace were varied. Some participants reported that HIT would be a novel and engaging activity, which was a finding echoed by Kinnafick et al., (2018) in a process evaluation of a workplace HIT intervention. In the present study some participants perceived that HIT may increase the risk of musculoskeletal injury and may not be enjoyable or acceptable for all individuals. One management representative suggested that “physically exertive” exercise may not be favoured by inactive individuals. The appropriateness of SIT (a form of HIT at the highest end of the intensity spectrum) in inactive populations has been criticised previously in academic circles (Hardcastle et al., 2014). However, employees also noted that if the relative intensity of HIT were explained to potential participants of the BE@Work programme, this may alleviate concerns about inactive individuals’ ability to participate in HIT.

4.4.3 Exercise modality

Participants in the present study requested that range of activities within an intervention with stair stepping, stair climbing and boxing the most popular activities. These exercise modalities were perceived as practical and novel within a workplace environment. In previous work, a lack of novel exercise modalities was identified by individuals who chose not to participate in a workplace physical activity programme as a reason for their decision (Edmunds et al., 2013). Although dance was popular with some individuals, as it was highly unpopular with others, and was outside of the knowledge base of the thesis author who would be facilitating the HIT sessions during the BE@Work trial, it was removed from the available modality options. A choice of exercise modalities both within and between sessions was most important for participants in the present study which has also been identified previously in a process evaluation of a workplace resistance training programme to avoid boredom and monotony (Bredahl, 2015).

4.4.4 Group based vs. individual exercise sessions

Within BE@Work, the scheduled exercise sessions will be group based, but participants will be offered the option to request individual sessions outside of these times if preferred. Social support has been identified as an important facilitator for workplace physical activity programmes (Fletcher et al., 2008), which could be promoted through group-based exercise. This may be particularly important because participating in group based exercise in the workplace has been reported to enhance motivation and reduce anxiety related to exercising alone, hence promoting attendance (Edmunds et al., 2013; Phipps et al., 2010).

4.4.5 Location

It was important for participants in the present study that HIT sessions were conducted within, or at least commence from and terminate at their workplace to limit travel requirements. Similarly, an exercise location in close proximity to the workplace was also reported as a facilitator in a process evaluation of a workplace HIT intervention (Kinnafick et al., 2018). The planning of exercise session location for BE@Work will be largely dictated by room availability. The participating organisation will not have a dedicated exercise space and priority for indoor space is allocated for work related activities. For this reason, 70% of the sessions are planned to be outdoor exercise sessions, with the remaining sessions conducted in an indoor meeting room, with furniture removed before each session. The organisation is in close proximity to a range of public parks and footpaths.

4.4.6 Outcome variables

Following examination of senior management teams motivations for participating in workplace health promotion Martinsson, Lohela-Karlsson, Kwak, Bergström, & Hellman (2016) suggested that future studies should include outcome variables that are pertinent to the participating organisation. The physical fitness and cardiometabolic health outcomes suggested by the thesis author were perceived as acceptable by both employees and management representatives. As there is a preliminary body of evidence suggesting that HIT can positively affect mental health outcomes (Bhosle et al., 2018; Lunt et al., 2014), and participants in this study expressed an interest in these outcomes, questionnaire assessed measures of mental health will also be included in the battery of outcome variables (health-related quality of life, psychological wellbeing and perceived stress).

4.4.7 Promotion of a workplace HIT programme

Based on employee feedback, one-off taster HIT sessions will be scheduled in the month prior to BE@Work data collection commencement. Here, taster session participants will have the opportunity to try HIT and the exercise modalities to be conducted in the intervention before the intervention commences. The thesis author will also explain HIT, including a description of the relative intensity of HIT, which was deemed important by participants in the present study. Although the provision of taster sessions has not been reported in any of the workplace physical activity or exercise training interventions previously described in this thesis, taster sessions were reported as an important aspect of successful recruitment to dance-based activity sessions for adolescent girls (Jago et al., 2011). A summary of the modifications that were made to the planned intervention based on the findings of this formative evaluation is presented in Table 22.

Table 22 Modifications made to the planned intervention based on formative evaluation

Intervention component	Initial BE@Work plan	Modifications made	Rationale
Frequency	Three sessions per week	No modifications made	Employees and management perceived this frequency as acceptable.
Time of day	Guided by participant and organisation requirements	Four exercise sessions facilitated Mon-Thurs (8:30am, 12:30pm, 4:30pm and 5pm). Two sessions on Friday (8:30am and 12:30pm) due to a shortened working day on a Friday	No single time point would suit all availability, flexibility needed
Length of exercise sessions	20-30 minutes	No modifications made	Session fit within 30-minute lunch break, perceived as acceptable by employees and management
Length of intervention	6-10 weeks	8 weeks	Short term programme perceived as acceptable to employees and management teams alike
Intensity	HIT	No modifications made to intensity of planned exercise	Important for understanding of HIT

		Relative intensity of HIT explained to potential participants in BE@Work promotional material	
Modality	Walking/ jogging/ running, stair stepping, stair climbing, boxing, skipping, dance	A range of activities within an intervention Stair stepping, stair climbing, boxing	Participants reported that these modalities as most feasible and acceptable Choice in modalities most important
Individual/ Group based	Group based	Group based with option for individual sessions if requested	Group preferred but choice of group/ individual exercise important
Location of exercise	Guided by participant requirements and availability of space in the participating organisation	Meeting room booked in advance where possible However, 70% of sessions conducted outdoors but commencing from the main foyer of the organisation	Outdoor exercise sessions acceptable for participants however location largely based on room availability
Outcome variables	Markers of physical fitness and cardio-metabolic health	Cardiorespiratory fitness; leg extensor muscle power; isometric hand grip strength; systolic and diastolic blood pressure; blood lipids; blood glucose; anthropometry; habitual physical activity; health-related quality of life; psychological wellbeing and perceived stress	All physical fitness and cardiometabolic health outcomes were acceptable to employees and management representatives Employees and management representatives expressed desire to include measure of wellbeing and stress
Promotion of a programme	Guided by organisational facilities and participant suggestions	“Taster” exercise sessions facilitated in the fortnight before baseline data collection Emails sent via all staff email distribution lists Advertisements placed in organisational newsletters and on notice boards in prominent places around the workplace	Participants requested one-off taster sessions of HIT before they decided to participate in the full programme.

4.4.8 Limitations

Although this formative evaluation provided important insights into the specific way in which a novel workplace HIT intervention could be developed and implemented, it is not without limitations. The sample was drawn from organisations where the employees were predominantly office based, and so the findings will likely not extend to a range of other organisational environments such as healthcare or manual labour settings. Although attempts were made by the thesis author to obtain employee information such as the gender balance and average age of employees, the participating organisations were unable or unwilling to provide this information. As such, it is unknown if the sample in the present study were representative of the organisations themselves. Future studies could seek to collect organisational information to further contextualise the recruited sample. Additionally, to be permitted to approach employees for participation in this study, senior management team permission was first required. This may suggest that the participating organisations have a supportive culture or value employee health and wellbeing, which may bias the results of this study. The views of participants in an organisation where health and wellbeing are not considered a priority by management, may have been vastly different to those expressed in the present study. Furthermore, six organisations participated in the present study. Due to the phased nature of the BE@Work programme development and implementation (Craig et al., 2008), it was not known during data collection which of the participating organisations would be willing or able to participate in the programme when development had been finalised. Although immediately following data collection, it became apparent which organisation would be willing to participate in the BE@Work trial, the results of this study may have differed if only the findings from this organisation were considered. Nonetheless, the purpose of this study was to examine the acceptability and feasibility of the BE@Work trial in a range of organisations with as many participants as possible to maximise the range of opinions received. It was not appropriate to disregard the data that was obtained from the five other study sites. Lastly, a convenience sample was used in the present study which has been criticised due to the likelihood of selection bias (Robinson, 2014). Convenience sampling assumes that the members of the target population are homogeneous (Robinson, 2014), that is, that there would be no difference in the research results obtained from a random sample. Given that recruitment material for the present study stated that the purpose of the study was to plan a workplace exercise intervention, it is possible that individuals uninterested in physical activity or exercise would not feel willing or able to participate, resulting in

respondents who are already physically active or willing to participate in physical activity and exercise. Despite this limitation, the intention in this study was to include as many participants as possible, therefore any individual who was willing to participate was invited to attend a focus group or interview, thus maximising the sample size.

The findings of this study demonstrate the vital role that formative evaluation plays in the development of interventions in settings outside of the laboratory. The varying and competing demands of a workplace setting are evident throughout the data presented. If not adequately investigated during intervention development, these factors could impact on the recruitment, implementation fidelity and participant retention of a potential programme and ultimately lead to intervention failure. As such, this study supports calls for detailed intervention planning data to be published alongside intervention protocols (Bauman & Nutbeam, 2013).

4.5 Conclusion

This study represents the first formative evaluation of a workplace HIT trial, using data from focus groups with employees and one-to-one interviews with management representatives of six different organisations to further develop the proposed BE@Work workplace HIT trial protocol. The findings of the formative evaluation informed the logistics and content of the planned BE@Work trial, including the exercise modalities, timing and location of exercise sessions and outcome variables. Participants expressed a range of positive and negative views on HIT but reported that an explanation of the relative intensity of HIT would be important to potential BE@Work trial participants. Participants expressed a preference for exercise modalities to be included in the BE@Work trial including boxing, stair stepping and stair climbing. However, a choice in modalities both between and within HIT sessions was important to participants. According to the MRC framework for intervention development (Craig et al., 2008) following the initial planning stage, the next stage of intervention development is pilot work to further develop the intervention, prior to a larger exploratory study. As such, the following chapter explores the acute physiological and psychological responses to three novel modes of HIT that were selected by participants in the present study.

Chapter 5: Study Three. Acute physiological and perceptual responses to three novel modes of high-intensity interval exercise.

5.1 Introduction

The chronic effects of high-intensity interval training (HIT) on physical fitness and cardiometabolic health variables are well studied. Nevertheless, fewer studies have examined the acute responses to HIT (Olney et al., 2018). As described in Chapter Two, HIT has traditionally been confined to equipment such as cycle ergometers and treadmills. Participants of the formative evaluation of the BE@Work trial presented in Chapter Four identified stair climbing, stepping and boxing as their preferred exercise modalities to be included in a workplace HIT programme. These activities were perceived as novel, as well as feasible given the need for limited equipment and space. Although employees may prefer these modalities, it is unclear if they elicit physiological responses indicative of high-intensity exercise. Given that the intensity of exercise is an important mediator in the physiological and morphological adaptations promoted by chronic training (MacInnis & Gibala, 2017), it is vital to evaluate the capacity for novel exercise modalities to elicit a high-intensity response prior to implementation within a HIT programme. As HIT can elicit adaptations in a range of physiological and psychological variables (Costa et al., 2018; Stork et al., 2017; Weston et al., 2014b), the acute effects of HIT on a range of variables should also be considered prior to programme implementation.

A combination of objective and subjective measures represents the best practice for prescribing and evaluating exercise intensity (Weston et al., 2016b). The objectively measured criterion for high-intensity work is exercise eliciting a heart rate of $\geq 85\%$ of maximal heart rate (HR_{max}) (Weston et al., 2014a). Although percentage of HR_{max} ($\%HR_{max}$) is the more commonly used metric for estimating the relative intensity of HIT, percentage of heart rate reserve ($\%HRR$) ($HRR = HR_{max} - \text{resting heart rate}$) (Cheng et al., 2002) has also been used as an alternative. Exercise eliciting 60-89 $\%HRR$ is classified as vigorous intensity and exercise eliciting $\geq 90\%HRR$ is classified as maximal or near maximal intensity (Garber et al., 2011). Although there is no established subjectively measured criteria specifically for HIT, an accepted criteria for general high-intensity exercise is ≥ 17 arbitrary units (AU) or 'very hard' on the original Borg scale (6-20) (Borg, 1982) or ≥ 7 AU or 'very hard' on the revised category ratio scale (CR-10) (0-10) (Borg, 1998) (Norton et al., 2009). Furthermore, exercise at the

second ventilatory threshold has been linked to the qualitative descriptor 'very hard' (i.e. 7 AU), albeit in a sample of elite athletes (Seiler & Kjerland, 2006).

While there is some literature exploring the acute physiological and psychological responses to cycle ergometer-based HIT (e.g. Falz et al., 2019; Olney et al., 2018), novel exercise modes are seldom incorporated into HIT protocols. Stair climbing is one HIT modality that has been successfully implemented into a previous described workplace HIT programme, where participants undertook 3x 20 second or 3x 60 second bouts of "all-out" stair climbing (Allison et al., 2017). Although the acute effect of the stair climbing on percentage of HR_{max} was not directly reported, as the mean age of participants was 19 ± 2 years, the peak heart rate achieved in an average stair climbing session corresponded to $85 \pm 7\%$ and $85 \pm 6\%$ of age predicted HR_{max} , for the 3x 20 second and 3x 60 second groups respectively. Furthermore, in a workplace stair climbing intervention included in the meta-analysis presented in Chapter Three, participants were required to climb the stairs in their office building daily for 10 minutes. Heart rate monitoring during one of the stair climbing bouts confirmed that heart rate after 10 minutes of stair climbing corresponded to $90 \pm 9\%$ HRR (Andersen et al., 2013), which is indicative of high-intensity exercise (Garber et al., 2011). However, in a study examining the acute effects of a single bout of stair climbing, following an 11-storey stair climb lasting approximately 135 ± 8 seconds (~2 minutes), heart rate corresponded to 82% HR_{max} (Teh & Aziz, 2002). This suggests that while stair climbing could be practically implemented into a workplace HIT programme, a single bout of stair climbing may not be sufficient to achieve a high-intensity response and subsequent climbs may be required.

Although stair climbing may be a feasible exercise modality in some workplaces, not all workplaces have access to multiple flights of stairs. In this case, stair stepping which involves repeatedly stepping onto and off a single step, may be a feasible alternative. Mair et al., (2016) examined the acute heart rate responses to 3 minutes of stepping at different step heights and cadences in young and middle aged women. At the lowest step height and cadence (17cm at 80 steps per minute), heart rate corresponded to between $60 \pm 14\%$ HRR and $45 \pm 14\%$ HRR in middle aged and young women, respectively, which is not indicative of high-intensity exercise (Garber et al., 2011). However, at the highest step height and cadence (34cm at 110 steps per minute), heart rate corresponded to between $111 \pm 16\%$ HRR and $86 \pm 9\%$ HRR in middle aged and young women, respectively. Although this study did not utilise an

interval training protocol, this finding indicates that stair stepping at higher heights at a fast pace can elicit a high-intensity exercise response.

Non-contact boxing (boxing) has been implemented into a limited number of HIT interventions. Heart rate responses to boxing HIT involving 15x 2 minute high-intensity bouts interspersed with 1 minute of rest indicated that participants attained between 86-89% of age predicted HR_{max} across a 12 week HIT intervention (Cheema et al., 2015). Although useful, the number of high-intensity repetitions is significantly higher than the number of repetitions that were intended to be used in the BE@Work programme. Therefore, it is unclear if a high number of repetitions are required to elicit a high-intensity response using boxing as the HIT modality. However, boxing has also been used as a HIT modality with adolescents (Taylor, 2014). Here, the mean peak heart rate following 4x 45 seconds of boxing, interspersed with 60 seconds of rest, corresponded to 96 ± 5 % of age predicted HR_{max} (Taylor, 2014). Whether these findings can be replicated in adults is unknown.

With regards to blood pressure responses to HIT, there is evidence to suggest that HIT may elicit similar chronic reductions in the blood pressure of hypertensive or pre-hypertensive individuals compared to moderate intensity continuous training (MICT) (Costa et al., 2018). The acute effect of HIT on blood pressure, however, is unclear. Morales-Palomo et al., (2017) explored the acute effect of a cycle ergometer based aerobic interval training (AIT) protocol consisting of 5x 4 minute high-intensity bouts at 90% HR_{max} interspersed with 3 minutes of active recovery at 70% HR_{max} on acute blood pressure in 14 obese (BMI: 31 ± 1 kg/m², mean age: 57 ± 2 years) participants with metabolic syndrome. Post-exercise there was a reduction in both systolic blood pressure (SBP) and diastolic blood pressure (DBP) in both hypertensive (n=7) (SBP: 134 ± 7 to 114 ± 1 mmHg; DBP 81 ± 3 to 73 ± 1 mmHg) and normotensive participants (n=7) (SBP: 114 ± 4 to 107 ± 3 mmHg; no difference in DBP in normotensive) (Morales-Palomo et al., 2017). Although encouraging, further work is required to examine the acute effect of HIT, particularly using novel modes, on blood pressure.

Positive psychological responses to exercise, such as favourable changes in affect and enjoyment, are critical for sustained exercise participation (Cocks et al., 2013). In a scoping review examining the effects of HIT on psychological variables, Stork et al., (2017) reported that while affect was generally more negative during HIT, compared with moderate intensity continuous training (MICT), post-exercise affect improved such that there were no significant differences between post-exercise affect

in HIT and MICT (Stork et al., 2017). Furthermore, post-exercise enjoyment has been reported to be similar or greater between HIT protocols and continuous moderate or vigorous intensity protocols (Oliveira et al., 2018; Stork et al., 2017). However the vast majority of studies examining acute psychological responses to HIT use exercise modalities such as cycle ergometers and so the psychological responses to novel HIT modes are unclear.

Accordingly, the aim of this study was to explore whether novel modes of HIT could elicit a high-intensity exercise response (e.g. $\geq 85\%$ HR_{max}) and to assess the psychological responses to these modes of HIT. The objectives of the study are to: a.) use a randomised cross-over trial to assess the acute physiological (heart rate and blood pressure) and psychological (rating of perceived exertion, mood and enjoyment) responses to prototype HIT protocols in adults based on stair climbing, stepping and boxing and b.) explore whether these outcomes substantially differed across HIT modes.

5.2 Method

This study was approved by the School of Health and Social Care Research Governance and Ethics Sub-committee from Teesside University (study number: 162/17) and the protocol was prospectively registered on clinicaltrials.gov (identifier: NCT03359928). The study was conducted between December 2017 and March 2018. All data collection, scale administration and exercise facilitation in the study was conducted solely by the thesis author.

5.2.1 Study Design

Using a randomised cross-over trial design, each participant completed a total of three laboratory-based HIT sessions (one session each of stair climbing, stepping and boxing). Participants attended the laboratory on four separate occasions (three data collection sessions and one familiarisation session) with at least 48 hours between each data collection session, with each session lasted approximately 45 minutes.

5.2.2 Recruitment and Participants

Eighteen participants (n=9 females) gave written informed consent to participate in this study. As there were three conditions in this randomised cross-over trial, it was necessary to recruit participants in blocks of three to ensure blinding and randomisation procedures could be upheld. Participants were recruited from a large tertiary institution via staff email distribution lists and were from office-based (n= 14) and non-office based support roles (e.g. cleaners and maintenance staff) (n= 4) within the organisation. The participant information sheet can be found in Appendix E. Inclusion criteria were adults (aged ≥ 18 years) with no health conditions that precluded them from exercise and on no medication. Exclusion criteria were symptoms of, or known presence of cardiovascular or metabolic disease, conditions or injury or co-morbidity affecting the ability to undertake exercise, early family history of sudden cardiac death and pregnancy or likelihood of pregnancy. All participants underwent pre-exercise screening using the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Bredin et al., 2013). If via the PAR-Q+ any of the inclusion/exclusion criteria were not met, the individual was not allowed to participate further.

5.2.3 Outcome Measures

5.2.3.1 Anthropometry

Body mass and height were measured to the nearest 0.1 kg or 0.1 cm, respectively, without shoes and with participants in light clothing using the Seca 799 electronic column scale, fitted with a Seca 224 stadiometer rod (Seca, Hamburg, Germany). Body mass index (BMI) was calculated using the equation $\text{BMI (kg/m}^2\text{)} = \text{body mass (kg)} / \text{height (m)}^2$.

5.2.3.2 Habitual Physical Activity

The short-form International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003) was used to assess self-reported physical activity in the previous 7 days. The IPAQ is an open access self-report measurement tool that quantifies physical activity (in bouts of more than 10 minutes) into three categories: walking, moderate-intensity and vigorous-intensity physical activity. Although the IPAQ has acceptable test-retest reliability (Spearman's $\rho=0.81$), the validity of the IPAQ in comparison to accelerometer assessed physical activity is poor (median $\rho=0.3$) (Craig et al., 2003). Although it has been noted that self-report measures of physical activity are prone to measurement error and adults have been shown to over-report physical activity levels

using the IPAQ (Rzewnicki et al., 2003) the validity of the IPAQ is similar to other self-report measures of physical activity (Sallis & Saelens, 2000) such as the Godin exercise leisure time questionnaire (median $\rho=0.31$) (Godin & Shephard, 1985).

Scoring protocols outlined by the questionnaire developers (International Physical Activity Questionnaire, 2005) were followed to obtain both a continuous and categorical PA score. For the categorical score “high” activity levels are categorised as: vigorous intensity activity on ≥ 3 days per week of at least 20 minutes per day and achieving 1500 MET·min of physical activity or 7 or more days of a combination of walking, moderate intensity or vigorous intensity activities and ≥ 3000 MET·min of physical activity. “Moderate” activity levels are defined as 3 or more days of vigorous-intensity activity of at least 20 minutes per day or 5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day, or 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET·min per week. “Low” activity levels are defined as not achieving the moderate or vigorous intensity activity guidelines.

5.2.3.3 Blood Pressure

Blood pressure was measured using an OMRON M6 AC (HEM-7322-E) monitor (Omron Healthcare UK, Milton Keynes, UK). This monitor has been validated for clinical and personal use, using the European Society of Hypertension International protocol (Takahashi et al., 2010). Following the guidelines outlined by the European Society of Hypertension (O'Brien et al., 2010), participants were required to have 10 minutes of seated rest before the standard sized Omron cuff (22 to 32cm) was placed tightly on the participant's upper left arm. During the measurement participants sat quietly with their arm resting on a table at 90°. Three readings were taken with at least 30 seconds rest between each reading, and the average of the three was calculated. The data taken and used in the analysis was pre- and post-exercise SBP and DBP.

5.2.3.4 Heart rate

Second-to-second heart rate monitoring was conducted throughout each exercise session using wrist-worn monitors (Polar A360, Polar Electro, Kempele, Finland). Wrist-worn monitors were used in place of chest-worn monitors because it was envisaged that similar monitors would be used in the planned BE@Work intervention since they can be easily and quickly applied and removed. This would minimise disruption to exercise sessions and employees' working day. Early work aiming to

validate the A360 demonstrated moderate validity (ICC 0.52 and mean absolute percentage error 19%) compared with electrocardiogram assessed heart rate during exercise of various intensities (Boudreaux et al., 2018). Although this was similar to the seven other wrist-worn heart rate monitors assessed in the same study (median ICC: 0.58), the participants wore four wrist-worn heart rate monitors on each arm simultaneously during the validation protocol. This is questionable as the monitors use optical sensing to measure blood volume directly beneath the surface of the skin (Stahl et al., 2016), and wearing a number of wrist-worn devices around the arm could feasibly impact on blood flow. A more recent study demonstrated a strong level of agreement between the A360 and a previously validated chest-worn heart rate monitor (ICC: 0.98, standard error of measurement 0.35) (Rider et al., 2019).

Age predicted HR_{max} was calculated for each participant using the Tanaka equation ($208-0.7 \times \text{age in years}$) (Tanaka et al., 2001). If a participant exceeded this predicted value during any HIT session conducted as part of this study their HR_{max} was amended to the higher observed value (Weston et al., 2004). A cut-off point of $\geq 85\%$ of age-predicted HR_{max} was used as the criterion for high-intensity exercise, based on the definitions of HIT described by Weston et al., (2014a). This criterion was used to confirm the intensity of the exercise rather than prescribe it, and participants were not made aware of what 85% of their HR_{max} corresponded to. Following each exercise session, individual participant heart rate files were downloaded into the Polar Flow software (Polar Electro, Kempele, Finland). The data taken and used in the analysis was the highest 1 second value from each high-intensity bout, expressed as a percentage of the participants' age predicted HR_{max} for each exercise modality. Additionally, time spent at $\geq 85\% HR_{max}$ was calculated for each exercise modality.

5.2.3.5 Ratings of Perceived Exertion

Rating of perceived exertion (RPE) was measured using the Borg CR-10 scale (Borg, 1998). This scale ranges from “nothing at all” (0) to “absolute maximum” (10) and has been established as a reliable and valid measure of physical exertion during exercise (test-retest; Spearman's $\rho = 0.92$, concurrent validity with heart rate Spearman's $\rho = 0.91$) (Borg, 1998). Each participant was familiarised with the CR-10 scale and the concept of RPE during the familiarisation sessions as recommended by Borg (1998). The RPE familiarisation protocol and CR-10 RPE scale are shown in Appendices F, G and H.

RPE was measured within 15 seconds of the end of each high-intensity bout (referred to herein as bout RPE), and session RPE was taken following a 2 minute cool down. Bout RPE was administered using the following prompt every time: "*How physically demanding was the entire minute, from start to finish?*". Session RPE was administered using the following prompt every time: "*How physically demanding was the entire session from start to finish?*". The data taken and used in the analysis comprised of four individual bout RPEs and one session RPE for each HIT modality.

5.2.3.6 Affect

Affect was assessed using the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988). The PANAS is a self-report questionnaire which comprises ten positive affect states and ten negative affect states that participants rate on a five point Likert scale ranging from very slightly or not at all (1) to extremely (5). The PANAS is a reliable measure of both positive and negative affect (test-retest Cronbachs alpha 0.86 to 0.90 for positive and 0.84 to 0.87 for negative affect) (Watson et al., 1988). However when used with appropriate instructions (e.g. today or this week) it is also sensitive to fluctuations in acute affect states (Watson et al., 1988).

The PANAS measures positive and negative affect independently such that the sum of all negative affect states is calculated to give a total negative affect score with the same procedure applied for all positive affect states. Possible scores for both positive and negative affect states range from 10-50, with higher scores indicating higher positive or negative affect. The instructions printed on the paper based form preceding the scale items were: "*This scale consists of a number of words that describe different feelings and emotions. Read each item and then indicate on the scale below next to each word to what extent you feel this way right now, that is, at the present moment*". This instruction was not modified from the originally validated scale (Watson et al., 1988). As the scale developers did not provide guidance on scale familiarisation (Watson et al., 1988), in the present study participants were shown the PANAS in the familiarisation session. Here the administration instruction stated above was read aloud and participants were given the opportunity to read the scale and ask the thesis author questions.

The PANAS was administered at three time points in each HIT session: pre-exercise (during the 10 minutes of seated rest required before blood pressure measurement) post-exercise (when heart rate had returned to ± 10 beats per minute (BPM) from

when participants arrived at the laboratory) and 60 minutes post-exercise. The assessment criterion for the timing of affect assessments post-exercise (i.e. when heart rate had returned to ± 10 BPM from when participants arrived at the laboratory) was suggested by Blanchard et al., (2001) to alleviate concerns described by Thayer (1996) regarding the impact that physiological arousal (as occurs during exercise) has on affective state. Post-exercise recovery time from physiological arousal is moderated by fitness level (Foss et al., 1998); therefore Blanchard et al., (2001) recommended that administration of post-exercise affect scales are linked to a physiological marker of recovery (such as heart rate), in an effort to ensure that participants of different fitness levels are at a similar stage of recovery (or arousal) when the scales are administered. The PANAS was also administered 60 minutes post-exercise in light of work demonstrating that changes in psychological responses to HIT can be detected up to 60 minutes post-exercise (Stork et al., 2015) . The questionnaires intended to be administered 60 minutes post-exercise were given to the participants, with an exact completion time, as they left the laboratory following each HIT session. The reason for this was two-fold, firstly to reduce participant burden and prevent them having to remain in the laboratory for an extended period of time and secondly participants were able to return to work therefore more closely simulating what would happen in a workplace intervention setting. Data taken and used in the analysis were the change in positive and negative affect sum scores from pre-exercise, post-exercise and 60 minutes post-exercise for each exercise modality. The PANAS questionnaire can be found in Appendix I).

5.2.3.7 *Enjoyment*

Enjoyment was assessed using the Physical Activity Enjoyment Scale (PACES) (Kendzierski & DeCarlo, 1991). The PACES is a self-report questionnaire with 11 negatively worded and seven positively worded items that participants' rate on a seven point bipolar scale (from one to seven). The administration instructions preceding the scale items were: "*please rate how you feel at the moment about the exercise session that you completed today*". This instruction was modified slightly from the originally validated scale which states "*please rate how you feel at the moment about the physical activity that you have been doing*". Such modifications were deemed appropriate by the scale developers (Kendzierski & DeCarlo, 1991). To score the PACES, the scores for the seven positively worded items are reversed and the scores of all items are then summed to give an overall score. Possible scores range from 18-126, with higher scores indicating higher enjoyment. A procedure for

familiarisation with this scale is not described by the scale developers (Kendzierski & DeCarlo, 1991). However during the familiarisation sessions the participants were shown the PACES, the administration instruction stated above was read aloud, and participants were reminded that the positively and negatively worded items were not always on the same side of the scale, therefore care should be taken to ensure they are indicating the correct side of the scale in their responses (e.g. the first item reads “I enjoyed it and I hated it” whereas the second item reads “I felt bored and I felt interested”). Following this, participants were given the opportunity to ask questions.

The PACES was administered with the PANAS at two time points: post-exercise when heart rate had returned to within ± 10 BPM from when participants arrived at the laboratory, and 60 minutes post-exercise. Administration timing of the PACES was aligned with the administration of the PANAS, as described previously. In contrast to the PANAS, PACES was not administered pre-exercise because participants are unable to prospectively assess their enjoyment of the HIT modality. Data taken and used in the analysis was the total PACES score from both time points (post-exercise and 60 minute post-exercise) for each HIT modality. Questionnaires were administered in the same order at both post-exercise data collection points (PANAS then PACES). The PACES questionnaire can be found in Appendix J).

5.2.4 Protocol

Participants were advised to arrive well rested and drink plenty of fluids in the 24 hours before their appointment on each occasion, they were also advised to avoid eating a heavy meal or drinking alcohol and caffeine for 3 hours before and avoid strenuous exercise on the day of each scheduled session.

5.2.4.1 Session 1: Familiarisation

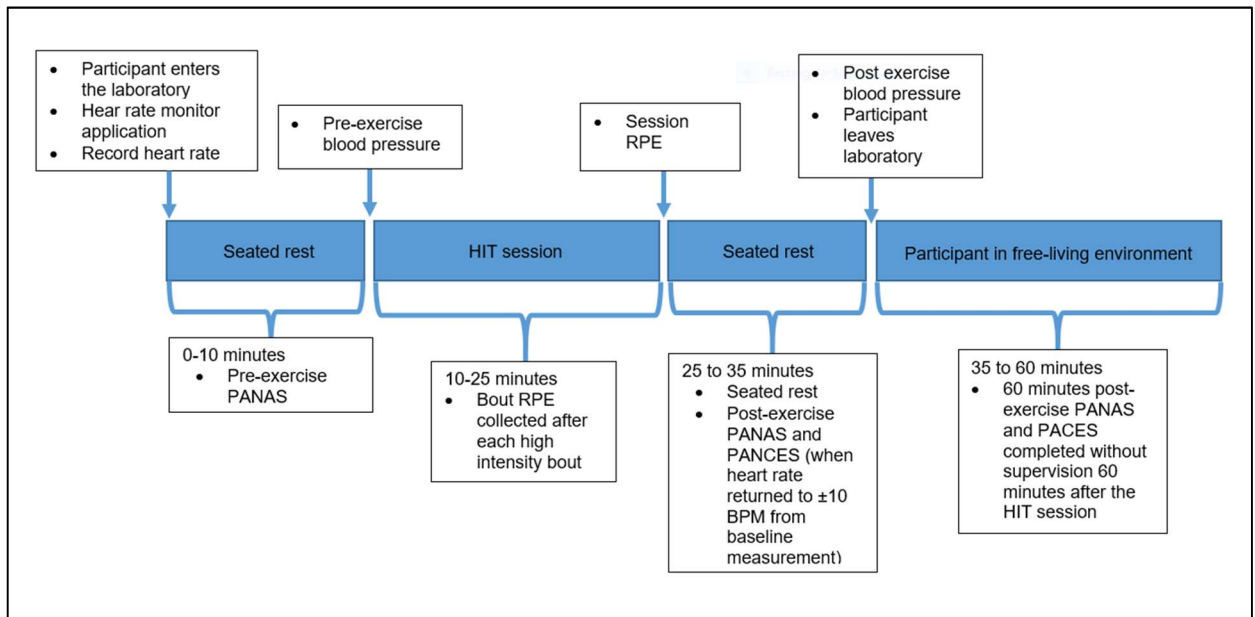
The first session was a familiarisation session that included informed consent procedures, pre-exercise screening, assessment of anthropometric variables, assessment of habitual physical activity (IPAQ) and familiarisation with RPE, PANAS, PACES and HIT.

The explanation of HIT was standardised across all participants and based on the definition of HIT provided to participants of the formative evaluation in Chapter Four. Participants were informed that they should work as hard as they could in each high-intensity bout, which would always be followed by a rest period. They were informed that their heart rate and breathing would increase substantially such that by the end of each high-intensity bout they should feel that they needed a rest and may find it difficult to speak in full sentences. To familiarise the participants with high-intensity exercise, following a 5 minute warm up comprising of power walking or jogging around the laboratory and practice with the boxing and stepping techniques, participants completed one 60 second bout each of stair climbing, stepping and boxing (3x 60 seconds of exercise in total), with 75 seconds rest between each modality. Participants were encouraged to work maximally during each of the three high-intensity bouts.

5.2.4.2 Session 2-4: High-intensity interval exercise

After the familiarisation session participants were randomised by another researcher using random number generation to sequences in which they were exposed to the three HIT modalities (stair climbing, stepping and boxing). Participants were informed of which condition they would be conducting immediately prior to commencing the exercise on each occasion, following pre-exercise blood pressure measurement and scale administration. Exercise sessions were conducted at the same time of day (± 2 hours) as the familiarisation session. The protocol for data collection during sessions 2-4 is shown in Figure 10.

Figure 10 Sessions 2-4 data collection protocol



In the remaining three data collection sessions, participants completed one modality per session following a HIT protocol (4x 60secs of exercise interspersed with 75 secs of recovery). An outline of the exercise in each modality is presented in Table 23. The HIT sessions were supervised by the thesis author who administered all of the scales and strongly encouraged participants to work maximally during each high-intensity bout.

Table 23 Example HIT drills for each exercise modality

Modality focus	Example drill
Boxing	20 fast jabs/ upper cuts/ hooks on the focus pad and shuttle run/ power walk to the end of the laboratory and back or 10 jumping jacks 20 knees to the punch pads and shuttle run/ power walk to the end of the laboratory and back or 10 jumping jacks
Stair climbing	Continuously ascending stairs in a 10 storey office tower
Stair stepping	Continuously stepping onto and off a single step

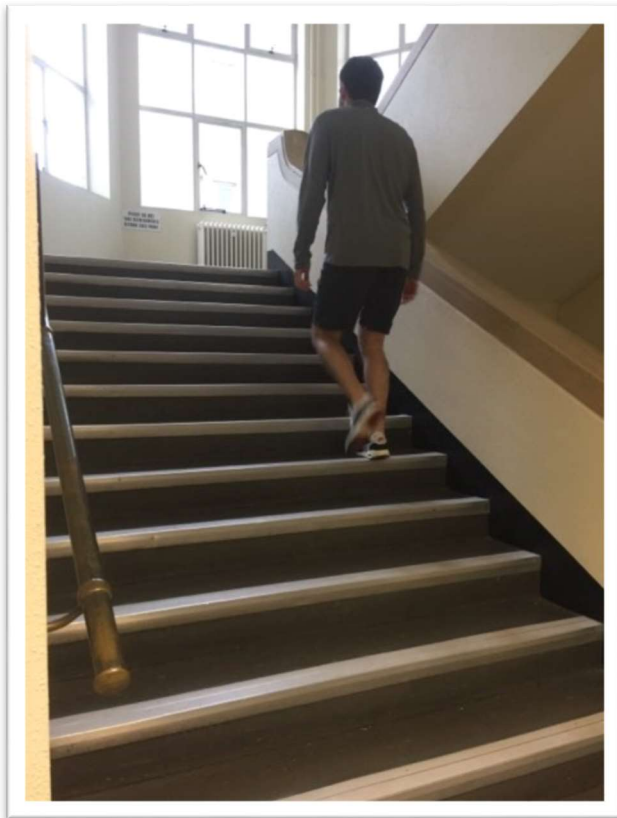
The HIT protocol that was explained to participants of the formative evaluation presented in Chapter Four (4x 60 second intervals with 60 seconds rest) was originally intended to be used in the present study. However, although the length and number of high-intensity repetitions was not modified from the originally described protocol, the rest period was extended from 60 seconds to 75 seconds. The intention

was to use the same HIT protocol in the larger scale BE@Work trial which would likely incorporate group based exercise sessions. If boxing were to be used in a group-based exercise session participants would have to exercise in pairs, with one partner holding the contact pads during their rest period, while the other partner was completing their high-intensity bout. If a 1:1 work to rest ratio was use in these sessions, the start of each high-intensity bout would be compromised when the participants had to change from wearing the boxing gloves to holding the pads. Therefore the decision was made to extend the rest period by 15 seconds to allow participants time to change gloves and pads. In order to standardise the HIT protocol between the modalities, the same protocol was used for all three HIT modalities. Similar low volume HIT protocols have been used successfully in diabetic populations (Little et al., 2010) and individuals with other cardiometabolic risk factors (Phillips et al., 2017). The high-intensity protocol was preceded by a standardised 5 minute warm-up using exercises similar to that included in the high-intensity bouts and was followed by a 2 minute cool down. The total exercise session time including warm-up, cool down and rest periods was 14 minutes and 45 seconds.

5.2.4.3 Exercise modalities

Stair climbing involved continuously ascending a public access staircase (10 floors), in a university owned building nearby to the laboratory (Figure 11). Stepping cadence was self-selected by the participant. The rest period involved descending the staircase and slow walking on flat ground at the participant's self-selected pace. If a participant reached the top floor before the end of a high-intensity bout they were instructed to descend to the nearest floor and step up and down off the bottom step for the remaining time, until the next rest period. This was done to prevent participants from attempting to descend the staircase at speed during a high-intensity bout.

Figure 11 Example of stair climbing HIT mode



Stair stepping involved continuously stepping on to and off an exercise bench in an “up, up, down, down” command pattern (Figure 12). The step height (15, 20, 25 or 30cm) was selected by the thesis author based on participants age and usual activity level, as per guidance for the Chester step test (Buckley et al., 2004). Participants were encouraged to ensure their whole foot was on the exercise bench for each step, to avoid trips. Stepping cadence was self-selected by the participant and the rest period involved slow walking on flat ground at the participant’s own pace.

Figure 12 Example of stair stepping HIT mode



Boxing involved continuously punching “punch pads” held by the thesis author (Figure 13). Prior to the study commencing, the thesis author received training from a registered Boxercise™ instructor on how to safely execute and teach basic boxing movements and the punches and leg movements included were jabs, upper cuts, hooks and knees. The boxing cadence was self-selected by the participant. The recovery period involved slow walking on flat ground at the participants self-selected pace. During the boxing sessions each 20 punches were interspersed with running or power walking to the end of the laboratory and back or jumping jacks, to prevent excessive upper body fatigue.

Figure 13 Example of non-contact boxing HIT mode



5.2.5 Statistical Analysis

Plots of the model residuals versus the predicted values were visually inspected by the thesis author and one other researcher. The residual plots of all analyses were correctly specified (uniform variance and normal distribution of residuals), so the analyses of the raw, untransformed data were deemed appropriate. All data are presented as mean \pm SD, with uncertainty in the estimates expressed as 90% confidence intervals.

Data were analysed using linear mixed modelling (SPSS v.25, Armonk, NY: IBM Corp) with fixed effects (HIT mode) specified. In addition, for blood pressure and affect data pre-exercise values were used as a co-variate. As there was no pre-exercise measure of enjoyment which would permit a linear mixed model to be applied with pre-exercise values used as a co-variate, only descriptive data (mean \pm SD) for PACES were calculated.

Magnitude based inferences (Hopkins et al., 2009) were used to help interpret the clinical relevance of the 90% confidence intervals for between-mode differences in heart rate, RPE and enjoyment data. For blood pressure and affect data both changes from baseline and between-mode differences in the change from baseline were established and interpreted using magnitude based inferences. This process was completed for each variable using a custom-made spreadsheet designed to derive a confidence interval and either a non-clinical (heart rate, RPE, affect and enjoyment) or clinical (blood pressure) inference from a p-value derived from the linear mixed model (Hopkins, 2007). For non-clinical inferences, the spreadsheet gives the chances (expressed as probabilities) that the true value is either meaningful (positive or negative) or trivial. For clinical inferences the spreadsheet gives the chances that the true value is either beneficial, trivial or harmful. The chance of the difference being meaningful vs. trivial or harmful vs. beneficial was interpreted using the following scale of qualitative descriptors: 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; >99.5%, most likely (Batterham & Hopkins, 2006). Given the pilot nature of the study and the small sample size, effects were only declared meaningful when the probability likelihood for the effect was $\geq 75\%$ (i.e., likely) and the qualitative inference was either beneficial/ harmful or positive/ negative (i.e. a likely trivial effect although has a probability of $\geq 75\%$, a trivial effect would not be considered meaningful).

Threshold values for minimal important differences were:

- Two percentage points for heart rate, based on the findings of a trial demonstrating differences in the magnitude of physiological adaptations following training programmes at different intensities (i.e. the smallest difference in exercise intensity was 2 percentage points of $\%HR_{\max}$) (Seiler et al., 2013).
- One Arbitrary Unit (AU) was selected for RPE. In the absence of a robust anchor for RPE, a standardised approach can be adopted where 0.2 of the standard deviation is taken as the minimal important difference (Cohen, 1988). However, for RPE data a standardised approach often results in the use of values that are not practically useful when considering the smallest detectable difference on an RPE scale. For example, in the case of the CR-10 scale, a change of one AU reflects the smallest practical value that can be detected on the scale (i.e. a change of one AU would indicate a change from the qualitative descriptor of “easy” (2 AU) to “moderate” (3 AU)).

- 4.8 mmHg for SBP and 3.2 mmHg for DBP based on the findings of a meta-analysis demonstrating the acute effect of moderate intensity continuous exercise on blood pressure (Carpio-Rivera et al., 2016).
- In the absence of a robust anchor for the PANAS data, the minimal important difference was defined as 7.5 AU for both the positive and negative affect scales. A change of 7.5 AU would represent a one point change in 75% of the scale items on the 10 point composite positive and negative affect scales. Similarly, the minimal important differences for PACES data was defined as 13 AU because this would represent a one point change in 75% of the scale items.

Threshold values for minimal important differences were established and agreed *a priori*.

5.2.5.1 Sensitivity analysis

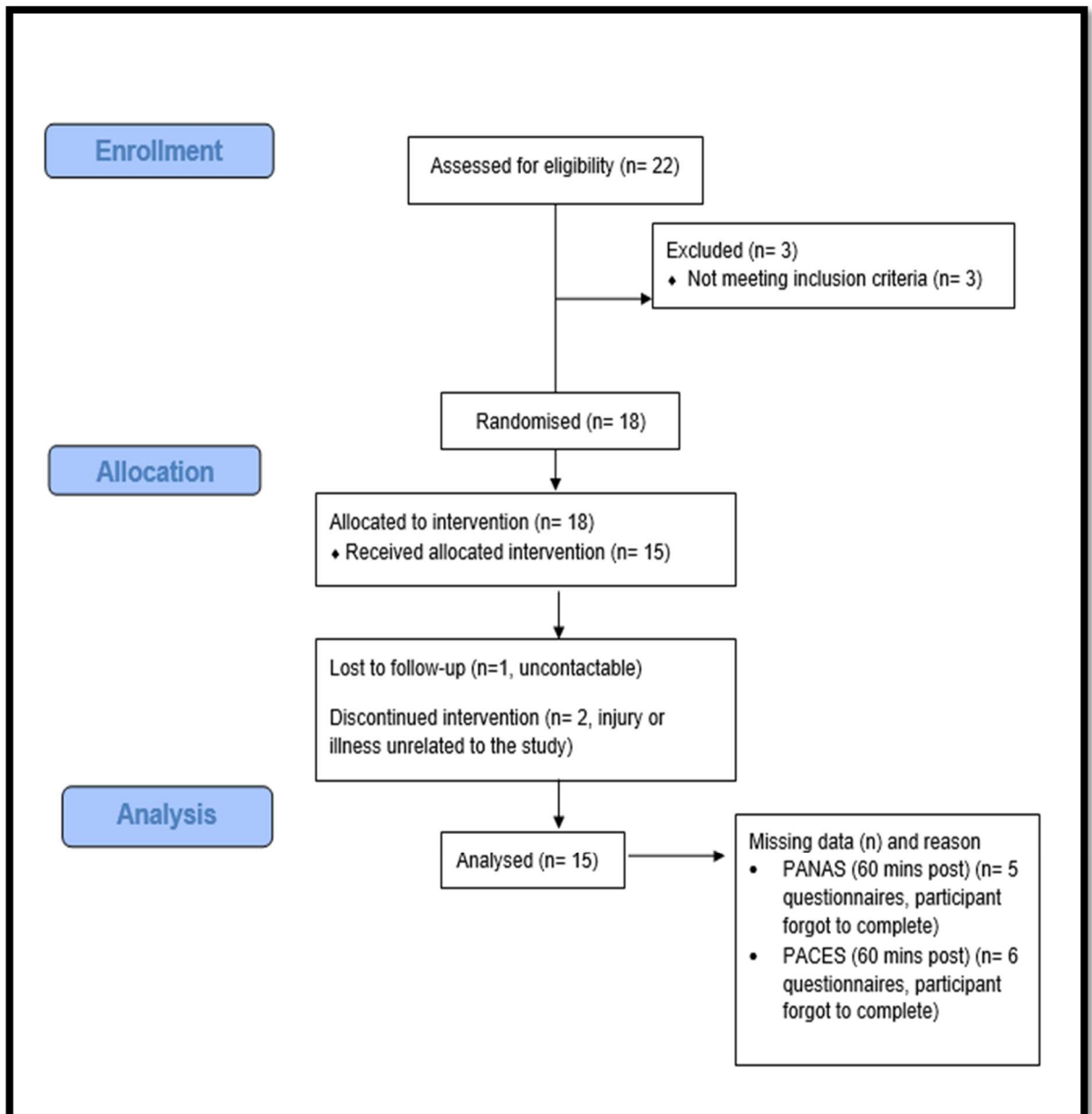
Inspection of the residual plots identified three outliers for post-exercise negative affect and one outlier for 60 minute post-exercise negative affect. Sensitivity analyses were conducted by removing the outliers from the model; however, given that removal did not have a substantial impact on the effect or the precision of the estimates, the decision was made to include the outliers in the model.

Some of the PANAS (n=5/45) and PACES (n=6/45) questionnaires that were intended to be self-administered by the participants at 60 minutes post-exercise were not included in the analysis because participants forgot to complete them.

5.3 Results

Participant flow through the study is shown in Figure 14. Across the study, 15 participants (n=8 males) received each of the HIT conditions and were included in the analysis (mean \pm SD age: 39 \pm 11 years; BMI 24.9 \pm 3.4 kg·m²). Participants undertook a mean (\pm SD) of 1795 \pm 1271 MET·min⁻¹ of physical activity in the previous 7 days. Two, eight and five participants were categorised in the low, moderate and high physical activity categories, respectively.

Figure 14 Flow of participants through the study



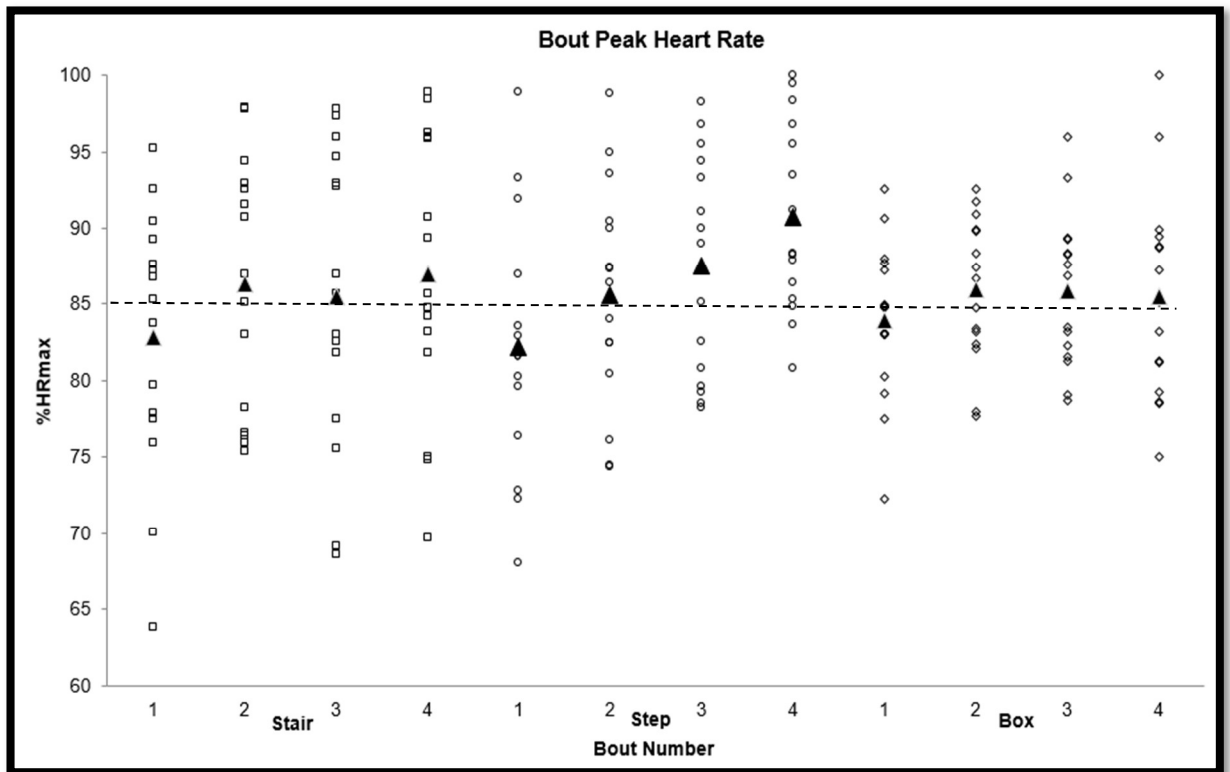
5.3.1 Exercise Intensity Quantification

Heart rate traces from 45 HIT sessions were collected, comprising 180 high-intensity bouts. The mean (\pm SD) peak heart rate across the four high-intensity bouts for each modality was $85 \pm 8\%$ HR_{max} for stair climbing, $86 \pm 7\%$ HR_{max} for stepping and $85 \pm 5\%$ HR_{max} for boxing, with no meaningful between-mode differences (stair vs. step -1% HR_{max} [90% CI -3.6 to 1.4% HR_{max}], box vs. stair -0.06% HR_{max} [90% CI -2.5 to 2.6% HR_{max}], box vs. step -1% HR_{max} [90% CI -3.7 to 1.4% HR_{max}]). Figure 15 and Figure 16 show the mean peak heart rates and bout-by-bout mean peak heart rates, respectively, across the three HIT modes along with individual data points to illustrate variability around the mean. Figure 17, Figure 18 and Figure 19 show mean heart rates throughout each HIT session. During the HIT sessions, participants spent a mean (\pm SD) of 129 ± 138 seconds (equivalent to 2 minutes, 9 seconds), 143 ± 161 seconds (equivalent to 2 minutes 23 seconds) and 92 ± 101 seconds (equivalent to 1 minute 32 seconds) with heart rates corresponding to $\geq 85\%$ HR_{max} for stair climbing, stepping and boxing, respectively.

Figure 15 Mean peak heart rate for each HIT mode (closed triangles) and individual participant mean peak heart rate for each HIT mode (open circles). Dashed line indicating criterion for high-intensity work (85% HR_{max}).



Figure 16 Mean peak heart rate for each high-intensity bout for each HIT mode (closed triangles) and individual participant peak heart rate for each high-intensity bout for each HIT mode (open circles). Dashed line indicating criterion for high-intensity work (85% HR_{max}).



Mean session RPE (\pm SD) was 7 ± 3 AU for stair climbing, 7 ± 3 AU for stepping and 6 ± 2 AU for boxing. An RPE value of 7 corresponds to the qualitative descriptor “very hard” and an RPE value of 6 is between the qualitative descriptors of “hard” and “very hard” on the CR-10 scale. There was no meaningful difference in RPE between stair climbing and stepping (0.07 AU 90% CI: -0.9 to 1 AU), however RPE was lower for boxing compared with both stair climbing (-2 AU 90% CI: -1 to -3 AU) and stepping (-2 AU 90% CI: -1 to -3 AU). Figure 20 and Figure 21 show mean session RPE and bout RPE, respectively, across the three HIT modes along with individual data points to illustrate variability around the mean.

Figure 17 Mean heart rate (white line) and standard deviation (grey shading) throughout the stair climbing session.

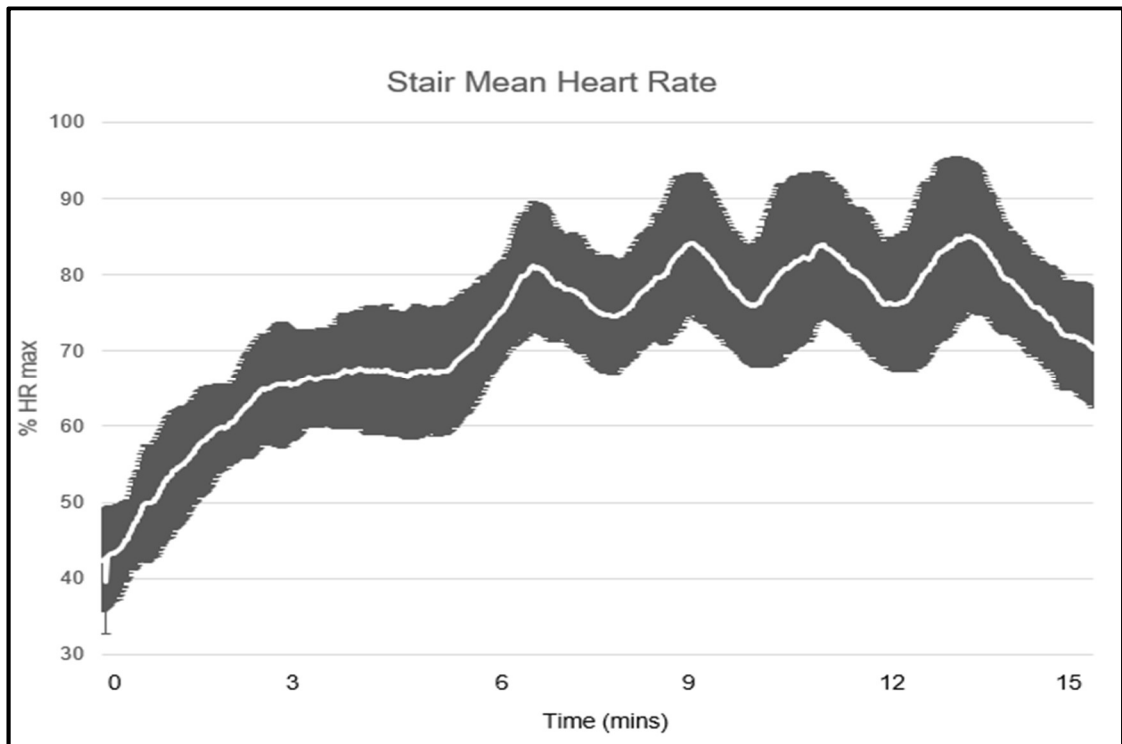


Figure 18 Mean heart rate (white line) and standard deviation (grey shading) throughout the step session.

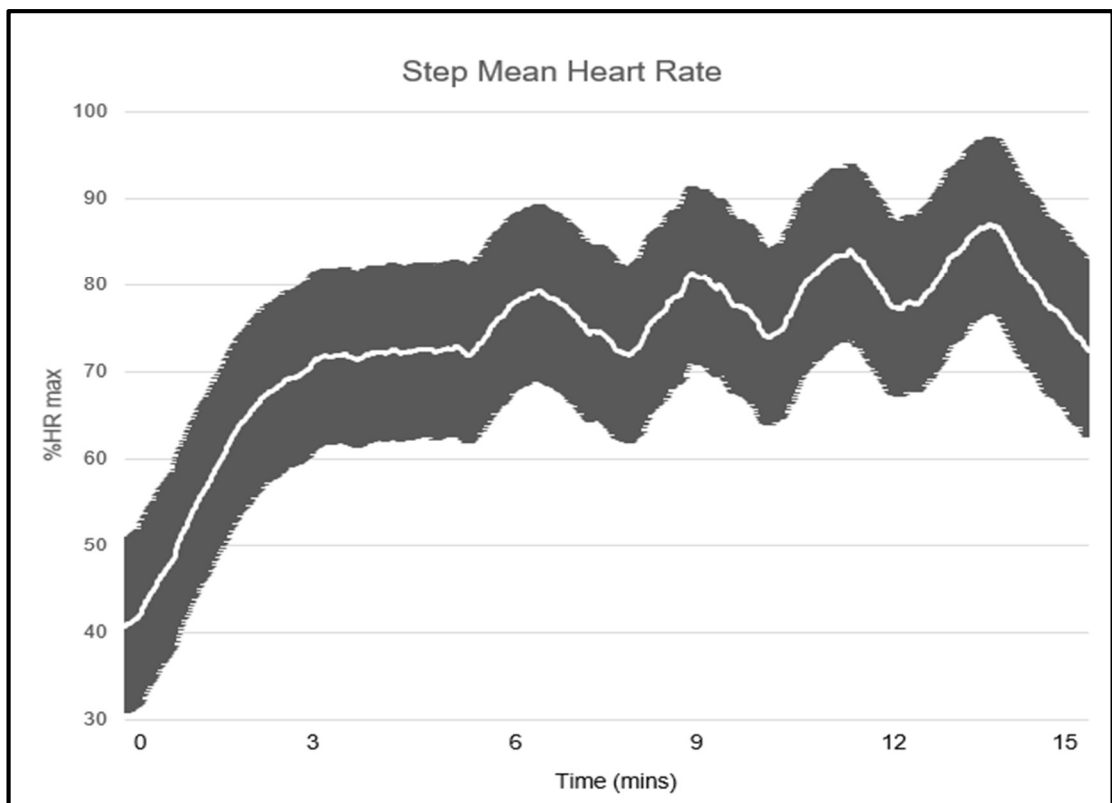


Figure 19 Mean heart rate (white line) and standard deviation (grey shading) throughout the boxing sessions.

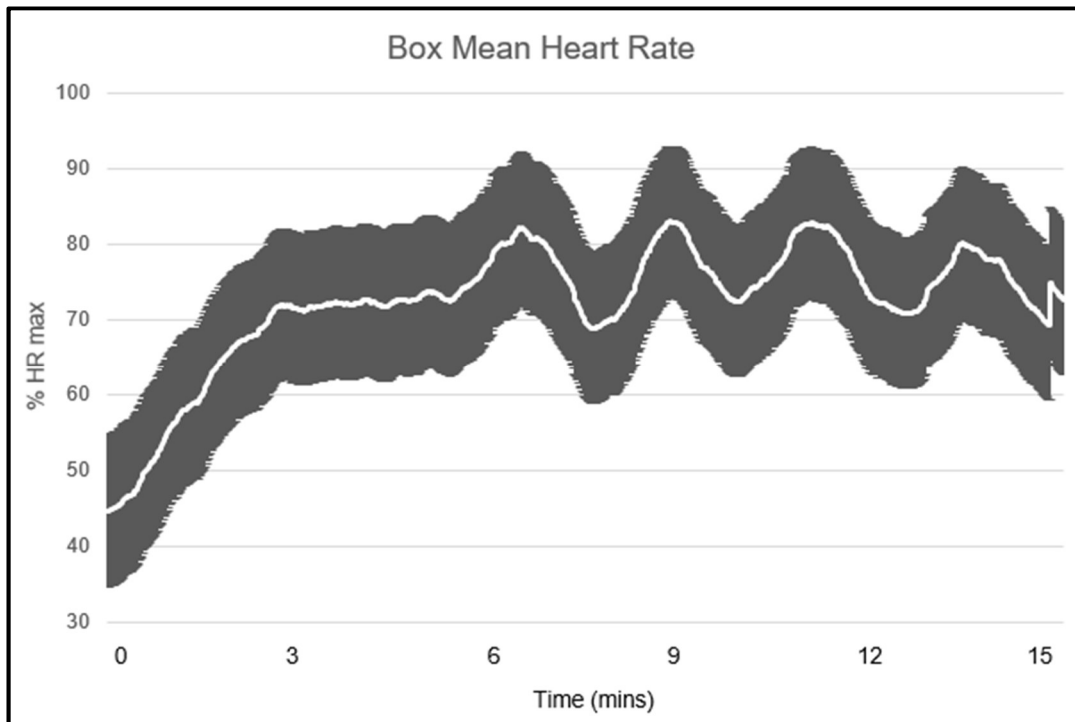


Figure 20 Session RPE for each HIT mode (closed triangles) and individual participant session RPE for each HIT mode (open circles).

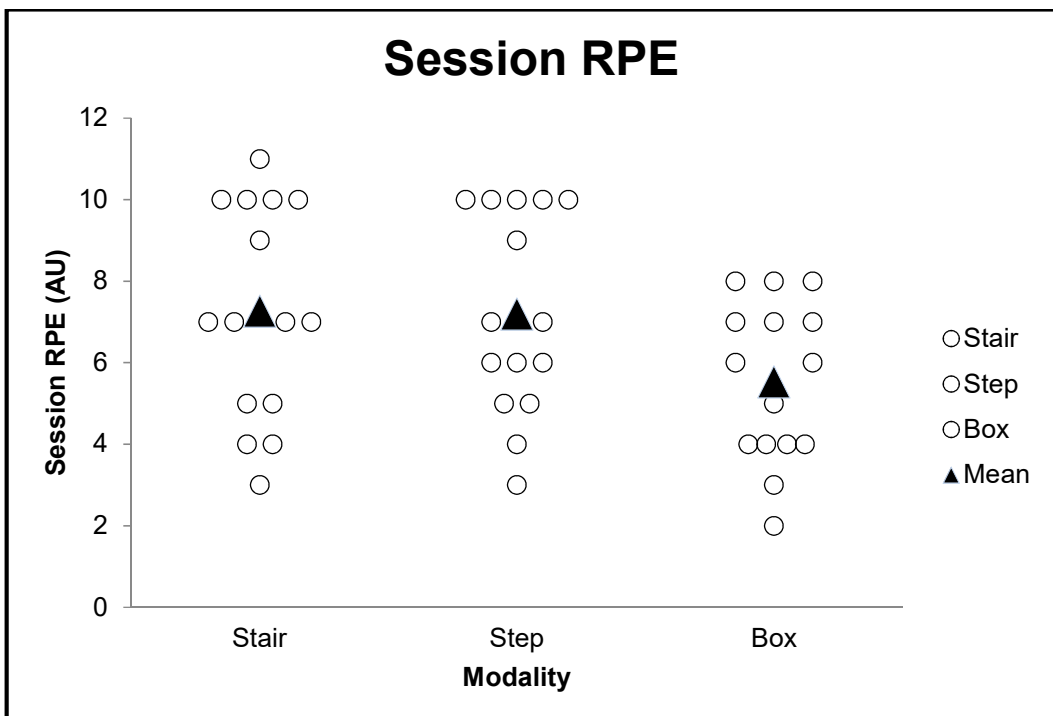
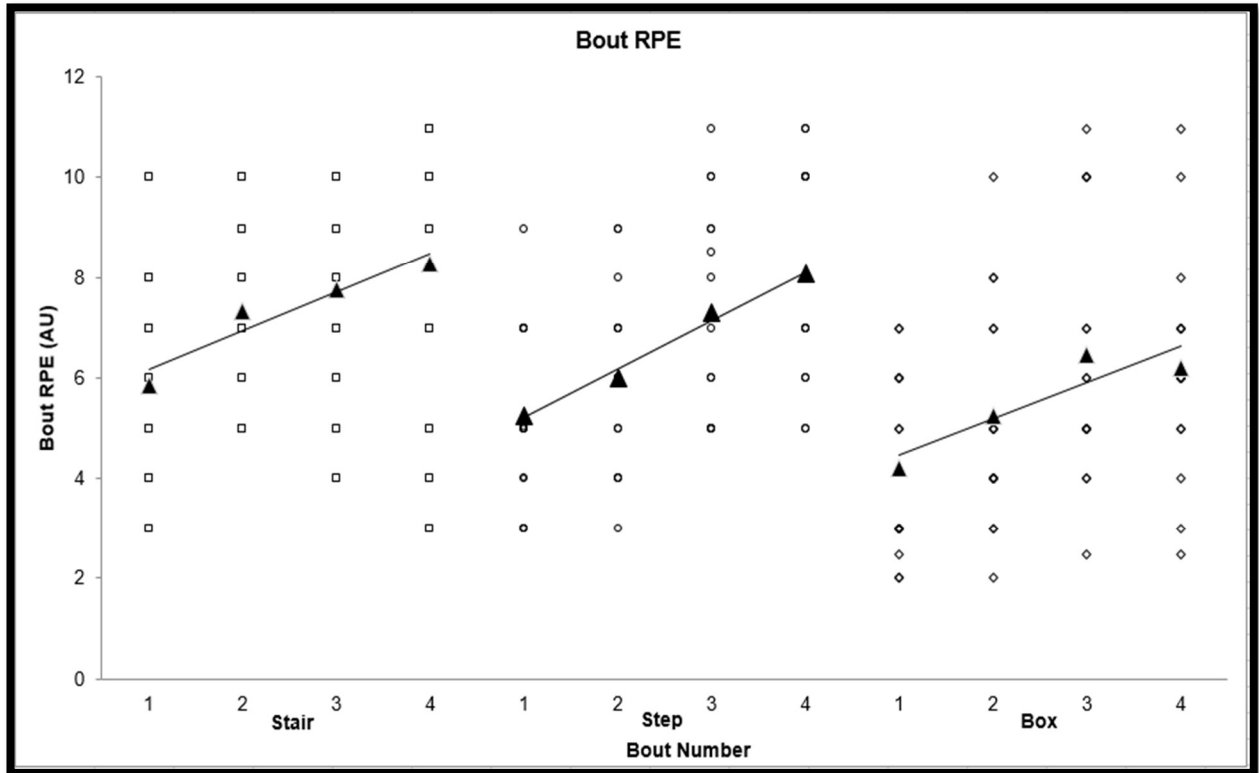


Figure 21 RPE for each high-intensity bout for each HIT mode (closed triangles) and individual participant RPE for each high-intensity bout for each HIT mode (open circles).



5.3.2 Blood pressure

The mean change in SBP and DBP for each HIT mode is shown in Table 24. There were no meaningful differences in SBP or DBP responses from baseline or between modes (Table 25).

Table 24 Baseline to post-exercise changes in blood pressure

Mode	Pre-exercise SBP (mmHg) (Mean \pm SD)	Mean post-exercise SBP (mmHg) [90% CI]	Inference Δ	Pre-exercise DBP (mmHg) (Mean \pm SD)	Mean post-exercise DBP (mmHg) [90% CI]	Inference Δ
Stair	119 \pm 10	-1 [-5 to 2]	Likely trivial	76 \pm 7	1 [-2 to 4]	Likely trivial
Step	119 \pm 10	-1 [-5 to 2]	Likely trivial	75 \pm 8	1 [-1 to 4]	Likely trivial
Box	120 \pm 12	-1 [-5 to 2]	Very likely trivial	75 \pm 9	-2 [-5 to 1]	Likely trivial

Table 25 Between-mode differences in change in blood pressure

	Mean between mode differences SBP (mmHg) [90% CI]	Inference	Mean between mode differences DBP (mmHg) [90% CI]	Inference
Stair vs. step	-0.2 [-4.8 to 4.4]	Very unlikely beneficial	0.5 [-2.5 to 3.5]	Very unlikely harmful
Box vs. stair	0.3 [-4.3 to 4.8]	Unlikely harmful	-3 [6 to -0.07]	Possibly beneficial
Box vs. step	0.1 [-4.4 to 4.6]	Very unlikely harmful	-2.5 [-5.5 to 0.47]	Possibly beneficial

5.3.3 Affect

There were no meaningful changes from baseline (Table 26) or between-mode differences (Table 27) in positive and negative affect scores at post-exercise and 60 minute post-exercise time points.

Table 26 Baseline to post-exercise and 60 minute post-exercise changes in affect scores

Mod e	Positive affect score (AU)					Negative affect score (AU)				
	Pre-exercise (mean ±SD)	Mean Δ post-exercise [90% CI]	Inference	Mean Δ 60 mins post-exercise [90% CI]	Inference	Pre-exercise (mean ±SD)	Mean Δ post-exercise [90% CI]	Inference	Mean Δ 60 mins post-exercise [90% CI]	Inference
Stair	33 ±9	4 [1 to 6]	Very likely trivial	5 [2 to 7]	Very likely trivial	13 ±2	-0.6 [-2 to 0.7]	Most likely trivial	-2 [-3 to 0.6]	Most likely trivial
Step	34 ±9	4 [2 to 6]	Very likely trivial	4 [1 to 7]	Very likely trivial	14 ±3	-1 [-3 to 0]	Most likely trivial	-1 [-2 to 0]	Most likely trivial
Box	33 ±8	6 [3 to 8]	Likely trivial	5 [3 to 8]	Likely trivial	12 ±1	-1 [-2 to 0.2]	Most likely trivial	-1 [-2 to 0.2]	Most likely trivial

Table 27 Post-exercise and 60 minute post-exercise between-mode differences in affect scores

	Positive affect (AU)				Negative affect (AU)			
	Mean	Inferenc	Mean	Inferenc	Mean	Inferenc	Mean	Inferenc
	between	e	between	e	between	e	between	e
	mode		mode		mode		mode	
	differenc		differenc		differenc		differenc	
	e post-		e 60 mins		e post-		e 60 mins	
	exercise		post-		exercise		post-	
	[90% CI]		exercise		[90% CI]		exercise	
			[90% CI]				[90% CI]	
Stair vs. step	-0.1 [-2 to 2]	Most likely trivial	1 [-2 to 4]	Most likely trivial	0.7 [-1 to 3]	Most likely trivial	-0.4 [-2 to 1]	Most likely trivial
Box vs. stair	2 [0.3 to 4]	Most likely trivial	1 [-2 to 3]	Most likely trivial	-0.5 [-2 to 1]	Most likely trivial	0.4 [-1 to 2]	Most likely trivial
Box vs. step	2 [-0.4 to 4]	Most likely trivial	2 [-5 to 8]	Likely trivial	0.2 [-2 to 2]	Most likely trivial	-0.1 [-2 to 1]	Most likely trivial

5.3.4 Enjoyment

The mean (\pm SD) post-exercise PACES score was 97 ± 24 AU, 102 ± 17 AU, and 108 ± 13 AU for stair climbing, stepping and boxing, respectively. There were no meaningful between-mode differences in enjoyment scores, post-exercise (stair vs. step -5 AU [90% CI -13 to 2 AU], box vs. stair 11 AU [90% CI 3 to 19 AU], box vs. step 5 AU [-3 to 13 AU]). Mean (\pm SD) 60 minute post-exercise PACES score was 96 ± 24 AU, 107 ± 16 AU and 109 ± 14 AU for stair climbing, stepping and boxing, respectively. There were no meaningful between-mode differences in enjoyment scores at 60 minutes post-exercise (stair vs. step 9 AU [90% CI -17 to -2 AU], box vs. stair 11 AU [90% CI 4 to 17 AU], box vs. step 2 AU [-5 to 9 AU]).

5.4 Discussion

The intensity of exercise is critical for promoting training related adaptations (MacInnis & Gibala, 2017). Therefore prior to the incorporation of novel exercise modes into a training programme, the intensity of the prescribed exercise should be quantified. Furthermore, positive psychological responses to exercise such as favourable changes in affect or enjoyment responses are critical for sustained exercise participation (Cocks et al., 2013). Accordingly, the aim of this study was to explore the capacity for novel modes of HIT, based on stair climbing, stepping and boxing, to elicit a high-intensity exercise response and to assess the psychological responses to these modes of HIT.

Mean peak heart rate recorded across the three HIT modes (85 ± 8 % HR_{max} , 86 ± 7 % HR_{max} and 85 ± 5 % HR_{max} for stair climbing, stepping and boxing, respectively) were indicative of high-intensity exercise (e.g. $\geq 85\%$ HR_{max}), with no meaningful differences between modes. Heart rates in the present study were slightly lower than peak heart rates observed using similar low-volume HIT protocols involving 8-10x 60 second high-intensity bouts on cycle ergometers (range 90-95% HR_{max}) (Olney et al., 2018; Skelly et al., 2014; Wood et al., 2015). Although this could be because of the lower number of repetitions in the present study, it could also be because the intensity of the modalities of exercise in the present study cannot be manipulated in the same manner as electronically braked cycle ergometers and therefore the exercise was ultimately self-paced. Despite this, the findings suggest that the HIT protocol applied is capable of eliciting a high-intensity stimulus and therefore each of the novel modes of HIT could be incorporated into a HIT programme. As there were no meaningful differences in heart rate responses between modes, this suggests that the modes could be used interchangeably within a programme without compromising the intensity of the prescribed

exercise. This finding is of particular significance to the present programme of work because participants of the formative evaluation (Chapter Four) identified 'choice' and 'variety' in HIT sessions as of particular importance for sustained engagement within a workplace HIT programme. Therefore in the planned BE@Work programme, participants will be provided with a choice between the three exercise modalities both within and between HIT sessions.

When comparing Figure 16 and Figure 21 which demonstrate peak heart rate and RPE over each high intensity bout for each modality, it is observed that while RPE increases linearly over each bout, with the exception of the step modality, heart rate does not follow this pattern. This pattern is unexpected because RPE and physiological markers of exercise intensity, such as heart rate, have been shown to be highly correlated during exercise (Scherr et al., 2013). While reasons for the difference in the observed trends in mean RPE and mean peak heart rate across the modes in the present study are likely multifaceted, one potential explanation could have been that localised muscular fatigue may have occurred for some modalities more than others, which the participants may have considered in their perceived exertion responses. As the exercise was ultimately self-paced (participants were not given a target "work-load" but were instructed to work maximally during each high-intensity bout), participants could have changed their pace which may have affected the physiological responses across the HIT session. However, given the data collected in the present trial these explanations are purely speculative. To further investigate the effect of localised muscular fatigue during novel HIT modalities, differential rating of perceived exertion scales could be used in future trials which separately assess lower body exertion, upper body exertion and central exertion (breathlessness) (McLaren et al., 2017).

Participants spent an average of 1 minute 30 seconds for boxing, 2 minutes 9 seconds for stair climbing and 2 minutes 23 seconds for stair stepping with heart rate at or above the high-intensity criterion of $\geq 85\%$ HR_{max} , over the four 60 second high-intensity bouts conducted in each HIT session. There is no established cut-point or guideline for the total amount of time individuals should spend with heart rates corresponding to high-intensity work for HIT protocols. This data were provided for illustrative purposes, however it cannot be compared to the findings of other work and future studies could include this data to inform the development of further HIT guidelines which may be useful in dose quantifications.

The intensity of the HIT protocol applied was perceived as 'hard' to 'very hard' on the CR-10 scale (mean RPE values 6-7 AU), which are similar to mean RPE values reported following low-volume HIT protocols conducted on cycle ergometers (between 'hard' and 'very hard') (Olney et al., 2018; Wood et al., 2015). Although peak heart rate responses did not differ across modes, RPE was lower for boxing when compared with both stair climbing and stepping. Although the data collected as part of this study cannot elucidate the reason for this finding, given that boxing was the most technical modality, it is plausible that if participants were unfamiliar with boxing and therefore had to concentrate on the technique, this may have distracted them from subjective feelings of exertion. The lower amount of time spent with heart rates indicating high-intensity work in the boxing modality (1 minute 32 seconds compared with 2 minutes 9 seconds and 2 minutes 32 seconds for stair climbing and stepping, respectively), could add further support to the hypothesis that the technical aspect of boxing may compromise the exercise intensity. Further longer term work is needed to assess if the perception of exertion and heart rate responses during boxing HIT change as participants gain experience in the modality.

A minor modification was made to the planned HIT protocol for the BE@Work programme based on the findings of this study. The final high-intensity bout of the boxing HIT session required participants to kick the punch pad with their knees twenty times followed by a run or power walk to the end of the laboratory, which was repeated for the duration of the high-intensity bout. However, as demonstrated in Figure 21, mean bout RPE values generally increased across the high-intensity bouts for each modality, but the final bout of boxing did not follow this trend. Although anecdotal, participants reported that the intensity of the bout was compromised because they felt unable to maintain their balance while performing the kicking exercise. For this reason kicking was removed from the protocol that was planned for the BE@Work programme.

Although acutely exercise has been shown to reduce SBP by 5 mmHg and DBP by 3 mmHg in both normotensive and hypertensive individuals (Carpio-Rivera et al., 2016), in the present study there were no meaningful changes in blood pressure post-exercise. Although this is an unexpected finding given that exercise at higher intensities has been shown to cause larger reductions in SBP (Carpio-Rivera et al., 2016), this could be a reflection of the limitations in the assessment tool used. Although the automatic blood pressure monitor used has been appropriately validated for use in clinical settings (Takahashi et al., 2010), it may not have

been sensitive enough to detect acute fluctuations in blood pressure (O'Brien et al., 2010). A Portapres device is an alternative non-invasive technique that can be used to assess blood pressure (Wesseling et al., 1993). This small finger-worn device can continuously measure arterial blood pressure. Although due to the cost of this equipment it was not feasible to use a Portapres device in the present study, future laboratory-based studies aiming to assess acute blood pressure responses to novel HIT modes could use a Portapres device to continuously monitor blood pressure before, during and after HIT.

No meaningful changes from baseline or between-mode differences in positive or negative affect were detected in the present study. Shepherd et al., (2015) reported a significant improvement in PANAS assessed positive affect (0.21 AU, $p=0.0001$) and negative affect (-0.13 AU, $p=0.05$) in the HIT group following a previously described workplace HIT intervention. However scores were presented using a 1-5 scale as opposed to the 10-50 scale described by the developers (Watson et al., 1988). Although direct comparison of their findings are precluded, the improvement in affect noted by Shepherd et al., (2015) indicates that a training intervention, as opposed to an acute HIT session, may be required to observe improvements in affect using the PANAS. Furthermore, baseline affect scores of participants in the present study (positive affect 33-34 AU, negative affect: 12-14 AU) were similar to normative PANAS values for healthy individuals (mean positive affect: 31 AU and mean negative affect: 16 AU) (Crawford & Henry, 2004), which may explain the lack of effect.

In the present study post-exercise and 60 minute post-exercise enjoyment scores ranged from 96 AU to 109 AU out of a possible 126 AU, with no meaningful between-mode differences detected. As a mean PACES score of 98 AU has been linked to the descriptor of "enjoyable" (Tew et al., 2017), data from this study suggests the participants perceived HIT as enjoyable. However, the large standard deviations of the post-exercise enjoyment scores (± 24 , ± 17 and ± 13 for stair climbing, stepping and boxing respectively) indicate variation in the perceived enjoyment of the HIT modes. Although given the analysis performed, the meaningfulness of this variation cannot be explored further. Furthermore, despite evidence to suggest that changes in psychological responses to HIT can be detected up to 60 minutes post-exercise (Stork et al., 2015), enjoyment scores were similar at both post-exercise and 60 minutes post-exercise time points in the present study suggesting that on reflection, perceptions regarding the enjoyment of the HIT sessions did not change. Enjoyment scores in the present study were similar or higher than previously published HIT studies. For example in a recent meta-

analysis of seven HIT trials, Oliveira et al., (2018) reported PACES assessed enjoyment scores ranging from 80 ± 5 AU (Jung et al., 2014) to 104 ± 9 AU (Thum et al., 2017) in a range of participants from recreationally active healthy men (Bartlett et al., 2011) to physically inactive obese women (Decker & Ekkekakis, 2017). However all of the HIT protocols applied across these studies were conducted on treadmills or cycle ergometers, therefore the higher enjoyment scores in the present study could reflect differences in exercise modalities, although further work is needed to confirm or refute these findings.

5.4.1 Limitations

Although the findings of this study indicate that stair climbing, stepping and boxing can be incorporated interchangeably into a HIT protocol, it is acknowledged that this study is not without limitations. A major limitation of this study is the use of age predicted HR_{max} for quantifying participants' responses to the HIT protocols. As previously described in Chapter Two, this is potentially problematic because of the between-subject variation in true HR_{max} (~7 to 11 BPM) (Tanaka et al., 2001). Given that the confirmation of the intensity of the prescribed exercise was based on age predicted HR_{max} , this could have led to misclassification of the true intensity of the exercise. However the purpose of this study was to further develop the HIT protocol that would eventually be used in the BE@Work programme. It has been suggested that the use of predicted as opposed to actual HR_{max} in real-world HIT trials improves the potential for the translation of HIT to settings outside of the laboratory, because it is not practical or feasible that all individuals complete maximal exercise test before engaging in this form of exercise (Scott et al., 2019). Indeed it was deemed unlikely that a CPET could be undertaken in a workplace in order to establish true HR_{max} , and to more closely simulate the planned intervention age predicted HR_{max} was used in the present study. Future work aiming to quantify the heart rate response to novel modes of HIT in a laboratory could seek to establish true HR_{max} via a maximal cardiopulmonary exercise tests.

Secondly, it is acknowledged that this was a small sample of mostly moderately or highly active participants, according to self-report physical activity levels. Therefore it cannot be known if the findings would have differed if the sample were predominantly inactive at baseline. Nevertheless, as adults have been reported to overestimate physical activity levels using self-report measures (Rzewnicki et al., 2003), it is possible that participants in this sample were less active than they perceived. Although some previous HIT trials have excluded participants who were physically active at baseline (Lunt et al., 2014; Shepherd et al., 2015),

the decision was made not to exclude active participants in the present study because a range of inactive and active individuals are likely to be present in a workplace, and excluding certain individuals from workplace-based activities may not be perceived favourably by organisations. The intention was to invite all employees within participating organisations to the BE@Work programme regardless of activity level at baseline, therefore the same procedures were enacted in the present study to simulate this. Future studies could seek to recruit more inactive or unfit participants at baseline in order to assess psychological responses in a broader range of participants.

In this study, participants were asked to complete affect (PANAS) and enjoyment (PACES) questionnaires 60-minutes after completing each of the three acute HIT sessions. To reduce participant burden and to more closely simulate a workplace HIT session, participants were not required to stay in the laboratory for 60 minutes after their HIT session, but were given the questionnaires to complete in their own time. Although participants were asked to set an alarm reminder on their mobile phone before leaving the laboratory, nonetheless this resulted in some missing data ($n=5/45$ for PANAS and $n=6/45$ for PACES). Although the presence of missing data necessitates caution when interpreting the 60-minute post-exercise mood and enjoyment data, the missing data constitutes a minimal percentage of total data (11 and 13%). Future studies could request that participants remain in the laboratory for 60-minutes following exercise to avoid missing data.

While the PANAS and PACES questionnaires were conducted in the same order at each data collection time-point to standardise the delivery protocol, it is acknowledged that order effects (where the order of questions impacts on participant responses) (Sudman & Bradburn, 1983) may have been reduced if the order of questionnaires were randomised. Furthermore, the completion of the PANAS and PACES questionnaires required participants to complete 38 individual questions at each data-collection time point. It is acknowledged that this may have resulted in questionnaire or response fatigue, which occurs when participants respond to survey questions but do not provide truthful or consistent responses to reduce the burden of answering questions (Egleston et al., 2011). It cannot be ruled out that both order effects and questionnaire fatigue may have impacted on the results of this study and therefore the findings should be interpreted with caution. To avoid these issues in future trials, the order of questionnaires could be randomised to avoid order effects, and the questionnaires could be interspersed throughout the data collection procedures to avoid questionnaire fatigue.

Floor and ceiling effects occur when a considerable proportion ($\geq 15\%$) of participants score at either the highest or lowest extreme of the scale (Ehrenbrusthoff et al., 2018). Floor and ceiling effects were investigated for the PANAS and PACES data by assessment of the positive and negative affect scores at all assessment time points. Although there was no evidence of floor or ceiling effects for the positive affect or PACES scores, there was evidence of a floor effect for the negative affect score; where 60%, 75% and 64% of participants scored the lowest possible score for negative affect at the pre-, post-, and 60 minutes post-exercise time points, respectively. This indicates that the PANAS may not be suitable to discriminate meaningful differences between participants at this extreme end of the scale (Ehrenbrusthoff et al., 2018; Fitzpatrick et al., 1998). If floor and ceiling effects are present, it has been recommended that all data at the extreme end of the scale is removed from the analysis (Fitzpatrick et al., 1998). However in this study the negative affect data were not removed from the analysis for two reasons. Firstly, the participants were not specifically recruited from a clinical psychiatric population and so extreme positive or negative affect is not necessarily expected. Secondly, removal of such a meaningful proportion of the data from the analysis would have resulted in no complete negative affect data sets (i.e. from all three HIT sessions), therefore the linear mixed model analysis could not be conducted. The presence of the floor effect in the negative affect data is acknowledged as a limitation of the PANAS tool, and therefore the findings of this data should be interpreted with caution.

5.5 Conclusion

This randomised cross-over trial has demonstrated that novel modes of HIT based on stair climbing, stepping and boxing can be implemented into a HIT protocol aimed at eliciting a high-intensity exercise response (e.g. $\geq 85\% \text{HR}_{\text{max}}$). Furthermore, there were no meaningful differences in heart rate responses between modes which indicates that the HIT modes could be used interchangeably within an intervention without compromising the intensity of the exercise. Although perceived exertion responses were between descriptors of 'hard' and 'very hard' for all three modalities, perceived exertion responses for boxing were lower than stair climbing and stepping. This may have been due to the technical aspects in the boxing HIT, however this conjecture warrants further investigation. There were no meaningful changes in blood pressure or affect from baseline, and no meaningful differences were detected across the HIT modes in blood pressure or affect. Perceptions of enjoyment were high and relatively similar for all modalities immediately following each exercise session and 60 minutes following the exercise sessions. However large standard deviations around the mean enjoyment scores

indicate variation in perceived enjoyment scores between participants, although the meaningfulness of the variation cannot be explored further with the analysis performed. The findings of this study suggest that the HIT protocol applied using novel modes could be incorporated into a longer term HIT programme that may be viewed favourably by participants. Accordingly the following chapter of this thesis will explore the feasibility and effects of an 8-week workplace-based HIT intervention named BE@Work on markers of physical fitness, cardiometabolic and mental health in office based employees.

Chapter 6: Study Four. Brief Exercise at Work (BE@Work): a controlled feasibility trial of a high-intensity interval training intervention delivered in the workplace

6.1 Introduction

High-intensity interval training (HIT) can elicit favourable adaptations in cardiorespiratory fitness (CRF) (Weston et al., 2014b), markers of cardiometabolic health (Costa et al., 2018; Jelleyman et al., 2015; Su et al., 2019) and body composition (Viana et al., 2019). Furthermore, adaptations are often similar to those elicited by traditional prescriptions of moderate intensity continuous training (MICT), despite a lower exercise time commitment (Milanovic et al., 2015). However the vast majority of work conducted to date has used tightly controlled laboratory-based protocols with direct researcher supervision (Gillen & Gibala, 2014). Although such trials demonstrate the efficacy of HIT, the potential for HIT to promote population wide health and fitness in settings outside of the laboratory has been questioned (i.e. the effectiveness of HIT) (Biddle & Batterham, 2015).

This assertion has been challenged by recent evidence demonstrating the potential effectiveness of HIT in adults in various 'real-world' settings including home-based (Blackwell et al., 2017; Scott et al., 2019) and community park or gym settings (Lunt et al., 2014; Reljic et al., 2018). The workplace is another setting in which the effectiveness of HIT has begun to be explored (Allison et al., 2017; Shepherd et al., 2015). The meta-analysis presented in Chapter Three demonstrated that workplace exercise interventions can elicit meaningful adaptations in CRF. However participation rates in workplace health promotion programmes vary widely (Bull et al., 2003; Robroek et al., 2009) and loss to follow up has been reported to range from 4-40% (Rongen et al., 2013). Poor reach and high attrition may indicate that novel and time efficient exercise training strategies, such as HIT, could be viewed as a viable alternative to traditionally prescribed MICT (Conn et al., 2009). Especially as lack of time is a commonly reported barrier to workplace exercise participation (Hunter et al., 2018).

Two non-controlled trials have explored the effects of stair climbing and cycle ergometer-based HIT in the workplace (Allison et al., 2017, Shepherd et al., 2015). Post-intervention both trials reported improvements in VO_{2max} of between 2.1 to 3.5 mL·kg⁻¹·min⁻¹. Furthermore, Shepherd et al., (2015) also reported improvements in blood lipids and fat mass. However a lack of no-exercise control group in both trials limits the confidence with which the findings can

be interpreted, given the substantial biases that can occur in uncontrolled trial designs (Hariton & Locascio, 2018). Additionally, both workplace HIT trials evaluated to date were conducted in academic workplaces, which may not be representative of other working environments. Finally, a single exercise modality was used in each intervention, which may not be feasible or engaging for some individuals. This suggestion was supported by participants of the formative evaluation of the BE@Work workplace HIT trial described in Chapter Four. Here, participants expressed a preference for a choice in a variety of exercise modalities within a workplace HIT programme, with stair climbing, stepping and boxing selected as preferred modalities. In Chapter Five, the modalities selected by formative evaluation participants were incorporated into a HIT protocol and it was demonstrated that the protocol elicited a high-intensity exercise response. From this, it could be suggested that novel modes of HIT may also elicit adaptations in physical fitness and cardiometabolic health outcomes comparable to more 'traditional' HIT modes. To address these limitations and further assess the effectiveness of HIT, there is a need for controlled workplace HIT trials, implemented in non-academic workplaces that utilise a range of novel HIT modes.

BE@Work was conducted in organisations located in two of the five local authorities in the Tees Valley region of North East England (Stockton-on-Tees and Redcar & Cleveland). Given that residents of both regions have lower life expectancies and higher cardiovascular disease (CVD) mortality rates (Public Health England, 2017) and may participate in less physical activity (NatCen Social Research, 2017) than residents in more affluent areas of England, the implementation of cardioprotective health promotion programmes in the Tees Valley region is vital. Accordingly, the aim of this study is to explore the feasibility and effects of a HIT intervention delivered in the workplace. The objectives of the study are to: a.) implement a controlled feasibility trial of an 8-week multi-activity workplace-based HIT intervention, and b.) explore the feasibility and effects of a workplace-based HIT intervention on markers of physical fitness, cardiometabolic and mental health in employees.

6.2 Methods

This study was approved by the School of Health and Social Care Research Governance and Ethics Sub-committee from Teesside University (study number: 036/18) and the protocol was prospectively registered on clinicaltrials.gov (identifier: NCT03467594). The reporting of this study conforms with the Template for Intervention Description and Replication (TIDieR) checklist (Hoffmann et al., 2014).

6.2.1 Study Design

This study used an exploratory non-randomised controlled trial design, with two groups. Participants in the intervention group were from one organisation and received an 8-week workplace-based HIT programme and participants from a second separate organisation acted as a no-intervention control group. To ensure that the allocation of participants to each group cannot be predicted, randomisation is considered the best method to allocate participants to intervention or control groups (Deeks et al., 2003). Although it was initially intended that the BE@Work programme would utilise a cluster randomised controlled trial (RCT) design, during planning discussions with the senior management team of one of the participating organisations, it became apparent that they would only allow their staff to participate if they were offered the intervention. Therefore the pragmatic decision was made to utilise a non-randomised controlled trial design. This decision could have introduced bias at various levels (Shrier et al., 2007). The greatest distinction between the results of randomised and non-randomised studies is the potential for selection bias; where systematic differences in groups are present at baseline (Deeks et al., 2003). This may lead to either over or underestimation of intervention effects, depending on the allocation decision. This may have been the case with the BE@Work trial because participants were allocated to either the intervention or control group based on which organisation they were employed by. However because the allocation of participants was based on their place of employment, rather than participant or researcher choice, this could have partially reduced the impact of selection bias. To partly overcome selection bias the individual participants' baseline values for each outcome were controlled for in the statistical analysis.

As shown in the Gantt chart in Figure 22, the BE@Work trial was implemented across two organisations over the course of 12 weeks between April and June 2018. This included two weeks of baseline outcome variable testing, followed immediately by an 8-week workplace HIT intervention for the intervention group, followed immediately by two weeks of post-intervention outcome variable testing. Control participants were asked to continue their usual routines during the intervention period and were not made aware of the BE@Work intervention arm.

Figure 22 BE@Work programme Gantt chart

Month	April 2018				May 2018				June 2018			
Week	1	2	3	4	5	6	7	8	9	10	11	12
Baseline testing												
BE@Work programme												
Post-intervention testing												

6.2.2 Recruitment and participants

Recruitment of individual study participants was facilitated by the participating organisations. Following consent from the management team of the participating organisations, promotional material was distributed via global staff email lists, e-newsletters and posters placed in prominent locations around the workplace (e.g. in bathrooms and kitchens). Participant information sheets for the intervention and control sites can be found in Appendices K and L. The thesis author also conducted presentations at the commencement of staff departmental meetings to advertise the project. Recruitment began three weeks before baseline testing (March, 2018). Recruitment was initially planned to begin at least one month prior to the commencement of the baseline testing (e.g. February 2018), however due to extreme weather conditions in February and March 2018, resulting in the closure of the sponsoring university, confirmation of ethical clearance was delayed by a significant time period and therefore recruitment could not begin as scheduled.

Based on feedback from participants of the formative evaluation of the BE@Work trial (Chapter Four), introductory HIT taster sessions were conducted in the two weeks prior to baseline testing at the intervention site. Taster sessions involved a single HIT session that was similar to the sessions to be delivered in the first week of the intervention. The purpose of these sessions was to promote the programme and allow potential participants to try the exercises that were to be conducted during the programme. Taster sessions were advertised using the same channels as the main intervention, and following each taster session participants were provided with information about the BE@Work trial. Fourteen individuals participated in the HIT taster sessions, of which 12 subsequently signed up to the BE@Work trial. The HIT taster sessions were advertised and conducted following Easter, during school holidays. Anecdotal feedback from participants indicated that interest in the taster sessions may have been greater if they were advertised earlier or conducted outside of school holiday dates, as many individuals in their organisation were on annual leave during this time.

Inclusion criteria were adult (aged ≥ 18 years) employees of the participating organisations with no health conditions that precluded them from exercise and on no medication. Exclusion criteria were symptoms of, or known presence of cardiovascular or metabolic disease, conditions or injury or co-morbidity affecting the ability to undertake exercise, early family history of sudden cardiac death and pregnancy or likelihood of pregnancy. All participants underwent pre-exercise screening using the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Bredin et al., 2013). If via the PAR-Q+ any of the inclusion/exclusion criteria were not met, the individual was not allowed to participate further.

Across the intervention and control sites, 54 office-based employees were recruited. Thirty participants (10 males) were recruited from the intervention organisation and 24 participants (10 males) from the control site. The BE@Work trial is a feasibility trial, of which one of the key outcomes is securing assumptions about effect size and variability (Craig et al., 2008). Given that this information is required for sample size power calculations, performing one for a feasibility trial is counterintuitive. The target sample size for this study was 60 employees, consisting of ~ 30 participants per study site. Given that this study was delivered largely by the thesis author with limited assistance from other researchers, this sample size was deemed feasible for both data collection and exercise session facilitation. This could then inform a future definitive trial by examining whether the intervention could be delivered as intended, in regards to intervention fidelity.

6.2.3 Outcome measures

Outcome data was collected at two time points from intervention and control participants. Baseline data was collected in April 2018 (3 to 14 days prior to the commencement of the intervention) and post-intervention in June 2018 (3 to 14 days following the final training session) for both the intervention and control groups. Where possible, the post-intervention data collection was completed within the first five days after the end of the intervention (June 2018). In the intervention group 21 of the 25 remaining participants completed post-intervention testing within 5 days of the end of the intervention (84%). The remaining participants were on annual leave during the week immediately following the intervention and completed testing upon their return to work. In the control group post-intervention testing was conducted within 5 to 11 days following the end of the intervention, with nine participants

tested within 5 days, and subsequently a further four within 6 days, a further six within 10 days and a further six within 11 days, post-intervention.

The following outcome variables were measured at baseline and post-intervention in intervention and control participants: CRF (predicted VO_{2max}); leg extensor muscle power; hand grip strength; systolic blood pressure (SBP); diastolic blood pressure (DBP); blood lipids and glucose; anthropometry (body mass index [BMI] and waist circumference); health-related quality of life (HR-QoL); psychological wellbeing and perceived stress. All outcome variable assessments were conducted in a private room in the participants' workplace by the thesis author, with the assistance of one other graduate student researcher. Further information on each outcome is detailed below. Outcomes were tested in the same order at both time points (HR-QoL, wellbeing, perceived stress, blood pressure, hand grip, finger prick blood sample, height and weight, waist circumference, lower limb power, CRF). Participants were advised to arrive well rested and to drink plenty of fluids in the 24 hours before, avoid eating a heavy meal or drinking alcohol and caffeine for 3 hours before and avoid strenuous exercise on the day of their scheduled session. Post-intervention testing was conducted within ± 2 hours of the baseline appointment time. Upon arrival to their baseline appointment the content and time of the participant's last meal was documented and before the post-intervention data collection participants were reminded of this information and asked to replicate their eating patterns as closely as possible.

At the stipulation of the Research Ethics and Governance Committee at the sponsoring university, the thesis author was required to advise participants to seek medical advice if any outcome variables were outside of expected 'healthy' parameters at the baseline or post-intervention data collection time points.

6.2.3.1 Primary outcome: Cardiorespiratory fitness

The gold standard test for the measurement of CRF (as measured by maximal oxygen consumption [VO_{2max}]) is a cardiopulmonary exercise test (CPET) (Shephard, 1968). However in the present study this test was not pragmatically possible for two reasons; firstly it was not possible to transport the required equipment to the organisations for data collection; secondly the organisations participating in the project permitted employees only 60 minutes each for the baseline and post-intervention data collection, therefore given the considerable time commitment required for a CPET, time restrictions did not permit this test. Therefore in the

present study CRF was estimated using the Chester step test (Sykes, 2018) (Cartwright Fitness, Huntington, United Kingdom). The validation, reliability and protocol for the Chester step test was described in Chapter Two (section 2.2.1). Briefly, the test consists of five, two minute stages. Stepping cadence begins at 15 steps per minute and increases by 5 steps per minute at the end of every two minute stage, with step frequency controlled by an electronic metronome. Participants continue stepping until they reach 80% of age predicted maximal heart rate (HR_{max}), or they report a rating of perceived exertion of ≥ 15 arbitrary units (AU) (hard) on the Borg 7-20 scale (Borg, 1982), or they complete all five stages of the test (Sykes, 1998; Sykes & Roberts, 2004). Four step heights are available (15cm, 20cm, 25cm or 30cm). Step height for each participant was selected by the thesis author, based on recommendations from Sykes (2018) considering individual participants' age and habitual activity level. Consequently, 23, 14, 12 and 4 participants used the 15 cm, 20 cm, 25 cm and 30 cm step heights, respectively. Step height was recorded to ensure standardisation across baseline and post-intervention testing. Heart rate was recorded throughout the test using wrist-worn monitors (Polar A380, Polar Electro, Kempele, Finland) and age-predicted HR_{max} was calculated as previously described (Tanaka et al., 2001). Following completion of the test, VO_{2max} was estimated using the Chester step test calculator (Cartwright Fitness, Huntington, UK <https://www.chesterstep.com/>) which uses a regression line through submaximal heart rate up to a horizontal line that corresponds to predicted HR_{max} , which in turn predicts VO_{2max} . The predicted VO_{2max} from the Chester step test software was taken and used in the analysis.

As CRF was the primary outcome of interest in the present study, and with the previously described limitations associated with the Chester step test in mind, it was originally intended to conduct CPETs with a sub-sample of participants. Although this was offered to all participants in both the intervention and control group, no participants agreed to attend a CPET at the university. Anecdotally, the reasons for this were the time commitment associated with travel to the university laboratory to conduct the test and concerns associated with a maximal exercise test.

6.2.3.2 Leg extensor muscle power

Leg extensor muscle power was assessed using the Nottingham leg extensor power rig (henceforth called "leg rig" [Medical Engineering Unit, University of Nottingham, Nottingham, UK]), which has recently been demonstrated to have excellent short and long term reliability in both middle aged and older adults (Hurst et al., 2018). Given that three repeated trials are

recommended at baseline to reduce habituation effects (Hurst et al., 2018), in the present study it was initially intended that participants would undertake three repeated trials at baseline. However due to the significant time commitment required (~15 minutes per trial) the participating organisations were reluctant to allow staff this extra time away from work given that other testing procedures took 60 minutes. Despite the agreement of senior management teams, the repetition of this measure caused various issues with middle management who frequently did not permit participants to return for the full testing procedure. Therefore 4, 28 and 22 participants undertook the testing one, two and three times, respectively, at baseline.

Testing procedures outlined by Bassey & Short (1990) were followed for the administration of this test. Participants were seated with a flexed knee in an upright position with arms folded across their chest. Participants performed a unilateral leg extension until the footplate was fully depressed while the other foot rested on the floor. Seat position was determined so that the leg reached full extension at the end of the footplate movement. Seat position was recorded to ensure standardisation across all trials. Participants were asked to wear flat, comfortable lace-up shoes and to wear the same footwear during each trial. A standardised warm-up was conducted prior to the testing protocol, which consisted of three warm-up leg extensions at increasing submaximal intensity (~50, ~75 and ~90% of self-perceived maximal effort). Then, ten maximal effort leg extensions were performed, each separated by 30 seconds of passive rest. Participants received standardised instructions before every individual leg extension (“push as hard and as fast as possible”) and strong verbal encouragement was provided throughout. After assessment of the first leg, participants then performed the same warm-up as previously described, followed by the testing protocol on the second leg. The tests were performed in a randomised counterbalanced order with participants performing all testing sessions in the same order (e.g., always dominant leg first or always non-dominant leg first, based on initial randomisation) with leg dominance determined using the lateral preference inventory (Coren, 1993). Scores were recorded in Watts (W) to the nearest whole unit. The highest value recorded over ten leg extensions was taken as the participants’ peak power output for data analysis.

6.2.3.3 Hand grip strength

Handgrip strength was measured using a hydraulic hand dynamometer (12-0240; Baseline Evaluation Instruments, Fabrication Enterprises Ltd, New York, United States). This instrument has acceptable reliability (ICC 0.99) and concurrent validity when compared with

other hand dynamometers (Summer et al., 2000). Testing procedures outlined by Perna et al., (2016) were followed for the administration of this test. The dynamometer was adjusted to the participants hand size, such that the index finger of each hand was at 90° flexion between proximal and middle phalangeal joint (Perna et al., 2016). Following a submaximal practice attempt, participants performed three maximal efforts on each hand, with 60 seconds rest following each attempt, alternating between hands each time. Body position was standardised with participants instructed to maintain the standard bipedal position, with the arm in complete extension and feet positioned hip width apart. Participants were provided with standardised instructions and strong verbal encouragement before every repetition (“squeeze as hard as you can, until you can’t squeeze any harder”). Testing was performed in a randomised, counterbalanced order with participants performing all testing sessions in the same order (e.g. always dominant hand first or always non-dominant hand first based on initial randomisation) with hand dominance determined using the lateral preference inventory (Coren, 1993). Scores were recorded in kilograms to the nearest 0.5 kg. The highest value recorded over three repetitions was taken and used in the analysis.

6.2.3.4 Blood pressure

Blood pressure was measured using an OMRON M6 AC (HEM-7322-E) monitor (Omron Healthcare UK, Milton Keynes, UK), using the procedures outlined in Chapter Five (section 5.2.3). This monitor has been validated for clinical use, using the European Society of Hypertension International protocol (Takahashi et al., 2014). Following 10 minutes of seated rest the standard sized Omron cuff (22 to 32cm) was placed tightly on the upper left arm. During the measurement participants sat quietly with their arm resting on a table at 90°. Three readings were taken and the average of the three was taken and used in the analysis.

6.2.3.5 Blood lipids and glucose

Non-fasting blood lipids (cholesterol, triglyceride and high density lipoprotein cholesterol (HDL-C)) and glucose profiles were assessed using a Cholestech LDX analyser (Cholestech Corporation, Hayward, CA, USA). Although the Cholestech LDX analyser also provides a value for low density lipoprotein cholesterol (LDL-C), this value is an estimation based on the triglyceride: cholesterol ratio. The equation used to estimate LDL-C assumes a constant triglyceride: cholesterol ratio that is not accurate when participants are not fasted (Krishnaveni & Gowda, 2015). Therefore LDL-C will not be reported further in the present study. The

justification for the use of non-fasting samples has been previously described in Chapter Two (section 2.2.4).

Blood lipid and glucose measurements were assessed by the thesis author at baseline and post-intervention. The thesis author has previously attended a full training course on the analyser and blood sampling techniques used in the present study. As per storage instructions the Cholestech LDX lipid panel plus glucose cassettes were refrigerated and returned to room temperature no more than 15 minutes before data collection. Before each data collection session, an optics check was performed and details recorded. Participants washed their hands with warm soapy water prior to the collection procedure. Following this, participants were seated with their non-dominant hand placed palm-up on their thigh. The area was sterilised with an alcohol swab and a firm puncture was made in the middle finger using a single use lancet (Unistik 3, Owen Mumford, UK). The first drop of blood was wiped away using a clean tissue and then moderate pressure was then applied to ensure adequate blood flow until another large drop appeared. The sample was drawn into a 35 μ L capillary tube coated with lithium heparin (Cholestech LDX, AR-MED Ltd, Egham, UK) and immediately transferred into a cassette sample well. The cassette was then placed into the device drawer for analysis and results were displayed on the analyser screen within 5 minutes. Medical gloves were worn by the researcher at all times and all materials contaminated with blood were disposed of in a biohazardous sharps bin. Values for cholesterol, triglycerides and HDL-C were taken and used in the analysis.

6.2.3.6 Anthropometry

Body mass and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, without shoes and socks and with participants in light clothing using the Seca 799 electronic column scale, fitted with a Seca 224 stadiometer rod (Seca, Hamburg, Germany). Body mass index (BMI) was calculated using the equation $BMI (kg/m^2) = \text{body mass (kg)} / \text{height (m)}^2$.

Waist circumference was measured using a non-elastic Gulick tape measure with a tension device, by the thesis author at both data collection time points. Testing procedures outlined by Stewart et al., (2011) were followed. The circumference of the abdomen was measured at the narrowest point between the lower costal border (10th rib) and the top of the iliac crest, perpendicular to the long axis of the trunk. The author stood in front of the participant and passed the tape around their abdomen. The participant stood in a relaxed position, with arms

crossed over their chest. The end of the tape and the housing were held in the right hand while the left hand was used to adjust the level of the tape until it was at the narrowest point of the waist. The stub was then passed back to the left hand to position the tape in front at the target level. The participant was asked to breathe normally and the measurement was taken at the end of their natural expiration, to the nearest 0.1cm. If there was no obvious narrowing the measurement was taken at the mid-point between the lower costal and the iliac crest. Measurements were taken twice and an average of the two measurements was used in the analysis.

6.2.3.7 Habitual physical activity

The International Physical Activity Questionnaire (IPAQ) short form (Craig et al., 2003) was used as a self-report measure of physical activity in the previous 7 days, as per the protocol described in Chapter Five (section 5.2.3.2). However because the minimal clinically important difference in habitual physical activity was taken from work using MET hours of physical activity per week ($\text{MET hour}\cdot\text{week}^{-1}$) and the IPAQ scoring system gives a score in $\text{MET min}\cdot\text{week}^{-1}$, the final score was divided by 60 to obtain a score in $\text{MET hour}\cdot\text{week}^{-1}$.

The use of the IPAQ to assess habitual physical activity is a deviation from the registered trial protocol. Although the trial protocol stated that physical activity would be assessed using tri-axial accelerometers the equipment was unavailable for the duration of the baseline testing period therefore it was necessary to use an alternative self-report measure of physical activity.

6.2.3.8 Health-related quality of life

Health-related quality of life (HR-QoL) is typically assessed using the Medical Outcomes 36-Item Short Form Health Survey 1.0 (SF-36) (Hays et al., 1993). The SF-36 is a 36 item questionnaire that assesses eight distinct domains of HR-QoL with multi-item Likert scales (physical functioning, role limitations caused by physical health problems, role limitations caused by emotional problems, social functioning, emotional wellbeing, vitality, bodily pain and general health perceptions). Reliability estimates for summary scores from the domains are acceptable ($r=0.90$) (Hays et al., 1993). Before administration of the SF-36 the wording of the questionnaires was modified from “in the past four weeks” to “in the past two weeks”, which is recommended for short term interventions by the scale developers (Hays et al., 1993). Scoring followed procedures outlined by Ware et al., (2002), whereby a sum score for each of

the eight domains was calculated. Possible scores range from 0 to 100 with higher scores indicating higher HR-QoL in all of the domains of the scale. An example copy of the SF-36 can be found in Appendix M.

6.2.3.9 Mental wellbeing

The Warwick Edinburgh Mental Wellbeing Scale (WEMWS) was used to assess mental wellbeing (Tennant et al., 2007). The WEMWS is a 14 item Likert scale questionnaire that has acceptable test-retest reliability in adults (intra-class correlation= 0.83) (Tennant et al., 2007). Furthermore, the WEMWS has moderate to high levels of construct validity with nine other comparable scales (median $r=0.73$, range 0.42 to 0.77) (Tennant et al., 2007). A total score is calculated by summing the 14 individual statement scores (Tennant et al., 2007). The minimum score is 14 and the maximum is 70, higher scores indicate more positive mental wellbeing. An example copy of the WEMWS is presented in Appendix N.

6.2.3.10 Perceived stress

Perceived stress was measured using the Perceived Stress Scale (PSS) (Cohen et al., 1995). The PSS is a 10 item likert scale questionnaire with four positively worded and ten negatively worded statements which has been used previously to explore the effect of HIT on perceived stress (Bhosle et al., 2018; Lark et al., 2017). The PSS has acceptable test-retest reliability ($r=0.7$) (Lee, 2012). Scoring followed procedures outlined by Cohen et al., (1995) whereby a total score was obtained by reversing responses to the four positively worded items and then summing across all scale items. Possible scores range from 0-40 with lower scores indicating lower perceived stress. A copy of the PSS is presented in Appendix O.

6.2.4 HIT Intervention

The HIT intervention began immediately following the baseline testing period. Participants completed three group-based HIT sessions each week for eight weeks (24 sessions in total). Exercise sessions were conducted on a grassed and paved area outside of the workplace or in a large meeting room inside the workplace. A bridge within 100m of the workplace with 30 steps on one side and a ramp on the opposite side were used for stair climbing sessions. All sessions commenced and terminated at the entrance foyer of the organisation and the group proceeded with the exercise facilitator (the thesis author) to the exercise location.

Exercise sessions were organised as outlined in Table 21 of Chapter Four. Briefly, four sessions per day (morning, midday and evening sessions) were conducted on Monday through Thursday, with two sessions on a Friday (morning and midday) (18 total per week). Participants were asked to attend whichever three sessions suited their availability over the week. To maximise attendance no restrictions were placed on minimum length of time between sessions. Exercise modes within each session were based on stair climbing, stepping and boxing. Participants were able to choose any of the three modes based on their preference. Example drills are demonstrated in Table 28 with images of the BE@Work exercise sessions shown in Figure 23 and Figure 24.

Table 28 Example BE@Work HIT drills

Modality focus	Example drill
Boxing	Ten fast jabs/ upper cuts/ hooks on the focus pad and 50m shuttle run/ power walk
	Ten fast jabs/ upper cuts/ hooks on the focus pad and 50 jumping hacks
	Ten fast jabs/ upper cuts/ hooks on the focus pad and 50 skips or jumps over a rope on the ground
Stair climbing	One stair climb (30 steps), and 100m shuttle run/ power walk
	Repeated stair climbs (30 steps up, 30 steps down)
Stair stepping	20 step ups and downs and 20 jumping jacks or side taps
	20 steps up and down and 50 m shuttle run/ power walk

Figure 23 Example of stair climbing/ stepping exercise modality

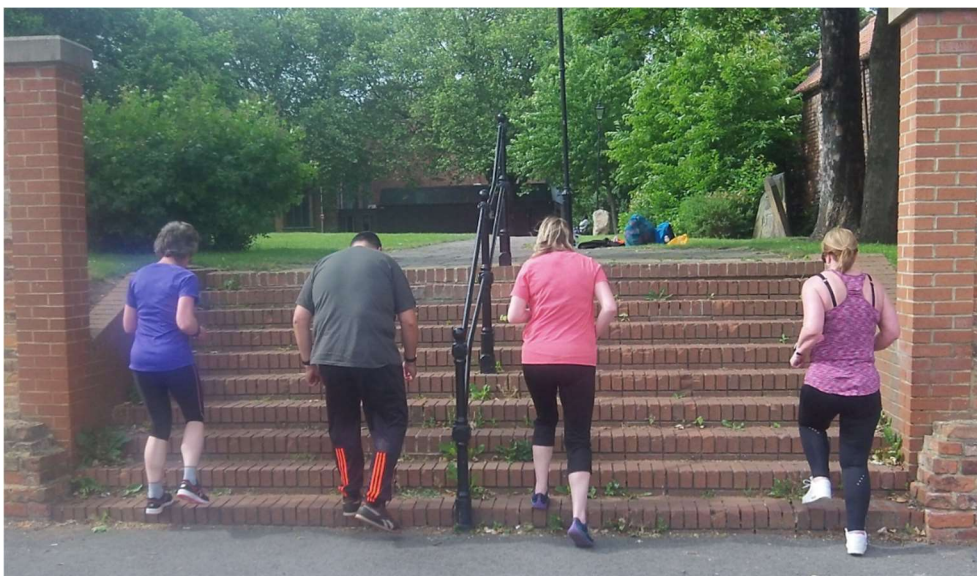


Figure 24 Example of boxing HIT modality



6.2.4.1 Exercise intensity prescription

The HIT protocol used in the present study was based on the protocol of the randomised cross over trial presented in Chapter Five (4x 60 second high-intensity bouts, interspersed with 75 seconds of rest). The justification for this HIT protocol was described in Chapters Four and Five. The intensity of the prescribed exercise was quantified in Chapter Five with findings indicating that the protocol satisfied the criterion for high-intensity exercise (e.g. $\geq 85\%HR_{max}$) for all three modalities, with no substantial difference between modes. The number and length of high-intensity bouts was based on HIT protocols which have previously been shown to elicit adaptations in markers of muscle metabolism, CRF and cardiometabolic health variables (Hood et al., 2011; Little et al., 2011; Weston et al., 2016a). Progression in the exercise prescription was provided by increasing the number of high-intensity bouts by one 60-second repetition every fortnight, from four repetitions in weeks one and two of the intervention, to seven repetitions in weeks seven and eight. The progression of the HIT prescription over the intervention was based on HIT protocols previously shown to elicit improvements in CRF in adults (Phillips et al., 2017).

The explanation of HIT was standardised across all participants, based on the description provided to participants in Chapter Five. Participants were provided with strong verbal encouragement to work maximally throughout each HIT session. Each session began with a 5 minute warm-up consisting of exercises relevant to the session activity which progressed in intensity to $\sim 75\% HR_{max}$ and concluded with a 2 minute cool down. Therefore exercise

sessions lasted ~15 minutes in the earlier weeks of the intervention to a maximum of 25 minutes in the later weeks of the intervention.

6.2.4.2 Intervention implementation monitoring and quantification

6.2.4.2.1 Heart rate responses

Second-to-second heart rate monitoring was conducted as described in Chapter Five, during HIT sessions using wrist-worn heart rate monitors (Polar A360, Polar Electro, Kempele, Finland). The handling of heart rate data, calculation of age predicted HR_{max} and the criterion used for high-intensity exercise were all conducted as described in Chapter Five (section 5.2.3.4). Briefly, the highest 1 second value from each high-intensity bout was taken and expressed as a percentage of the participants' age predicted HR_{max} . The peak heart rate for each HIT bout conducted across the intervention was taken and used in the analysis. Due to limited availability of heart rate monitors (only 10 monitors available for use over the duration of the study); heart rate traces were available for 94% of the attended exercise sessions across the intervention. Heart rate monitors were available at every HIT session, however if more than 10 participants attended any single session, only 10 could wear the monitors. Monitors were allocated on a "first come, first serve" basis, unless participants had previously attended a session that week where a heart rate monitor was also unavailable, in which case, priority was given to those who had not worn a monitor in their previous HIT session.

6.2.4.2.2 Ratings of perceived exertion

Session RPE was recorded after the 2 minute cool down following each HIT session. Familiarisation and data collection procedures were enacted as described in Chapter Five. Briefly the participant recorded their unique study identification code and session RPE privately on a paper based copy of the CR-10 scale (Borg, 1998). This scale ranges from "nothing at all" (0) to "absolute maximum" (10). Individual participant session RPE values were then transferred to a spreadsheet. The session RPE for each attended HIT session was taken and used in the analysis.

6.2.4.2.3 Acute affect and enjoyment responses

Acute affect was assessed using the Positive and Negative Affect Scale (PANAS) (Watson et al., 1988), which was also used to assess affect in the study presented in Chapter Five (section 5.2.3.6). The PANAS questionnaire was sent electronically (via email) to participants at fortnightly intervals during the intervention on the Monday morning of each fortnight, with the

request to return them to the thesis author (via email) by Wednesday of that week. It was initially intended to administer the PANAS at baseline (prior to the first HIT session) and at fortnightly intervals for the duration of the intervention (weeks two, four, six and eight). However during week four of the intervention, an error occurred in the email system of the participating organisation which resulted in all emails from the thesis author being sent directly to the spam folders of the participants. Unfortunately, this did not become apparent to the thesis author until Thursday of that week. It is possible that the PANAS could have been administered in week five of the intervention (in place of week four) however it became apparent that management representatives in the participating organisation had concerns regarding the volume of assessments being sent to participants. Therefore to reduce participant burden associated with completing the assessments in both week five and six, the PANAS was administered at four time points only (baseline and weeks two, six and eight). Enjoyment of the exercise sessions was assessed using the PACES questionnaire (Kendzierski & DeCarlo, 1991) which is the same tool used to assess enjoyment in Chapter Five. All familiarisation, administration and data handling of the PACES were enacted as outlined in Chapter Five (section 5.2.3.7). The PACES questionnaire was administered at fortnightly intervals during the intervention (week two, four, six and eight). As described above, the PACES was sent via email with the PANAS questionnaire. Due to technical issues outlined previously, the email containing the PACES scale was not received by participants in week four of the intervention, therefore the PACES was administered in week two, six and eight of the intervention. All enjoyment data were handled as described in Chapter Five.

Despite repeated prompts from the researcher during HIT sessions and via email, return of the PANAS and PACES data was particularly poor, resulting in missing data. For this reason, a cautious approach was taken in the interpretation of this data, and only descriptive data is presented.

6.2.5 Statistical analysis

Heart rate and RPE data were quantified to indicate the quality of intervention implementation in terms of the intensity of the HIT sessions using the analysis procedures described by Taylor et al., (2015). For heart rate data, the proportion of completed repetitions over the intervention where heart rate data were available (2735 repetitions) in which the high-intensity exercise criterion (e.g. $\geq 85\%HR_{max}$) was attained, was determined for each participant. The median and interquartile range of these individual proportions was calculated. Then, to provide the

correct overall between and within-subject variability (expressed as an SD) in both peak heart rate across the high-intensity bouts and session RPE, a linear mixed model was applied, with exercise session specified as a fixed effect (SPSS v.25, Armonk, NY: IBM Corp). Data are expressed as mean \pm SD, with uncertainty in the estimates expressed as 90% confidence intervals. Descriptive data (mean \pm SD) is presented for acute affect and enjoyment data for each data collection time-point, due to the data collection issues previously described.

Outcome data were analysed using an analysis of covariance (ANCOVA) model (SPSS v.25, Armonk, NY: IBM Corp) (Vickers, 2005). Plots of the model residuals versus the predicted values were visually inspected by the thesis author and one other researcher to check they were correctly specified (uniform variance and normal distribution of residuals). The fixed effect was the group (intervention or control), and the dependent (outcome) variable was the change from baseline time-point to post-intervention time-point. Model covariates were sex, age and baseline value of the outcome, to adjust for any imbalances between the intervention and control groups at baseline. For the blood lipid and glucose measures only, fasting status was included as an additional covariate. This variable was defined as the number of hours fasted post-intervention minus number of hours fasted at baseline. Data are expressed as mean \pm SD, with uncertainty in the estimates expressed as 90% confidence intervals.

Currently, there is much debate about how confidence intervals should be interpreted in both Bayesian and frequentist contexts (Greenland et al., 2016). For interpretation using the magnitude-based inferences framework (Hopkins et al., 2009), the mean effect of the intervention (versus control) for each outcome was estimated and uncertainty of the estimates were expressed as 90% confidence intervals. The probability that the effect was beneficial, trivial, and harmful was assessed against a threshold of a minimal clinically important difference (MCID). Where possible, MCIDs were based on clinical anchors but in the absence of a robust clinical anchor, the MCID is usually defined as a standardised mean difference of 0.2 between-subjects SD (Cohen, 1988). The SD of the pooled baseline values was used for this purpose, because the post-intervention SD can be affected by responses to the intervention. The MCIDs used in the analysis for each of the outcome variables are displayed in Table 29.

Table 29 Minimal clinically important differences used for each outcome variable

Outcome variable	MCID	Justification
VO _{2max}	+1 mL·kg ⁻¹ ·min ⁻¹	Increase of 1 mL·kg ⁻¹ ·min ⁻¹ in VO _{2max} is associated with a 9% relative risk reduction in all-cause mortality (Laukkanen et al., 2016).
Leg extensor muscle power	16 Watts	No robust clinical/ practical anchor therefore 0.2 of the SD of the pooled baseline values.
Hand grip strength	+5kg	Conclusions of a systematic review aiming to define a MCID for hand grip strength (Bohannon, 2019).
Blood pressure	SBP: -6mmHg DiBP: -3mmHg	Meta-analysis demonstrating reduction of 6/3mmHg lowered CHD risk by 14% and stroke by 18% (Salam et al., 2019).
TC	-0.19 mmol.L ⁻¹	No robust clinical anchor therefore 0.2 of the SD of the pooled baseline values.
HDL-C	+0.09 mmol.L ⁻¹	No robust clinical anchor therefore 0.2 of the SD of the pooled baseline values.
TG	-0.13 mmol.L ⁻¹	No robust clinical anchor therefore 0.2 of the SD of the pooled baseline values.
Glucose	-0.15 mmol.L ⁻¹	No robust clinical anchor therefore 0.2 of the SD of the pooled baseline values.
BMI	-0.8 kg.m ²	No robust clinical anchor therefore 0.2 of the SD of the pooled baseline values.
Waist circumference	-2 cm	≥2cm reduction in waist circumference associated with decreased risk of Metabolic Syndrome (odds ratio: 0.6) (Hosseinpanah et al., 2010).
Habitual physical activity	+6 MET hours.week ⁻¹	Meta-analysis demonstrating the largest reduction in CVD risk is derived when moving from inactive (0 MET hours.week ⁻¹) to moderately active 6 MET hours.week ⁻¹ (relative risk: 0.77) (Wahid et al., 2016).
HR-QoL	3 AU	3-5 AU estimated as a clinically important change in each HR-QoL domain in a systematic review (Samsa et al., 1999). Therefore 3 AU taken as the MCID.
Mental wellbeing	1.5 AU	No robust clinical anchor therefore 0.2 of the SD of the pooled baseline values.
Perceived stress	1.3 AU	No robust clinical anchor therefore 0.2 of the SD of the pooled baseline values.

Although there is epidemiological evidence to suggest an increased risk of CVD per 0.75 mmol.L⁻¹ increase in total cholesterol (Jeong et al., 2018), per 1 mmol.L⁻¹ increase in blood glucose (Asia Pacific Collaboration, 2004) and per 0.03 mmol.L⁻¹ decrease in HDL-C (Maron, 2000) these values were not used as the MCID in the present study. This is because values are based on fasted blood samples and assessments of blood lipids and glucose were non-fasted in this study, therefore the decision was made to base the MCID for these outcomes on 0.2 of the between-subject SDs as described above.

Using clinical inferences the qualitative probabilistic inferences were assigned to each effect using the following scale; <0.5%, most unlikely; 0.5 to 5%, very unlikely; 5 to 25%, unlikely; 25 to 75%, possibly; 75 to 95%, likely; 95 to 99.5%, very likely; >99.5%, most likely (Hopkins et al., 2009). In light of recent debates surrounding the validity and robustness of magnitude based inferences (Sainani et al., 2019), the pilot design and consequent small sample size of this study, effects were only declared meaningful when the probability likelihood for the effect was ≥75% (likely) and the qualitative inference was either beneficial/ harmful or positive/ negative (i.e. a likely trivial effect although has a probability of ≥75%, a trivial effect would not be considered meaningful). Critiques of magnitude based inferences indicate that at small-to-moderate sample sizes, although magnitude based inferences reduce the type II error (false negative) rate, type 1 error (false positive) rates are increased (Sainani, 2018). Therefore Cohens d effect sizes (Cohen, 1988) are also reported. Effect sizes were interpreted as follows; trivial <0.2, small 0.2-0.3, moderate 0.4-0.8, and large >0.8 (Hopkins et al., 2009).

Given the controlled design of this study, any cases with missing post-intervention data contribute no information regarding the intervention effect (Weston et al., 2016a); therefore data from these participants were removed from the analysis. There were also some cases where post-intervention values were present but baseline values were missing. For example, physical activity data for three participants was missing at baseline but post-intervention data was obtained. The reason for this was because participants did not understand the questionnaire and despite assistance from the thesis author were unable to recall their physical activity level over the previous 7 days. Some values below the lower detection limit of the Cholestech LDX analyser were observed for triglyceride (<0.51 mmol.L⁻¹, n=3) and HDL-C (<0.39 mmol.L⁻¹, n=3). This missing data was imputed as the lowest detection limit for the LDX analyser for each outcome.

6.2.5.1 Sensitivity analyses

Sensitivity analyses were performed on the three outcomes where residuals demonstrated evidence of outliers (VO_{2max} , BMI and perceived stress). Removal of the outliers from the statistical model did not make a material difference in the effect or precision of the estimates and therefore outliers were not removed for the final analysis. In the case where residual plots were incorrectly specified the following data transformations were enacted: physical activity, triglyceride and glucose were log transformed; and two domains of HR-QoL (emotional wellbeing and bodily pain) were reflected and then log transformed. However the transformations had no material difference on the direction or magnitude of the effect or the subsequent inferences, therefore the decision was made to present the analysis for the raw untransformed data as described above.

6.3 Results

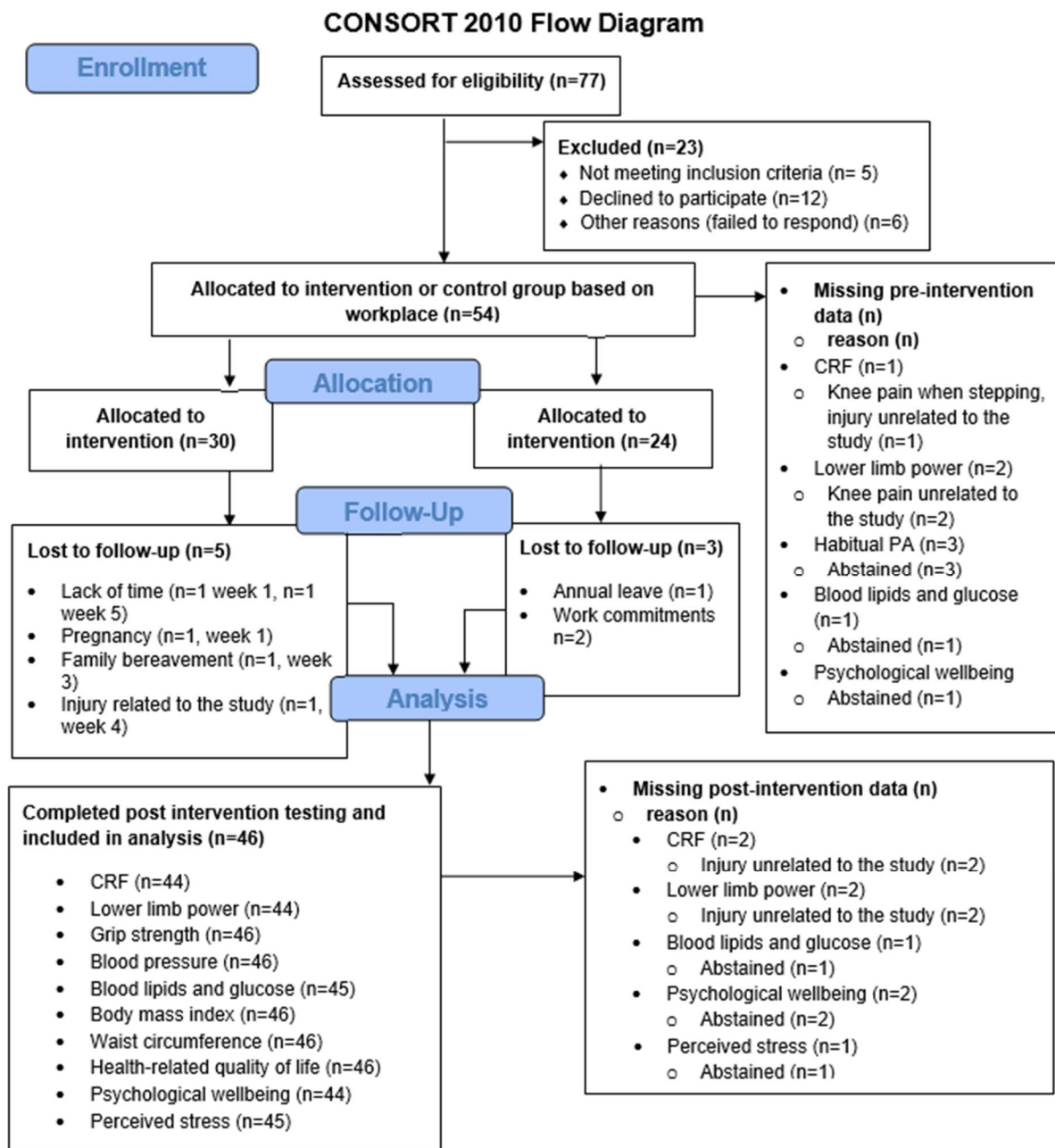
Participant flow through the study is shown in the Consort diagram (Figure 25), which details reasons for drop out from the study and missing data. Across the intervention and control sites, the BE@Work trial was advertised in office blocks where a total of ~400 employees were usually located. As shown in Figure 25, 77 individuals were screened for eligibility across the intervention and control sites, of which, 54 consented to participate in the study.

Baseline participant characteristics are shown in Table 30. Of the 54 participants that were allocated to the intervention or control group, 25 of 30 intervention and 21 of 24 control participants completed post-intervention testing. In the intervention group, one participant reported she was pregnant during week one of the intervention and therefore withdrew from the study, two participants withdrew reporting 'lack of time' (in weeks one and five) and one participant withdrew in week four due to an injury related to the study (details below).

Table 30 Baseline participant characteristics (mean \pm SD)

	Intervention (n=31) Mean (\pmSD)	Control (n=24) Mean (\pmSD)
Age (years)	48 (\pm 8)	46 (\pm 12)
Height (m)	1.7 (\pm 0.1)	1.7 (\pm 0.1)
Body mass (kg)	77.0 (\pm 15.0)	74.1 (\pm 10.1)
Body mass index (kg/m²)	27.0 (\pm 4.7)	26.2 (\pm 3.2)
Habitual PA (METmin⁻¹)	1354 (\pm 819)	2006 (\pm 1695)

Figure 25 Consort flow diagram of participants through the BE@Work trial



6.3.1 Intervention attendance

Across the BE@Work programme, 144 HIT sessions were scheduled (18 sessions per week for 8 weeks), of which participants were asked to attend 24 (three sessions per week for eight weeks). Mean (\pm SD) session attendance was 20 (\pm 3) (range= 14 to 24 sessions) out of a 24 possible sessions (82% \pm 15%). Reasons for non-attendance included work and family commitments, annual leave from work, injuries unrelated to the study, and in two participants, injuries related to the intervention. Over the intervention a total of 539 'participant sessions' were attended across the intervention. If all participants recruited to the intervention at baseline (n=30) attended 24 sessions over the intervention, this would have equated to 720 'participant sessions'.

6.3.2 Injuries related to the intervention

Two injuries attributable to the intervention occurred during BE@Work. During the final interval of a HIT session in week four, one participant tripped and fell over their feet while completing a shuttle run resulting in a fractured elbow. The session was terminated and standard first aid procedures enacted. The participant was encouraged to present to their healthcare provider and subsequently made a full recovery, but withdrew from the study. One participant suffered a calf strain during a HIT session in week four which resulted in one missed session. Their session was terminated and standard first aid procedures were enacted and once recovered, they were able to participate fully in the rest of the intervention.

6.3.3 Intervention implementation and intensity quantification

Over the attended HIT sessions, individual participant heart rate traces were available from 94% of attended HIT sessions. This resulted in 506 (of 539 participant sessions) heart rate data files, comprising 2735 high-intensity bouts. Specific reasons for missing heart rate data included equipment shortage (n=21), equipment failure (n=11) and one instance where the participant forgot to switch the device on at the start of the session (n=1).

Of the 2735 high-intensity bouts recorded over the intervention, the median (interquartile range) proportion of completed repetitions where heart rate corresponded to the *a priori* specified criterion for high-intensity work ($\geq 85\%HR_{max}$) was 70% (53% to 84%). Of the attended exercise sessions where heart rate was recorded, the mean (\pm SD) peak heart rate across the BE@Work intervention was 87% HR_{max} with a within-subjects SD of 5.5% (95% CI: 5.3 to 5.6%) and between-subjects SD of 3.7% (95% CI: 2.8 to 4.8).

From the attended exercise sessions, 526 of a possible 539 individual session RPEs were recorded. Reasons for missing data included participants forgetting to complete the RPE form post-session (n=11) and participants needing to leave immediately following the cool down due to work commitments and therefore declining to complete the RPE scale (n=2). Mean session RPE over the whole intervention was 6 AU (e.g. between the qualitative descriptors of “hard” and “very hard” on the CR-10 scale), with a within-subjects SD of 1.3 AU (95% CI: 1.3 to 1.4 AU) and between subjects SD of 1.4 AU (95% CI: 1.1 to 1.9 AU).

6.3.4 Affect and enjoyment

Acute affect scores were available for 30 out of 30 participants at baseline, 20 out of 29 participants in week two of the intervention, 17 out of 25 participants at week six and six of 25 participants in week eight. Mean positive and negative affect scores for each data collection time-point are shown in Table 31.

Table 31 Acute mood over the BE@Work intervention

	Positive affect score (mean (±SD) (AU)	Negative affect score (mean (±SD) (AU)
Baseline (n=30)	30 (±8)	14 (±4)
Week Two (n=20)	33 (±8)	14 (±4)
Week Six (n=17)	38 (±8)	12 (±2)
Week Eight (n=6)	36 (±8)	12(±2)

Enjoyment scores were available for 20, 16 and 5 participants respectively in weeks 2, 6 and 8 of the intervention. Mean (±SD) enjoyment scores were 112 ±10 AU in week 2, 116 ±7 AU in week 6 and 110 ±16 AU in week 8 of the intervention.

6.3.5 Outcome Variables

Baseline values, along with effect statistics and qualitative inferences for the between-group (intervention vs. control) comparisons for physical fitness, cardiometabolic health and mental health outcome variables are presented in Tables 31 to 33. After controlling for age, sex and baseline values, the effect of the intervention when compared with control was a likely meaningful increase in VO_{2max} (3.9 mL·kg⁻¹·min⁻¹; 90%CI: 0.48 to 7.4 mL·kg⁻¹·min⁻¹, d=0.55). Further, there were likely meaningful effects on two domains of HR-QoL (vitality: +8.7 AU; 90% CI 2.8 to 14.6 AU, d= 0.51 and general health perceptions: +4.8 AU; 90% CI: 0.6 to 8.9,

d= 0.4) and a likely meaningful decrease in perceived stress (-2.6 AU; 90% CI: -5.2 to 0.1 AU, d= -0.41). There were no other meaningful changes in any other outcome variables, post-intervention.

Table 32 Intervention effect on physical fitness variables

	Intervention (BE@Work; n =26)		Control (CON; n =21)		Between group comparison (BE@Work – CON)		
	Baseline value (mean ± SD)	Adjusted mean change (mean [90%CI])	Baseline value (mean ± SD)	Adjusted mean change (mean [90%CI])	Adjusted mean change (mean [90%CI])	Qualitative Inference	Effect size
VO ₂ max (mL·kg ⁻¹ ·min ⁻¹)	37.8 ±7.3	4.8 [2.5 to 7.0]	37.0 ±7.1	0.8 [-1.7 to 3.4]	3.9 [0.5 to 7.4]	Likely beneficial	0.55
Leg extensor muscle power (dominant leg, watts)	202.2 ±67.0	-2.6 [11.6 to 6.5]	230.0 ±95.5	-19.6 [-29.6 to - 9.5]	17.0 [2.5 to 32]	Possibly beneficial	0.21
Leg extensor muscle power (non- dominant leg, watts)	213.1 ±68.7	-10.9 [-19.3 to - 2.5]	236.6 ±89.6	-31.5 [-40.7 to - 22.2]	21.0 [7.2 to 34.0]	Possibly beneficial	0.26
Hand grip strength (dominant hand, kg)	36.3 ±10.7	0.2 [-1.0 to 1.4]	38.1 ±9.2	1.4 [0.1 to 2.8]	-1.2 [-3.0 to 0.6]	Most unlikely harmful, most unlikely beneficial	-0.12
Hand grip strength (non- dominant hand, kg)	34.3 ±11.0	0.5 [-0.4 to 1.4]	36.6 ±9.0	-0.3 [-1.3 to 0.7]	0.8 [-0.6 to 2.1]	Most unlikely harmful, most unlikely beneficial	0.08

Table 33 Intervention effect on cardiometabolic health variables

		Intervention (BE@Work; n =26)		Control (CON; n =21)		Between group comparison (BE@Work – CON)		
		Baseline value (mean ± SD)	Adjusted mean change (mean [90%CI])	Baseline value (mean ± SD)	Adjusted mean change (mean [90% CI])	Adjusted mean change (mean [90% CI])	Qualitative Inference	Effect size
Systolic Pressure (mmHg)	Blood	128 ±12	-6.8 [-9.8 to - 3.8]	135 ±14	-8.0 [-11.3 to -4.7]	1.2 [-3.4 to 5.8]	Very unlikely harmful, most unlikely beneficial	0.09
Diastolic pressure (mmHg)	blood	80 ±7	-2.5 [-4.7 to - 0.4]	86 ±8	-2.6 [-5.0 to - 0.2]	0.1 [-3.2 to 3.5]	Unlikely harmful, unlikely beneficial	0.01
Total cholesterol (mmol.L ⁻¹)		5.3 ±1.0	-0.2 [-0.4 to 0.0]	5.4 ±1.0	-0.2 [-0.4 to 0.0]	0.01 [-0.3 to 0.3]	Unlikely harmful, unlikely beneficial	0.00
HDL cholesterol (mmol.L ⁻¹)		1.6 ±0.5	-0.1 [-0.2 to 0.0]	1.6 ±0.5	-0.03 [-0.1 to 0.1]	-0.1 [-0.2 to 0.02]	Possibly harmful	-0.15
Triglycerides (mmol.L ⁻¹)		1.2 ±0.6	-0.03 [-0.2 to 0.1]	1.4 ±0.6	-0.1 [-0.3 to 0.1]	0.06 [-0.2 to 0.3]	Possibly harmful	0.10
Glucose (mmol.L ⁻¹)		5.2 ±0.6	0.2 [-0.1 to 0.6]	5.5 ±0.9	0.2 [-0.2 to 0.5]	0.08 [-0.4 to 0.6]	Possibly harmful	0.12
Body mass index (kg.m ²)		27.0 ±4.7	-0.07 [-0.3 to 0.2]	26.2 ±3.2	-0.06 [-0.3 to 0.2]	-0.02 [-0.4 to 0.3]	Unlikely harmful, unlikely beneficial	0.00
Waist circumference (cm)		87.6 ±13.8	-0.3 [-1.0 to 0.3]	85.4 ±8.7	-0.1 [-0.8 to 0.6]	-0.2 [-1.2 to 0.8]	Most unlikely harmful, most unlikely beneficial	-0.02
Habitual physical activity (MET.hour.week ⁻¹)		22.5 ±13.7	10.0 ±14.3	33.4 ±28.3	15.7 ±16.6	-5.9 [-25 to 13]	Possibly harmful	-0.26

Table 34 intervention effect on mental health variables

	Intervention (BE@Work; n =26)		Control (CON; n =21)		Between group comparison (BE@Work – CON)		
	Baseline value (mean ± SD)	Adjusted mean change (mean ± 90%CL)	Baseline value (mean ± SD)	Adjusted mean change (mean ± 90% CL)	Adjusted mean change (mean; ±90% CL)	Qualitative Inference	Effect size
HR-QoL: vitality (AU)	60.6 ±18.5	11.4 [7.4 to 15.3]	62.8 ±16.3	3.0 [-1.7 to 7.0]	8.7 [2.8 to 14.6]	Likely beneficial	0.51
HR-QoL: General health perceptions (AU)	64.8 ±16.7	3.9 [1.1 to 6.7]	65.5 ±12.2	-0.8 [-3.9 to 2.2]	4.8 [0.6 to 8.9]	Likely beneficial	0.4
Perceived stress scale (AU)	13.8 ±6.9	-2.9 [-4.6 to - 1.1]	12.9 ±6.2	-0.2 [-2.1 to 1.6]	-2.6 [-5.2 to 0.1]	Likely beneficial	-0.41
Warwick Edinburgh Mental Wellbeing Scale (AU)	50.3 ±7.9	5.7 [4.0 to 7.6]	51.2 ±6.4	3.3 [1.3 to 5.3]	2.5 [-0.2 to 5.2]	Possibly beneficial	0.34
HR-QoL: Social functioning	87.5 ±17.3	-0.6 [-7.0 to 5.8]	89.4 ±13.8	-0.6 [-7.6 to 6.4]	0.04 [-9.5 to 9.6]	Unclear	0.00
HR QoL: Role limitations due to physical health problems (AU)	94.2 ±17.8	-8.6 [-19 to 1.7]	95.2 ±15.0	-10.0 [-21.2 to 1.2]	-1.4 [-14.0 to 16.7]	Unclear	0.12
HR-QoL: Emotional wellbeing (AU)	80.8 ±13.1	4.7 [0.8 to 8.6]	77.3 ±13.3	2.9 [-1.3 to 7.2]	1.8 [-4.0 to 7.6]	Unclear	0.15
HR QoL: Role limitations due to emotional health problems (AU)	87.2 ±28.4	0.2 [-9.0 to 9.4]	90.5 ±26.1	-0.3 [-10.3 to 9.7]	0.5 [-13.0 to 14.0]	Unclear	0.02
HR QoL: Physical functioning (AU)	92.5 ±15.2	1.0 [-1.0 to 3.0]	96.7 ±4.3	1.0 [-1.3 to 3.2]	0.03 [-3.0 to 3.1]	Very unlikely harmful, very unlikely beneficial	0.00
HR-QoL : Pain (AU)	89.4 ±12.1	-11.7 [18.3 to -5.2]	91.1 ±10.1	-5.0 [-12.2 to 2.1]	-6.7 [-16.5 to 3.1]	Possibly harmful	-0.67

6.3.6 Feasibility of the outcome measures

The following section will describe the feasibility and potential considerations associated with both the acute and chronic outcome variables assessed during the BE@Work trial.

During the BE@Work trial, heart rate and RPE were collected to monitor intervention implementation. Wrist-worn heart rate monitors were selected over chest-worn monitors, due to the ease with which they can be applied and removed. To minimise the total session time, data collection procedures before and after HIT sessions needed to be time efficient. Therefore chest worn monitors, which are more time consuming to apply, were not feasible for this purpose. In the BE@Work trial, ten heart rate monitors were available for use. So, if more than ten participants attended a single HIT sessions, heart rate could not be assessed in all participants. The limited availability of heart rate monitors resulted in an incomplete heart rate data set, with heart rate monitored in 94% of attended sessions. Furthermore, researcher instruction and supervision was required for each session to ensure the heart rate monitors were recording correctly. Therefore if future trials included unsupervised HIT sessions, care should be taken to ensure participants are competent in the use of the monitors to ensure compliance with data collection procedures.

Although wrist-worn heart rate monitors are a time efficient and objective assessment of exercise intensity, it is acknowledged that the associated cost of a large volume of heart rate monitors may not be feasible in future trials. In the absence of heart rate monitors, RPE could be used as an alternative subjective assessment of exercise intensity. In the BE@Work trial, 526 individual RPE values were collected, demonstrating the quantity of data that can be generated using this tool. However, thorough familiarisation with the scale are recommended pre-intervention, in future trials to ensure the validity and reliability of the scale is upheld. In the BE@Work trial, paper based forms were used to collect RPE following each HIT session. This resulted in a large volume of paper-based data and therefore in future trials, device based applications could assist in the collection of this data.

In the BE@Work trial, it was intended to assess acute mood (PANAS) and enjoyment (PACES) at fortnightly intervals throughout the intervention. However as described in

Section 6.2.4.2.3, various issues were encountered during the collection of this data which resulted in a substantial proportion of missing data. In an attempt to standardise the time-period for assessment of mood and enjoyment, questionnaires were emailed to participants at the same time and day of the week at each assessment point. However, logistically this may have caused issues if the participants were unable to complete the questionnaires at that particular moment due to work commitments. This is one potential reason for the low compliance with this data collection procedure. Furthermore, the management team of the participating organisation raised issues with the volume of paper-work required of the BE@Work participants, as they perceived it may distract participants from their work commitments. This indicates that the PANAS and PACES may have limited feasibility for the repeated acute assessment of mood and enjoyment in a workplace intervention setting, when assessed together. Future trials could seek to assess mood and enjoyment separately, or seek to source a more time-efficient assessment of these variables, to reduce the participant burden.

In the BE@Work trial predicted CRF was assessed using the Chester Step test. At baseline and post-intervention, all intervention participants consented to undertake this test and one control participant abstained due to an injury unrelated to the study. The Chester step test takes approximately 15 minutes to conduct, including the set-up, explanation of the procedures and the test itself. In comparison to maximal exercise tests conducted in a laboratory setting, the Chester step test requires a limited amount of space, time and equipment. As the majority of participants were able to undertake this test and given the limited equipment, time and space requirements the Chester Step test presents a feasible and acceptable tool for the assessment of CRF in field-based research. It should be noted that a well ventilated room would be preferred for most participants as they may feel warm while undertaking the test.

Lower limb power was assessed using the Nottingham Leg Rig (leg rig). At baseline, all intervention participants consented to undertake this test and one control participant chose to abstain due to an injury unrelated to the study. At post-intervention two control participants abstained due to an injury unrelated to the study. The leg rig weighs approximately 80 kg and requires at least 2m² of space. Although the leg rig can be disassembled into three segments for transport to field-based research settings, the segments require two persons to carry them. In the BE@Work trial, the leg rig had to be transported from the university to two workplaces and

disassembled and assembled each time, this process takes approximately 20 minutes each time. Furthermore, when the foot plate of the leg rig is depressed, the mechanisms are particularly loud, which may interrupt the working environment. Lastly, at baseline it is advised that the leg rig procedures are repeated on three separate occasions, to reduced learning effects (Hurst et al., 2018a), however as the procedure takes 10 minutes each time, a thirty minute time commitment for a single outcome measure may not be feasible in studies with limited time availability. The limited feasibility of repeating the leg rig procedures is indicated by the limited percentage of BE@Work participants who completed all three tests at baseline (29 out of 54 participants). Collectively these findings indicate that the leg rig may have limited feasibility and acceptability in some field-based research studies, particularly if personnel, transportation, time or space are limited.

Grip strength was assessed using a hand dynamometer. At baseline and post-intervention all participants consented to undertake this assessment. Hand dynamometers are small and easily transportable and the full testing procedure takes four to five minutes per participant. The portable nature of hand dynamometers and the limited time required to conduct this measure coupled with the number of participants able and willing to undertake the grip strength assessment, indicate that it is a feasible and acceptable assessment for use in field-based research.

Blood pressure was assessed in all participants at baseline and post-intervention using an automatic blood pressure monitor. The blood pressure monitor is easily transportable and all participants consented to this measure, suggesting that automatic blood pressure monitoring is feasible and acceptable in workplace research studies. However, at the stipulation of the Research Ethics and Governance Sub-committee at the sponsoring university, the thesis author was required to advise participants to seek medical advice if any outcome variables were outside of expected 'healthy' parameters at the baseline or post-intervention data collection time points (i.e. if SBP >120 or DBP >80mmHg). Due to this stipulation, 15 (out of 30) intervention and 17 (out of 24) control participants were advised to consult their medical practitioner, however as per the exclusion criteria for the trial (PARQ+ criteria 4b) participants were only excluded from the trial if their blood pressure was over 160/90 mmHg.

Blood lipids and glucose were assessed using finger prick point-of-care testing procedures in all participants, with the exception of one intervention participant who

abstained from this measure at baseline and post-intervention due to a fear of needles. The point-of-care testing apparatus are easily transportable, however the cassettes require refrigeration until 15 minutes before use, therefore a refrigerator is required within the workplace to ensure correct storage. Furthermore a sharps and biological waste disposal unit is required for all used lancets and capillary tubes. Therefore, although the high proportion of participants consenting to this procedure in the BE@Work trial may indicate that point-of-care testing is acceptable for participants in a workplace setting, consideration should be given to appropriate storage of cassettes and disposal of waste. As previously described, the thesis author was required to advise participants to seek medical advice if their non-fasting total cholesterol was outside of expected 'healthy' parameters at the baseline or post-intervention data collection time points ($>5\text{mmol.L}^{-1}$ Nordestgaard et al., 2016). Due to this stipulation, 19 (out of 30) intervention and 10 (out of 24) control participants were informed that their blood cholesterol was outside of the 'healthy' parameter at baseline.

Anthropometry was assessed by waist circumference and height and weight. All participants in the BE@Work trial consented to these procedures at both data collection time points. For these assessment procedures to be undertaken in the workplace, a private room is required. Therefore in future studies screens may be needed if data collection is scheduled to take place in a room where a number of participants are present at once.

Self-report physical activity and mental health outcomes (wellbeing, HR-QoL and perceived stress) were assessed in the 10 minutes of seated rest required before blood pressure could be assessed, to stream line the data collection sessions at baseline and post-intervention. Although the thesis author was available to answer questions about the questionnaires during data collection, three participants reported that they could not recollect their physical activities over the previous seven days and therefore abstained from this measure and one of those participants abstained from completing the wellbeing questionnaire. Two participants abstained from completing the wellbeing questionnaire and one participant abstained from completing the stress questionnaire at post-intervention. Although the questionnaires were conducted together during the data collection session to streamline data collection, it is acknowledged that this is a large volume of questionnaires and participants may have experienced respondent fatigue (Rolstad et al., 2011). Participants may have felt more able to complete all of the questionnaires and not chosen to abstain from them

if completion of the questionnaires was interspersed throughout the data collection session.

6.4 Discussion

A growing body of evidence suggests that HIT can elicit improvements in various markers of health, fitness and body composition (Campbell et al., 2019; Milanovic et al., 2015; Viana et al., 2019). However the majority of studies to date have been confined to laboratory settings, therefore the effectiveness of HIT in real-world settings (such as the workplace) is unclear. A limited number of workplace HIT trials have been published to date (Allison et al., 2017; Shepherd et al., 2015) however both were uncontrolled trials, utilising a single exercise modality and were implemented in academic workplaces. To further explore the effectiveness of HIT, controlled workplace HIT trials were required, in non-academic workplaces, utilising a broader range of novel exercise modalities. Accordingly, the aim of this study was to explore the feasibility and effects of an 8-week workplace HIT trial on physical fitness, cardiometabolic and mental health in office-based employees.

In the present study a likely meaningful effect on VO_{2max} of $3.9 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (90% CI: 0.48 to $7.4 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) was observed post-intervention compared with controls; representing a 10% increase in VO_{2max} . The improvement in VO_{2max} observed in this study is similar to, or slightly higher than the 2.8 to $3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ increase in VO_{2max} reported following previous uncontrolled workplace HIT trials (Allison et al. 2017, Shepherd et al., 2015). Although the intervention effect observed in the present study is higher than the meta-analysed effect of workplace-based exercise training interventions observed in Chapter Three ($2.7 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), it is lower than the $5.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ increase in VO_{2max} reported in a meta-analysis of largely laboratory-based HIT trials (Milanovic et al., 2015). This may be unsurprising as the magnitude of intervention effects are thought to be attenuated and more variable under less tightly controlled conditions outside of the laboratory (Courneya, 2010).

Meaningful improvements in two domains of HR-QoL assessed using the SF-36, were observed post-intervention (general health perceptions; 4.8 AU [90% CI 0.6 to 8.9] and vitality; 8.7 AU [90% CI 2.8 to 14.6 AU]). Although one previous workplace HIT trial observed a 0.21 AU increase in general health perceptions (Shepherd et al., 2015), data were presented on a 1-5 AU scale. The reason for this decision is unclear as the scoring guide for the questionnaire uses a 0-100 AU scoring system (Ware et al., 2002). Similarly, in a community-based HIT trial Lunt et al., (2014) observed

improvements in aggregate scores of perceptions of physical (3.6 AU) and mental health (2.3 AU) in comparison to MICT. Again the validity of reporting aggregate scores from the SF-36 is questionable as this procedure is not detailed in the scoring manual (Ware et al., 2002). Although it appears that HIT may elicit improvements in perceptions of general health, direct between-study comparisons are precluded due to inconsistencies in scoring procedures.

Vitality is defined as the balance an individual feels between energy and fatigue (Ware et al., 2002). The meaningful increase in vitality observed in the present study (8.7 AU [90% CI 2.8 to 14.6 AU]) is greater than the effect observed in a previous laboratory-based HIT trial with 25 healthy older adults (5.3 ± 9.4 AU, $p=0.05$, assessed via the SF-36) (Knowles et al., 2015). Additionally although not assessed via the SF-36, following a previously described workplace HIT trial, Shepherd et al., (2015) also noted an increase in subjective vitality (from 4.1 AU to 4.7 AU on a 1-7 AU scale, $p=0.05$). There is now a preliminary but expanding body of evidence demonstrating that HIT may elicit improvements in vitality. Exercise training has been shown to increase perceptions of energy and reduce perceptions of fatigue (i.e. increase vitality) (Puetz et al., 2006). Therefore although the increase in vitality observed in this study could be directly attributable to HIT itself, there is evidence to suggest that social interaction during exercise can improve vitality more than exercising alone (McNeil et al., 1991) and so the effect could also be attributed to the group-based nature of BE@Work. However, as the mechanisms behind this effect are yet to be elucidated this is merely conjecture at this time.

In the present study, a meaningful reduction in perceived stress was observed (-2.5 AU; 90% CI: -5.2 to 0.1 AU) when assessed using the PSS (Cohen, 1993). This effect is smaller than the effect observed in one previous trampoline based HIT trial (-11AU, assessed using the PSS) (Bhosle et al., 2018) however it is higher than that observed in a circuit-based HIT case study with three police officers (-1.5 AU, assessed using the PSS) (Lark et al., 2017). However a lack of control group in these studies means that the findings should be interpreted with caution. Although purely conjecture, differences in stress responses could be attributed to differences in the populations (e.g. highly stressed participants in the study by Bhosle et al., 2018) or the exercise modalities used. Nevertheless, the improvement in perceived stress observed in the present study could be a particularly meaningful outcome for employers, because work-stress is associated with both absenteeism and presenteeism (Lauzier et al., 2017) and productivity (Hoboubi et al., 2017). Although the present study cannot

confirm the impact of HIT on these workplace outcomes, future workplace HIT trials could include measures of absenteeism or productivity if possible.

In BE@Work, the declaration of meaningful findings was set *a priori* at $\geq 75\%$ (i.e. likely) and accordingly there were no meaningful effects on any of the other physical fitness, cardiometabolic health and body composition variables assessed. A reduction in leg extensor muscle power was observed in both the intervention (dominant leg -2.6 Watts, non-dominant leg -10.9 Watts) and control group (dominant leg -19.6 Watts, non-dominant leg -31.5 Watts), post-intervention. However, as the reduction was less in the intervention group, the intervention effect (intervention minus control) was a possibly beneficial improvement in lower limb power. As effects were only declared meaningful when the probability likelihood was $\geq 75\%$, a possibly beneficial effect indicates that more data is required to assess the effect of workplace HIT on leg extensor muscle power, and conclusions cannot be drawn from this finding (Sainani et al., 2019). It is noted, however, that a reduction in leg extensor power was observed in both groups following the BE@Work trial. To reduce learning effects associated with the Nottingham Leg Rig, it is recommended that data collection procedures are repeated three times at baseline (Hurst et al., 2018a). As previously described, there were various logistical issues associated with the collection of this data at baseline in the BE@Work trial, which likely resulted in inadequate habituation with the Nottingham Leg Rig procedures (60% of participants did not undertake three full trials at baseline). Although it cannot be known from the data collected, this may explain why a reduction in leg extensor muscle power was observed in both groups. A reduction in blood pressure was observed in both groups (SBP: -6.6 mmHg and -8.0mmHg; DBP: -2.5 and -2.7, in the intervention and control group respectively). Following stipulations by the Research Governance and Ethics Committee at the sponsoring university, it was necessary for the thesis author to advise participants to seek medical advice if any outcome variables were outside of expected parameters (e.g. blood pressure $\geq 120/80$ mmHg) at baseline. Given that the average baseline blood pressure was outside of recommended parameters in the control group (mean baseline blood pressure: 135/86 mmHg) the reduction in blood pressure observed post-intervention could have been elicited by lifestyle modifications outside of the study. However this is purely speculative at this stage. As there is evidence to suggest that HIT can elicit clinically meaningful reductions in blood pressure in hypertensive individuals (-6.3mmHg and -3.8mmHg in SBP and DBP, respectively) (Costa et al., 2018), further work is needed to elucidate the impact of real-world HIT interventions on blood pressure. Furthermore, with the exception of total cholesterol (which was

slightly elevated above the recommended level of $\leq 5 \text{ mmol.L}^{-1}$ (Nordestgaard et al., 2016)), mean baseline levels of all lipid outcomes and blood glucose were within the recommended ranges; which could explain the lack of intervention effect on cardiometabolic health outcomes. Lastly, although preliminary evidence suggests that HIT can reduce waist circumference by $\sim 3\text{cm}$ in overweight and obese individuals (Wewege et al., 2017), mean baseline waist circumference values of 92.4cm in men and 82.3cm in women in the present study were not higher than the recommended parameters of $\geq 102\text{cm}$ for men and $\geq 88\text{cm}$ for women (Janssen et al., 2002), which could explain the lack of effect on this indicator of abdominal adiposity.

Notwithstanding any potential physiological or psychological adaptations induced by exercise training, to promote long term adherence and compliance, it is essential that interventions are practical, feasible and enjoyable for participants. Mean HIT session attendance for BE@Work was 83%, which is similar to reported attendance in other real-world HIT trials (range 59% (Lunt et al., 2014) to 99% (Allison et al. 2017)). To promote session attendance in BE@Work, a flexible approach was taken to exercise session attendance; such that 18 group HIT sessions were conducted each week. Participants were required to attend whichever three sessions their availability and work schedules permitted. Although this may have promoted attendance, the scalability of providing such a large volume of exercise sessions across a week is highly questionable. Indeed the cost of employing exercise facilitators may prohibit organisations from being able to provide such flexible services to employees. Although in BE@Work, in general afternoon sessions (4:30pm and 5pm) were more frequently attended than others, anecdotally participants reported that they would be more likely to attend morning or midday sessions if they had access to a shower within their workplace, which was not available in the participating organisation. Over the BE@Work intervention most of the scheduled sessions were attended by at least two participants, therefore a recommendation cannot be made for future studies in terms of optimal session timing. For the BE@Work participants, no single time period would have suited the availability of all participants, a finding which was supported by the formative evaluation in Chapter Four. It is likely that feasible programme logistics are highly context dependent, supporting the need for formative work during programme planning (Craig et al., 2008). To further promote attendance, although participants were discouraged from attending more than one session per day, no minimum time limit was placed on the duration of time between HIT sessions. This flexible approach was essential for participants who worked part-time. Although this may have promoted attendance, in older adults there is preliminary evidence to suggest that

recovery time following HIT can be up to 5 days (Herbert et al., 2015). Although there is not an established threshold for a minimum time period between HIT sessions in adults, it is possible that conducting HIT on consecutive days could have inhibited full recovery. This could have attenuated participants' ability to re-engage in high-intensity exercise in subsequent sessions, which in turn could have affected the chronic training effect. However, this is purely speculative at this stage and further work is needed to establish if a minimum duration of time is required between HIT sessions.

Although session attendance is often reported by authors as a measure of intervention adherence in exercise trials, it does not provide information regarding the extent to which the intervention was delivered as intended in a comparable manner to all participants; otherwise known as the intervention fidelity (Taylor et al., 2015). Given that exercise intensity is an important mediator in the adaptations promoted by chronic training (MacInnis & Gibala, 2017); exercise intensity quantification can provide a more thorough quantification of the "dose" of an exercise intervention (Taylor et al., 2015). The *a priori* specified high-intensity exercise criterion in BE@Work was $\geq 85\%$ of age-predicted HR_{max} (Weston et al., 2014a). Across the intervention, the median proportion (interquartile range) of repetitions where the high-intensity exercise criterion was attained was 70% (53% to 84%). Previous evaluations of intervention fidelity in HIT trials with older adults (Hurst et al., 2018b) and adolescents (Taylor et al., 2015) have categorised high-intensity exercise criterion attainment proportions of between 58% (Taylor et al., 2015) and 62% (Hurst et al., 2018b) of repetitions as 'moderate' intervention fidelity. With this in mind and using the recently proposed intervention implementation and fidelity thresholds of <50% 'low'; 50 to 70% 'moderate' and >70% 'high' (Hurst et al., 2018b), the intervention implementation in BE@Work could be described as moderate to high. However, caution is warranted when interpreting this data, because the analysis presented constitutes a per-protocol analysis (i.e. including only attended sessions). Furthermore due largely to limited equipment availability, heart rate was measured in 94% of attended sessions, rather than all sessions. Although it has been suggested that intention-to-treat analysis (i.e. also considering data from missed sessions) is the least biased and preferred approach for the analysis of intervention implementation and fidelity data (Taylor et al., 2015), given the exploratory nature of the BE@Work trial the intention was to explore if the intensity criterion was complied with by participants attending the exercise sessions. To conduct an intention-to-treat fidelity analysis with acute heart rate data, the preferred method is to input missed exercise

sessions with a heart rate value that corresponds to 40% of the participants HR_{max} (Taylor et al., 2015). In the BE@Work trial due to limited availability of heart rate monitors during HIT sessions, it was not possible to collect heart rate data for each participant at all of the HIT sessions they attended across the intervention. Therefore if an intention-to-treat analysis had been conducted with the data available from the BE@Work trial, this may have resulted in an inaccurate estimation of the true intervention fidelity because heart rate values would have been inputted as missed sessions (i.e. 40% HR_{max}), when in fact participants had attended the session but heart rate monitors were not available. If heart rate data is available for every attended session, future trials could conduct an intention-to-treat analysis to more rigorously quantify intervention fidelity.

Although mean peak heart rate across the BE@Work intervention was above the specified high-intensity criterion (87%) this is lower than the mean peak heart rate reported in previous community ($95 \pm 3\% HR_{max}$ Reljic et al., 2018) and workplace ($91 \pm 3\% HR_{max}$ Shepherd et al., 2015) HIT trials. Although between-study differences are likely multifaceted, one possible explanation could be differences in exercise modalities (Buchheit & Laursen, 2013a). Both Reljic et al., (2018) and Shepherd et al., (2015) exclusively used cycle ergometers as the HIT modality, whereas the BE@Work intervention used a range of novel exercise modalities that did not require extensive exercise equipment. However the intensity of the modalities used in the present study could not be manipulated in the same way as cycle ergometers, which may explain the lower relative intensity. With regards to the uniformity of the HIT dose, the relatively small within-subjects SD (5.5 percentage points of the mean peak heart rate) indicates that the intensity of the HIT intervals remained relatively similar throughout each high-intensity bout across the intervention. Furthermore the relatively small between-subjects SD (3.7 percentage points of the mean peak heart rate) indicates that the intensity was also relatively similar between the BE@Work participants. These findings demonstrate the quality of the delivery of the BE@Work intervention, and its receipt and enactment by the participants (Taylor et al., 2015). The mean session RPE score (6 AU) across the BE@Work intervention is between the qualitative descriptors of “hard” and “very hard”, which is similar to the mean session RPE reported following acute HIT sessions comprising stair climbing, stepping and boxing presented in Chapter Five and a previous workplace HIT trial (Allison et al., 2017). Similar to the heart rate data, the relatively small within and between-subjects SDs (1.3 AU and 1.4 AU, respectively) indicate that the perception

of effort in the HIT sessions was relatively uniform both across the intervention and between participants.

As previously described due to difficulties in obtaining responses to acute affect and enjoyment data collection attempts, a cautious approach was taken in the interpretation of this data. Descriptive data are presented with no further analysis conducted. Mean enjoyment scores ranged from 110 to 116 AU across the BE@Work intervention which is similar to, or slightly higher than the enjoyment scores reported following single sessions of HIT in the study presented in Chapter Five (96 AU to 109 AU). In the PACES, scores range from 40 to 126 AU with higher scores indicating higher enjoyment and so the findings here suggest high enjoyment in the BE@Work trial. Enjoyment responses observed in the present study are similar to those reported in a previous cycle ergometer based HIT trial with overweight and inactive adults (mean: 100 ± 4 AU) (Vella et al., 2017). Although there is evidence to suggest that enjoyment responses can increase over the duration of HIT programmes (Heisz et al., 2016), given the issues encountered in the collection of PACES data and the resultant small sample size, the present study cannot robustly assess if enjoyment changed over the course of the BE@Work intervention. This study is the first workplace HIT trial to assess enjoyment therefore direct comparisons with similar trials cannot be made.

Possible PANAS scores range from 10-50 for both positive and negative affect scores, with higher scores indicating higher positive and negative affect. Normative PANAS data indicate mean positive affect score of 31 AU and mean negative affect score of 16 AU (Crawford & Henry, 2004). Baseline affect scores in the BE@Work participants were 30 ± 8 AU and 14 ± 4 AU for positive and negative affect, respectively. These values are similar to normative values, indicating that the sample was sub-clinical in terms of affect as expected. Although it cannot be confirmed from the descriptive data presented, it appeared that positive affect increased steadily from 30 ± 8 AU at baseline to 38 ± 8 AU and 36 ± 8 AU in week six and eight respectively. However this observation should be interpreted with caution given the limited sample size, especially in the latter weeks of the intervention. Furthermore, negative affect scores remained slightly lower than normative values in the BE@Work sample from 14 ± 4 AU at baseline to 12 ± 2 AU in week eight of the intervention. Although the acute effect of HIT on psychological responses has been assessed in numerous trials (Bartlett et al., 2011; Hyodo et al., 2018; Jung et al., 2014), the chronic effect of HIT on affect is less well studied. The PANAS was used to assess the effect of 10 weeks

of cycle ergometer-based HIT on affect in a previous workplace HIT trial (Shepherd et al., 2015). Although post-intervention there was an increase in positive affect (0.21 AU) and a decrease in negative affect (0.47 AU) scores, the findings were presented on a 1-5 scale, which is not specifically recommended by the scale developers (Watson et al., 1988), and therefore direct between study comparisons are precluded.

Anecdotally, participants in the BE@Work trial reported that alongside completion of the RPE scale following each HIT session, completing the PANAS and PACES questionnaires were perceived as too cumbersome which may explain the poor response rate. This issue was exacerbated when management representatives expressed concerns relating to the volume of paper-work required of BE@Work participants, which they felt was impacting on work commitments. In light of these issues, to reduce participant burden, future studies could look to utilise single item affect scales such as the Affect Grid (Russell et al., 1989) or a single item exercise enjoyment scale (Stanley & Cumming, 2010).

Limitations

This is the first controlled trial exploring the feasibility and effects of a multi-modal HIT intervention delivered in a non-academic workplace on markers of physical fitness, cardiometabolic and mental health. Although meaningful improvements in CRF, vitality, general health perceptions and perceived stress were observed, the study is not without limitations. Due to the exploratory nature of the BE@Work trial and the resultant small sample size, effects were only declared meaningful when if the outcome probability emerged as likely ($\geq 75\%$), and this has recently been described as weak evidence (Sainani et al., 2019). While the confidence interval for the intervention effects that were declared meaningful contained more coverage for benefit than harm, these findings may need to be interpreted cautiously. Secondly, the non-randomised allocation of participants to study groups may have introduced selection bias, where systematic differences in the treatment groups arise at baseline (Deeks et al., 2003). Although the inclusion of baseline outcome values as a covariate in the statistical analysis may have partly mitigated this threat to validity, the findings should nonetheless be interpreted with caution. Another potential limitation relates to the use of a submaximal prediction of VO_{2max} (Chester step test). The gold standard test for the assessment of VO_{2max} (CPET) (Shephard, 1968) was not logistically possible in the present study due to time, equipment and space constraints during baseline and post-intervention data collection. As described in Chapter Two of this

thesis, it is acknowledge that the validity of predictive CRF assessments have been questioned (Grant et al., 1999). Of particular importance to the present body of work, it is unclear whether the Chester step test is valid for detecting a change in CRF over time, despite the test appearing to be acceptably reliable on a test-retest basis (Bennett et al., 2016). To determine the validity of the Chester step test for use in chronic training studies, future work is required comparing true CPET assessed and Chester step test predicted VO_{2max} in terms of their agreement in tracking changes in VO_{2max} . As such a study is yet to be conducted, the validity of the Chester step test assessed VO_{2max} predictions in the BE@Work trial could be questioned. However, the Chester step test provides a quantification of CRF in terms of VO_{2max} , meaning that the findings of the present study are directly comparable to previous HIT trials. The validity of the Chester step test may be impacted by the selection of the step height for each participant which is based on the age and usual physical activity levels of individual participants (Sykes, 2018). This required the thesis author to make a decision with the information available at the time of baseline data collection. Although the upmost care was taken to make an informed step height decision, given that four step heights are available it is not possible to know if step height selection was optimal for each participant. If the step was too high this may have resulted in a mechanical disadvantage, while if the step was too low this may not promote the desired cardiorespiratory response (Bennett et al., 2016). However, as step height was standardised for each participant between baseline and post-intervention data collection, the impact of step height decision on the reliability of the Chester step test was minimised (Sykes, 2018). To minimise learning effects that have been noted in the Chester step test (Buckley et al., 2004; Sykes & Roberts, 2004), it has been recommended that the test is administered twice at baseline (Bennett et al., 2016). Unfortunately, due to logistical issues (limited time and room availability in the participating organisations) it was not possible to administer the test more than once at baseline. Although this is a limitation, the mean differences between the repeated measurements noted by Sykes and Roberts (2004) and Buckley et al., (2004) were minimal and may not have been clinically meaningful ($-0.7 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and $-0.8 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, respectively).

The use of non-fasted finger prick blood samples could also be considered a limitation of this body of work. Although non-fasted blood samples are recommended for use in clinical practice as they appear to better predict CVD risk (Nordestgaard et al., 2016) it is acknowledged that the postprandial response for both glucose and triglycerides can be affected by a range of acute factors such as the content and timing of the

previous meal and previous physical activity (Lopez-Miranda et al., 2007; Dixon et al., 2009). Although in the BE@Work trial, efforts were made to ensure the content and timing of meals were the same at both data collection time-points, and fasting status was included as a co-variate in the analysis, it is acknowledged that it was not possible to acutely control and replicate all of the factors that may have affected non-fasting blood lipid and glucose concentrations. Therefore the detection of relatively small changes in blood lipids and glucose in response to training may not have been possible. Future workplace HIT trials could seek to assess fasted blood lipids and glucose, however this would necessitate that data collection was conducted early in the morning only, to avoid participants being required to fast for long periods of time into their working day. Clearly, this would have implications for the conduct of workplace research studies, as often the timing of data collection is dictated by the organisation due to room or staff availability.

It could be suggested that the extrapolation of the findings of this exploratory trial are limited due to the small number of participants and study sites. It is acknowledged that studies with small sample sizes may have low statistical power which can overestimate or exaggerate the magnitude of an effect (Button et al., 2013). However it should be noted that this study was conducted largely independently by the thesis author, and the inclusion of more participants or study sites without assistance from more researchers would have compromised the delivery of the intervention. Participants in the present study were healthy middle-aged adults; therefore the findings cannot be extended to other populations for example older adults or clinical populations. Furthermore, the participants involved in the present study exhibited moderate fitness levels at baseline (VO_{2max} 33.5 mL·kg⁻¹·min⁻¹ in women and 42.7 mL·kg⁻¹·min⁻¹ in men). Given the mean age of participants (49 years for females and 40 years for males) according to normative data from the American College of Sports Medicine, this fitness level would be classified as “fair” to “good” (Liguori, 2018). In the discourse surrounding the feasibility and acceptability of HIT for public health improvement, critiques of HIT commonly suggest that it will have limited appeal in unfit or inactive populations (Biddle & Batterham, 2015; Hardcastle et al., 2014). Based on the mean baseline VO_{2max} of participants in the present study, the acceptability and feasibility of HIT in very deconditioned individuals cannot be addressed from the results of this study *per se*. However, the relatively large standard deviation of the baseline VO_{2max} (± 5.0 mL·kg⁻¹·min⁻¹ in women and ± 6.3 mL·kg⁻¹·min⁻¹ in men) indicates that participants with a range of fitness levels were recruited to this study. Given the pilot nature of this study, it was not intended to exclude participants

based on their baseline fitness or habitual activity level, which has been enacted in previous HIT trials (Lunt et al., 2014; Shepherd et al., 2015). However, future studies could aim to specifically recruit low active or unfit individuals to further examine the acceptability of HIT in such groups. To date, real-world HIT interventions in adults have been largely short duration, with no longitudinal follow-up data available. Therefore the long term impact of HIT on markers of physical fitness, cardiometabolic and mental health is unknown. While it was not pragmatically possible, the absence of longitudinal follow-up data is a further limitation of this study.

Although the intervention implementation data and analysis presented in this study (heart rate and RPE data) begin to explore the process of implementation of the BE@Work trial, future work could assess participant or stakeholder perceptions of the intervention as part of a process evaluation (Bauman & Nutbeam, 2013). This could take the form of focus groups or semi-structured interviews with participants and management representatives from participating organisations (Bauman and Nutbeam, 2013).

6.5 Conclusion

The BE@Work trial was the first multi-activity workplace-based HIT trial to be implemented in a non-academic workplace. Compared with the control group, post-intervention meaningful improvements in predicted VO_{2max} , two domains of HR-QoL (vitality and perceptions of general health) and perceived stress were observed. Low levels of drop-out, high session attendance and promising preliminary implementation data indicate that multi-activity HIT could be feasibly integrated into a workplace exercise intervention. Whilst the limitations of the prediction of VO_{2max} and the exploratory nature of this trial are acknowledged, BE@Work could present a novel and viable workplace-based exercise intervention that may be feasible, acceptable and engaging for some individuals. The findings of this feasibility trial support the implementation of a definitive multi-site RCT.

Chapter 7: Synthesis of findings

The chapters of this thesis documented a programme of work undertaken with the overall aim of exploring the feasibility and effects of workplace-based high-intensity interval training (HIT) on markers of physical fitness, cardiometabolic and mental health in adult employees. In line with guidance from the Medical Research Council, for the development and evaluation of complex interventions (Craig et al., 2008), this programme of work used an iterative mixed methods approach to develop a workplace-based HIT intervention, named Brief Exercise at Work (BE@Work). Here, the findings of earlier studies informed the research questions and methods of subsequent work. The aim of this final chapter is to interpret and contextualise the findings of the studies presented throughout the thesis. Reflections on the programme of work and the limitations will be considered, and recommendations for future research will be discussed.

7.1 Summary of individual study findings

7.1.1 Study One. Effects of workplace-based exercise interventions on cardiorespiratory fitness: a systematic review and meta-analysis of controlled trials.

Workplaces may provide a relatively controlled setting in which to improve cardiorespiratory fitness (CRF) in adults through exercise training. However, limited work has been conducted to quantify the effect of delivering exercise in the workplace on CRF. This systematic review used random effects meta-analysis to quantify the effects of workplace-based exercise interventions on VO_{2max} and explored the modifying effects of study and participant characteristics. Twelve controlled trials including 733 participants were included in the final data set and random effects meta-analysis demonstrated that when compared with controls, workplace exercise interventions resulted in an improvement in VO_{2max} of $2.7 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (90% CI: 1.6 to $3.8 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). Although this is lower than the effects observed in a previous meta-analysis of broadly defined workplace physical activity interventions ($3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) (Conn et al., 2009), this may be due to the inclusion of non-controlled trials in the meta-analysis which can inflate effect estimates (Higgins & Green, 2008). As such this meta-analysis may present an updated and less biased estimate of the effect of workplace-based exercise interventions on CRF. Nonetheless, as a $1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ increase in VO_{2max} has been associated with a 9% relative risk reduction in all-cause mortality (Laukkanen et al., 2016); the magnitude of improvements in VO_{2max}

induced by workplace exercise interventions could be clinically meaningful. Furthermore, because the modifying effects of participant characteristics explained only a very limited proportion of the heterogeneity of the effect, it was concluded that no single group (e.g. older employees or less fit individuals) could be definitively identified as standing to benefit more from workplace exercise interventions at this stage.

7.1.2 Study Two. A formative evaluation of a workplace-based high-intensity interval training intervention: Brief Exercise at Work (BE@Work).

Although workplace-based exercise interventions can elicit meaningful adaptations in CRF, the data presented in Study One does not indicate how an exercise intervention could be practically implemented in to a workplace. Indeed, it has been recommended that formative work with key stakeholders is undertaken during intervention development (Bauman & Nutbeam, 2013). Accordingly, this study used qualitative focus group and interview data to formatively evaluate the proposed BE@Work workplace HIT trial and used the findings to further develop the trial protocol.

Eight focus groups (n=38) and four management interviews (n=4) were conducted across six organisations in the Teesside area of the North East of England. The BE@Work trial protocol described to participants involved 6-10 weeks of thrice weekly workplace-based HIT sessions. Based on participant feedback, no changes were made to the planned length of the intervention or frequency of exercise sessions. However, no consensus was established in terms of an appropriate time of day for HIT sessions and participants suggested that multiple HIT sessions should be facilitated across the day. Group-based HIT sessions were preferred rather than individual sessions, which is encouraging as group-based interventions may reduce attrition and promote long-term adherence to physical activity prescriptions (Mangeri et al., 2014). While some participants perceived that HIT would be a novel and engaging activity, others suggested that it could be perceived as inappropriate or could confer a risk of injury for inactive individuals. While there is evidence to suggest that some individuals can regard HIT positively (Stork et al., 2018) and that HIT can be perceived as a novel and interesting exercise option (Kinnafick et al., 2018), participants in this study perceived that explaining the relative intensity of HIT to potential BE@Work participants may alleviate concerns relating to the intensity of the exercise. Participants perceived that a choice in a variety of exercise modalities both within and between HIT sessions was important to enhance engagement. A variety

of exercise modalities has previously been reported as a motivating factor that enhanced attendance and adherence to gym-based HIT classes (Burn & Niven, 2018). Participants selected stair climbing, stepping and boxing as feasible and acceptable HIT modalities. The resultant trial protocol involved 8-weeks of thrice weekly workplace-based HIT sessions, involving stair climbing, stepping and boxing, with a number of group-based sessions offered throughout the working day.

Detailed information about how qualitative data can be used to tailor the development of exercise interventions is currently lacking in the literature. While qualitative methods have been used to undertake a process evaluation of a workplace HIT intervention following implementation (Kinnafick et al., 2018), this study is the first formative evaluation of a workplace HIT trial. As such, this study demonstrates how participant and stakeholder opinions can be incorporated into intervention development, which could be applied in a variety of health promotion contexts both within and beyond exercise trials.

7.1.3. Study Three. The acute physiological and perceptual responses to three novel modes of high-intensity interval training.

Although participants of the formative evaluation of the BE@Work trial selected stair climbing, stepping and boxing as preferred HIT modes, whether these modes can be incorporated into a HIT protocol is unknown. Accordingly, this randomised cross over trial assessed the acute physiological (heart rate and blood pressure) and psychological (rating of perceived exertion [RPE], mood and enjoyment) responses to a HIT protocol based on stair climbing, stepping and boxing and explored whether these outcomes substantially differed across HIT modes.

Eighteen adults were randomised to the order they completed three laboratory HIT sessions of stair climbing, stepping and boxing, and fifteen participants completed all three modes. It was demonstrated that the HIT protocol applied (4x 60sec high-intensity bouts, with 75secs of rest) incorporating the novel activity modes elicited mean peak heart rates ($85 \pm 8\%$ maximal heart rate [HR_{max}], $86 \pm 7\%$ HR_{max} $85 \pm 5\%$ HR_{max} for stair climbing, stepping and boxing respectively) indicative of high-intensity work (i.e. $\geq 85\%HR_{max}$), with no substantial differences between modes. Furthermore, participants perceived the exercise to be of 'hard' or 'very hard' intensity using the CR-10 RPE scale (Borg, 1998). While there were no substantial differences in RPE

between stair climbing and stepping, RPE was lower for boxing compared with both stair climbing (-2 arbitrary units [AU]) and stepping (-2 AU). There were no substantial differences from baseline or between modes in blood pressure or mood responses. Lastly, enjoyment scores ranged from 96 AU to 109 AU out of a possible 126 AU, with no substantial between-mode differences, indicating similar and high levels of enjoyment.

This is the first study to quantify the acute physiological and psychological responses to novel HIT modes based on stair climbing, stepping and boxing in adults. The findings indicate that the modes could be incorporated interchangeably within a HIT intervention, which may be perceived as enjoyable for some participants, without compromising the intensity of the exercise.

7.1.4 Study Four. Brief Exercise at Work (BE@Work): a controlled feasibility trial of a high-intensity interval training intervention delivered in the workplace.

The formative evaluation of the BE@Work trial explored participant views on the preferred implementation of a workplace HIT trial. Subsequently, the capacity for novel modes of HIT, selected by formative evaluation participants, to elicit a high-intensity response was investigated in a randomised cross-over trial, with findings indicating physiological and perceptual responses indicative of high-intensity exercise. However, the effects of novel HIT delivered in the workplace on health and fitness variables remains unknown. Accordingly, this study evaluated the feasibility and effects of a controlled feasibility trial of an 8-week multi-activity workplace-based HIT intervention on markers of physical fitness, cardiometabolic and mental health in employees. Fifty-four office-based employees (mean age \pm SD: 46 \pm 11 years) were recruited from two workplaces in the Teesside area of the Northeast of England; one as an intervention site (n = 30), the other as a no-treatment control group (n = 24). The 8-week intervention comprised of thrice-weekly workplace-based HIT sessions consisting of 4 to 7x 60 second maximal effort intervals interspersed with 75 seconds of rest, based on stair climbing, stepping and boxing. Outcomes assessed at baseline and post-intervention were cardiorespiratory fitness (maximal oxygen consumption [VO_{2max}]), leg extensor muscle power, handgrip strength, body mass index, waist circumference, blood pressure, blood lipids and glucose, health-related quality of life (HR-QoL), psychological wellbeing and perceived stress.

Mean (\pm SD) session attendance in BE@Work was high (82% \pm 15%) and similar to reported attendance in other real-world HIT trials in adults (range 63-99%) (Allison et al., 2017; Lunt et al., 2014). As 70% of the high-intensity bouts were performed at or above the high-intensity criterion (e.g. \geq 85% HR_{max}), the intervention fidelity could be described as moderate to high (Hurst et al., 2018b). Both the mean peak heart rate (87% HR_{max}) and session RPE (6 AU) across the intervention, were indicative of high-intensity work. Post-intervention, compared with control, there was a beneficial increase in VO_{2max} (3.9 mL·kg⁻¹·min⁻¹) which is similar to, or greater than, changes observed in similar community-based physical activity or exercise training programmes based on moderate to vigorous intensity activity (2.2 to 4 mL·kg⁻¹·min⁻¹) (Asikainen et al., 2002; Dalleck et al., 2014). However, the improvement in VO_{2max} observed in the BE@Work trial was achieved with a lower weekly time commitment (45 to 75 mins per week vs. 120 to 325 mins per week). Additionally following the BE@Work trial, there were likely beneficial effects on two domains of HR-QoL (vitality: +8.7 AU and general health perceptions: +4.8 AU), which were similar to the effect of a previous 6 month exercise training intervention based on moderate to vigorous intensity activity (vitality +6.2 AU and general health perceptions: +7.1 AU (Martin et al., 2009)). There was a beneficial decrease in perceived stress (-2.6 AU) following the BE@Work trial. Although there is evidence to suggest that workplace-based health and exercise interventions can improve perceived stress (Kettunen et al., 2015), direct between-study comparisons are problematic due to differences in assessment tools used across the studies.

The BE@Work trial extends the positive findings from previous laboratory and workplace HIT trials suggesting that HIT can improve VO_{2max} (Allison et al., 2017; Shepherd et al., 2015; Weston et al., 2014b). However this is the first controlled trial demonstrating that novel workplace HIT can elicit meaningful improvements in markers of mental health. These findings may be particularly important from an organisational health perspective, as mental ill health and stress are leading contributors to the burden of occupational disease and injury (Kivimäki et al., 2010; Marmot et al., 2006).

7.2 Implications of the findings

Although HIT has recently been included in public health physical activity guidelines (Department of Health and Social Care, 2019; 2018 Physical Activity Guidelines Advisory Committee, 2018), there is debate surrounding the potential public health

impact of HIT, with critiques focusing on possible poor reach and adoption of HIT as a physical activity behaviour (Biddle et al., 2015; Biddle & Batterham, 2015). One common misunderstanding is that the purpose of HIT is to increase population wide levels of physical activity (Biddle et al., 2015); however it is argued here that this is not the intended purpose of HIT. The purpose of HIT is to elicit the health and fitness adaptations associated with physical activity, independently of total physical activity behaviour change or energy expenditure. As there is now a growing body of evidence suggesting that HIT can elicit adaptations in important aspects of physical fitness, cardiometabolic and mental health, both within and outside of laboratory environments, it is argued here that HIT should be incorporated into public health physical activity guidelines. Proponents of HIT are not advocating that traditional physical activity guidelines are replaced with HIT prescriptions, rather that HIT warrants a place among a range of traditional physical activity prescriptions (Biddle & Batterham, 2015).

Similarly, it has been argued that HIT has limited scalability because it requires access to expensive specialist equipment and may be unappealing to some individuals (Hardcastle et al., 2014). Scalability is defined as *“the ability of a health intervention shown to be efficacious on a small scale and or under controlled conditions to be expanded under real world conditions to reach a greater proportion of the eligible population, while retaining effectiveness”* (Milat et al., 2012, pg. 288). The scalability of a health intervention is essential to maximise the potential population wide health impact of the intervention (Milat et al., 2012). As the BE@Work trial was implemented under real-world conditions, this body of work begins to explore the potential scalability of HIT. However, given the exploratory nature of the BE@Work trial and resultant small sample size, whether workplace HIT can be scaled to reach a larger proportion of the working population remains unknown. Furthermore, while this body of work contributes to a growing evidence base demonstrating that some individuals are willing to participate in HIT and can have positive psychological responses to HIT (Burn & Niven, 2018; Jung et al., 2014; Stork et al., 2018), it is acknowledged that this form of exercise may not be appealing for all individuals. However, it has been highlighted that a “one-size-fits-all” physical activity or exercise prescription is unlikely to meet the requirements of all individuals (Vollaard & Metcalfe, 2017) and therefore it is argued here that HIT provides a further opportunity to promote a menu of physical activity options and choices, that could be tailored to a range of settings to suit individual needs and preferences (Thompson et al., 2015), which may encourage more individuals to participate in some form of physical activity.

7.2.1 Research implications

The work presented in this thesis has begun to develop an understanding of how novel modes of HIT can be incorporated into a workplace HIT programme and the effects of workplace-based HIT on markers of physical fitness, cardiometabolic and mental health. Despite this, it is acknowledged that there were limitations in this body of work that may limit the generalisability and wider application of the findings, and as such a number of areas for further investigation and recommendations for future research practice have been identified.

Firstly, as the BE@Work trial was exploratory in nature, it is acknowledged that a multisite randomised controlled trial with a larger sample size is needed before more definitive conclusions can be made about the effectiveness of workplace-based HIT. Furthermore, the data presented throughout the thesis represent quantitative intervention implementation data and an outcome evaluation, where the effect of the intervention on health and fitness variables was explored (Bauman & Nutbeam, 2013). Although this data begins to explore the implementation and effects of the intervention, future workplace HIT trials could also conduct a process evaluation, to further explore the acceptability and feasibility of the intervention (Bauman and Nutbeam, 2013). This could take the form of qualitative focus groups with intervention participants and management representatives.

Although the BE@Work trial was the first workplace HIT trial to be implemented in a non-academic workplace, it is acknowledged that the organisations involved in this programme of work were office-based organisations, and so the acceptability and feasibility of implementing HIT in other types of organisations is unknown. The organisations involved in this body of work operated flexible and largely autonomous working policies, which allowed participants to schedule exercise or data collection autonomously. It is acknowledged that this may not be possible in all occupations or organisations. For example in manual labour working environments or health care settings, an individual may be unable to leave their workplace to participate in exercise with the relative ease of the participants in the present body of work. Furthermore, in hazardous working environments, it may not be safe or practical to participate in exercise within or nearby to the working environment. Future studies could aim to explore the feasibility and effects of HIT delivered in a broader range of occupational environments.

It was highlighted earlier in this thesis that cardioprotective health promotion programmes are needed in the areas where the BE@Work trial was implemented (Stockton-On-Tees and Redcar & Cleveland) due to high levels of deprivation and cardiovascular disease rates (Public Health England, 2017). It is, however, acknowledged that individuals working in the organisations where BE@Work was developed and implemented may not necessarily have lived in the areas where the organisations were located, and as such, may not have experienced such high levels of deprivation. To account for this, future studies could seek to control for the influence of socioeconomic status by collecting information on income or residential postcode at baseline and including this value as a covariate in the outcome variable analysis. Furthermore, employment in itself is an important determinant of physical and mental health and unemployed individuals have poorer morbidity and mortality outcomes than those in employment (Bartley et al., 2005). Therefore, it could be argued that as participants in this programme of work were in stable employment, they may not experience the same levels of deprivation and associated poor health as other residents in the geographical area. Nonetheless, as poor health is a risk factor for early exit from employment (i.e. before retirement age) (van Rijn et al., 2014), enhancing or maintaining the health of the workforce through cardioprotective health promotion programmes is essential.

As described throughout this thesis there is debate surrounding the acceptability and feasibility of HIT in inactive and deconditioned populations (Biddle & Batterham, 2015; Hardcastle et al., 2014). It was not intended in this body of work to specifically target these populations, and across the experimental studies, on average participants were not inactive at baseline (mean baseline physical activity: 1795 ± 1271 MET min^{-1} and 1591 ± 1338 MET min^{-1} in Study Three and Four, respectively) and the average baseline $\text{VO}_{2\text{max}}$ in the BE@Work trial was not notably poor (baseline $\text{VO}_{2\text{max}}$ women: 33.5 ± 5.0 mL \cdot kg $^{-1}\cdot$ min $^{-1}$ and men: 42.7 ± 6.3 mL \cdot kg $^{-1}\cdot$ min $^{-1}$). Although it could be argued that this body of work had limited reach in terms of the participants included in the studies, the large standard deviations around the mean values of the physical activity and baseline CRF levels of participants may indicate that a range of participants were recruited. Indeed, this may more accurately represent the individuals present in a working environment, as it is likely that individuals with a variety of physical activity experience and fitness levels will be employed within organisations. Furthermore, it may not be ethical to exclude willing participants from workplace health promotion programmes based on baseline activity or physical fitness level. The exclusion of selected employees from workplace health promotion

initiatives may not be viewed favourably by participating organisations, as this could be viewed as discrimination in the workplace.

Across the three primary data collection studies presented in this thesis 42, 18 and 55 participants were recruited and 63% of those participants were female. Although this may be unsurprising as women are more typically recruited to physical activity interventions than men (Waters et al., 2011) in the context of the wider body of HIT research, it is encouraging as the majority of early HIT trials included mostly male participants (Burgomaster et al., 2005; Rognmo et al., 2004; Whyte et al., 2010). The recruitment of a higher proportion of females in the present body of work may therefore represent a shift towards a higher representation of women in HIT trials, which increases the generalisability of the HIT literature as a whole. However this could also be indicative of the gender balance in the participating organisations, although this is purely speculative as the organisations were unable or unwilling to share this data with the thesis author. Future workplace HIT trials could aim to assess if the gender balance in recruited participants is indicative of the organisational gender balance.

In terms of the wider HIT literature, while it is acknowledged that the majority of work to date has utilised cycle ergometers or treadmills as the exercise modality, this thesis has demonstrated that scalable activities such as stair climbing and stepping can be successfully incorporated into a HIT protocol capable of improving physical fitness and markers of mental health. Although this modality may not be appealing or appropriate to all individuals, the use of accessible activities such as stair climbing and stepping begins to address these scalability issues. Future workplace HIT trials could seek to incorporate a wider range of novel HIT modalities, particularly those which require limited equipment (such as body weight only exercises like star jumps and squat jumps), which would lower the associated cost of an intervention and potentially increase scalability.

Although the majority of HIT trials conducted to date involve single sessions of HIT per day, there is systematic review evidence to suggest that the effects of accumulated bouts of exercise throughout a day, compared with a single continuous exercise session of the same intensity and total duration (e.g. 3x 10 minutes vs. 1x 30 minutes), on markers of physical fitness and cardiometabolic health are similar (Murphy et al., 2019). The efficacy of sprint interval training (SIT) “snacks” involving three 20 second all-out cycle sprints interspersed throughout the day (~1 to 4 hours)

has begun to be explored in young, healthy adults, with similar improvements in VO_{2max} observed when compared with traditional SIT (+1.5 mL·kg⁻¹·min⁻¹ in the snack group and 1.9 mL·kg⁻¹·min⁻¹ in the SIT group) (Little et al., 2019). Bouts of HIT spread throughout the day could be incorporated into a workplace HIT intervention, however the effectiveness of HIT “snacks” outside of the laboratory and with novel modes of HIT is yet to be explored. Indeed it is questionable whether such short bouts of HIT using the novel modes used in the BE@Work trial would elicit heart rates indicative of high-intensity exercise, which may attenuate the training response. Furthermore, the safety of completing all-out sprints of novel HIT modes without a thorough warm up may be questionable. Additionally, the participants of the formative evaluation of the BE@Work trial (Study Two) reported a preference for group-based workplace exercise, which has previously been reported to enhance adherence to exercise prescriptions (Mangeri et al., 2014). Indeed, although individual HIT sessions were offered to BE@Work participants if they preferred, no participants expressed an interest in these sessions. If HIT “snacks” were to be incorporated into a workplace programme, it is unlikely that such a protocol would be group-based in nature, which may have implications for adherence and intervention fidelity. Nonetheless, as this form of HIT has not been incorporated into a workplace HIT programme and a one-size-fits all approach to exercise prescriptions is unlikely to suit all individuals (Vollaard & Metcalfe, 2017), future studies could seek to explore the acceptability, feasibility and effects of multiple HIT bouts interspersed throughout the day, in workplaces.

The majority of HIT trials conducted to date are short term (2 to 12 weeks) and the long-term adherence to, and effects of HIT are understudied. As such, this thesis supports recent calls for the implementation of long-term (i.e. ≥6 month) HIT interventions (Campbell et al., 2019). Indeed, whether a single short-term intervention would lead to long-term behaviour change or adherence to any physical activity prescription is questionable, especially as poor adherence to physical activity guidelines has been observed following the termination of previous short-term physical activity trials (Saida et al., 2017). As such, although the BE@Work trial does not address the issue of long-term sustainability of workplace HIT programmes, short-term workplace physical activity or exercise programmes, such as the BE@Work trial, could play an important role in a “whole-system” approach to physical activity promotion and delivery, where opportunities to participate in physical activity in all aspects of an individuals’ daily life is enhanced (Speake et al., 2016). Furthermore, although purely speculative, the implementation of short-term workplace exercise

programmes could promote a culture of physical activity in a workplace, where even if individuals choose not to participate in exercise in the workplace, the presence of such programmes may encourage other forms of physical activity. For example, the implementation of workplace exercise programmes may require additional infrastructure, such as showers and changing rooms, which could encourage active transport.

In the BE@Work trial, to maximise attendance, multiple HIT sessions were delivered across the week. While this may be one of the reasons for the high attendance observed in the trial (83%), it is acknowledged that outside of a research trial it may not be feasible for organisations to employ an exercise facilitator to deliver such a large volume of workplace HIT sessions. This clearly has implications for the potential scalability of workplace HIT interventions. Previous studies have used online platforms to deliver workplace exercise trials (Andersen et al., 2013) which may be applicable for workplace HIT trials. Similarly, it may be possible to implement a “train the trainer” intervention, where volunteers from organisations are trained to deliver HIT sessions within their workplace. Although these novel solutions may improve the scalability of workplace-based HIT, the safety, acceptability and feasibility of delivering high-intensity exercise using these methods has yet to be explored, and should be considered before the implementation of a program.

As well as the promotion of aerobic physical activity, current public health physical activity guidelines also recommend two sessions of strength training per week to promote muscular fitness and bone health (Department of Health and Social Care, 2019). Therefore a comprehensive exercise prescription for workplace exercise programmes could also contain a strength training element. Although stair climbing is one of the recommended strength training modalities in physical activity guidelines (Department of Health and Social Care, 2019), as there were no meaningful improvements in markers of muscular fitness observed in the BE@Work trial, which incorporated a stair climbing element, this may suggest that alternative strength training modalities may be required in this group. Future workplace exercise programmes could seek to incorporate a combination of HIT and strength training, to simultaneously improve cardiorespiratory and muscular fitness.

As vigorous intensity exercise has been associated with increased risk of acute cardiovascular events in susceptible individuals (Thompson, 1996), there have been concerns regarding the safety of HIT (Biddle & Batterham, 2015). In the BE@Work

trial there were no serious adverse cardiac events, however participants were free from cardiac or metabolic conditions and therefore these findings cannot be generalised to clinical populations. It has been suggested that a “preconditioning phase” consisting of moderate intensity aerobic exercise (e.g. 20 to 30 min per session, a few times per week for several weeks) could be enacted prior to initiating HIT (Gillen & Gibala, 2014). This could be prudent in particularly deconditioned individuals as individuals with higher baseline fitness levels have reduced risks of exercise induced ischaemic events (Thompson et al., 2007). A pre-conditioning phase has been successfully incorporated into the exercise prescription in a previous HIT trial with older adults (Sculthorpe et al., 2017).

One musculoskeletal injury which resulted in the participant withdrawing from the intervention occurred during the BE@Work HIT sessions. Given that the participant tripped over their feet on flat ground, it could be argued that this may have occurred irrespective of the type of exercise undertaken. Nonetheless, in a recent review of HIT trials in inactive or sedentary participants, across the 67 included trials (n=1318 participants), twenty individuals withdrew from interventions due to musculoskeletal injuries related to the study protocol (Reljic et al., 2019). The majority of injuries (n=18) were sustained during running as opposed to cycle ergometer (n=2) HIT protocols. Musculoskeletal injuries are the most common complication associated with physical activity and exercise training (Garber et al., 2011), and annual musculoskeletal injury rates related to physical activity have been estimated at twenty five percent among previously inactive participants beginning a moderate intensity physical activity programme (Hootman et al., 2002). Of the reported injuries, a further one third of injuries related to physical activity result in withdrawal from the physical activity programme (Hootman et al., 2002). Although further work is needed to establish the risk of musculoskeletal injury associated with novel modes of HIT, the data available indicates that musculoskeletal injury rates in HIT may not be substantially different to other forms of physical activity.

Comprehensive assessment of the exercise intensity in exercise trials is often lacking (Taylor et al., 2015). In the experimental studies presented Chapters Five and Six (studies three and four) a combination of objective and subjective assessment measures were used, which represents the best practice for evaluating exercise intensity (Weston et al., 2016b). Although heart rate monitors are a useful tool for the objective assessment of exercise intensity, it is acknowledged that this may limit the scalability of HIT interventions and the real-world application of HIT, given the

associated cost of the equipment. In the absence of heart rate monitors, the use of perceived exertion scales (RPE) could represent a viable and scalable alternative due to the limited equipment needed. Over the course of this programme of work, 734 individual RPE values were collected, demonstrating the large volume of data that can be generated in exercise trials using this tool. Although previous work has recommended that three separate familiarisation sessions are required before the administration of RPE (Macpherson et al., 2019), it is acknowledged that such time intensive RPE familiarisation procedures may not always be feasibly possible in the context of real world HIT studies. Nonetheless, familiarisation with RPE scales is recommended in future studies seeking to quantify perceived exercise intensity using this subjective tool.

In the BE@Work trial, various issues were encountered when obtaining responses to mood and enjoyment questionnaires, which resulted in a large proportion of missing data. For this reason, the chronic psychological responses to novel modes of HIT delivered in the workplace cannot be explored further from this body of work, and is yet to be fully elucidated. It is recommended that future studies seek to assess these important variables which may have implications for long-term participation and adherence to physical activity and exercise (Bartlett et al., 2011). To minimise participant burden, mobile phone or tablet applications could be used to streamline the collection of this data. Alternatively, researchers could explore the use of single-item mood or enjoyment scales in both acute and chronic HIT trials such as the Affect Grid (Russell et al., 1989) or the single-item Exercise Enjoyment Scale (Stanley & Cumming, 2010).

While it was acknowledged that one limitation in the BE@Work trial is the use of Chester step tests to predict VO_{2max} , anecdotally it should be noted that some participants were nervous about the prospective of completing even a submaximal exercise test. Furthermore, no participants agreed to attend the laboratory for a maximal cardiopulmonary exercise test when offered. Indeed some participants noted that if they were required to undergo a maximal exercise test at baseline, they would reconsider their involvement in the trial entirely. Therefore although submaximal exercise tests are not the gold standard VO_{2max} test, this highlights the impracticality of maximal testing with non-athletic populations. Although future work could look to assess the effect of exercise trials in non-athletic populations on VO_{2max} via a cardiopulmonary exercise test, it is recommended that an alternative submaximal test

is considered to reduce the impact that maximal testing may have on participant burden and recruitment.

7.2.2 Practical Implications

As well as the implications for future research discussed previously, a number of broader practical implications have also arisen from this programme of work. Recruitment to physical activity and exercise trials is often problematic (Copeland et al., 2016). The three primary data collection studies presented in this thesis involved recruiting a total of 115 participants, all recruited solely by the author. Recruitment strategies included advertisements sent to staff email distribution lists, presentations by the thesis author at staff meetings and posters placed in prominent locations around the workplace. Although anecdotal, through informal discussions with participants it became apparent that although email advertisement of studies successfully recruited some participants across the three studies, the majority of participants were recruited following presentations in the workplace or via word of mouth from colleagues. This highlights the importance of face-to-face recruitment strategies and also indicates the importance of using multiple avenues to maximise recruitment. It is, however, acknowledged that such time intensive recruitment strategies such as attendance at multiple staff meetings may not be feasible in some studies. Although social media advertisements were not used in this body of work, future workplace physical activity or health research studies could utilise social media platforms as an alternative recruitment channel (Cooke & Jones, 2017). In the present body of work, the exact number of participants recruited via each recruitment strategy was not recorded as most participants became aware of the studies through a number of channels. There have been calls for physical activity trials to publish detailed recruitment information (Mutrie et al., 2010); therefore future HIT trials could aim to quantify the number of participants successfully recruited through various channels. Furthermore, to further improve the reporting of recruitment rates, future studies could report the number of participants recruited to workplace research studies as a percentage of the total number of staff within an organisation. However in the present body of work this was not possible, as the participating organisations were unable to provide the exact number of staff included in each of the email distribution lists used as part of the recruitment strategy.

Research studies conducted within workplaces have a number of unique considerations in terms of the logistical organisation of data collection. Firstly, when recruiting organisations to a research project it is important to consider the size of an

organisation in terms of the objectives, methods and limitations of the research. To illustrate, six organisations were involved in the formative evaluation of the BE@Work trial, whereas only one of those organisations acted as the intervention site in the trial itself. Although three small organisations (<20 employees in total) expressed interest in the BE@Work trial, this would have required the facilitation of multiple HIT sessions across each working day in a number of different organisations. As the HIT sessions were conducted solely by the thesis author, this was not feasibly possible. Therefore a single larger organisation acted as the intervention site in the BE@Work trial. A larger team of researchers or exercise facilitators would be required to conduct HIT trials across multiple organisations, which was not possible in this programme of work.

To maximise the potential reach and recruitment to workplace research studies, consideration should be given to peak times for high workloads in participating organisations. For example, informal discussions with management representatives may highlight that the end of the financial year is a particularly busy time-period in their organisation and therefore this time-period should be avoided for recruitment or conduct of research studies. Similarly, peak time-periods for annual leave should be avoided (i.e. school holidays), as this will reduce the availability of employees and likely negatively impact on recruitment.

Room availability for data collection was problematic across the primary data collection studies presented in this thesis. As expected, priority was given to work related activities as opposed to the requirements of the research projects. As such, it is recommended that planning of data collection is conducted in the months leading up to the planned data collection, in conjunction with management teams within the organisations. For this to be possible, organisations will require an estimation of the number of participants required for recruitment, the length of time required to conduct data collection with the planned number of participants and the space or location requirements for data collection. Room availability was also problematic for workplace HIT sessions in the BE@Work trial. For this reason indoor sessions were offered when room availability permitted, however the majority of BE@Work HIT sessions were outdoor (70% of scheduled sessions). For future studies it is recommended that provisions are made to facilitate outdoor HIT sessions if possible, unless the participating organisation has a dedicated space for exercise. This is a potential issue in the scalability of workplace physical activity interventions in general, and is not limited to workplace-based HIT research studies.

7.3 Conclusion

The work presented in this thesis demonstrated that a novel multi-activity workplace-based HIT trial, BE@Work, had beneficial effects on CRF, two domains of HR-QoL (vitality and general health perceptions) and perceived stress. The improvements in mental health variables elicited by the BE@Work trial could be particularly meaningful from an organisational perspective, as work-stress is a leading cause of sickness absence (Lauzier et al., 2017). It was demonstrated that a choice of multi-activity HIT options can be provided to participants both within and between HIT sessions, without compromising the intensity of the exercise and intervention implementation data suggested that HIT can be delivered as intended across a number of participants, across a workplace exercise programme. The importance of including key stakeholders during the intervention development process has been highlighted, and as such this thesis supports calls for detailed intervention planning data to be published alongside intervention protocols (Bauman & Nutbeam, 2013). Nonetheless, the limitations associated with the exploratory nature of the BE@Work trial are acknowledged and a definitive randomised controlled trial with a larger sample is needed, before more definitive conclusions can be drawn regarding the effectiveness of HIT. Future trials should seek to explore the long-term adherence to, and effects of workplace HIT, and explore the feasibility and acceptability of HIT in a broader range of non-office based workplaces.

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Appendices

Appendix A

Employee Participant Information Sheet from Study Two (formative evaluation)

Employee views and opinions of workplace physical activity and exercise

Participant Information Sheet

Miss Naomi Burn, Dr Kathryn Weston, Professor Greg Atkinson, Dr Matthew Weston and Mr Neil Maguire

You are being invited to take part in a research study examining your views and opinions of workplace physical activity and exercise. Before you decide whether or not you wish to participate, it is important that you understand why the study is being conducted and what it will involve. Please take time to read the following information carefully. Ask us if anything is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

In recent years there has been an interest in the scientific community surrounding workplace physical activity and exercise programmes. However little is known about what people think about engaging in physical activity and exercise in the workplace. Therefore we would like to ask employees within your organisation their views and opinions about physical activity and exercise in the workplace. The purpose of this study is, in part, fulfilment of the PhD award of Naomi Burn from Teesside University.

Why have I been asked to take part?

You are eligible to take part in this study if you are an adult aged 18+ and are a non-management employee of **organisation**. Non-management means that you do not consider yourself to be part of the senior management team of your organisation. Management views will be collected separately to the employee focus group interviews.

Do I have to take part?

Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. Your employment or working conditions will not be impacted by this decision. If you do decide to take part you will be asked to indicate your consent to participate by reading and signing a consent form. You will not be able to participate in this study if you do not understand and speak English. You can choose to abstain from answering any of the questions asked during the focus group interview, if you decide to take part. Because the interview will take place at your workplace, during work hours, other people may be aware that you have taken part in the focus group interviews. Therefore although your choice to participate will not be confidential, your responses to the questions will be confidential. Additionally, if you decide to participate in this study you are in no way expressing interest or consent to participate in any exercise programme that may be developed as part of this study.

What will my participation involve?

If you agree to take part in the study, you will be asked to indicate your consent to participate by a reading and signing a consent form. Taking part in this study will involve participating in a one-off focus group interview with a PhD student researcher from Teesside University and between 4-7 other colleagues from your workplace. The focus group will be conducted at your workplace (during normal working hours) at a time convenient to all focus group participants

and the researcher, at some point between June and September 2017. The focus group interview will be audio recorded and then transcribed afterwards. When deciding if you want to take part, or not, please consider that as the Focus Groups will take place at your workplace during working hours, you will have to seek permission from your line manager to attend. As a result, your choice will not be confidential.

What if something goes wrong?

If you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Alasdair MacSween, details below.

Is the study suitably covered for insurance purposes?

Through its School of Health and Social Care, Teesside University has agreed to act as a sponsor for the proposed study and suitable insurance cover is in place.

What if I change my mind about participating in the study?

You are free to withdraw from the study at any point before or during the focus group interview without giving a reason. Unfortunately due to the nature of focus group interviews, you will not be able to withdraw your responses after the focus group interview has been conducted. This is because we will not be able to reliably identify all of your responses from an audio recording of the focus group interview.

Informed consent and confidentiality

Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. If you do decide to take part you will be asked to indicate your consent to participate by a reading and signing a consent form before the focus group interview.

All information which is collected about you during the course of the study, will be kept strictly confidential. Any personally identifiable statements made during the focus group interviews will be anonymised during transcription. You will not be identified in any publication or report from this research study. As the focus groups will take place at your workplace during working hours, your choice will not be confidential.

All information collected will be stored securely in a locked filing cabinet for the length of the project, and/or stored electronically on password protected computers at Teesside University. After the project is completed all the study materials and information will be stored securely by Teesside University for a minimum of 20 years and anonymised data may be used for future study (what is called secondary analysis) but only in research projects that have received ethical approval from an appropriate committee.

What are the possible benefits of taking part?

There are no direct benefits to you for participating in this study. The information gained from this study may be used to plan a workplace exercise intervention that will be feasible in your workplace. By participating you will help the researchers to design an exercise programme that may be offered to employees in your workplace.

What are the possible risks or disadvantages of taking part?

Possible risks or disadvantages are minimal. You can choose to abstain from answering any of the questions asked during the focus group interview. The views of management representatives from your organisation will be collected in separate interviews, to minimise any embarrassment you may feel discussing your workplace in the presence of management staff. Because the focus groups will take place at your workplace during working hours, your choice to participate will not be confidential. Other people in your organisation may know that you have chosen to participate in this study.

Will I be informed of the results of the research study?

Individualised feedback cannot be provided from this study. Upon your request we will be happy to provide you with a summary of the research findings, when analysis is complete.

What will happen to the results of the study?

The full results of this study will inform the written thesis of a Graduate Research student as part of the requirements of a PhD award from Teesside University. The results will be used to inform the development of a workplace exercise programme. The results may also be published in an academic journal. You will not be identifiable in any form of publication from this research study.

Who is organising the study?

The School of Health and Social Care at Teesside University.

Who has reviewed the study?

Teesside University, School of Health and Social Care Research Governance and Ethics Committee has reviewed this study.

Thank you for reading through this information.

If you have any further questions please contact Naomi Burn or Professor Greg Atkinson.

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If you wish to speak with someone who is knowledgeable about the study but not directly involved in it, or if have any complaints or comments you may contact:

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Appendix B

Management Participant Information Sheet from Study Two (formative evaluation)

Organisational views and opinions of workplace physical activity and exercise

Participant Information Sheet

Miss Naomi Burn, Dr Kathryn Weston, Professor Greg Atkinson, Dr Matthew Weston and Mr Neil Maguire

You are being invited to take part in a research study examining your organisations views and opinions of physical activity or exercise in the workplace. It is important that you understand why the study is being conducted and what it will involve. Please take time to read the following information carefully. Ask us if anything is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

In recent years there has been an interest in the scientific community surrounding workplace physical activity and exercise programmes. However little is known about what people think about engaging in physical activity and exercise in the workplace. Therefore we would like to ask employees within your organisation their views and opinions about physical activity and exercise in the workplace. The purpose of this study is, in part fulfilment of the PhD award of Naomi Burn from Teesside University.

Why have I been asked to take part?

You are eligible to take part in this study if you are an adult aged 18+ and are a management representative (either Management or Human Resources representative) of (insert name of organisation as appropriate). You are a management representative if you consider yourself to be a member of the senior management team of your organisation. Employee views will be collected separately in focus group interviews.

Do I have to take part?

Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. Your employment or working conditions will not be impacted by this decision. If you do decide to take part you will be asked to indicate your consent to participate by a reading and signing a consent form. You will not be able to participate in this study if you do not understand and speak English. You can choose to abstain from answering any of the questions asked during the focus group, if you decide to participate. Because the interview will take place at your workplace, during work hours, other people may be aware that you have taken part in the focus group interviews. Therefore although your choice to participate will not be confidential, your responses to the questions will be confidential. Additionally, if you decide to participate in this study you are in no way expressing interest or consent to participate in any exercise programme that may be developed as part of this study

What will my participation involve?

If you agree to take part in the study, you will be asked to indicate your consent to participate by a reading and signing a consent form. You will then be invited to attend a one-off focus group with two researchers from Teesside University (Naomi Burn, PhD Researcher and Neil Maguire, Graduate Tutor) and between 4-7 other management representatives from your organisation. The focus group will be conducted at your workplace (during normal working hours), at a time convenient to you and the researchers at some point between June and September 2017. When deciding if you want to take part, or not, please consider that as the Focus Groups will take place at your workplace during working hours, you will have to seek permission from your line manager to attend. As a result, your choice will not be confidential. The focus groups will be audio recorded and then transcribed afterwards.

What if something goes wrong?

If you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Alasdair MacSween, details below.

Is the study suitably covered for insurance purposes?

Through its School of Health and Social Care, Teesside University has agreed to act as a sponsor for the proposed study and suitable insurance cover is in place.

What if I change my mind about participating in the study?

You are free to withdraw from the study at any point during the focus group without giving a reason. Due to the nature of focus group interviews, you will be unable to withdraw your responses after the focus group has ended.

Informed consent and confidentiality

Taking part is entirely voluntary, is up to you to decide if you want to take part or not. If you do decide to take part you will be asked to indicate your consent to participate by a reading and signing a consent form before the interview.

All information which is collected about you during the course of the study, will be kept strictly confidential. Any personally identifiable statements made during the interview will be anonymised during transcription. You will not be identified in any publication or report from this research study. As the interviews will take place at your workplace during working hours, your choice to participate will not be confidential.

All information collected will be stored securely in a locked filing cabinet for the length of the project, and/or stored electronically on password protected computers at Teesside University. After the project is completed all the study materials and information will be stored securely by Teesside University for a minimum of 20 years and anonymised data may be used for future study (what is called secondary analysis) but only in research projects that have received ethical approval from an appropriate committee.

What are the possible benefits of taking part?

There are no direct benefits to you for participating in this study. The information gained from this study will be used to plan a workplace exercise intervention that will be feasible in your organisation. By participating you may help the researchers to design an exercise programme that could be offered to employees within your organisation, should the organisation wish to do so. If you choose to participate in this study, you are not required to participate in any exercise programme that may be offered to employees in your workplace in the future.

What are the possible risks or disadvantages of taking part?

Possible risks or disadvantages are minimal. You can choose to abstain from answering any of the questions asked during the interview. Because the focus groups will take place at your workplace during working hours, your choice to participate will not be confidential. Other people in your organisation may know that you have chosen to participate in this study

Will I be informed of the results of the research study?

Individualised feedback cannot be provided from this study. Upon your request we will be happy to provide you with a summary of the research findings, when analysis is complete.

What will happen to the results of the study?

The full results of this study will inform the written thesis of a Graduate Research student as part of the requirements of a PhD award Teesside University. The results will be used to inform the development of a workplace exercise programme. The results may also be published in an academic journal. You will not be identifiable in any form of publication from this research.

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The School of Health and Social Care at Teesside University.

Who has reviewed the study?

Teesside University, School of Health and Social Care Research Governance and Ethics Committee has reviewed this study.

Thank you for reading through this information.

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Appendix C

Employee focus group interview schedule

Employee Focus Group Interview Schedule		
Question	Prompt	Justification
Introduction		
<p>Researcher introduces herself and moderator and summarises the purpose of the focus group interview (to explore employee views and opinions of a workplace exercise programme). Explain “rules” of the focus group: there are no right or wrong answers, please respect everyone’s opinions, don’t talk over each other for the recording, but discussion amongst the group is encouraged.</p> <p>Q1. Tell us your name and your job role within your organisation and how long you have been working here.</p>		<p>Opening question. Ensures the researcher can address participants by their name, and that participants are familiar with each other in the group.</p>
Notes:		
Part 1- exercise and workplace exercise		
<p>Q2. Describe what physical activity or exercise means to you.</p> <p>Q3. Describe what experiences have you had of physical activity or exercise in your life.</p>	<p>General discussion about exercise experiences</p>	<p>Starts group discussion</p> <p>Gets group discussion on the topic of physical activity/ exercise</p>
Notes:		
<p>Q4. Do you have experiences of physical activity/ exercise being encouraged or offered in your workplace, either past or present?</p> <p>Q5. Describe these experiences.</p>	<p>Did you participate/ not participate?</p> <p>Did you change behaviour? Why/ why not?</p> <p>Positive/ negative experience?</p>	<p>Do they have any previous experience of workplace exercise interventions?</p>
Notes		
<p>Q6. What do you think about physical activity or exercise</p>	<p>What could employees gain/ lose if exercise was</p>	<p>Explores perceived acceptability of</p>

<p>being offered to employees in a workplace?</p>	<p>offered to them in the workplace? What could organisations gain/lose if exercise was offered to employees in the workplace?</p>	<p>workplace exercise interventions</p>
<p>Notes:</p>		
<p>Q7. In your workplace, what do you think are the barriers to participating in a workplace exercise programme in your workplace? Rephrase: what would make it difficult for you to exercise in your workplace?</p>	<p>Policy- e.g. set working hours/flexible working hours? Management support for the exercise programme. Physical environment- a space available to conduct the exercise, timing of the exercise sessions Social environment-level of colleague participation?</p>	<p>Explores feasibility of a workplace exercise programme.</p>
<p>Notes:</p>		
<p>Q8. In your workplace, what do you think are facilitators to participating in a workplace exercise programme? Rephrase: what would make it easy for you to exercise in your workplace?</p>	<p>Policy- e.g. set working hours/flexible working hours? Management support for the exercise programme. Physical environment- a space available to conduct the exercise, timing of the exercise sessions Social environment-level of colleague participation? Incentives for participation?</p>	<p>Explores feasibility of a workplace exercise programme.</p>

Notes:		
Part 2- Attitudes/ beliefs/ opinions of HIT	Introduce HIT as a form of exercise-very briefly	
Q9. What do you know about high-intensity interval training?		Attitudes/ opinions/ beliefs on HIT
Notes:		
Q10. Does anyone have any previous experience with HIT?	Researcher to explain definition of HIT	Explores understanding of HIT
Notes:		
Q11. Given our definition of HIT, describe your thoughts on HIT		Attitudes/ opinions/ beliefs on HIT given research definition of HIT
Notes:		
Q12. Given our definition of HIT, is this a form of exercise that you would consider participating in?	Why/ why not?	Acceptability of HIT
Notes:		
Part 3- Attitudes/ beliefs/ opinions of workplace exercise- individual thoughts	Researcher to explain the outline of a hypothetical exercise programme. Between 10-30 minutes, 3 times per week of high-intensity interval training that is tailored to individual fitness levels in the workplace or very near the workplace.	To be able to discuss opinions/ beliefs and attitudes of a hypothetical exercise programme participants need to understand what the programme would entail
Q13. What types of exercises do you think you would like/ dislike in a workplace exercise programme to include?	Researcher to give examples of a few HIT exercises if they are struggling.	Acceptability of HIT
Notes:		
Q14. What time of day do you think the exercises should be done at?	Before work/ after work/ lunchtime during work time?	Feasibility in their workplace

Notes:		
Q15. What do you think about the length of the exercise sessions?	Too long/ short? Why?	Feasibility in their workplace
Notes:		
Q16. What do you think about the frequency of exercise sessions?	Too frequent/ not frequent enough? Why?	Feasibility in their workplace
Notes:		
Q17. Where in your workplace could the exercises be conducted?	Why?	Feasibility in their workplace
Notes		
Q18. Should the exercises be conducted in groups or individual?	Why?	Feasibility in their workplace
Notes:		
Q19. What outcome measures would you be interested to know might have changed as the result of a workplace exercise programme?	Physical health/ mental health Fitness- 4 weeks Blood outcomes- 10 weeks	Informs length of intervention
Notes:		
Q20. If this exercise programme was offered to you in your workplace, would you consider participating?	Why/ why not? What could the team designing the programme do to make you want to participate- incentives?	Acceptability of HIT in the workplace
Notes:		
Closing remarks		
Thank you for your time, your opinions are very valuable to the research project. Q21. Before we finish, is there anything else that we haven't covered today that you think is important in terms of a workplace exercise programme?		

Appendix D

Management Interview schedule

Management/ HR representative interview schedule		
Question	Prompt	Justification
Part 1- workplace exercise		
Q1. Can you tell me about the number of employees that you have in your organisation and the types of job roles	Blue/ white collar workers? Full time/ part time? All based in one site or over multiple sites?	Need to understand basic demographics and number of sites to know how an intervention could be developed in this organisation.
Notes:		
Q2. Has your organisation ever offered or promoted physical activity/ exercise to employees?	How was the experience for the organisation? % Uptake?	Do they have any previous experience of workplace exercise interventions?
Notes:		
Q3. What do you expect the impact of an exercise programme offered in the workplace to be?	Health/ fitness/ productivity/ sick leave?	Outcome measures pertinent to the organisation
Q4. How would organization you assess the impact of an exercise programme?		
Notes:		
Part 2- Organisational perspectives of workplace exercise	Researcher to explain the exercise programme. Between 10-30 minutes, 3 times per week of high-intensity interval training that is tailored to individual fitness levels in the workplace or very near the workplace.	
Q5. Do you think your organisation would consider giving employees between 10-	Why/ why not?	Feasibility in their workplace

30 minutes on 3 days per week of paid working time to participate in this programme?		
Notes:		
Q6. What do you think about length of the exercise sessions?	Too long/ short? Why?	Feasibility in their workplace
Notes:		
Q7. What time of day do you think the exercises should be done at?	Before work/ after work/ lunchtime during work time?	Feasibility in their workplace
Notes:		
Q8. What do you think about the frequency of exercise sessions?	Too frequent/ not frequent enough? Why?	Feasibility in their workplace
Notes:		
Q9. Where in your workplace do you think the exercises be conducted?	Why?	Feasibility in their workplace
Notes:		
Q10. Do you think the exercises should be conducted in groups or individually?	Why?	Feasibility in their workplace
Notes:		
Part 3- Feasibility of workplace exercise in the organisation/ workplace		
Q11. Do you foresee any barriers to participation in workplace exercise?	Policy- e.g. set working hours/ flexible working hours? Management support for the exercise programme. Physical environment- a space available to conduct the exercise, timing of the exercise sessions Social environment- level of colleague participation?	Barriers
Notes:		
Q12. Do you foresee any facilitators to participation in workplace exercise? Q13. What do you think would encourage staff to participate in workplace exercise?	As above and incentives for participation	Facilitators

Notes:		
Closing remarks		
<p>Thank you for your time, your opinions are very valuable to the research project.</p> <p>Q14. Before we finish, is there anything else that we haven't covered today that you think is important in terms of a workplace exercise programme?</p>		

Appendix E

Participant Information Sheet for Study Three

Heart rate and feelings during high intensity exercise

Participant Information Sheet

Miss Naomi Burn, Dr Kathryn Weston, Professor Greg Atkinson, Dr Matthew Weston and Mr Neil Maquire

You are being invited to take part in a research study investigating if novel forms of exercise can be used as a form of high-intensity interval exercise. Before you decide whether or not you wish to participate, it is important that you understand why the study is being conducted and what it will involve. Please take time to read the following information carefully. Ask us if anything is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

In recent years there has been an interest in the scientific community surrounding a form of exercise called high-intensity interval training (or HIT for short). However most research studies use stationary cycling as the form of exercise. We asked employees from organisations in Teesside what types of exercise they might like to participate in, and based on this we would like to see if these novel forms of exercise can be used as part of a HIT exercise session. The purpose of this study is, in part, fulfilment of the PhD award of Naomi Burn from Teesside University

Why have I been asked to take part?

You have been asked to take part in this study because you are an employee of (insert name of organisation as appropriate). To participate in the present study, you must be healthy and aged 18 or older. Importantly, you are not eligible if you:

- have any diagnosis or symptoms of cardiovascular or metabolic diseases (e.g. heart disease, diabetes)
- have an injury requiring alterations of the established exercise protocol
- are physically unable to complete the intervention
- have been advised by a health professional to avoid physical exercise or activity
- are pregnant or might be pregnant
- cannot understand or speak English

Do I have to take part?

Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. Your employment or working conditions will not be impacted by this decision. If you do decide to take part you will be asked to indicate your consent to participate by a reading and signing a consent form.

What will my participation involve?

If you agree to take part in the study, you will be asked to indicate your consent to participate by a reading and signing a consent form. You will be invited to attend four exercise sessions taking place at the Exercise Physiology Laboratory in the Olympia Building/Constantine Building at Teesside University. The sessions will take 45 minutes, and the exercise will last for 14 minutes.

For each session we request that you:

- Wear comfortable, loose fitting clothing and sensible footwear
- Arrive well rested and drink plenty of fluids in the 24 hours before
- Avoid eating a heavy meal or drinking alcohol and caffeine for 3 hours before
- Avoid strenuous exercise on the day of your scheduled session.

Session 1:

At the first session, we will check your responses to the attached Physical Activity Readiness Questionnaire to ensure that you may take part. Please read the Physical Activity Readiness Questionnaire before deciding if you would like to participate. Once it has been confirmed that there are no medical conditions precluding your participation in the research project, you will be asked to read and sign an informed consent form. We will then collect information on your age, sex, height, weight, blood pressure and habitual physical activity. This information will be collected in a private area and recorded anonymously.

We will then introduce you to the three forms of exercise that will be conducted in sessions 2-4, there is more detailed information on each of the exercises below. We will teach you the correct technique for the exercises and you will have the opportunity to practice each of the exercise forms.

Session 2-4

In each of the following sessions you will complete three different forms of exercise (stair stepping, stair climbing and non-contact boxing). Before you start the exercise we will measure your blood pressure, after 10 minutes of seated rest.

Stair stepping involves stepping onto and off a Reebok stepper, pictured below. Stair climbing will involve climbing the stairs in the Middlesbrough Tower building of Teesside University. Non-contact boxing involves wearing protective gloves and punching a soft punch pad, as pictured below.



The exercise will be conducted following a high-intensity interval protocol. This means you will complete four 60 second bursts of exercise at an intensity that will cause your heart rate to increase to approximately 85% of your predicted maximum heart rate. The 60 seconds of exercise will always be followed by 60 seconds of rest and recovery. During the exercise sessions we will need you to wear a heart rate monitor around your chest. You will be asked to indicate how hard you think the exercise is (rating of perceived exertion) after each 60 second exercise bout and after the whole session. We will also assess your mood using a questionnaire before and after completing the exercise sessions and we will assess how much you enjoyed the exercise session afterwards. We will measure your blood pressure again 10 minutes after you have finished the exercise.

Each session will last approximately 45 minutes (with 11 minutes of exercise) and will take place at time convenient to you. It does not matter what days you do the sessions on (weekdays only), but we do require them to be conducted at roughly the same time of day on each occasion (e.g. morning/ afternoon).

After the exercise in sessions 2-4 when you leave the laboratory you will be asked to take a mood and enjoyment questionnaire with you to complete after 1 hour. You can either give the questionnaire back to the researchers in person at the next exercise session or we will arrange to collect it from you at a mutually convenient time on the university campus.

What if something goes wrong?

If you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Alasdair MacSween, details below.

Is the study suitably covered for insurance purposes?

Through its School of Health and Social Care, Teesside University has agreed to act as a sponsor for the proposed study and suitable insurance cover is in place.

What if I change my mind about participating in the study?

You are free to withdraw from the study at any point before or during the exercise sessions without giving a reason, until the completion of the last exercise session. At the first exercise session you will be assigned a participant identification (ID) number. If you wish to withdraw your data from the analysis in the first instance you should contact the project supervisor Dr Kathryn Weston with your participant ID number, contact details below.

Informed consent and confidentiality

Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. If you do decide to take part you will be asked to indicate your consent to participate by a reading and signing a consent form before the first data collection session.

All information which is collected about you during the course of the study, will be kept strictly confidential. Unless through participation in this study any previously unknown medical condition becomes known to us, in which case we will inform you and suggest you consult your medical practitioner.

You will not be identified in any publication or report from this research study. All information collected will be stored securely in a locked filing cabinet for the length of the project, and/or stored electronically on password protected computers at Teesside University. After the project is completed all the study materials and information will be stored securely by Teesside University for a minimum of 20 years.

The exercise sessions will be conducted in the laboratory, apart from the stair climbing which will be conducted in the Middlesbrough Tower building of Teesside University. Because of this, other people may see you exercising and because of this your choice to participate may not be confidential. However you will not have to wear anything that will make you immediately identifiable as a participant in this study.

The mood and enjoyment questionnaires that you will be asked to take with you to complete one hour after you have finished the exercise will contain your unique participant ID number and no other identifying information about you, so that only the researchers involved in this study will know who has completed the questionnaire. You can either give the questionnaire back to the researchers in person at the next exercise session or we will arrange to collect it from you at a mutually convenient time on the university campus.

What are the possible benefits of taking part?

There are no direct benefits to you for participating in this study. You may however enjoy participating in the exercise sessions.

What are the possible risks or disadvantages of taking part?

There are certain risks to participating, such as discomfort or injury from undertaking high intensity exercise. However the exercise sessions that we have planned have been used safely in a range of populations including people with heart disease and diabetes. The likelihood of physical injury occurring will be minimised by conducting a standardised warm up and cool down. You can terminate the exercise at any point if you feel uncomfortable or distressed. The exercise sessions will be facilitated by qualified personnel from the university.

Will I be informed of the results of the research study?

If you would like to know any of the measurements taken in the first session (height, weight, blood pressure) we will only tell you if you ask us to do so. If through participation in this study any previously unknown medical conditions become apparent we would like to be able to tell you.

We will be unable to provide any more individualised feedback. Upon your request we will be happy to provide you with a summary of the research findings, when analysis is complete.

What will happen to the results of the study?

The full results of this study will inform the written thesis of a Graduate Research student as part of the requirements of a PhD award from Teesside University. The results may also be included in academic journal articles or conference proceedings. You will not be identifiable in any form of publication from this research study.

Who is organising the study?

The School of Health and Social Care at Teesside University.

Who has reviewed the study?

Teesside University, School of Health and Social Care Research Governance and Ethics Committee has reviewed this study.

Thank you for reading through this information.

If you have any further questions please contact Naomi Burn or Dr Kathryn Weston.

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If you wish to speak with someone who is knowledgeable about the study but not directly involved in it, or if have any complaints or comments you may contact:

Alasdair MacSween Ph.D B.Sc.(Hons) MCSP
Chair of School of Health & Social Care Research Governance and Ethics Committee
School of Health & Social Care
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Appendix F

Rating of Perceived Exertion Familiarisation Protocol

Adapted from Borg, 1998, pg. 51.

I want you to rate your perception of exertion, that is, how physically demanding the exercise feels to you. The perception of exertion depends mainly on the strain and fatigue in your muscles and on your feeling of breathlessness or aches in the chest.

I want you to use this scale from 0 to 10 and □ where 0 means “no exertion at all” and 10 means “extremely hard” that is the maximal exertion you have previously experienced.

1 corresponds to “very easy” exercise. For a normal healthy person it is like walking slowly at his or her own pace for several minutes.

3 on this scale is “moderate” exercise, it is not especially hard, it feels fine and it is no problem to continue exercising.

5 corresponds to “hard” exercise, it feels hard and you are tired, but you don’t have any great difficulties going on.

7 is “very hard” and very strenuous. A healthy person can still go on but he or she has to push himself or herself a lot. It feels very hard and the person is very tired.

10 on the scale is “extremely hard” or extremely strenuous exercise level. For most people this is an exercise as strenuous as they have ever experienced before in their lives.

□ The dot denotes a perceived exertion that is stronger than 10, “extremely hard”. It is your “absolute maximum” for example 12 or 13 or even higher. It is the highest possible level of exertion.

Try to appraise your feeling of exertion as honestly as possible without thinking about what the actual physical load is. Do not underestimate it, do not over estimate it either. It is your own feelings of effort and exertion that is important, not how it compares to other peoples. What other people think is not important either. Look at the scale and the expressions and then give a number. What maximum exertion have you previously experienced in your life? Use that as “10”.

Any further questions?

Appendix G

Bout Rating of Perceived Exertion Template

How physically demanding was the entire minute, from start to finish?

Rating	Descriptor
0	Nothing at all
0.3	
0.5	Extremely easy
0.7	
1	Very easy
1.5	
2	Easy
2.5	
3	Moderate
4	
5	Hard
6	
7	Very hard
8	
9	
10	Extremely hard
11	
□ possible	Absolute maximum / highest

Appendix H

Session Rating of Perceived Exertion Template

How physically demanding was the entire session, from start to finish?

Rating	Descriptor
0	Nothing at all
0.3	
0.5	Extremely easy
0.7	
1	Very easy
1.5	
2	Easy
2.5	
3	Moderate
4	
5	Hard
6	
7	Very hard
8	
9	
10	Extremely hard
11	
□ possible	Absolute maximum / highest

Appendix I

PANAS Questionnaire

This scale consists of a number of words that describe different feelings and emotions. Read each item and then indicate on the scale below next to each word to what extent you feel this way right now, that is, at the present moment.

	Very slightly or not at all 1	A little 2	Moderately 3	Quite a bit 4	Extremely 5
Interested	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Distressed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Excited	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Upset	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Strong	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Guilty	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Scared	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hostile	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Enthusiastic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Proud	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Irritable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Alert	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ashamed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inspired	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nervous	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Determined	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Attentive	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Jittery	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Active	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Afraid	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Appendix J

Physical Activity Enjoyment Scale (PACES)

Please rate how you feel at the moment about the exercise session that you completed today.

Please fill in both pages of this questionnaire.

I enjoyed it	1	2	3	4	5	6	7	I hated it
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I felt bored	1	2	3	4	5	6	7	I felt interested
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I disliked it	1	2	3	4	5	6	7	I liked it
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I found it pleasurable	1	2	3	4	5	6	7	I found it unpleasurable
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I was very absorbed in this activity	1	2	3	4	5	6	7	I was not at all absorbed in this activity
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
It was no fun at all	1	2	3	4	5	6	7	It was a lot of fun
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I found it energising	1	2	3	4	5	6	7	I found it tiring
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
It made me depressed	1	2	3	4	5	6	7	It made me happy
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
It was very pleasant	1	2	3	4	5	6	7	It was very unpleasant
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I felt good physically while doing it	1	2	3	4	5	6	7	I felt bad physically while doing it
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
It was very invigorating	1	2	3	4	5	6	7	It was not at all invigorating
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
I was very frustrated by it	1	2	3	4	5	6	7	I was not at all frustrated by it
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
It was very gratifying	1	2	3	4	5	6	7	It was not at all gratifying
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
It was very exhilarating	1	2	3	4	5	6	7	It was not at all exhilarating
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
It was not at all stimulating	1	2	3	4	5	6	7	It was very stimulating
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
It gave me a strong sense of accomplishment	1	2	3	4	5	6	7	It did not give me any sense of accomplishment at all
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

It was very refreshing	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>	4 <input type="checkbox"/>	5 <input type="checkbox"/>	6 <input type="checkbox"/>	7 <input type="checkbox"/>	It was not at all refreshing
I felt as though I would rather be doing something else	1 <input type="checkbox"/>	2 <input type="checkbox"/>	3 <input type="checkbox"/>	4 <input type="checkbox"/>	5 <input type="checkbox"/>	6 <input type="checkbox"/>	7 <input type="checkbox"/>	I felt as though there was nothing else I would rather be doing

Appendix K

Intervention Group Participant Information Sheet (Study Four)

BE@Work: Brief Exercise at Work
A workplace physical activity programme

Naomi Burn (PhD Student)

Supervisors: Dr Kathryn Weston, Professor Greg Atkinson, Dr Matthew Weston
PhD students assisting with health and fitness testing: Neil Maguire, Ryan Kenny, Kirsti
Loughran, Phillip Williamson and Lesley Cooper

You are being invited to take part in a research study that involves participating in a physical activity programme in your workplace. Before you decide whether or not you wish to participate, it is important that you understand why the study is being conducted and what it will involve. Please take time to read the following information carefully. Ask us if anything is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

This study will investigate if an 8 week programme of exercise in your workplace has an impact on your health and wellbeing. The purpose of this study is, in part, fulfilment of the PhD award of Naomi Burn from Teesside University.

Who will be invited to take part?

You and your colleagues are being invited to participate in this study. You are eligible to take part in this study if you are an employee of *organisation*, aged over 18 years of age. You do not need any experience with any form of physical activity to participate in this study.

Your organisation has agreed to help recruit and provide facilities for the research project but they will not ever know who did or did not participate in the study.

In order to confirm that you do not have any medical conditions that may preclude you from participating in this study, attached to this document is a questionnaire called the Physical Activity Readiness Questionnaire Plus (PARQ+). Please answer the questions on this questionnaire. The questionnaire will tell you if you are cleared for physical activity participation and therefore eligible to participate in this study.

Unfortunately you will not be able to participate if you:

- have any diagnosis or symptoms of cardiovascular or metabolic disease (such as history of heart attack, stroke or diabetes).
- have been advised by a health professional to avoid physical exercise or activity.
- are pregnant or might be pregnant.
- cannot understand or speak English.

When will this project run?

The programme will begin in early April 2018 and will finish in June 2018. You will have the opportunity to attend a one-off taster session of physical activity in your workplace, facilitated by Naomi Burn (PhD Student) before you decide if you would like to participate in the programme, if you would like (dates available upon request) details below.

Do I have to take part?

No. Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. Your employment or working conditions will not be impacted by this decision.

What will my participation involve?

If you agree to take part in the study, you will be asked to indicate your consent to participate by a reading and signing a consent form.

The programme involves attending three group exercise sessions per week, with some of your colleagues in your workplace, for 8 weeks. If you prefer, a one-to-one session can be facilitated at a separate time. The exercise sessions will last between 15-20 minutes and will include a range of exercises such as walking, stair stepping, non-contact boxing, stair climbing and exercise to music. You can choose which type of exercise appeals most to you.

There will be a choice of at least 2 sessions each day for the exercise sessions in your workplace, you can attend whichever session suits you best on each day. The sessions will either be in the morning before work (approximately 8:30am), at lunch time (approximately 12pm) or in the afternoon (approximately 4:30pm). You will be given the opportunity to indicate your preferred timing during the health and fitness testing before the programme starts.

The activities are suitable for all fitness levels and will be conducted in an interval training format (60 second exercise bursts, followed by 75 seconds rest). The exercise bursts are designed to elicit $\geq 85\%$ of your age predicted maximum heart rate and will be tailored to each person's fitness level and ability. The exercise will make your heart beat much faster than when you are at rest, make your breathing rate increase significantly (both during and for some time after the interval), and make you feel warm and possibly sweaty. The sessions will be facilitated by Naomi Burn (PhD student) and Neil Maguire (Graduate Tutor) from Teesside University.

In order to assess the impact of the programme, a range of health and wellbeing tests will be conducted both before and after the programme. The tests will be conducted in a private room in your workplace and include:

- **Wellbeing measures:** quality of life, mental wellbeing, stress and perceived work productivity will be measured using standardised paper based questionnaires.
- **Height and weight:** Will be assessed using standard scales and measuring tape.
- **Waist and hip circumference:** We will measure this by passing a tape measure around your bare stomach.
- **Blood pressure:** Taken using an automatic blood pressure monitor.
- **Blood glucose and cholesterol:** These will be obtained by taking a quick finger prick blood sample from your middle finger. The blood will be collected in a small thin tube and assessed through a simple automatic blood analyser which processes the sample in 5 minutes. Medical gloves will be worn by the researcher at all times and all materials contaminated with blood will be disposed of in a biohazardous waste container/sharps bin. No storage of blood will occur.
- **Aerobic fitness:** The fitness of your heart and lungs during exercise will be assessed using a "Chester Step Test". This involves stepping onto and off a box at a height relevant to each individual's age and usual physical activity level, at a set pace for a maximum of 10 minutes or until the heart rate reaches $\geq 80\%$ of age-predicted maximum, whichever is first. We will monitor your heart rate throughout using a wrist worn heart rate monitor.
- **Upper body strength:** will be measured using a piece of equipment called a hand dynamometer. You will squeeze the dynamometer as hard as you can in your dominant hand.
- **Lower body strength:** This involves sitting on a piece of equipment called a Nottingham Leg Rig with your foot pressed into a foot pedal. You will push down with your foot onto the pedal as hard as you can and this measures your lower body strength.
- **Physical activity levels:** We will measure your physical activity level over a 7 day period using a device called an accelerometer. The accelerometer is worn at your hip and is the size of a small match box. It is discreet and can be covered with clothing. This device tracks when you are sitting, standing or stepping, but does not track your location or where you travel or move to.
- **Additional measure of aerobic fitness:** if you would like, you can also elect to come to the Exercise Physiology laboratories at Teesside University in order to undertake another test of your aerobic fitness called a VO_{2peak} test, on a stationary bike. This test will let us know more accurately how effectively your body can transport and utilise oxygen to produce energy during exercise and what your maximum heart rate is. This test is progressive, which means that the resistance on the bike will increase until you can't pedal anymore and/or choose to terminate the test. To obtain your maximum oxygen uptake, we need you to wear a lightweight portable metabolic system with a small face mask throughout the test. The face mask will be attached for approximately 5 minutes prior to the start of the test to allow you to get used to it. The mask will cover your nose and mouth

and will be kept in place by an elasticised head strap. To obtain your maximum heart rate, we will also require you to wear a wrist worn heart rate monitor.

During the exercise sessions you will wear a heart rate monitor on your wrist. You will be asked to indicate how hard you think the exercise is (rating of perceived exertion) after each session. We will use a standardised paper based questionnaire to assess your mood at fortnightly intervals throughout the programme and we will also assess whether you enjoyed the exercises or not during the final week of the programme, using a paper based questionnaire.

Taster Sessions

You will have the opportunity to come and try a one-off taster session of exercise before you decide if you would like to participate in the research project (dates and times here). At this session you will have the opportunity to try the exercises that will be conducted in the research project and have the chance to ask questions. At the taster session we will ask you to complete a PARQ+ to let us know if you are eligible to participate and a consent form to let us know you agree to participate in the taster session. No other data will be collected from you at that time, and by participating in the taster session you are not consenting to participate in any research study.

What if something goes wrong?

If you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Alasdair MacSween, details below.

Is the study suitably covered for insurance purposes?

Through its School of Health and Social Care, Teesside University has agreed to act as a sponsor for the proposed study and suitable insurance cover is in place.

What if I change my mind about participating in the study?

You are free to withdraw from the study at any point until the completion of the last data collection session. At the first session you will be assigned a participant identification (ID) number. If you wish to withdraw your data from the analysis in the first instance you should contact the project supervisor Dr Kathryn Weston with your participant ID number, contact details below.

Informed consent and confidentiality

Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. If you do decide to take part you will be asked to indicate your consent to participate by reading and signing a consent form before the first data collection session.

All information which is collected about you during the course of the study, will be kept strictly confidential. Unless through participation in this study any previously unknown medical condition or findings which you would be wise to have investigated becomes known to us, we will inform you and suggest you consult your medical practitioner.

You will not be identified in any publication or report from this research study. All information collected will be stored securely in a locked filing cabinet for the length of the project, and/or stored electronically on password protected computers at Teesside University. Only the PhD student (Naomi Burn) and supervisors named on this document will have access to the data that is collected about you by participating in this study. After the project is completed all the study materials and information will be stored securely by Teesside University for a minimum of 20 years.

The non-identifiable research data will be stored indefinitely on a secure password protected server at Teesside University. This is in case other scientists wish to raise questions about the results that need checking against the dataset. In the event that the study is published in a scientific journal, the non-person identifiable research dataset may be made publicly available (for example, as a supplement to the journal article, or stored on an on-line scientific data repository).

The exercise sessions will be initiated at your workplace in groups with your colleagues. Because of this, other people may see you exercising and therefore your choice to participate in the study may not be confidential. If you would like, we can facilitate individual sessions out with of the group exercise sessions, however because they will be initiated at your workplace other people may still see you exercising and therefore your choice to participate in the study may not be confidential.

What are the possible risks or disadvantages of taking part?

There are certain risks to participating, such as discomfort or injury from undertaking exercise. However the exercise sessions that we have planned have been used safely in a range of populations. The likelihood of physical injury occurring will be minimised by conducting a standardised warm up and cool down. You can terminate the exercise at any point if you feel uncomfortable. The exercise sessions will be facilitated by qualified personnel (Naomi Burn, PhD Student and Neil Maguire (Graduate Tutor)) from Teesside University. Naomi Burn has both undergraduate and postgraduate level qualifications in physical activity for health and Neil Maguire has an undergraduate level qualification in Sports Science and a postgraduate qualification in Physiotherapy.

You can choose to abstain from any of the health and wellbeing measurements if you choose.

Will I be informed of the results of the research study?

If you would like we will be able to provide individualised feedback on your results after the completion of the study. Upon your request we will be happy to provide you with a summary of the research findings, when analysis is complete.

What will happen to the results of the study?

The full results of this study will inform the written thesis of a Graduate Research student (Naomi Burn) as part of the requirements of a PhD award from Teesside University. The results may also be included in academic journal articles or conference proceedings. You will not be identifiable in any form of publication from this research study.

Who is organising the study?

The School of Health and Social Care at Teesside University.

Who has reviewed the study?

Teesside University, School of Health and Social Care Research Governance and Ethics Committee has reviewed this study.

Thank you for reading through this information.

If you have any further questions please contact Naomi Burn: or Dr Kathryn Weston (project supervisor).

Naomi Burn
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School of Health and Social Care
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☎: 01642 384126

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Dr Kathryn Weston (Project Supervisor)
Senior Lecturer in Applied Bioscience for Health
School of Health and Social Care
Teesside University
Middlesbrough, TS1 3BA
☎: 01642 342939
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If you wish to speak with someone who is knowledgeable about the study but not directly involved in it, or if have any complaints or comments you may contact:

Alasdair MacSween Ph.D B.Sc.(Hons) MCSP
Chair of School of Health & Social Care Research Governance and Ethics Committee
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Appendix L Control Group Participant Information Sheet (study four)

Assessment of health and wellbeing of employees

Naomi Burn (PhD Student)

Supervisors: Dr Kathryn Weston, Professor Greg Atkinson, Dr Matthew Weston
PhD students assisting with health and fitness testing: Neil Maguire, Ryan Kenny, Kirsti
Loughran, Phillip Williamson and Lesley Cooper

You are being invited to take part in a research study looking at the health and wellbeing of employees in the Teesside area. Before you decide whether or not you wish to participate, it is important that you understand why the study is being conducted and what it will involve. Please take time to read the following information carefully. Ask us if anything is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

The purpose of this study is to assess various health and wellbeing outcomes in employees from organisations in the Teesside area. The purpose of this study is, in part, fulfilment of the PhD award of Naomi Burn from Teesside University.

Who will be invited to take part?

You and your colleagues are being invited to participate in this study. You are eligible to take part in this study if you are an employee of *insert name of organisation*, aged over 18 years of age. Your organisation has agreed to help recruit and provide facilities for the research project but they will not ever know who did or did not participate in the study. In order to confirm that you do not have any medical conditions that may preclude you from participating in this study, attached to this document is a questionnaire called the Physical Activity Readiness Questionnaire Plus (PARQ+). Please answer the questions on this questionnaire. The questionnaire will tell you if you are cleared for physical activity participation and therefore eligible to participate in this study.

Unfortunately you will not be able to participate if you:

- have any diagnosis or symptoms of cardiovascular or metabolic disease (such as history of heart attack, stroke or diabetes)
- have been advised by a health professional to avoid physical exercise or activity
- are pregnant or might be pregnant
- cannot understand or speak English

What will my participation involve?

If you agree to take part in the study, you will be asked to indicate your consent to participate by a reading and signing a consent form.

You will be invited to have the following health and wellbeing measures taken at two time points, one in April 2018 and one in June 2018 (dates to be confirmed).

The measures will be conducted in a private room in your workplace and include:

- **Wellbeing measures:** quality of life, mental wellbeing, stress and perceived work productivity will be measured using standardised paper based questionnaires.
- **Height and weight:** Will be assessed using standard scales and measuring tape.
- **Waist and hip circumference:** We will measure this by passing a tape measure around your bare stomach.
- **Blood pressure:** Taken using an automatic blood pressure monitor.
- **Blood glucose and cholesterol:** These will be obtained by taking a quick finger prick blood sample from your middle finger. The blood will be collected in a small thin tube and assessed through a simple automatic blood analyser which processes the sample in 5 minutes. Medical gloves will be worn by the researcher at all times and all materials contaminated with blood will be disposed of in a biohazardous waste container/sharps bin. No storage of blood will occur.
- **Aerobic fitness:** The fitness of your heart and lungs during exercise will be assessed using a "Chester Step Test". This involves stepping onto and off a box at a height relevant

to each individuals age and usual physical activity level, at a set pace for a maximum of 10 minutes or until the heart rate reaches $\geq 80\%$ of age-predicted maximum, whichever is first. We will monitor your heart rate throughout using a wrist worn heart rate monitor.

- **Upper body strength:** will be measured using a piece of equipment called a hand dynamometer. You will squeeze the dynamometer as hard as you can in your dominant hand.
- **Lower body strength:** This involves sitting on a piece of equipment called a Nottingham Leg Rig with your foot pressed into a foot pedal. You will push down with your foot onto the pedal as hard as you can and this measures your lower body strength.
- **Physical activity levels:** We will measure your physical activity level over a 7 day period using a device called an accelerometer. The accelerometer is worn at your hip and is the size of a small match box. It is discreet and can be covered with clothing. This device tracks when you are sitting, standing or stepping, but does not track your location or where you travel or move to.
- **Additional measure of aerobic fitness:** if you would like, you can also elect to come to the Exercise Physiology laboratories at Teesside University in order to undertake another test of your aerobic fitness called a VO_{2peak} test, on a stationary bike. This test will let us know more accurately how effectively your body can transport and utilise oxygen to produce energy during exercise and what your maximum heart rate is. This test is progressive, which means that the resistance on the bike will increase until you can't pedal anymore and/or choose to terminate the test. To obtain your maximum oxygen uptake, we need you to wear a lightweight portable metabolic system with a small face mask throughout the test. The face mask will be attached for approximately 5 minutes prior to the start of the test to allow you to get used to it. The mask will cover your nose and mouth and will be kept in place by an elasticised head strap. To obtain your maximum heart rate, we will also require you to wear a wrist worn heart rate monitor.

When will this project run?

The same health and wellbeing measures will be taken at two time points, one in April 2018 and one in June 2018 (dates to be confirmed).

Do I have to take part?

No. Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. Your employment or working conditions will not be impacted by this decision.

What if something goes wrong?

If you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Alasdair MacSween, details below.

Is the study suitably covered for insurance purposes?

Through its School of Health and Social Care, Teesside University has agreed to act as a sponsor for the proposed study and suitable insurance cover is in place.

What if I change my mind about participating in the study?

You are free to withdraw from the study at any point until the completion of the second data collection session. At the first session you will be assigned a participant identification (ID) number. If you wish to withdraw your data from the analysis in the first instance you should contact the project supervisor Dr Kathryn Weston with your participant ID number, contact details below.

Informed consent and confidentiality

Taking part is entirely voluntary, it is up to you to decide if you want to take part or not. If you do decide to take part you will be asked to indicate your consent to participate by a reading and signing a consent form before the first data collection session.

All information which is collected about you during the course of the study, will be kept strictly confidential. Unless through participation in this study any previously unknown medical condition or findings which you would be wise to have investigated becomes known to us, we will inform you and suggest you consult your medical practitioner.

You will not be identified in any publication or report from this research study. All information collected will be stored securely in a locked filing cabinet for the length of the project, and/or stored electronically on password protected computers at Teesside University. Only the PhD student (Naomi Burn) and supervisors named on this document will have access to the data that is collected about you by participating in this study. After the project is completed all the

study materials and information will be stored securely by Teesside University for a minimum of 20 years. The non-identifiable research data will be stored indefinitely on a secure password protected server at Teesside University. This is in case other scientists wish to raise questions about the results that need checking against the dataset. In the event that the study is published in a scientific journal, the non-person identifiable research dataset may be made publicly available (for example, as a supplement to the journal article, or stored on an on-line scientific data repository).

Because the data collection will take place at your workplace during working hours, your choice to participate may not be confidential. Other people in your organisation may know that you have chosen to participate in this study.

What are the possible risks or disadvantages of taking part?

Possible risks or disadvantages are minimal. You can choose to abstain from any of the health and wellbeing measurements if you choose.

The "Chester Step Test" that will be used in order to test your aerobic fitness involves performing relatively vigorous intensity exercise. There are certain risks to participating in vigorous intensity exercise such as discomfort or injury. However this type of fitness tests is regularly used in a range of populations. You can terminate the exercise at any point if you feel uncomfortable.

Contamination from the blood measures will be prevented by using one-piece single used lancets and gloves will be worn by the trained researcher at all times. Additionally, all materials contaminated with blood will be disposed of in a biohazardous waste container/sharps bin.

Will I be informed of the results of the research study?

If you would like we will be able to provide individualised feedback on your results after the completion of the study. Upon your request we will be happy to provide you with a summary of the research findings, when analysis is complete.

What will happen to the results of the study?

The full results of this study will inform the written thesis of a Graduate Research student (Naomi Burn) as part of the requirements of a PhD award from Teesside University. The results may also be included in academic journal articles or conference proceedings. You will not be identifiable in any form of publication from this research study.

Who is organising the study?

The School of Health and Social Care at Teesside University.

Who has reviewed the study?

Teesside University, School of Health and Social Care Research Governance and Ethics Committee has reviewed this study.

Thank you for reading through this information.

If you have any further questions please contact Naomi Burn or Dr Kathryn Weston (project supervisor).

Naomi Burn

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Dr Kathryn Weston (Project Supervisor)

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If you wish to speak with someone who is knowledgeable about the study but not directly involved in it, or if have any complaints or comments you may contact:

Alasdair MacSween Ph.D B.Sc.(Hons) MCSP

Chair of School of Health & Social Care Research Governance and Ethics Committee

School of Health & Social Care

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Appendix M

SF-36 Medical Outcomes 36-Item Short Form Health Survey 1.0

Choose one option for each questionnaire item.

1. In general, would you say your health is:

- 1 - Excellent
- 2 - Very good
- 3 - Good
- 4 - Fair
- 5 - Poor

2. **Compared to one year ago**, how would you rate your health in general **now**?

- 1 - Much better now than one year ago
- 2 - Somewhat better now than one year ago
- 3 - About the same
- 4 - Somewhat worse now than one year ago
- 5 - Much worse now than one year ago

The following items are about activities you might do during a typical day. Does **your health now limit you** in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
3. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
4. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
5. Lifting or carrying groceries	1	2	3
6. Climbing several flights of stairs	1	2	3
7. Climbing one flight of stairs	1	2	3
8. Bending, kneeling or stooping	1	2	3
9. Walking more than a mile	1	2	3
10. Walking several blocks	1	2	3
11. Walking one block	1	2	3
12. Bathing or dressing yourself	1	2	3

During the **past two weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of your physical health**?

13. Cut down the amount of time you spent on work or other activities	<input type="checkbox"/> Yes	<input type="checkbox"/> No
14. Accomplished less than you would like	<input type="checkbox"/> Yes	<input type="checkbox"/> No
15. Were limited in the kind of work or other activities	<input type="checkbox"/> Yes	<input type="checkbox"/> No
16. Had difficulty performing the work or other activities (for example, it took extra effort)	<input type="checkbox"/> Yes	<input type="checkbox"/> No

During the **past two weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of any emotional problems** (such as feeling depressed or anxious)?

17. Cut down the amount of time you spent on work or other activities	<input type="checkbox"/> Yes	<input type="checkbox"/> No
18. Accomplished less than you would like	<input type="checkbox"/> Yes	<input type="checkbox"/> No
19. Didn't do work or other activities as carefully as usual	<input type="checkbox"/> Yes	<input type="checkbox"/> No

20. During the **past two weeks**, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups?

- 1 - Not at all
- 2 - Slightly
- 3 - Moderately
- 4 - Quite a bit
- 5 – Extremely

21. How much **bodily** pain have you had during the **past two weeks**?

- 1 - None
- 2 - Very mild
- 3 - Mild
- 4 - Moderate
- 5 - Severe
- 6- Very severe

22. During the **past two weeks**, how much did **pain** interfere with your normal work (including both work outside the home and housework)?

- 1 - Not at all
- 2 - A little bit
- 3 - Moderately
- 4 - Quite a bit
- 5 – Extremely

These questions are about how you feel and how things have been with you **during the past two weeks**. For each question, please give the one answer that comes closest to the way you have been feeling.

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
23. Did you feel full of pep?	1	2	3	4	5	6
24. Have you been a very nervous person?	1	2	3	4	5	6
25. Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
26. Have you felt calm and peaceful?	1	2	3	4	5	6
27. Did you have a lot of energy?	1	2	3	4	5	6
28. Have you felt downhearted and blue?	1	2	3	4	5	6
29. Did you feel worn out?	1	2	3	4	5	6
30. Have you been a happy person?	1	2	3	4	5	6
31. Did you feel tired?	1	2	3	4	5	6

32. During the **past two weeks**, how much of the time has **your physical health or emotional problems** interfered with your social activities (like visiting with friends, relatives, etc.)?

1. 1 - All of the time
2. 2 - Most of the time
3. 3 - Some of the time
4. 4 - A little of the time
5. 5 - None of the time

How TRUE or FALSE is **each** of the following statements for you.

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false
33. I seem to get sick a little easier than other people	1	2	3	4	5
34. I am as healthy as anybody I know	1	2	3	4	5
35. I expect my health to get worse	1	2	3	4	5
36. My health is excellent	1	2	3	4	5

Appendix N

Warwick Edinburgh Mental Wellbeing Scale

Below are some statements about feelings and thoughts. Choose one option for each questionnaire item.

Please circle the box that best describes your experience of each, over the last 2 weeks	None of the time	Rarely	Some of the time	Often	All of the time
• I've been feeling optimistic about the future	1	2	3	4	5
• I've been feeling useful	1	2	3	4	5
• I've been feeling relaxed	1	2	3	4	5
• I've been feeling interested in other people	1	2	3	4	5
• I've had energy to spare	1	2	3	4	5
• I've been dealing with problems well	1	2	3	4	5
• I've been thinking clearly	1	2	3	4	5
• I've been feeling good about myself	1	2	3	4	5
• I've been feeling close to other people	1	2	3	4	5
• I've been feeling confident	1	2	3	4	5
• I've been able to make up my own mind about things	1	2	3	4	5
• I've been feeling loved	1	2	3	4	5
• I've been interested in new things	1	2	3	4	5
• I've been feeling cheerful	1	2	3	4	5

Appendix O

Perceived Stress Scale

The questions in this scale ask you about your feelings and thoughts **during the last two weeks**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.

	Never	Almost Never	Sometimes	Fairly Often	Very Often
1. In the last two weeks, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last two weeks, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last two weeks, how often have you felt nervous and "stressed"?	0	1	2	3	4
4. In the last two weeks, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
5. In the last two weeks, how often have you felt that things were going your way?	0	1	2	3	4
6. In the last two weeks, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
7. In the last two weeks, how often have you been able to control irritations in your life?	0	1	2	3	4
8. In the last two weeks, how often have you felt that you were on top of things?	0	1	2	3	4
9. In the last two weeks, how often have you been angered because of things that were outside of your control?	0	1	2	3	4
10. In the last two weeks, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4