UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Concurrent Exercise Training for Physical and Mental Health in the Academic Workplace

by Samuel Higham

Thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

Under the supervision of
Professor Rob Duffield
Dr Amy Mendham
Dr Simon Rosenbaum

University of Technology Sydney
Faculty of Health

October 2021

Certificate of Original Authorship

I, Sam Higham declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Sport, Exercise and Rehabilitation, Faculty of Health, at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

Production Note:
Signature removed
prior to publication.

_____

Samuel Higham

Date: 17th of October 2021

Acknowledgements

Firstly, a massive thanks to Professor Rob Duffield. You've been my go-to supervisor since Honours and have been an amazing support throughout the PhD. Thanks for the numerous invaluable, life-long lessons you've taught me.

To Dr. Amy Mendham, after doing this research I didn't think it was possible for an academic to provide so much time and put in so much effort for a student! You've answered all my curve ball questions and have contributed in a major way to a Thesis that I can be proud of.

To Dr. Simon Rosenbaum, thanks for being the gentle hand that reaches over and adjusts the steering wheel before the car veers off the road… Your guidance and expertise have been invaluable.

To Dr. Nick Allen, you've been a legendary friend and source of knowledge throughout this PhD. The study would not have run as smoothly as it did, without you.

Special thanks to the entire crew that helped with the testing and training sessions, you were the pillars of this thesis.

Big thanks to all the academic participants that made this Thesis possible, the EAP crew at UTS who were extremely helpful, understanding and patient, Dr. Greg Smith for coming to the rescue, the other PhD students cooped up in the HDR workspace who were a continuous source of motivation, and of course the UTS Sport and Exercise Science group that were an endless source of wisdom and discussion ☺ .

Lastly, to my family and Caz, you guys have made this thing “easy”. I’ve been extremely fortunate and privileged to have you as my base. Caz, we made it!

Preface

This thesis for the degree of Doctor of Philosophy is in the format of Thesis by compilation and abides by the 'Procedures for Presentation and Submission of Theses for Higher Degrees – University of Technology Sydney; Policies and Directions of the University'.

From the research design and data collection by the candidate, three research study chapters have been developed. An introduction chapter provides background information, research problem, as well as the purpose and significance of the three studies. A literature review chapter provides an overview of the cardiometabolic and mental health risk factors that may be present in the academic workplace, and how concurrent exercise training could be used to counter these risks. The research study chapters are then presented in a logical sequence following the development of research ideas within this thesis. Each chapter has a similar outline of introduction, methods, results, discussion, and conclusion. Findings from all studies are combined into a discussion chapter, where collective results are discussed in reference to related literature. This thesis finishes with an overall conclusion, practical applications, and directions for future research.

Table of Contents

List of Figures

List of Tables

Abbreviations

BMI	Body mass index
BP	Blood pressure
bpm	Beats per minute
C:HDL	Total Cholesterol to HDL-C ratio
CI	Confidence Interval
cm	Centimetre
CO_2	Carbon dioxide
CONSORT	Consolidated Standards of Reporting Trials
CRP	C-reactive protein
CT	Concurrent training
CVD	Cardiovascular disease
DASS-21	Depression, anxiety and stress scales
DBP	Diastolic blood pressure
DEXA	Dual Energy X-ray Absorptiometry
EDTA	Ethylenediaminetetraacetic acid
EMA	Ecological momentary assessment
ERI	Effort reward imbalance
GLTEQ	Godin Leisure-Time Exercise Questionnaire
GXT	Graded exercise test
h	Hour
HASS	Humanities, Arts, and Social Sciences
HDL-C	High density lipoprotein cholesterol
HOMA-IR	Homeostatic model assessment for insulin resistance
HR	Heart rate
HREC	Human research ethics committee
IL-6	Interleukin-6
IQR	Interquartile range
K10	Kessler scale
kg	Kilogram
L	Litre
LDL-C	Low density lipoprotein cholesterol
MET	Metabolic equivalent

MetS	Metabolic Syndrome
min	Minute
mL	Millilitre
mmHg	Millimetre of mercury
mmol	Millimoles
MVPA	Moderate to vigorous physical activity
n	Number
NHANES	National health and nutrition examination survey
O_2	Oxygen
OR	Odds ratio
PPO	Peak power output
REDCap	Research Electronic Data Capture
RHR	Resting heart rate
RR	Risk ratio
RR	Relative risk
SBP	Systolic blood pressure
SD	Standard deviation
SMD	Standardised mean difference
SPSS	Statistical Package for the Social Sciences
SST	Serum separator tube
STEM	Science, Technology, Engineering, and Mathematics
TNF-α	Tumor necrosis factor-alpha
VAT	Visceral adipose tissue
VO_{2max}	Maximal oxygen consumption
VO_{2peak}	Peak oxygen consumption
W	Watts
WC	Waist circumference
WMD	Weighted mean difference
y	Years
µU	Micro unit

Abstract

Competing work responsibilities and high workload experienced in the academic workplace likely contribute to the higher stress and longer work hours reported in academics compared to other employees. High stress and long work hours are associated with lower levels of physical activity, which is a risk factor for mental and cardiometabolic disorders. Low amounts of physical activity are reported in the academic workplace, though few studies report concurrent assessments of mental and cardiometabolic health in inactive academics. Limited research also exists on interventions designed to increase physical activity in academics with the aim of improving cardiometabolic and mental health outcomes. Concurrent exercise training (CT) combines endurance and resistance exercise and has been shown to improve cardiometabolic and mental health; however, minimal workplace-based CT interventions have been reported in inactive academics (150 min/week of weighted physical activity).

This thesis firstly aimed to describe the cardiometabolic and mental health of inactive full-time academics within an Australian University and compare cardiometabolic and mental health risk factors by sex and academic level (study 1). Secondly, this thesis aimed to determine the effect of a 14-week CT program on components of the metabolic syndrome (MetS), insulin resistance, body composition, aerobic capacity and markers of systemic inflammation in inactive full-time academics from an Australian University (study 2). Thirdly, this thesis aimed to evaluate the effect of 14-weeks of CT on symptoms of depression, stress and anxiety in inactive full-time academics within an Australian University (study 3). Lastly, this thesis aimed to investigate the relationships between metabolic risk factors (e.g. fat mass, insulin resistance and systemic inflammation), stress and symptoms of depression (study 1, 2 and 3).

Study 1 was a cross-sectional study to describe the cardiometabolic and mental health of inactive academics (n=59), in relation to sex and level of appointment. Results showed that 20% of inactive academics had MetS and nearly half (48%) were overweight or obese. Twenty-two percent experienced moderate to severe symptoms of anxiety, stress and/or depression. Lower ranking academics (Associate Lecturers and Lecturers) experienced significantly greater feelings of distress, depression and stress compared to their more senior colleagues. No difference in mental health measures were evident between males and females. Higher job stress was associated with higher depressive symptoms and higher anxiety was associated with lower aerobic capacity. In addition, a relationship between mental and cardiometabolic health was evident, whereby higher distress and depressive symptoms were associated with an increased likelihood of MetS.

Study 2 involved a randomised controlled trial comparing the effect of 14-weeks of CT to normal behaviour (control group) on the cardiometabolic health of inactive academics (n=59). Measures of MetS, body composition, insulin resistance, aerobic capacity and markers of systemic inflammation including interleukin-6 (IL-6) and tumor necrosis factor (TNF-α) were measured before and after training. Results showed significant decreases in fat mass (%) and central adiposity, and increases in lean mass and aerobic capacity in CT compared to control. There were no changes to IL-6, TNF-α, insulin resistance or lipid profile in CT or control groups. Of note, changes in insulin resistance were positively associated with IL-6 in the control group only.

Using the same 14-week randomised controlled trial as study 2, study 3 aimed to determine the effect of CT on mental health in inactive academics (n=59). Symptoms of depression, anxiety, and stress (job specific and general), effort-reward imbalance, and systemic inflammation (IL-

6 and TNF-α) were measured pre- and post-intervention. Further, measures of wellness (sleep duration, sleep quality, stress, fatigue, mood and workload) were self-reported daily, before and during the last 2-weeks of the intervention. Results showed a significant decrease in symptoms of depression after CT. However, there were no changes observed in effort-reward imbalance or symptoms of anxiety, stress (general or job-specific) or daily wellness measures. No relationships were evident between changes in stress and changes in systemic inflammation or symptoms of depression.

This thesis reports evidence of poor mental and cardiometabolic health in academics with low levels of physical activity. In turn, a 14-week concurrent exercise program was implemented within the academic workplace, with subsequent improvements in cardiometabolic and mental health. In particular, CT resulted in improvements to body composition, aerobic capacity, and symptoms of depression in the inactive academic workplace. The findings relay the benefits of CT for non-clinical populations at higher risk of mental and physical health disorders. The results may have important implications for both inactive academics and the broader university sector.

Chapter 1

Introduction

Introduction

The academic workplace is a predominantly desk-based workplace wherein over 66% of academics report low to moderate levels of physical activity (≤150 min of weighted physical activity per week), which compares to 85% of Australian adults reporting <150 min of weighted physical activity per week (Australian Bureau of Statistics. 2018). Low levels of physical activity have been previously associated with high levels of stress and long workhours (Cooper & Barton 2016; Kirk & Rhodes 2011; Prince et al. 2019), which may at least partly explain the low physical activity reported by academics. Indeed, competing teaching, administrative and research demands may underlie the higher job stress and psychological strain experienced by academics compared to other professions (Fontinha, Easton & Van Laar 2019; Kinman 2016; Siegrist 1996; Winefield et al. 2003). Long work hours may limit the leisure time available for physical activity (Kirk & Rhodes 2011), and high stress has been associated with reduced levels of physical activity (Stults-Kolehmainen & Sinha 2014). Consequently, these characteristics of the academic workplace may represent challenges to engaging in regular physical activity, predisposing academics to risk-factors associated with chronic disease development.

Low engagement in physical activity is common in many desk-based workplaces (Prince et al. 2019), and may increase the risk of both cardiometabolic and mental health disorders, including type 2 diabetes (Smith et al. 2016a), cardiovascular disease (CVD) and depression (Kraus et al. 2019; Schuch et al. 2018). For example, meta-analyses of prospective cohort studies have reported a 26% decrease in the risk of developing type 2 diabetes (Smith et al. 2016a), and a 17% lower odds of incident depression in individuals with higher levels of physical activity compared to inactive individuals (Schuch et al. 2018). Furthermore, low levels of physical activity can increase risk factors associated with cardiometabolic and mental health, such as

systemic inflammation (Hamer et al. 2012), fat mass and insulin resistance (Leskinen et al. 2009; Shibata et al. 2016; Tsenkova 2017), whilst decreasing protective factors such as aerobic capacity and lean mass (Aspenes et al. 2011; Fukumoto et al. 2018; Shephard et al. 2013). In turn, increasing moderate to vigorous physical activity (MVPA) in inactive workplaces is important for industries, including academia, aiming to protect employees from developing type 2 diabetes or depression (Schuch et al. 2018; Smith et al. 2016b).

Despite the low physical activity engagement reported within the academic workplace (Safi et al. 2021), there is limited research describing the cardiometabolic health of academics. A cross-sectional study of 2428 employees from a university in China reported that 5% of academics had MetS (Cheserek et al. 2014). Furthermore, Alkhatib (2015) reported average body mass index (BMI) of 26±4 kg/m^2, peak oxygen consumption (VO_{2peak}) of 32.7 $mL \cdot kg^{-1} \cdot min^{-1}$, systolic blood pressure (SBP) of 120 mmHg and diastolic blood pressure (DBP) of 75 mmHg in a small descriptive study of 23 UK academics (Alkhatib 2015). Although these data show many cardiometabolic health variables to be within normal ranges, they are limited to a small population of academics and are missing further primary measures of cardiometabolic disease risk; including fat mass, lean mass and systemic inflammation, and clinical endpoints related to MetS.

Stress, long work hours and low levels of physical activity are positively associated with symptoms of depression (Dishman, McDowell & Herring 2021; Lee. 2020; Virtanen et al. 2018). In contrast to the limited cardiometabolic health data available for academics, reports on the mental health of academics are more abundant. Previous research has reported that university staff experience greater symptoms of stress, anxiety and depression compared to the general population (Mark & Smith 2012), and academics experience higher job stress and

psychological strain compared to other university staff (e.g. administrative and technical staff) (Fontinha, Easton & Van Laar 2019; Winefield et al. 2003). Higher job stress may be due to an effort reward imbalance (ERI), wherein workers experience more effort outputs (e.g. job demands) than reward inputs (e.g. promotion prospects, respect from colleagues), which has been associated with a 1.5 fold increased risk of developing depression (Rugulies, Aust & Madsen 2017). In addition, Pan et al. (2012) reported a bilateral relationship between depression and MetS (Pan et al. 2012), suggesting that the higher psychological strain in academics may be associated with poor cardiometabolic health outcomes. Given the interrelated nature of mental and cardiometabolic health markers, physical activity interventions can decrease the risk of both depression and MetS (Schuch et al. 2018; Zhang et al. 2017), and should be assessed within the inactive academic workplace.

Exercise is an organised and structured form of physical activity (Caspersen, Powell & Christenson 1985), and resistance and endurance training are divergent exercise modes that can improve risk factors of mental and cardiometabolic health (Gordon et al. 2018; Grgic et al. 2019; Schuch, Vancampfort, Richards, et al. 2016; Schwingshackl et al. 2013). Whilst resistance training primarily results in increased muscle hypertrophy and strength (Grgic et al. 2019), endurance training increases aerobic capacity and decreases fat mass (Coffey & Hawley 2016; Schwingshackl et al. 2013). Both training modes improve symptoms of anxiety and depression in adults (Gordon et al. 2018; Gordon et al. 2017; Schuch, Vancampfort, Richards, et al. 2016; Stubbs, Vancampfort, et al. 2017); however, combined endurance and resistance training is associated with the lowest prevalence of symptoms of depression compared to either exercise mode alone (Bennie et al. 2019). Concurrent exercise training (CT) is defined as a combination of both endurance and resistance exercise and results in improvements to fat mass, lean mass and aerobic capacity, indicating adaptations to respective endurance and resistance

modes of training (Willis et al. 2012). Indeed, participating in regular CT is associated with a 25% lower risk of developing MetS when compared to inactive individuals (Bakker et al. 2017). CT may have a synergistic effect on mental and cardiometabolic health compared to endurance or resistance exercise alone (Bennie et al. 2020; Coffey & Hawley 2016), though to our knowledge, no studies have investigated the impact of CT in inactive academics.

CT has previously resulted in improvements to body composition and aerobic capacity in inactive desk-based workers. Hunter et al. (2020) reported an increase in lean mass (1.2±1.2kg) and VO_{2peak} (10±11%), and a decrease in fat mass (-2.2±2.2%) following 16 weeks of supervised CT in 78 university employees, though participants were not required to be inactive at baseline and academics were pooled with other staff, obfuscating the effects of CT on academics. Whilst CT studies in the general population have consistently reported increased lean mass and reduced fat mass (Schroeder et al. 2019; Stewart et al. 2005), there have been mixed effects for measures of systemic inflammation and insulin resistance (Brunelli et al. 2015; Donges et al. 2013). This is interesting given cross-sectional research reveals significant associations between body composition, insulin resistance and systemic inflammation (Kunz et al. 2021), indicating the need for further research into the associations between these risk factors of cardiometabolic diseases. Notwithstanding, academics may be at risk of increased fat mass (Leskinen et al. 2009), systemic inflammation (Hamer et al. 2012), and insulin resistance (Tsenkova 2017), and decreased aerobic capacity and lean mass due to low participation in physical activity (Aspenes et al. 2011; Shephard et al. 2013). Given that long work hours may limit participation in physical activity outside of work (Kirk & Rhodes 2011), an onsite CT program may enhance exercise adherence and improve these cardiometabolic risk factors in this population (Jakobsen et al. 2015).

Although research within academics is limited, CT within other inactive workers has resulted in decreases in symptoms of depression and stress (Atlantis et al. 2004; Greco 2020), with mixed results for changes in anxiety (Atlantis et al. 2004; Genin et al. 2018). Preliminary research has also reported positive associations between stress, depression, and systemic inflammation (Lee. 2020; Piantella et al. 2021), suggesting a relationship between physical and mental health. CT has mixed effects on systemic inflammation (Donges et al. 2013; Ihalainen et al. 2018), but can decrease stress and symptoms of depression in workers (Atlantis et al. 2004), and further research is required into the association between changes in stress and changes in systemic inflammation and symptoms of depression. Such research is pertinent in academics experiencing high psychological strain and job stress, alongside low amounts of physical activity (Fontinha, Easton & Van Laar 2019; Safi et al. 2021; Winefield et al. 2003). However, to our knowledge, no research has assessed the effect of CT on the mental and cardiometabolic health of inactive academics.

Thesis aims

The high stress and low levels of physical activity involved in the academic workplace may increase the risk of cardiometabolic and mental health disorders. CT has been reported to improve risk factors for cardiometabolic and mental health disorders in other inactive workplaces. In turn, this thesis aims to:

1. Describe the cardiometabolic and mental health of inactive full-time academics within an Australian University and compare cardiometabolic and mental health risk factors by sex and academic level (study 1).
2. Determine the effect of a 14-week CT program on components of MetS, insulin resistance, body composition, aerobic capacity and markers of systemic inflammation in inactive full-time academics from an Australian University (study 2).

3. Evaluate the effect of 14-weeks of CT on symptoms of depression, stress and anxiety in inactive full-time academics within an Australian University (study 3).
4. Investigate the relationships between metabolic risk factors (e.g. fat mass, insulin resistance and systemic inflammation), stress and symptoms of depression (study 1, 2 and 3).

Limitations

- The current cohort were inactive, apparently healthy academics from a single Australian University, with access to supervised training at an onsite facility. In turn, caution must be taken when extrapolating results to the wider academic community, other desk-based workplaces, and populations with pre-existing cardiometabolic or mental disorders.
- Participants were asked to adhere to their normal lifestyle behaviours outside of the study. However, this could only be verified via self-reported methods.
- Due to the nature of the study, participants and training instructors were not blinded to group allocation, which may result in a risk of performance bias during the data collection phase.
- Though the sample size was large enough to detect moderate effect sizes, it was not large enough to detect the small effect sizes previously reported for tumor necrosis factor-α (TNF-α), which was the smallest effect size of interest. Resource constraints and a finite recruitment period meant that recruitment was stopped prior to meeting the full sample size required to detect small effect sizes.
- There are different diagnostic criteria for MetS and this made it difficult to compare study results.

- The various types of stress (e.g. physical, general, job specific, acute, chronic) and numerous techniques (e.g. questionnaires and saliva samples) used to measure stress make it challenging to compare results between studies.
- The voluntary nature of the study may have introduced a self-selection bias.
- The per-protocol analysis may have introduced a bias given participants with higher baseline depression scores may be less likely to adhere to exercise.

Delimitations

- Only participants without known metabolic disease or treatment for depression, diabetes, cardiovascular disease or inflammation were recruited because there were inadequate resources to conduct the study with the large sample size required to enable statistical adjustments of these confounders.
- The CT program was designed to be adaptable, easily implementable, low cost and engaging. In turn, we did not include objective intensity measures for endurance exercise (e.g. 70% predicted HR_{max}). However, participants were encouraged to progressively increase endurance training intensity (distance and power) and external load was monitored via training diaries to provide anchors for progressive overload.
- Due to the significant costs involved in analysis of circulating cytokines, we delimited the study to IL-6 and TNF-α given their association with primary outcomes.
- Daily wellness measures were measured once per day to minimise participant burden.
- Physical activity and exercise were the primary foci of the current thesis. Sedentary behaviour has been previously associated with cardiometabolic and mental health risk factors, independent of MVPA (Knaeps et al. 2018; Zhai, Zhang & Zhang 2015), and consequently was outside the scope of this thesis.

Chapter 2

Literature Review

Overview

The academic workplace is a desk-based environment involving high stress and low levels of physical activity (Cooper & Barton 2016; Fontinha, Easton & Van Laar 2019). Chronic stress and low levels of physical activity are positively associated with both cardiometabolic and mental health risk factors, including fat mass (Bradbury et al. 2017; Geiker et al. 2018), insulin resistance (Tsenkova 2017), systemic inflammation and symptoms of depression, stress and anxiety (Lee. 2020; Nicklas et al. 2016; Schuch et al. 2018). Consequently, academics participating in low amounts of physical activity may be at heightened risk of developing cardiometabolic and mental health disorders, such as depression and type 2 diabetes. Exercise training can improve the respective risk factors for cardiometabolic and mental health and reduce the risk of associated disorders (Bakker et al. 2017; Bennie et al. 2020). Whilst both aerobic and resistance exercise have respective mode-specific responses, combining both modes within a session, termed concurrent training (CT) provides complimentary benefits in untrained populations (Coffey & Hawley 2016). However, the effects of CT on the mental and cardiometabolic health of academics with low levels of physical activity have not been investigated. Accordingly, the following literature review is composed of research regarding 3 primary topics:

1. The mental and cardiometabolic health risk factors in desk-based workers, particularly academics.
2. The interrelationships between cardiometabolic and mental health risk factors.
3. The effect of CT on the mental and cardiometabolic health of workers with low levels of physical activity, highlighting the lack of such research in academics.

Literature Search Methods

Articles in this literature review were primarily sourced from Google Scholar and PubMed using key search terms related to “academics”, “workplace”, “metabolic syndrome”, “insulin resistance”, “body composition”, “systemic inflammation”, “depression”, “anxiety”, “stress”, “effort reward imbalance”, “physical activity” and “concurrent resistance and endurance exercise training”. Abstracts were screened for relevance and highly relevant studies were included. A secondary search was conducted through the reference lists of the included publications, and articles that cited the included research (via Google Scholar). Furthermore, related review papers were screened for additional studies. Articles were then included in a narrative review format.

Physical Activity and the Desk-based Workplace

Over 50% of Australian full-time workers undertake their work duties within a mostly seated, desk-based environment (Sugiyama et al. 2020). The desk-based workplace involves lower levels of physical activity compared to other workplaces (Prince et al. 2019). For example, a meta-analysis of objectively measured physical activity in different occupations reported that desk-based workers had a lower daily step count and spent significantly less time in light physical activity and MVPA compared to other employees in the workplace (Prince et al. 2019). Low levels of physical activity are associated with cardiometabolic disease and mental health disorders, whereby highly active individuals have a reduced risk of developing MetS (Hazard ratio=0.87, 95% CI=0.84, 0.91) and type 2 diabetes (Hazard ratio=0.84, 95% CI=0.78, 0.90) compared to individuals with low levels of physical activity (Martinez-Gomez et al. 2020). Furthermore, increased physical activity is associated with a 22% lower odds of incident depression or an incident increase in subclinical symptoms of depression (Dishman, McDowell & Herring 2021). Consequently, increasing the physical activity of desk-based workers to meet

the World Health Organisation recommendations (>150 min of weighted physical activity and ≥2 d of muscle strengthening activities per week) is a priority for both public health and corporate initiatives to assist in protecting workers from the development of cardiometabolic diseases and mental health disorders (Bull et al. 2020).

The academic workplace is primarily desk-based and research has reported no MVPA whilst at work (Safi et al. 2021). Less than 1 in 3 academics engage in high amounts of physical activity (≥1500-3000 metabolic equivalent; MET minutes/week) throughout the week. These activities include work-based and leisure-time behaviours, which commonly comprise of light physical activity and MVPA, respectively (Cooper & Barton 2016; Prince et al. 2019). Self-reported data indicated that over 70% of Australian academics worked hours in surplus of their contract, and the mean excess hours worked was 18 ±15 h over a 14-day period (Fetherston et al. 2020). There is a negative association between work hours and leisure time physical activity when working over 45-50 h per week and the excess overtime reported by academics may represent a significant barrier to increasing physical activity (Kirk & Rhodes 2011). Whilst workers from other desk-based professions engage in more physical activity in their leisure-time compared to non-desk-based workers (Kirk & Rhodes 2011; Prince et al. 2019), the long-work hours experienced by academics may contribute to lower levels of MVPA (ie. reduced leisure time physical activity). This suggests that interventions aiming to increase MVPA in this population need to be easily accessible and may need to be incorporated into the workplace.

Low levels of physical activity are positively associated with cardiometabolic and mental health risk factors including obesity (Bradbury et al. 2017), insulin resistance (Tsenkova 2017), chronic systemic inflammation (Nicklas et al. 2016), stress (Burg et al. 2017; Gerber et al. 2014) and symptoms of depression (Dishman, McDowell & Herring 2021); whilst being

negatively associated with protective factors such as lean mass and aerobic capacity (Aspenes et al. 2011; Fukumoto et al. 2018; Shephard et al. 2013). In turn, these risk factors may be highly prevalent in academics with low levels of physical activity, increasing their risk of developing chronic diseases such as type 2 diabetes and depression (Schuch, Vancampfort, Sui, et al. 2016; Wang et al. 2013). However, these risks are speculative due to the lack of descriptive evidence available on academic populations.

Metabolic Syndrome in the Inactive Academic Workplace

MetS involves a cluster of cardiometabolic risk markers that are also associated with mental health disorders (Marott et al. 2016). A commonly used definition identifies MetS when at least 3 of the following 5 conditions are met: 1) waist circumference (WC) ≥94 cm for males or ≥80 cm for females; 2) triglycerides; ≥1.7 mmol/L; 3) high density lipoprotein cholesterol (HDL-C) <1.0 mmol/L in males or <1.3 mmol/L in females; 4) systolic blood pressure (SBP) ≥130 mmHg and/or diastolic blood pressure (DBP) ≥85 mmHg; or 5) elevated fasting glucose (≥5.6 mmol/L) (Alberti et al. 2009). In turn, MetS can increase the risk of developing depression and type 2 diabetes (Ford, Li & Sattar 2008; Moazzami et al. 2019). A meta-analysis of cohort studies reported a dose-response relationship between physical activity and MetS, wherein each 10 MET h/week increase in leisure-time physical activity is associated with an 8% decreased risk of MetS (RR=0.92, 95%CI=0.89,0.96) (Zhang et al. 2017). Physical activity intensity appears to be particularly important with prospective research (n=10,145) showing a significantly decreased likelihood of developing MetS in individuals participating in more vigorous intensity physical activity compared to those performing light intensity physical activity (OR=0.63, 95%CI=0.4, 0.89) (Hidalgo-Santamaria et al. 2017). Longitudinal and cross-sectional studies have found that this association remains after adjustment for physical activity volume, indicating an independent effect of physical activity intensity on risk of MetS

(Janssen & Ross 2012; Laursen et al. 2012). Evidently, increasing physical activity, particularly MVPA in desk-based workers may reduce the risk of MetS, which has been associated with the development mental health disorders and cardiometabolic diseases.

Improving and preventing MetS is important given its positive association with depression (Moradi et al. 2021), CVD and type 2 diabetes (Ford, Li & Sattar 2008; Mottillo et al. 2010). A prospective study of 95,756 adults with mean follow-up time of 6 y reported that participants with all 5 metabolic syndrome components at baseline had 79 times the risk of developing type 2 diabetes compared to those with no components (Hazard ratio=79, 95%CI= 50,127). Each component of MetS was associated with type 2 diabetes, wherein an increased risk of type 2 diabetes was observed with every 1 unit increase in WC (OR=1.05, 95%CI=1.04,1.05), triglycerides (OR=1.12, 95%CI=1.10,1.15), SBP (OR=1.01, 95%CI=1.01,1.01), DBP (OR=1.01, 95%CI=1.00,1.01) and glucose (OR=1.32, 95%CI=1.30,1.34), or decrease in HDL-C (OR=2.23, 95%CI=1.98,2.51) (Marott et al. 2016). Despite the multiple criteria available to define MetS (Kassi et al. 2011), all definitions have been associated with increased incidence of type 2 diabetes (Ford, Li & Sattar 2008). In regard to mental health, meta-analysis of cross-sectional studies has reported a positive association between MetS and depression (OR=1.42, 95%CI=1.28,1.57), and meta-analysis of cohort studies reported that individuals with MetS have a 49% increased likelihood of developing depression (OR=1.49, 95%CI=1.19,1.89) (Pan et al. 2012). Thus, it is important to prevent or reduce MetS in workers to decrease the risk of developing both cardiometabolic and mental health disorders.

Prevalence of MetS in the general Australian adult population ranges between 21.7% (95%CI=19.0,24.3) and 30.7% (95%CI=27.1,34.3) depending on the definition used (Cameron et al. 2007). Though limited data are available for desk-based workers, Engelen et al. (2017)

reported that Australian adults engaging in low physical activity and high amounts of sitting, akin to desk-based workers, are at increased risk of MetS (OR=2.37, 95%CI=1.63,3.45) (Engelen et al. 2017). Cross-sectional research with employees from a desk-based workplace in Spain reported a MetS prevalence of 12.8% (95%CI=12.4,13.1) in males (n=48,094) and 4.7% (95%CI=4.4,5.0) in females when using the Adult Treatment Panel II definition of MetS (Sanchez-Chaparro et al. 2008). Interestingly, prospective research from the Netherlands (n=34,834) reported that incidence of MetS in desk-based workers after a 3.85 y follow-up period was between 7.9% (high skilled white-collar workers) and 8.8% (low skilled white-collar workers), and low participation in leisure-time physical activity was associated with greater risk of MetS (Runge et al. 2021). These findings emphasise the importance of increasing the leisure-time physical activity of desk-based workers. The high work hours experienced by academics may limit the leisure time available for physical activity (Fetherston et al. 2020; Kirk & Rhodes 2011), and thus academics may be at increased risk of MetS. However, limited research has investigated the prevalence of MetS in academics. A cross-sectional study from a Chinese university (n=2,273) reported that 5% of academics had MetS (Cheserek et al. 2014). To our knowledge, no studies have assessed cardiometabolic risk factors including the components of MetS in Australian academics, particularly those participating in low amounts of physical activity.

Aerobic Capacity in the Inactive Academic Workplace

Aerobic capacity is an important indicator of cardiovascular and cardiorespiratory health (Myers et al. 2015), and is relevant in desk-based workers because it is positively associated with physical activity (Baumann et al. 2020; Mundwiler et al. 2017; Zeiher et al. 2020). Munwiler et al. (2017) reported that workers participating in ≥30 min MVPA per day on both workdays and non-workdays had significantly higher estimated maximal oxygen consumption

(VO_{2max}; 42 $mL \cdot kg^{-1} \cdot min^{-1}$) compared to those completing <30 min MVPA per day on workdays and non-workdays (30 $mL \cdot kg^{-1} \cdot min^{-1}$). In addition, MVPA on workdays was positively associated with estimated VO_{2max} (β=0.10, P=0.013) (Mundwiler et al. 2017). Findings from the National Health and Nutrition Examination Survey (NHANES) reported that individuals in the highest quintiles of physical activity (>1261 MET/min/week) had higher estimated VO_{2max} compared to those engaging in <1260 MET/min/week (P=0.01) (Ceaser et al. 2013). Physical activity intensity appears to be particularly important for increasing aerobic capacity (Mundwiler et al. 2017; Swain & Franklin 2002; Swain & Franklin 2006). The majority of clinical trials report greater improvements in aerobic capacity in groups participating in higher intensity aerobic exercise (Swain & Franklin 2006), and cross-sectional research reveals a positive association between vigorous leisure-time physical activity and estimated VO_{2max} (β=0.155, P<0.001) (Mundwiler et al. 2017). Evidently, both volume and intensity of physical activity have a significant impact on aerobic capacity, which is subsequently negatively associated with incident depression and MetS (Gianfredi et al. 2020; Lee 2020).

Cross-sectional and prospective studies show that aerobic capacity has a negative relationship with both depression and MetS (Gianfredi et al. 2020; LaMonte et al. 2005; Lee 2020). A meta-analysis of cross-sectional research found that individuals with a normal body mass index (BMI) but low aerobic capacity were at increased risk of MetS (RR=1.62, 95%CI=1.32, 1.98, P<0.01), more so than those with obesity and high aerobic capacity (Lee 2020). A 6 y prospective study showed a decreased risk of developing MetS in males (n=9007, hazard ratio=0.47, 95%CI=0.40,0.54, P<0.001) and females (n=1491, hazard ratio=0.37, 95%CI=0.18,0.80, P=0.01) in the highest tertile of aerobic capacity compared to those in the lowest tertile (LaMonte et al. 2005). Furthermore, a meta-analysis of prospective research

reported that individuals with low aerobic capacity had a 76% (95%CI=1.61-1.91, P<0.001) increased risk of developing depression (Schuch, Vancampfort, Sui, et al. 2016). The desk-based academic work environment may contribute to low aerobic capacity and subsequently increase the risk of mental and cardiometabolic health disorders.

Cross-sectional research reported a VO_{2peak} of 34.1±8.1 $mL \cdot kg^{-1} \cdot min^{-1}$ in 46 desk-based workers following a maximal graded exercise test on a cycle ergometer (Strauss et al. 2021); with clear age and sex differences in aerobic capacity evident (Kaminsky et al. 2017). Further cross-sectional research in employees from various types of desk-based work reported an estimated VO_{2max} range between 35.3±10.1 to 37.3±10.4 $mL \cdot kg^{-1} \cdot min^{-1}$ in females and 35.0±9.9 to 38.1±10.3 $mL \cdot kg^{-1} \cdot min^{-1}$ in males as measured from a submaximal test on a cycle ergometer (Vaisanen et al. 2020). This compares to reference values from the general population, which report 20.1±5.1 $mL \cdot kg^{-1} \cdot min^{-1}$ in females and 28.0±6.7 $mL \cdot kg^{-1} \cdot min^{-1}$ in males aged 40-49 y (Kaminsky et al. 2017). Disregarding the influence of gender, age and method of measurement on aerobic capacity when comparing studies, higher aerobic capacity is associated with lower risk of depression and type 2 diabetes (Chow et al. 2016; Schuch, Vancampfort, Sui, et al. 2016). Given that academics experience low MVPA at work and may have limited leisure time to participate in physical activity due to long work hours (Kirk & Rhodes 2011; Safi et al. 2021), increasing the physical activity of this population via exercise may provide an avenue to increase aerobic capacity and therefore reduce risk markers of depression and type 2 diabetes (Zeiher et al. 2020).

Despite experiencing low levels of physical activity there is limited research on the aerobic capacity of academics (Cooper & Barton 2016). Alkhatib (2015) measured aerobic capacity via graded exercise test on a treadmill in academics (n=23, 53±6 y) and administrative staff (n=33, 49±12 y) from a UK university and reported a VO_{2peak} of 32.7±4.7 $mL \cdot kg^{-1} \cdot min^{-1}$ in male

and 32.1±9.1 $mL \cdot kg^{-1} \cdot min^{-1}$ in female academics, with no differences found between sex, or academics and administrative staff (Alkhatib 2015). This compares to reference values from the general population (n=4631) that were also measured via a graded exercise test on a treadmill, reporting 33.7±5.7 $mL \cdot kg^{-1} \cdot min^{-1}$ in females and 42.1±7.6 $mL \cdot kg^{-1} \cdot min^{-1}$ in males aged 50-59 (Aspenes et al. 2011). Other research in mixed-role university staff (including 47% full-time academic staff) reported a VO_{2peak} of 27.4±5.4 $mL \cdot kg^{-1} \cdot min^{-1}$ in females and 36.2±7.1 $mL \cdot kg^{-1} \cdot min^{-1}$ in males, though results of the specific academic participants were not reported (Hunter et al. 2020). Although academics participate in low amounts of physical activity (Cooper & Barton 2016), current research into the aerobic capacity of academics is sparce.

Body Composition in the Inactive Academic Workplace

Relevance of Fat Mass

The low amounts of physical activity experienced in the desk-based workplace may increase fat mass and decrease lean mass, which may subsequently increase the risk of cardiometabolic and mental disorders (Alshehri et al. 2019; Hjerkind, Stenehjem & Nilsen 2017; Hong et al. 2017; Li et al. 2014). Low levels of physical activity are associated with higher BMI, WC and total body fat mass (Bradbury et al. 2017; Cardenas Fuentes et al. 2018). A cross-sectional study (n=259,808) by Bradbury et al. (2017) reported lower total body fat mass (%) in males (-1.7%, 95% CI=-1.6,-1.7) and females (-1.5%, 95% CI=-1.4,-1.6) participating in ≥100 MET-hours/week compared to those performing <5 MET-hours/week (Bradbury et al. 2017). Prospective research from the Australian Diabetes, Obesity, and Lifestyle Study (n=3261) showed that increasing MVPA attenuated increases in WC, with lower MVPA a strong predictor of increases in WC (5.5±7.7 cm) over a 12 y follow-up period (Shibata et al. 2016). These results highlight the benefits of increasing MVPA for preventing an increase in central adiposity, which is a key determinant of MetS. Waist circumference is a clinical measure that

is used as a proxy for visceral adipose tissue (VAT), which is of particular interest due to the relationship between VAT and insulin resistance and depression (Murabito et al. 2013; Preis et al. 2010). A cross-sectional study (n=3010) by Whitaker et al (2017) reported a decrease in VAT (-7.6 cm^3, 95%CI=-9.5, -5.6), subcutaneous adipose tissue (-6.7 cm^3, 95%CI=-9.6,-3.8) and intermuscular adipose tissue (-8.1 cm^3, 95%CI=-10.1,-6.0) with every 1 SD increase (or 275 exercise units) in self-reported MVPA related activities (occupational and leisure) ($P<0.001$). Increasing MVPA in inactive workers may help to reduce central and ectopic fat accumulation, which may reduce the risk of both mental and cardiometabolic health disorders (Alshehri et al. 2019; Lee et al. 2018).

Limiting increases in total body and central fat mass in workers with low levels of physical activity is important due to its positive association with depression and MetS (Kim & Park 2018; Speed et al. 2019). A 4.5 y prospective study (n=1964) by Kwon et al. (2017) reported an 11% increased risk (HR=1.11, 95%CI=1.08–1.14) of developing MetS in individuals with a 1 cm increase in WC during follow-up. Individuals in the 5th quintile for VAT had over three times the risk of developing MetS (HR=3.73, 95%CI=2.22, 6.28) compared to those in the 1st quintile (Kwon, Kim & Kim 2017). Although central adiposity is a more significant risk factor for MetS compared to other measures of fat mass (Matsha et al. 2019), total body fat also has a positive association with MetS. (Kim, Oh, et al. 2019; Lee 2020). A cross-sectional study of 1687 adults reported significantly higher fat mass (%) in both males (23.5±7.5%) and females (37.3±6.0%) with MetS compared to those without (14.5±5.7% in males, 26.2±6.8% in females) (Ramírez-Vélez et al. 2017).

Alongside the increased risk of MetS, cross-sectional and prospective studies have revealed that total fat mass and VAT have a positive relationship with symptoms of depression (Alshehri

et al. 2019; Becofsky et al. 2015; Luppino et al. 2010; Murabito et al. 2013). A Mendelian randomization study reported that total fat mass was positively associated with depression (Log OR=0.20, SD=0.04) (Speed et al. 2019), whilst a 9 y prospective study (n=12,599) reported a greater likelihood of elevated depressive symptoms in females (OR=1.36, 95%CI=1.07, 1.71) and males (OR=1.23, 95%CI=1.08, 1.40) with higher body fat % (males cut off = 25%, female cut off = 30%) (Becofsky et al. 2015). Evidently, fat mass and VAT can increase the risk of both mental and cardiometabolic health disorders and may be higher in desk-based workers participating in low levels of physical activity such as academics.

Whilst there are no clinical cut offs for fat mass (%), the WC cut-offs within the MetS criteria are a proxy for VAT. Cross-sectional research of full-time desk-based workers in Australia has reported a mean WC of 97.7±12.8 cm in males and 86.9±14.9 cm in females, relating to abdominal obesity prevalence of 30.7% and 39.5%, respectively (Sugiyama et al. 2020). Additionally, a meta-analysis reported a mean body fat, BMI and WC of 30.2%, 26.5 kg/m^2 and 87.1 cm, respectively, in desk-based workers (Prince et al. 2019). Detailed measures of fat mass and central adiposity in academics is currently limited, but Alkhatib (2015) reported a mean BMI of 28.5±4.1 kg/m^2 in male and 24.4±3.7 kg/m^2 in female academics, which was significantly higher in males compared to females ($P<0.05$) (Alkhatib 2015). Hunter et al. (2020) reported a BMI of 26.1±3.5kg/m^2 (overweight) in 78 university employees including academic, professional and technical staff. Further, total body fat mass was reported as 39.8±7.6% in females and 26.0±6.8% in males using Dual-energy X-ray Absorptiometry (DEXA) (Hunter et al. 2020). The low levels of occupational and leisure time MVPA reported by academics suggests a potential for increased risk of overweight and obesity (Cooper & Barton 2016; Safi et al. 2021). However, this data is limited and requires further investigation.

Relevance of Lean Mass

In contrast to the negative association between total body and central adiposity, and physical activity, lean mass has a positive association with physical activity and a negative relationship with depression and MetS (Atlantis et al. 2009; Heo et al. 2018). Cross-sectional findings from NHANES (n=7547) showed that every 30 min/week increase in weighted weekly physical activity was associated with an increase in appendicular lean mass index in males (0.001 kg/m^2; β=0.001, 95%CI=0.001-0.002) and females (0.003 kg/m^2; β=0.005, 95%CI=0.003-0.007) (Xu et al. 2020). Prospective studies have also reported a positive association between physical activity and lean mass (Fukumoto et al. 2018), wherein older individuals (65-84 y) in the lowest two quartiles of objectively measured daily physical activity showed a significant reduction in lean mass after 5 y, compared to those in the highest two quartiles who maintained their lean mass (Shephard et al. 2013). Consequently, the low levels of physical activity experienced in the academic workplace may increase the risk of reduced lean mass in academics, which is a risk factor for cardiometabolic and mental health disorders (Kim et al. 2018; Li et al. 2014).

Preventing a decline in lean mass through increasing physical activity may reduce the risk of MetS and increased symptoms of depression (Kim et al. 2018; Li et al. 2014). A 7-y prospective study (n=14,830) found that individuals in the highest tertile for skeletal muscle mass index at baseline had a decreased risk of incident MetS (Hazard ratio=0.60, 95% CI=0.54,0.68, P<0.001) compared to those in the lowest tertile (Kim et al. 2018). Furthermore, an increase in skeletal muscle mass index (>1%) over the first year resulted in a 29% decreased risk of MetS compared to those with a reduction (Hazard ratio=0.71, 95%CI=0.59,0.84, P<0.001) (Kim et al. 2018), highlighting the importance of increasing lean mass to prevent the development of MetS. In regard to mental health, cross-sectional research showed that every 1 kg/m^2 decrease in lean mass was associated with higher prevalence of moderate to severe depressive symptoms

in males (n=1151, OR=1.95, 95%CI=1.10,3.44), but not females (n=2176) (Heo et al. 2018). Data from NHANES (n=2046) found significantly lower total lean mass (%) in adults (18-69 y) experiencing moderate to severe symptoms of depression compared to those experiencing minimal symptoms (Li et al. 2014). Due to the low levels of physical activity in the workplace (Safi et al. 2021), academics may have low lean mass and thus increased risk of mental and cardiometabolic health disorders (Atlantis et al. 2009; Heo et al. 2018).

Insulin Resistance in the Inactive Academic Workplace

Insulin resistance is primary risk-factor for type 2 diabetes as it is usually apparent during the progressive dysfunction and apoptosis of pancreatic β-cells that occurs in type 2 diabetes (American Diabetes Association 2021). The prevention of insulin resistance is a public health priority, particularly given the rising world-wide prevalence of type 2 diabetes (Saeedi et al. 2019). Low physical activity, in particular MVPA is an important risk factor for insulin resistance given the negative association reported between the two variables (Fuezeki, Engeroff & Banzer 2017; van der Velde et al. 2018). For example, a 10 y longitudinal study of 913 adults showed that despite an overall increase in fasting insulin, individuals who replaced objectively measured sedentary activity with MVPA had a 1.13 μU/mL decrease in fasting insulin (95%CI=-1.95,-0.31, P=0.007) at follow-up (Whitaker et al. 2019). This may have important implications for Australian desk-based workers who spend up to 9 h per day sitting (Bennie et al. 2015). Furthermore, when low-intensity physical activity was replaced with MVPA, a 0.93 μU/mL (95%CI=-1.80,-0.06, P=0.035) decrease in fasting insulin was reported at follow-up (Whitaker et al. 2019), indicating the importance of MVPA to improve insulin resistance (Assah et al. 2008). Indeed, inconsistent associations are reported between light intensity physical activity and insulin resistance after adjustment for MVPA (Amagasa et al. 2018). Cross-sectional and prospective (1 y) research of 192 individuals with family history of type 2

diabetes showed that MVPA was significantly associated with the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR; β=-0.004, 95%CI=-0.008,-0.00001, P=0.048) at baseline, and was a significant predictor of fasting insulin at follow-up (β=-0.004, 95%CI=-0.007,-0.001, P=0.022), but low-intensity physical activity was not (P>0.05) (Ekelund et al. 2009). Given the importance of MVPA for the moderation of insulin resistance, the low levels of MVPA reported in the academic workplace may increase the risk of insulin resistance (Safi et al. 2021).

Preventing insulin resistance in inactive workers is important given its positive association with both depression and type 2 diabetes (Kan et al. 2013; Soulimane et al. 2011). A longitudinal study (6.4±0.5 y mean follow-up) of 1349 adults without type 2 diabetes at baseline reported an increased risk of incident type 2 diabetes in individuals in the highest quintile of HOMA-IR compared to those in the lowest quintile (OR=2.8, 95%CI=1.4,5.6) (Ruijgrok et al. 2018). Moreover, meta-analysis of longitudinal, case-control and cross-sectional studies reported a significant positive association between insulin resistance and depression (d=0.46, 95%CI=0.22,0.71) (Kan et al. 2013). These findings indicate that insulin resistance is not only a risk factor for type 2 diabetes, but also depression. Accordingly, it is pertinent to assess insulin resistance in high-risk populations, such as desk-based workers reporting low levels of physical activity to evaluate their risk of these mental and cardiometabolic health disorders.

Though studies have assessed insulin resistance in the desk-based workplace (Prince et al. 2019), limited data are available on academics. A systematic review and meta-analysis reported a mean fasting glucose of 5.1 mmol/L (95%CI=4.88,5.34) in workers within inactive workplaces including desk-based workers (5 studies) and taxi drivers (1 study) (Prince et al. 2019). Other cross-sectional research of 231Australian desk-based workers has reported mean

fasting insulin of 10.2±18.3 μU/mL and glucose of 5.1±1.4 mmol/L (Healy et al. 2017), which indicates normal fasting glucose in this cohort (Alberti et al. 2009; American Diabetes Association 2021). However, whilst research in university staff has reported a mean fasting glucose of 5.1±0.8 mmol/L (Cheserek et al. 2014), subgroup data from the academic population was not provided. Furthermore, other measures of insulin resistance such as fasting insulin and HOMA-IR have not been measured in the academic workplace and are needed to further understand the risk of cardiometabolic and mental health disorders in this population (Ruijgrok et al. 2018).

Chronic Systemic Inflammation in the Inactive Academic Workplace

A normal local or systemic increase in inflammation occurs when an acute threat is present (e.g. bacterial infection) and decreases once the threat has passed (Furman et al. 2019). However, certain phenotypes (e.g. central fat accumulation and increased total body adiposity) are related to increased chronic low-grade systemic inflammation, which is associated with both depression and type 2 diabetes (Osimo et al. 2020; Wang et al. 2013). Meta-analysis of cohort, cross-sectional and case-control studies has reported an increased risk of type 2 diabetes of 32% (95%CI=1.14,1.51) and 45% (95%CI=1.18,1.73) for every 1 log pg/ml increment in IL-6 and C-reactive protein (CRP), respectively (Liu et al. 2016). Furthermore, the meta-analysis of case-control studies by Osimo et al. (2020) showed that systemic levels of CRP, IL-6 and TNF-α were significantly elevated in individuals with depression (hedges g between 0.54 and 0.71) (Osimo et al. 2020). Systemic inflammation is also positively associated with mental health and cardiometabolic risk factors including fat mass (Kunz et al. 2021), insulin resistance and MetS (Kunz et al. 2021; Moazzami et al. 2019), and negatively associated with protective factors such as lean mass and aerobic capacity (Crossland et al. 2019; Madssen et al. 2019; Wedell-Neergaard et al. 2018). In turn, current hypothetical causal pathways for

depression and type 2 diabetes include systemic inflammation as an underlying cause (Hotamisligil 2017b; Slavich & Irwin 2014). IL-6 and TNF-α are cytokines of particular interest given their close association with depression and type 2 diabetes (Dowlati et al. 2010; Wang et al. 2013).

IL-6 is a pleiotropic cytokine that can have anti-inflammatory and insulin sensitising effects when acutely expressed from myocytes during exercise (Pedersen 2017), but chronic low-grade elevation in IL-6 is associated with obesity, depression and type 2 diabetes (Kern et al. 2001; Mac Giollabhui et al. 2021; Wang et al. 2013). Indeed, IL-6 is expressed from adipose tissue and is higher in obese compared to non-obese individuals (Kern et al. 2001). It has also been shown to contribute to increasing insulin resistance (Rotter, Nagaev & Smith 2003; Senn et al. 2002), and symptoms of depression (Engler et al. 2017). A meta-analysis of longitudinal studies (n=10) showed that higher IL-6 increased the risk of future depression (f(r)=0.043, P<0.0001) (Mac Giollabhui et al. 2021). Furthermore, a 4 y prospective study of 27,628 females found that individuals in the highest quantile of IL-6 had a significantly higher risk of developing type 2 diabetes compared to those in the lowest quantile (RR=7.5, 95%CI=3.7,15.4, P<0.001) (Pradhan et al. 2001). This association was attenuated after adjusting for variables such as BMI and physical activity (RR=2.3, 95%CI=0.9,5.6, P=0.07), highlighting the relationships between these cardiometabolic risk factors. Regardless, reducing low-grade systemic levels of IL-6 may provide protection against both cardiometabolic and mental health disorders.

In congruence with long-term systemic elevation of IL-6, TNF-α has been positively associated with type 2 diabetes and depression in cross-sectional studies (Liu et al. 2016; Osimo et al. 2020). However, the meta-analysis of prospective studies (n=27) by Mac Giollabhui et al.

(2020) reported no association between TNF-α and incident depression, justifying further investigation into this relationship. TNF-α appears to have a mechanistic role in insulin resistance (Krogh-Madsen et al. 2006; Plomgaard et al. 2005), and has a positive association with both type 2 diabetes and CVD (Kaptoge et al. 2014). Meta-analysis of prospective research found that a 1 SD higher baseline level of TNF-α increased the risk of non-fatal myocardial infarction or coronary heart disease death by 17% (95%CI=1.09,1.25) (Kaptoge et al. 2014). Interestingly, both IL-6 and TNF-α are secreted from adipose tissue, and systemic levels of these cytokines are higher in obese compared to non-obese individuals (Popko et al. 2010). Given fat mass is also positively associated with type 2 diabetes and CVD (Lee et al. 2018; Ortega, Lavie & Blair 2016), reductions in fat mass via increases in MVPA may help to moderate IL-6 and TNF-α, and subsequently reduce the risk of cardiometabolic disease.

Physical activity has a negative association with IL-6 and TNF-α (Elosua et al. 2005; Nicklas et al. 2016). A prospective study of 4289 adults reported a negative correlation between meeting physical activity guidelines (self-report ≥2.5 h/week of MVPA) and IL-6 (β=-0.04, 95%CI=-0.06,-0.02, P=0.001), at baseline (Hamer et al. 2012). In addition, individuals adhering to physical activity guidelines throughout the 10 y follow up also had lower IL-6 (β=-0.07, 95%CI=-0.10,-0.03) compared to those rarely meeting the guidelines (Hamer et al. 2012). Importantly, participants who increased their physical activity by ≥2.5 h/week had lower IL-6 at follow up compared to those who did not change their physical activity engagement (Hamer et al. 2012), indicating a potential benefit of increasing physical activity in desk-based workers. Indeed, a cross-sectional study of 396 adults used isotemporal substitution modelling to show that replacing 30 min of objectively measured sedentary behaviour (e.g. sitting at a desk) with 30 min of MVPA was associated with lower IL-6 (*B*=-0.32, 95%CI=-0.53,-0.11) (Phillips, Dillon & Perry 2017). However, TNF-α had a positive association with sedentary behaviour

(P<0.05) and no relationship with MVPA or light physical activity (Phillips, Dillon & Perry 2017). Other cross-sectional research (n=1004) has reported higher TNF-α in inactive males compared to males participating in moderate to high physical activity (≥5 h/week at ≤4 METs or ≥1-2 h/week at >4 METs), but this difference was not shown in females (Elosua et al. 2005). Interestingly, the negative association between systemic inflammation and physical activity was attenuated after adjustment for BMI, indicating that the relationship may be indirect and rather dependent on body fat (Elosua et al. 2005). Regardless, it appears that increasing physical activity can decrease markers of systemic inflammation in adults, which may help to reduce the risk of developing type 2 diabetes, CVD and depression. However, there is no research on chronic systemic levels of IL-6 and TNF-α, nor the effect of increasing MVPA on these markers in academics.

Stress in the Inactive Academic Workplace

Stress is a complex component of mental and cardiometabolic health because it has multiple classifications, including job-specific or general (Bergmann, Gyntelberg & Faber 2014), acute or chronic (Rohleder 2019), and physical or perceived (Koolhaas et al. 2011). In general, stress increases when perceptions of control and predictability are challenged (Koolhaas et al. 2011). Acute, general and job specific stress are relevant to desk-based academics due to their negative, bidirectional association with physical activity (Burg et al. 2017; Kouvonen et al. 2013; Oshio, Tsutsumi & Inoue 2016; Stults-Kolehmainen & Sinha 2014). As such, stress represents a potential barrier to increasing physical activity alongside long work hours (Kirk & Rhodes 2011; López-Bueno et al. 2020). A 7-day ecological momentary assessment (EMA) study found that higher stress during the day was associated with lower self-reported physical activity in the following hours, and vice versa (Schultchen et al. 2019). Similarly, cross-sectional research showed that general stress over the previous month was higher in individuals

not meeting the recommendations for vigorous intensity exercise (≥20 min of VPA at least three times per week) (Gerber et al. 2014). In regard to job stress, a meta-analysis of prospective studies found that individuals with high job stress had an increased odds of becoming physically inactive at follow-up (OR=1.21, 95%CI=1.11,1.32) (Fransson et al. 2012). Overall, research conveys a inverse association between psychological stress and physical activity (Stults-Kolehmainen & Sinha 2014), indicating the need to consider this relationship when introducing interventions to increase physical activity in academics.

Chronic stress is important to prevent given its association with several cardiometabolic and mental health disorders, including MetS (Chandola, Brunner & Marmot 2006), type 2 diabetes and depression (Heraclides et al. 2009; Rugulies, Aust & Madsen 2017). A meta-analysis of prospective studies has shown that high job stress is associated with a 1.5-fold increased risk of depression (95%CI=1.23,1.80, P<0.001) (Rugulies, Aust & Madsen 2017). Other prospective research (n= 941, 6 y follow-up) has found general stress also significantly predicts an increase in symptoms of depression (B=0.11, 95%CI=0.10,0.13, P<0.001) (Lee. 2020). However, though both job stress and general stress negatively impact mental health, job stress is also detrimental to cardiometabolic health (Sara et al. 2018). A positive association between higher job stress and MetS has been reported in meta-analyses of both cross-sectional (OR=1.695, 95%CI=1.270,2.262, P<0.001, n=19) and longitudinal studies (OR=1.388, 95%CI=1.027,1.877, P=0.033, n=11) (Kuo et al. 2019). Whilst crude models incorporating both job specific and general stress showed a significant association with MetS in cross-sectional (OR=1.435, 95%CI=1.176,1.750, P<0.001) and longitudinal studies (OR=1.314, 95%CI=1.063,1.625, P<0.012); the relationship was no longer significant in longitudinal studies after adjustment for confounders such as physical activity, sex and age (P=0.058), suggesting stress may increase the risk of MetS indirectly through its effect on variables such

as physical activity (Kuo et al. 2019). This is an important consideration for high-stress workers who are already participating in low levels of physical activity.

The high job stress in academics is likely due to high workloads and competing work responsibilities (Lee et al. 2021), and may be associated with the desk-based nature of the academic workplace. A cross-sectional study of 428 desk-based workers found that 53% had high levels of general stress as measured by the Reeder stress scale (Dedele et al. 2019). However, another cross-sectional study (n=2528) showed that 32.4% of male and 38.6% of female desk-based workers reported high job-specific stress via the job content questionnaire (Piantella et al. 2021). These contrasting results demonstrate how rates and severity of stress can be affected by different types of stress and the measurement method used (Hassard et al. 2018; Houdmont, Cox & Griffiths 2010); indicating the importance of assessing both job specific and general stress to provide a comprehensive description in workers. Regardless, studies from universities in the UK (Fontinha, Easton & Van Laar 2019; Tytherleigh et al. 2005) and Australia (Gillespie et al. 2001) have shown higher job stress in academics compared to other university staff, signifying that academics may be at increased risk of low physical activity and mental and cardiometabolic health disorders.

The high workloads, poor management, job insecurity and limited support services reported in the academic workplace likely contribute to the higher job stress experienced by academics compared to other employees (Gillespie et al. 2001; Lee et al. 2021). The increased job stress in academics may be due to an effort reward imbalance (ERI) (Siegrist 1996), whereby an imbalance between effort outputs (e.g. work demands) and reward inputs (e.g. salary and promotion prospects) results in a violation of social reciprocity at work, resulting in stress and negative emotions (Siegrist 2012). Though not a clinical threshold, an ERI score >1.0

theoretically represents the tipping point at which an individual perceives more effort outputs than reward inputs (Siegrist, Li & Montano 2014). Previous research in academics (n=458) from universities in the UK has reported an ERI of 0.8±0.6 (Kinman 2019), though there is a lack of research from academic populations outside of the UK. A 2021 scoping review revealed that competing work demands, role overload, funding pressure and work-life conflicts were the key contributors to stress in Australian and New Zealand academics, though few interventions have been implemented to address this issue (Lee et al. 2021).

Symptoms of Depression in the Inactive Academic Workplace

Mental health and mental illness are two concepts on separate continuums (Figure 2.1), meaning that an individual with poor mental health does not necessarily have a mental illness, and vice versa (Keyes 2002). Symptoms of depression include feelings of being unhappy, worthlessness and hopelessness, which have been positively associated with stress and low levels of physical activity (Dishman, McDowell & Herring 2021; Hammen et al. 2009; Lee. 2020; Schuch et al. 2018). A meta-analysis of prospective studies reported that physical activity was associated with a 21% lower adjusted odds of both incident depression (OR=0.79, 95%CI=0.76,0.83) and a 22% decreased likelihood of an increase in subclinical symptoms of depression (OR=0.78, 95%CI=0.72,0.86) (Dishman, McDowell & Herring 2021). There was evidence of a dose-response relationship wherein higher volumes of physical activity were associated with lower odds of depression (Dishman, McDowell & Herring 2021). Importantly, there is also a dose-response relationship between physical activity and happiness (Richards et al. 2015). The odds of being happy compared to inactive individuals (0-9 min/week of weighted physical activity) are increased by 20% (95%CI=1.03,1.39) in insufficiently active (10-149 min/week of weighted physical activity), 29% (95%CI=1.11,1.49) in sufficiently active (150-299 min/week of weighted physical activity) and 52% (95%CI=1.28,1.80) in very active

individuals (≥300 min/week of weighted physical activity) (Richards et al. 2015). These results convey that increasing physical activity may not only help prevent depression but may also promote positive mental health outcomes, though prospective cohort and intervention studies are required to elucidate cause and effect.

Symptoms of depression in inactive desk-based workers are important to moderate given the relationship between depression and cardiometabolic disease. For example, a meta-analysis reported that individuals with depression have an increased risk of MetS in both cross-sectional (OR=1.34, 95%CI=1.18,1.51) and longitudinal studies (OR=1.52, 95%CI=1.20,1.91) (Pan et al. 2012). Furthermore, a meta-analysis of prospective cohort studies found a 30% (95%CI=1.22,1.40) increased risk of developing CVD in individuals with high symptoms of depression (Gan et al. 2014). Graham et al. (2020) also reported that depression was associated with an 18% (95%CI=1.12,1.24) increased risk of type 2 diabetes in adults (Graham et al. 2020). Importantly, a bilateral relationship exists between MetS and depression (Pan et al. 2012), justifying the use of interventions that are effective in improving both comorbidities, such as exercise (Battista et al. 2021; Bellón et al. 2021). These findings emphasise the importance of reducing symptoms of depression, which may be more prevalent amongst workers participating in minimal amounts of physical activity.

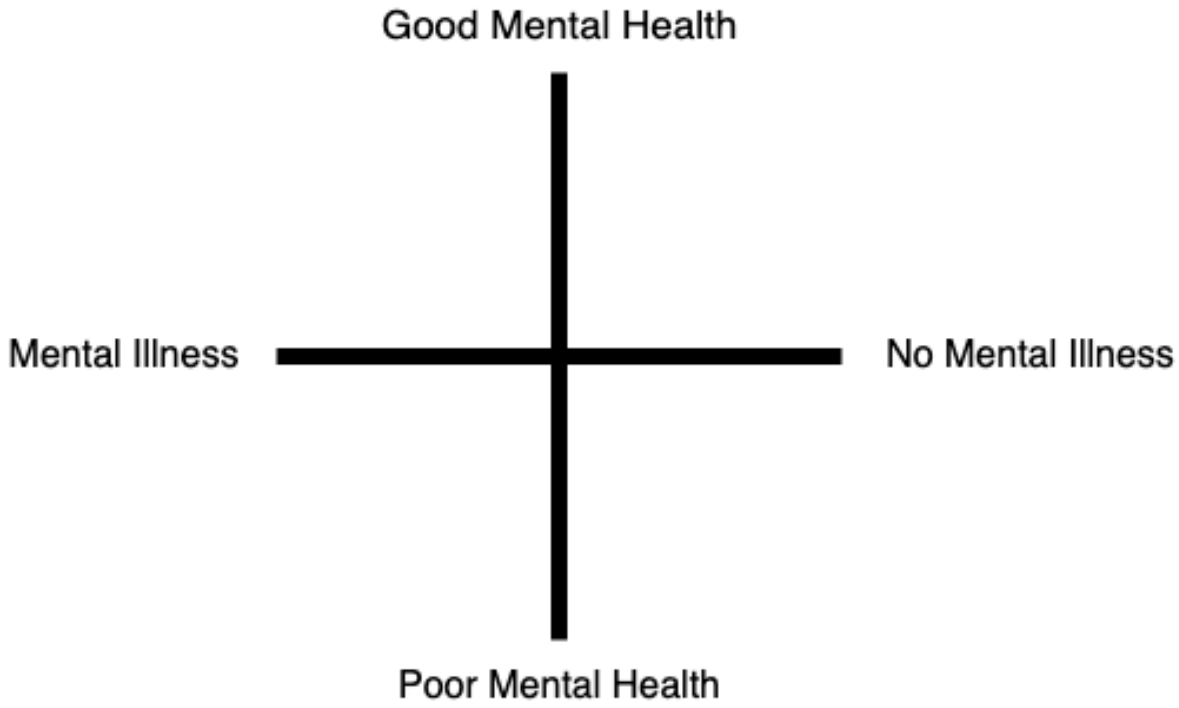


Figure 2.1 The Mental Health Continuum Adapted from Keyes 2002.

Mental health and mental illness are on two separate continuums, highlighting that an individual can have a mental illness but good mental health, whilst another individual can have poor mental health without a mental illness.

The low levels of physical activity in the desk-based workplace may pre-dispose workers to increased symptoms of depression. A cross-sectional study of the broader Australian workforce (n=2783) reported that over 30% experienced mild to severe symptoms of depression (McTernan, Dollard & LaMontagne 2013). Within desk-based workers from the UK, data from the longitudinal cohort Whitehall study II showed that 13% of males (n=1929) and 19% of females (n=599) had high-risk scores for depression (Marmot & Brunner 2005; Piantella et al. 2021). Other cross-sectional research found that 38% of desk-based workers (n=222) scored above the clinical threshold for depression according to the hospital anxiety and depression scale (Kang et al. 2016). Notwithstanding the different questionnaires used to measure depressive symptoms in these studies, a substantial portion of desk-based workers experience significant symptoms of depression.

The low levels of physical activity and higher stress experienced by academics may increase their risk of depression given symptoms of depression are positively associated with stress and low levels of physical activity (Dishman, McDowell & Herring 2021; Rugulies, Aust & Madsen 2017). A 2012 study from the UK found that university employees (n=307) had higher symptoms of depression compared to the general population (n=120) (Mark & Smith 2012). Moreover, academics have presented with high psychological strain compared to other university staff (Winefield et al. 2003), which may be related to the higher job stress in academics (Bell, Rajendran & Theiler 2012; Fontinha, Easton & Van Laar 2019). However, most studies in academics have assessed the risk of mental illness via the 12-item general health questionnaire (Kinman 2016, 2019; Winefield et al. 2002), which amalgamates symptoms of depression, anxiety and distress to provide a global mental illness risk score (Goldberg 1988). This makes it difficult to differentiate depressive symptoms from other symptoms of mental

distress (Hystad & Johnsen 2020), which should be measured independently in academics given stress, depression and anxiety are different constructs (Lovibond & Lovibond 1995). Regardless, the long-work hours (Virtanen et al. 2018), high job stress and low physical activity experienced by academics are all associated with increased symptoms of depression (Rugulies, Aust & Madsen 2017), justifying further research into the mental heath of academics.

Symptoms of Anxiety in the Inactive Academic Workplace

In line with stress and depression, symptoms of anxiety have a negative association with physical activity (Da Silva et al. 2012). A cross-sectional study of 237,964 adults from n=47 countries found that low levels of physical activity were associated with a 32% increased likelihood of experiencing anxiety (Stubbs, Koyanagi, et al. 2017). Baseline data from a longitudinal study by Hallgren et al. (2019) reported that individuals meeting (≥150 min/week of MVPA) or exceeding (≥300 min/week of MVPA) physical activity guidelines had a 24% (95%CI=0.68,0.86) and 36% (95%CI=0.57,0.72) lower odds of anxiety, respectively (n=27,053) (Hallgren et al. 2019). However, physical activity was not associated with anxiety at the 13 y follow-up, potentially because cases were obtained from specialist inpatient and outpatient registers, which may have led to an underestimation of anxiety disorders (Hallgren et al. 2019). Regardless, a meta-analysis of prospective studies found that physical activity was not significantly associated with either self-reported anxiety symptoms (mean OR=0.87, 95%CI=0.77,0.99, P=0.09) or anxiety disorders (mean OR=0.66, 95%CI=0.53,0.82, P=0.26) (McDowell et al. 2019). Another meta-analysis by Schuch et al. (2019) reported contrary findings, in which physical activity was significantly associated with decreased risk of incident anxiety (OR=0.74, 95%CI=0.62,0.88, P=0.001) (Schuch et al. 2019). However, subgroup analysis revealed that the association was only significant for agoraphobia and post-traumatic stress disorder (Schuch et al. 2019), and post-traumatic stress disorder was not included in the

analysis by McDowell et al. (2019) as it is classified as a trauma and stress related disorder as opposed to anxiety disorder (McDowell et al. 2019). Notwithstanding, desk-based workers have been found to engage in less physical activity and experience greater symptoms of anxiety compared to workers in more physically active jobs (Kang et al. 2016), warranting further investigation into academics where data on anxiety is lacking.

Mitigating anxiety should be a priority for both employees and employers given it not only affects mental health, but also has a positive association with MetS (Tang, Wang & Lian 2017), type 2 diabetes and cardiovascular disease (Batelaan et al. 2016; Meurs et al. 2016; Roest et al. 2010; Smith et al. 2013). A meta-analysis of cross-sectional research reported a small but significant positive association between anxiety and MetS (OR=1.07, 95%CI=1.01,1.12); though no relationship was found between anxiety and most components of MetS, including hyperglycemia, high blood pressure, hypertriglyceridemia and low HDL-C (Tang, Wang & Lian 2017). In comparison, a prospective study of 523 women with mean follow-up of 15±3.7 y reported no association between trait anxiety and MetS defined by any criteria (Räikkönen, Matthews & Kuller 2007). Indeed, the relationship between anxiety and MetS is equivocal when comparing evidence from cross-sectional and longitudinal research (Tang, Wang & Lian 2017). Anxiety appears to have a stronger relationship with cardiometabolic disorders such as type 2 diabetes and CVD. For example, meta-analysis of cross-sectional studies found a higher likelihood of type 2 diabetes in individuals with anxiety disorders (OR=1.21, 95%CI=1.10,1.31) and elevated symptoms of anxiety (OR=1.48, 95%CI=1.02,1.93) (Smith et al. 2013), whilst a meta-analysis of prospective studies showed that individuals with anxiety had a 41% increased risk of developing CVD (95%CI=1.25,2.43) (Batelaan et al. 2016). Given the consequences of increased anxiety for both mental and cardiometabolic health, it is important to identify interventions to mitigate anxiety symptoms in workers. However, the

low-levels of physical activity involved in desk-based jobs may increase the risk of anxiety and subsequent mental and cardiometabolic health disorders (Kang et al. 2016; Meurs et al. 2016).

Desk-based workers may be at increased risk of symptoms of anxiety due to the low amounts of physical activity involved at work and this association may be bidirectional (Prince et al. 2019; Stubbs, Koyanagi, et al. 2017). A cross-sectional study of desk-based (n=222) and non-desk based (n=1552) employees reported that 14% of desk-based workers scored above the clinical cut-off for anxiety, which was a higher proportion compared to non-desk-based workers (6.8%, n=1552, $P<0.01$) (Kang et al. 2016). Interestingly in this study, desk-based workers also participated in lower amounts of physical activity ($P<0.01$) (Kang et al. 2016). Despite low amounts of MVPA involved in the academic workplace, prevalence and severity of symptoms of anxiety in academics is currently unknown. Mark and Smith (2012) reported higher symptoms of anxiety in university staff (academic and administrative, n=307) compared to the general population (n=120) in the UK. Furthermore, within Australian universities, academics have presented with higher psychological strain compared to other staff (Winefield et al. 2003). However, like symptoms of depression, anxiety has been commonly measured in combination with other components of mental health via the 12-item general health questionnaire (Boyd et al. 2011; Goldberg 1988; Kinman 2019; Kinman & Jones 2003), which does not effectively differentiate these independent domains (Hystad & Johnsen 2020). Given that low physical activity and long work hours are positively associated with symptoms of anxiety (Hallgren et al. 2019; Kang et al. 2016; Virtanen et al. 2011), assessment of symptoms of anxiety in academics is necessary.

Relationships Between Risk Factors of Mental and Cardiometabolic Health Disorders

The previous sections outline how the low levels of MVPA commonly experienced in desk-based work are associated with risk factors for cardiometabolic diseases and mental health disorders. Whilst evidence shows that MetS, fat and lean mass, systemic inflammation, insulin resistance, aerobic capacity and symptoms of stress, depression and anxiety increase the risk of disorders such as major depression, CVD and type 2 diabetes, there are also strong interrelationships between these risk factors (Kunz et al. 2021; Slavich & Irwin 2014). For example, cross-sectional research of 2,287 adults reported significantly higher insulin resistance and systemic inflammation in individuals with obesity and/or low amounts of lean mass (Levine & Crimmins 2012). Furthermore, data from the NHANES (n=18,025) showed that systemic inflammation and symptoms of depression were highest in obese individuals with MetS and lowest in normal weight individuals without MetS ($P<0.001$) (Moazzami et al. 2019). Though MetS and obesity were independently associated with depressive symptoms, there was a significant association between the two ($P<0.001$), and systemic inflammation partially mediated the association between metabolic status and symptoms of depression (Moazzami et al. 2019).

The interrelationships between stress, inflammation and fat mass are emphasised in prospective research with cardiometabolic disease endpoints. For example, Spranger et al. (2003) showed a positive association between TNF-α and incident type 2 diabetes, which was no longer significant after adjustment for BMI or waist to hip ratio (Spranger et al. 2003). Furthermore, Emeny et al. (2013) showed that the association between job stress and incident CVD was attenuated by some markers of systemic inflammation (Emeny et al. 2013). There is a positive association between chronic stress and both IL-6 and TNF-α (Rohleder 2019), though limited prospective studies have adjusted for inflammation when investigating the relationship

between stress and depression (Lee. 2020; Rugulies, Aust & Madsen 2017). Acknowledging that some of these relationships are bidirectional, hypothetical causal pathways have been proposed for both depression and type 2 diabetes (Figure 2.2), whereby chronic stress increases systemic inflammation which causes depression (Slavich & Irwin 2014), and accumulation of fat mass increases systemic inflammation which causes insulin resistance and type 2 diabetes (Hotamisligil 2017a). Ongoing investigation of these hypothetical pathways is required to enable and refine the development of effective interventions to prevent both type 2 diabetes and depression.

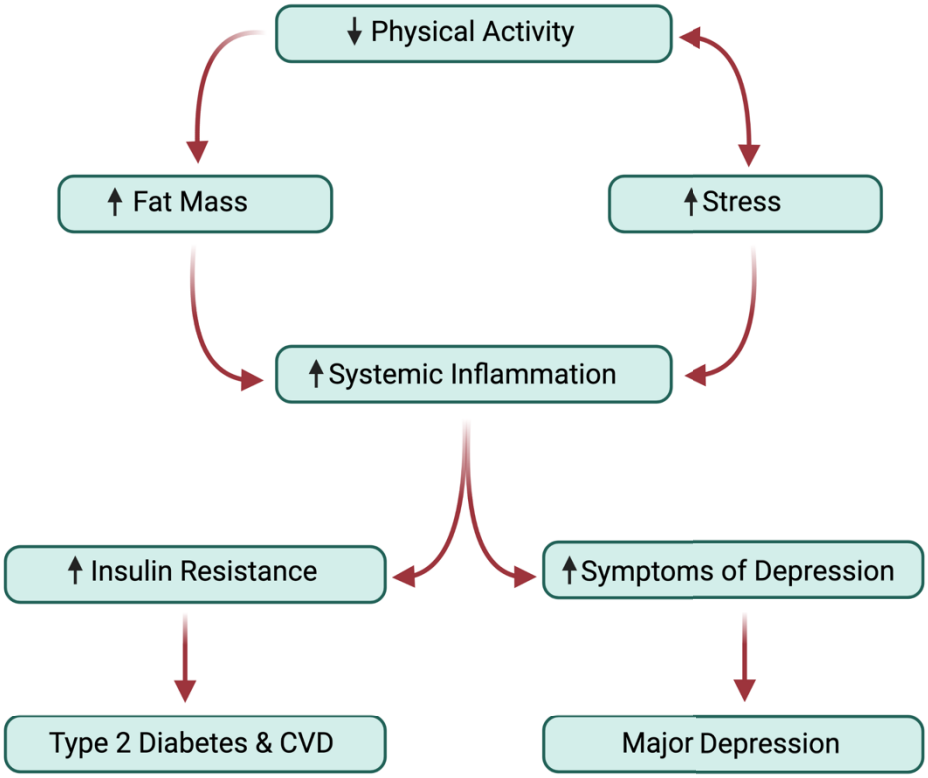


Figure 2.2 Hypothetical Pathways to Cardiometabolic Disease and Major Depression.

The Relationship Between Stress, Inflammation and Depression

General, job-specific and acute stress have been associated with increased systemic inflammation (Polacchini et al. 2018; Rohleder 2019). A previous meta-analysis has found that acute stress results in significant increases in IL-6 from 11 to 120 mins post stressor and increases in TNF-α from 31 to 50 min post stressor (Marsland et al. 2017). Although acute stress and inflammatory responses are a normal reaction to a threat (Rohleder 2019), repeated exposure to a stressor eventually results in chronic stress which is associated with low-grade systemic inflammation (Kiecolt-Glaser et al. 2003; von Kanel et al. 2012). Accordingly, chronic low-grade systemic inflammation shows a positive association with symptoms of depression (Dowlati et al. 2010). Cross-sectional research of 6622 adults reported significantly higher IL-6 in individuals with higher levels of chronic stress (Ranjit et al. 2007), and a 3 y longitudinal cohort study of 169 older (75±8 y) caregivers (chronic stress group) and non-caregivers showed that chronic stress was associated with a 15.7% greater TNF-α level over time (von Kanel et al. 2012). A meta-analysis of cross-sectional studies found that job-specific stress (as measured by ERI) was also positively associated with IL-6 (Eddy et al. 2016). Evidently, stress has a close relationship with systemic inflammation, and both are positively associated with the development of depression (Lee. 2020; Mac Giollabhui et al. 2021). However, the majority of studies are cross-sectional and causal pathways are still equivocal. Further research into the hypothetical pathway between stress, inflammation and depression is required.

Though outside the scope of the current thesis, molecular research has shown that stress can stimulate a central inflammatory response (Cheng et al. 2016; Fleshner, Frank & Maier 2017; Weber et al. 2015), which may disrupt neurotransmitter production and signalling (Miller et al. 2013), and induce sickness symptoms such as depressed mood (Benson et al. 2017; Eisenberger

et al. 2010; Engler et al. 2017). However, applied research has provided mixed support for the hypothetical pathway from stress to inflammation to depression. A 6 y longitudinal study of 941 adults found that symptoms of depression at follow-up were significantly predicted by general stress (*B*=0.11, 95% CI=0.10, 0.13, P<0.001) but not IL-6 (Lee. 2020). However, cross-sectional analysis at baseline showed that IL-6 had a positive association with symptoms of depression (*B*=0.07, 95% CI=0.05, 0.10, P<0.001), but not general stress (Lee. 2020). Other cross-sectional research within originally desk-based workers from the Whitehall II study (n=2528) reported a positive association between job stress and symptoms of depression in both males and females (Piantella et al. 2021). Furthermore, IL-6 was positively associated with depression symptoms in females only, which is similar to other cross-sectional findings of a 22% higher level of TNF-α in females (but not males) with high symptoms of depression (Webb et al. 2017). Evidently, there is need for further research into the relationship between job stress, systemic inflammation and depression.

The Relationship Between Fat Mass, Systemic Inflammation and Insulin Resistance

A hypothetical pathway exists from increased fat mass to systemic inflammation to insulin resistance (Kawai, Autieri & Scalia 2021; Longo et al. 2019). The proposed pathway begins with a prolonged positive energy balance resulting in hypertrophy and hyperplasia of adipocytes (Haczeyni, Bell-Anderson & Farrell 2018; Shook et al. 2015). Eventually, expanding adipose tissue can be impaired by hypoxia, fibrosis and cellular senescence, triggering a stress response (Crewe, An & Scherer 2017; Sun et al. 2013). This leads to macrophage recruitment into adipose tissue and M1-like macrophage polarization (Crewe, An & Scherer 2017; Guzik et al. 2017; Weisberg et al. 2003), contributing to a state of low-grade systemic inflammation commonly observed in obesity (Molli et al. 2017). Systemic inflammation is positively associated with insulin resistance and the future onset of type 2

diabetes (Wang et al. 2013). Mechanistic studies have indicated that IL-6 may directly increase insulin resistance in adipocytes (Rotter, Nagaev & Smith 2003), myocytes (Kim et al. 2004), and hepatocytes (Klover et al. 2003; Senn et al. 2002), though other research has found no direct impact of IL-6 on insulin sensitivity (Krogh-Madsen et al. 2006), and suggests a protective effect of IL-6 on metabolic homeostasis (Mauer et al. 2014; Wunderlich et al. 2010). Separately, TNF-α can induce insulin resistance via downstream inhibition of insulin receptor substrate-1 and Akt substrate 160 (Plomgaard et al. 2005), and through increasing expression of other proinflammatory cytokines (Krogh-Madsen et al. 2006). However, the pathway from increased adiposity to systemic inflammation to insulin resistance is highly complex given the pleiotropic roles of TNF-α and IL-6 (Han et al. 2020; Hotamisligil 2017b; Hunter & Jones 2015). Although the molecular aspects of this pathway are outside the scope of this thesis, upper level associations between these risk factors still require further investigation.

Cross-sectional research has reported positive associations between fat mass, systemic inflammation, and insulin resistance. Kunz et al. (2021) showed that adults with BMI>30 (n=20) had significantly higher insulin resistance, IL-6 and TNF-α compared to those with BMI <30 kg/m^2 (n=19). Furthermore, there was a positive association between TNF-α and insulin resistance (Kunz et al. 2021). Other research has reported higher levels of CRP and HOMA-IR in obese individuals compared to non-obese individuals (Molli et al. 2017).

Kern et al. (2001) reported higher IL-6 in adults with >45% fat (n=18) compared to those with <30% body fat (n=10; P<0.05), and a positive association between IL-6 and insulin sensitivity (r=-0.71, P<0.001). However, no associations between fat mass and TNF-α, or TNF-α and insulin sensitivity were evident (Kern et al. 2001). In comparison, a cross-sectional study of 2131 adults showed a significant positive association between TNF-α and HOMA-IR, which was attenuated but remained significant after adjustment for WC (Hivert et al. 2010),

highlighting the role of central adiposity in the relationship between inflammation and insulin resistance. Overall, there are positive cross-sectional associations between fat mass, systemic inflammation and insulin resistance, but longitudinal results are mixed and further evidence is required (Wiebe et al. 2021).

Meta-analysis of longitudinal studies and randomized clinical trials reported that HOMA-IR had a positive unidirectional association with both BMI (β=0.19, 95%CI=0.03,0.34, P<0.05) and fat mass (%; β=0.25, 95%CI=0.02,0.48, P<0.05) (Wiebe et al. 2021). However, neither IL-6 or TNF-α were associated with BMI, fat mass (%), fasting insulin or HOMA-IR (Wiebe et al. 2021). Other prospective research has also reported no association between adipose tissue insulin resistance and development of IL-6 or TNF-α (Semnani-Azad et al. 2021). Given the contrasting results from cross-sectional and longitudinal research, further investigation into the relationship between fat mass, IL-6, TNF-α and insulin resistance is required.

The Role of Exercise for Mental and Cardiometabolic Health

Physical activity volume is associated with improvements in risk factors for mental and cardiometabolic disorders including lean mass (Xu et al. 2020), fat mass (Cardenas Fuentes et al. 2018), MetS (He et al. 2014), insulin resistance (Fuezeki, Engeroff & Banzer 2017), systemic inflammation (Nicklas et al. 2016), and symptoms of stress, anxiety and depression (Burg et al. 2017; Dishman, McDowell & Herring 2021; Rebar et al. 2015). In turn, physical activity offers an effective method to help protect high-risk populations such as academics from developing type 2 diabetes and depression (Dishman, McDowell & Herring 2021; Yerramalla et al. 2020). In addition, increasing physical activity is a relatively low-cost, low-risk and easily accessible method to reduce the risk of these disorders compared to alternative interventions such medication (Fiuza-Luces et al. 2013). Whilst physical activity involves all movement that

increases energy expenditure, exercise is a planned and structured physical activity often used to increase weekly MVPA and target the aforementioned risk factors (Caspersen, Powell & Christenson 1985). For example, endurance training is used to prioritise improvements in aerobic capacity and fat mass (AbouAssi et al. 2015; Schroeder et al. 2019; Schwingshackl et al. 2013), compared to resistance training which results in greater increases in lean mass (Grgic et al. 2019; Schwingshackl et al. 2013). However, concurrent training (CT) combines both endurance and resistance exercise and provides combined adaptations to both modes (Coffey & Hawley 2016).

Endurance and Resistance Training for Cardiometabolic Health

Endurance exercise traditionally involves contractile stimulus at relatively lower force outputs for long durations (Wilson et al. 2012), and has been shown to increase aerobic capacity and decrease systemic inflammation, insulin resistance, fat mass and components of MetS (Grace et al. 2017; Myers et al. 2019; Wood et al. 2021). A meta-analysis of randomized controlled trials revealed that endurance training decreased systemic levels of IL-6 (Standardised mean difference; SMD=0.75, 95%CI=0.31,1.19, P<0.001) and TNF-α (SMD=0.71, 95%CI=0.24,1.17, P=0.003) in middle aged and older (≥40 y) adults without pre-existing conditions (Zheng et al. 2019). Another meta-analysis of randomized controlled trials found that endurance training significantly improved lipid profile, including total cholesterol (-0.29 mmol/L, 95%CI=-0.36,-0.21, P<0.001), triglycerides (-0.17 mmol/L, 95%CI=-0.19,-0.14, P<0.001), HDL-C (0.08 mmol/L, 95%CI=0.05, 0.10, P<0.001) and low density lipoprotein cholesterol (LDL-C; -0.12 mmol/L, 95%CI=-0.19,-0.14, P<0.001) in inactive adults with MetS but without type 2 diabetes (Wood et al. 2021). These findings have implications for apparently healthy inactive academics who may be at increased risk of cardiometabolic diseases due to underlying MetS. Meta-analyses have also shown that only 12 weeks of endurance running

training in inactive adults can decrease body fat mass (%; Weighted mean difference; WMD=1.3%, 95%CI=-2.0,-0.6) and triglycerides (WMD=-12.9 mg/dL, 95%CI=-24.6,-1.2), and increase aerobic capacity (WMD=3.8 $mL \cdot kg^{-1} \cdot min^{-1}$, 95%CI=3.1,4.6) (Junior et al. 2015). However, no changes in lean mass were evident even after 1 y of endurance running (Junior et al. 2015). Despite the various cardiometabolic benefits provided by endurance training, it appears ineffective in increasing lean mass (AbouAssi et al. 2015; Schroeder et al. 2019), which is important given lean mass has a negative association with MetS and type 2 diabetes (Kim et al. 2018; Maliszewska et al. 2019). Rather, lean mass is increased to a greater extent by resistance training (Grgic et al. 2019).

Resistance exercise involves contracting skeletal muscle against higher external resistance requiring increased force outputs for short periods (Wilson et al. 2012), and has been shown to increase lean mass (Grgic et al. 2019), and decrease the risk of MetS (Bakker et al. 2017). Prospective research (4 y) of 7418 adults reported a 17% lower risk of incident MetS in individuals participating in ≥ 2 days/week of resistance training (HR=0.83, 95%CI=0.73,0.96, P=0.009), independent of endurance training (Bakker et al. 2017). Furthermore, AbouAssi et al. (2015) showed significant increases in both lean mass (1.0±1.8 kg) and aerobic capacity (1.4±2.9 $mL \cdot kg^{-1} \cdot min^{-1}$) following 8 months of resistance training in 38 inactive adults with overweight/obese adults and mild to moderate dyslipidaemia (AbouAssi et al. 2015). This compared to the endurance training group (n=27) which showed no change in lean mass but a significantly higher increase in VO_{2peak} (AbouAssi et al. 2015). Indeed, a meta-analysis has shown significantly greater increases in lean mass from resistance compared to endurance training (pooled hedge's g=0.66, 95%CI=0.41,0.9) (Grgic et al. 2019). However, other meta-analysis have found significantly larger improvements in WC (MD=-1.10 cm, 95%CI=-1.85, -0.36, P=0.004), fat mass (MD=-1.14 kg, 95%CI=-1.83,-0.45) and VO_{2max} (MD=2.53 $mL \cdot kg^{-}$

^{1}·min^{-}1, 95%CI=1.62,3.44) following endurance compared to resistance training (Schwingshackl et al. 2013). Given the divergent signalling pathways stimulated by resistance and endurance training (Coffey & Hawley 2016), it is unsurprising that resistance training results in greater muscle hypertrophy, and endurance training is more beneficial for aerobic capacity and fat mass (AbouAssi et al. 2015; Schroeder et al. 2019). However, adaptations to both modes may be achieved when they are combined as CT (Coffey & Hawley 2016).

Endurance and Resistance Training for Mental Health

Endurance and resistance training have independent effects on symptoms of depression (Gordon et al. 2018), anxiety (Gordon et al. 2017), and stress (Chovanec & Gropel 2020; Klaperski & Fuchs 2021; Norris, Carroll & Cochrane 1990). A meta-analysis (n=19) reports that both endurance and resistance exercise training modes are effective at improving symptoms of anxiety in individuals without pre-existing mental illness (Conn 2010). Furthermore, meta-analyses of randomized controlled trials have shown endurance and resistance exercise improve symptoms of anxiety (endurance; hedges d=0.18, 95%CI=0.03,0.33, resistance; hedges d=0.13, 95%CI=0.03,0.29) and depression (endurance; hedges d=0.46, 95%CI=0.22,0.70, resistance; hedges d=0.64, 95%CI=0.34,0.93) to a similar extent (P>0.05) (Gordon et al. 2018; Gordon et al. 2017). General symptoms of stress have also decreased following 8-weeks of either endurance or resistance training, with no between-group differences (P>0.05) (Chovanec & Gropel 2020). Evidently, both endurance and resistance training improve symptoms of stress, anxiety and depression. However, large improvements in mental health are also shown when both modes are performed concurrently as CT (Rethorst, Wipfli & Landers 2009).

A Role for Concurrent Training

Endurance and resistance training can each improve risk factors for cardiometabolic and mental disorders (Bateman et al. 2011; Gordon et al. 2018). However, complimentary effects on risk factors are evident when both modes are performed concurrently (Coffey & Hawley 2016). Concurrent exercise training involves concomitant participation in endurance and resistance training, wherein each mode can be performed within the same session, or on separate days as part of a periodised training program (Petre et al. 2021). CT is often used in athletes competing in sports that demand high levels of strength and power, alongside high aerobic endurance (e.g. rugby, football and tennis) (Robineau et al. 2017). Within these trained populations, adaptations to endurance training can interfere with those from resistance training, resulting in lower lean mass and strength gains compared to resistance training alone (Petre et al. 2021; Wilson et al. 2012). However, this interference effect has not been found within untrained, inactive populations (Coffey & Hawley 2016; Petre et al. 2021), such as academics with low levels of physical activity. Thus, CT in inactive individuals can result in concomitant improvements to lean mass, strength, fat mass and aerobic capacity (Willis et al. 2012), and may have a synergistic effect on reducing the risk of cardiometabolic and mental disorders compared to either endurance or resistance training alone (Bennie et al. 2019; Grontved et al. 2012).

Cross-sectional research of 17,839 adults reported that compared to individuals meeting neither endurance (150 min/week of MVPA) or resistance training (2 sessions/week) guidelines, those meeting both had the lowest adjusted prevalence ratio of symptoms of depression (range: 0.28,0.47), followed by meeting endurance training guidelines only (range: 0.35,0.63) and resistance training guidelines only (range: 0.49,0.84) (Bennie et al. 2019). A similar cross-sectional study in Australian females (n=5180) showed that the probability of high symptoms

of depression and anxiety was lower in participants meeting endurance (RR=0.61, 95%CI=0.59,0.97), and endurance and resistance training (RR=0.47, 95%CI=0.33,0.67) guidelines compared to those meeting neither (Oftedal et al. 2019). However, after adjustment for chronic disease, BMI and prior diagnoses of depression and anxiety, this association was no longer significant for participants meeting endurance training guidelines (RR=0.87, 95%CI=0.67,1.13), but remained for those meeting both (RR=0.55, 95%CI=0.39,0.80) (Oftedal et al. 2019). Whilst this emphasises the relationship between risk factors for cardiometabolic and mental health, it also indicates a synergistic effect of combining endurance and resistance training on symptoms of depression and anxiety.

The synergistic effect of combined endurance and resistance training has also been demonstrated on type 2 diabetes (Grontved et al. 2012). An 18 y prospective study involving 508,332 person-years of follow-up reported a 59% (RR=0.41, 95%CI=0.27,0.61) decreased risk of type 2 diabetes in individuals completing endurance and resistance training (≥150 min each per week) compared to those completing only endurance (RR=0.48, 95%CI=0.42,0.55) or resistance training (RR=0.66, 95%CI=0.46,0.93) (Grontved et al. 2012). Furthermore, a 4 y prospective study of 7418 adults reported a 25% decreased risk of developing MetS (HR=0.75, 95%CI=0.63,0.89, P<0.001) in individuals meeting both resistance and endurance training guidelines compared to those not meeting either (Bakker et al. 2017). Regular engagement in CT results in a significant decrease in risk of incident MetS and type 2 diabetes, warranting further investigation into its use as an intervention in populations at high risk of such diseases.

Cross-sectional and prospective research convey a negative association between regular CT and risk of type 2 diabetes and depression (Bennie et al. 2020; Grontved et al. 2012). However, conclusions as to whether CT is more effective than endurance or resistance training at

reducing the risk of cardiometabolic and mental health disorders is precluded by the increased training volume involved in CT that is often not adjusted for in analysis (Bennie et al. 2019; Grontved et al. 2012). Indeed, physical activity has a dose-response relationship with MetS and symptoms of depression (Dishman, McDowell & Herring 2021; Zhang et al. 2017), indicating that the negative association between CT and MetS and depression may be due to training volume rather than mode. Regardless, the benefits of regular CT justify an investigation into the effects of a CT program on cardiometabolic and mental health in inactive academics. The following sections will review the effects of CT interventions on risk factors for type 2 diabetes, CVD and depression, particularly within the academic workplace.

Concurrent Training for the Metabolic Syndrome in the Academic Workplace

High intensity physical activity reduces the risk of MetS to a greater extent than low intensity physical activity (Hidalgo-Santamaria et al. 2017). CT is an exercise mode often utilising higher intensity exercises due to the shorter duration of either isolate training mode (Langleite et al. 2016; Stewart et al. 2005), and results in significant improvements to components of MetS (Ostman et al. 2017). A recent systematic review found no randomised controlled trials of CT in adults with MetS but without type 2 diabetes (Wewege et al. 2018), indicating a lack of research within high-risk adults without pre-existing cardiometabolic disease. Though studies have been performed in other populations, they rarely evaluate MetS as a binary variable due to limits in study power and the sensitivity of the dichotomous variable to effects of CT (Bateman et al. 2011; Ramirez-Velez et al. 2020).

Research has reported mixed effects of CT on components of MetS in adults without pre-existing metabolic conditions (Mann, Beedie & Jimenez 2014). The randomised controlled trial by Tseng et al. (2013) reported improvements in HDL-C, WC, SBP, DBP, glucose and

triglycerides after 12 weeks of CT in obese males (n=10, 22±1 y) (Tseng et al. 2013). However, Ho et al. (2012) showed a decrease in WC, but no change in lipid profile following 12 weeks of CT in 64 inactive, overweight or obese adults (Ho et al. 2012). Other research in 104 inactive older adults (64±6 y) reported reductions in WC, HDL-C and DBP, but no change in SBP, triglycerides or glucose after 6 months of CT (Stewart et al. 2005). Similar mixed findings have been shown in individuals with MetS. A meta-analysis of randomised or controlled trials in adults with MetS found that CT decreased WC (MD=-3.8 cm, 95%CI=-5.65,-1.95, P<0.001) and SBP (MD=-3.79 mmHg, 95%CI=-6.18,1.40, P=0.002), and increased HDL-C (MD=0.14 mmol/L, 9%CI=0.04,0.25, P=0.009), but did not affect DBP, glucose or triglycerides (Ostman et al. 2017). Though mixed, the significant results from previous research indicate that CT can improve components of MetS, justifying its application in high-risk populations such as academics.

To date, very few studies have investigated the impact of CT on components of MetS in either the desk-based or academic workplace. Karatrantou (2020) reported a significant decrease in SBP (-8±7%) and DBP (-5±4%) following 6 months of CT in 36 inactive desk-based workers (P<0.001), but other components of MetS were not evaluated. This lack of research is surprising given that desk-based workers who meet physical activity guidelines are less likely to have MetS (Browne et al. 2017). Evaluating the impact of a CT program on components of MetS in inactive academics may be of particular interest for the tertiary education sector, as MetS has a negative association with not only cardiometabolic health but also productivity (Schultz & Edington 2009).

Concurrent Training for Aerobic Capacity in the Academic Workplace

Regular CT results in large improvements in aerobic capacity. Participation in three CT sessions per week for 12 weeks resulted in an 11% improvement in VO_{2max} (P=0.026) in 17 inactive adults (54±5 y) (Amaro-Gahete et al. 2019). This compares to a 6% increase in VO_{2max} after 2-3 CT sessions per week for 24 weeks in 34 moderately physically active males (30±5 y) (Schumann et al. 2014). Despite the influence that differences in age, sex and baseline training status can have on aerobic capacity (Aspenes et al. 2011; Kaminsky et al. 2017), both studies showed significant improvements in VO_{2max}, highlighting the consistent effect of CT on aerobic capacity. This is further demonstrated in studies comparing the effects of CT and endurance training on aerobic capacity. Slentz et al. (2011) found that CT and endurance training resulted in similar improvements in VO_{2peak} (≈14%) following 8 months of training (Slentz et al. 2011). However, the CT group performed the entire endurance training program in addition to resistance training, resulting in significantly higher training volume which likely affected outcomes (Bonafiglia et al. 2021). Regardless, Schroeder et al. (2019) reported similar increases in VO_{2peak} following 8 weeks of either CT (n=18) or endurance training (n=17, P>0.05) in inactive adults, whereby CT involved half the duration of endurance training in the endurance group (Schroeder et al. 2019). Meta-analyses have also reported no difference in the effect of endurance training compared to CT on aerobic capacity in overweight or obese adults (O'Donoghue et al. 2021; van Baak et al. 2021). Accordingly, CT is an effective exercise mode to increase aerobic capacity to a similar extent as endurance training, which is important for desk-based workers at increased risk of low aerobic capacity due to low levels of physical activity.

Implementing CT within the inactive desk-based workplace has been shown to counter the detrimental impact of low physical activity on aerobic capacity. A quasi-experimental study

reported significant increases in aerobic capacity as measured indirectly by a 6 min walking test following 3 times/week CT for 12 weeks in 47 desk-based workers (Saavedra et al. 2021). Similarly, 10 months of CT in 224 desk-based workers from a university showed significant increases in estimated aerobic capacity (via HR response to a step test) (Genin et al. 2018). However, only 55% of participants adhered to the whole intervention (Genin et al. 2018). Exercise adherence is particularly important for aerobic capacity given the dose-response relationship that has been previously demonstrated (Bonafiglia et al. 2021). Hunter et al. (2020) compared the effects of 16 weeks of supervised and non-supervised CT on aerobic capacity in 85 university staff (47% academic and 53% other university staff) and reported a significantly higher increase in VO_{2peak} after supervised CT (10±11%) compared to unsupervised CT (4±9%, $P<0.05$) (Hunter et al. 2020). Importantly, exercise adherence was also significantly higher in supervised compared to unsupervised CT ($P<0.05$). Indeed, exercise adherence has been shown to increase with supervised training, and training conducted during work hours (Hunter et al. 2020; Jakobsen et al. 2015). These factors are important to consider for inactive academics with long work hours, who may experience difficulties in adhering to exercise due to lack of training experience and less leisure-time to engage in exercise (Kirk & Rhodes 2011). Although CT has been previously implemented within the university environment, its effect on aerobic capacity in inactive academics is yet to be assessed.

Concurrent Training for Body Composition in the Academic Workplace

CT provides concurrent adaptations from endurance and resistance training (Coffey & Hawley 2016), resulting in improvements to both fat mass and lean mass in inactive adults (Stewart et al. 2005; Willis et al. 2012). Donges et al. (2013) reported a significant decrease in body fat (%; 6±2%) after 12-weeks of CT in 47 inactive males (Donges et al. 2013), in which participants trained 3 times per week and endurance training made up approximately 50% of

each session (Donges et al. 2013). In comparison, Willis et al. (2012) showed significant but small decreases in fat mass (%; 2±3%) and WC (2%) following 8 months of CT in inactive adults ($P<0.01$), wherein participants also trained 3 times per week and endurance training accounted for approximately 40% of training time (Willis et al. 2012). Other CT interventions incorporating approximately 50% endurance training have resulted in decreases in WC and VAT (Stewart et al. 2005; Tseng et al. 2013). Indeed, the volume of endurance training is an important consideration in CT programs given it decreases fat mass and WC to a larger extent than resistance training (Schwingshackl et al. 2013). The proportion of CT dedicated to resistance training is also crucial for increasing lean mass given the evidence of a dose-response relationship (Figueiredo, de Salles & Trajano 2018). Most CT studies in which resistance training accounts for at least 50% of each session have resulted in increases in lean mass within inactive adults (Schroeder et al. 2019; Stewart et al. 2005; Willis et al. 2012). For example, Schroeder et al. (2019) showed a 1.5% increase ($P<0.05$) in lean mass after 8 weeks of CT, wherein resistance training accounted for 50% of each session (Schroeder et al. 2019). Willis et al. (2012) also reported a 1.5% increase in lean mass following 8 months of CT in inactive adults ($P<0.01$), in which 60% of CT was comprised of resistance training (Willis et al. 2012).

Notwithstanding the importance of the relative proportions of endurance and resistance exercise within CT for body composition, progressive overload is another training variable that facilitates improvements in body composition. Indeed, studies ensuring progressive overload of both endurance and resistance training report concurrent decreases in fat mass and increases in lean mass. Stewart et al. (2005) ensured relative progressive overload of endurance training by training participants at 60 to 90% of their max heart rate (HR) achieved in baseline testing. For resistance training, weight was increased when 15 repetitions could be completed with little difficulty (Stewart et al. 2005). In comparison, inactive participants in the 8 week study

by Schroeder et al. (2019) gradually progressed endurance training from 40% to 70% of their HR reserve, and resistance training was relatively progressed because participants completed repetitions (10 to 20) until failure (Schroeder et al. 2019). Both studies resulted in concomitant decreases in fat mass and increases in lean mass (Schroeder et al. 2019; Stewart et al. 2005). In turn, a CT program that provides appropriate progressive overload of endurance and resistance training may result in improvements to lean mass and fat mass within inactive academics, which could help reduce the risk of both cardiometabolic and mental disorders (Lee et al. 2018; Li et al. 2014).

There is limited research on the effects of CT on fat mass, fat distribution and lean mass in inactive academics, though studies in other desk-based workplaces have reported improvements in body composition following CT. Pedersen et al. (2009) showed a decrease in fat mass (%) following 6 months of CT in 549 desk-based workers ($P<0.01$), with training performed 3 times per week for 20 min (Pedersen et al. 2009). Furthermore, Karatrantou et al. (2020) reported significant improvements in fat mass (8±8%) and lean mass (4±3%) following 6 months of CT in 36 inactive desk-based workers, wherein CT was performed for 15 to 20 min twice per day for 5 days each week (Karatrantou et al. 2020). The randomised controlled trial in university staff by Hunter et al. (2020) found a within-group decrease in fat mass (2±2%) and increase in lean mass (1.2±1.2 kg) after 16 weeks of CT, though a significant interaction effect with the control group was only found for fat mass ($P<0.05$) (Hunter et al. 2020). These results clearly demonstrate the benefits of CT for body composition in inactive desk-based workers and justify an investigation of CT in academics given their low levels of total and MVPA may increase the risk of fat mass accumulation and lean mass deterioration.

Concurrent Training for Insulin Resistance in the Academic Workplace

Despite the negative association between physical activity and insulin resistance, CT interventions have shown mixed results in apparently healthy individuals and those with pre-existing cardiometabolic conditions. CT performed for 1 h, 3 times per week for 12 weeks did not change fasting glucose, insulin or HOMA-IR in 48 adults with type 2 diabetes (Jorge et al. 2011). However, 45 min of CT, 3 times per week for 12 weeks decreased fasting glucose, insulin and HOMA-IR in 40 obese males with MetS (Mohammad Rahimi, Bijeh & Rashidlamir 2020). Given the similar duration of both studies, exercise intensity may influence the effect of CT on insulin resistance. In the study by Mohammad Rahimi, Bijeh & Rashidlamir (2020), endurance training involved 4x4 min intervals at 90% HR_{peak} interspersed by 3 min at 70% HR_{peak} on a treadmill and resistance training gradually progressed from 2 sets of 15-20 repetitions at 40-45% one-repetition max (1RM) to 3 sets of 8 to 12 repetitions at 70-80% 1RM. However, Jorge et al. (2011) did not provide details of training intensity. Regardless, a meta-analysis of randomised controlled trials did not find a difference in the effect of moderate and high intensity exercise interventions on insulin resistance (Lin et al. 2015), though as previously discussed, higher intensity physical activity is associated with a greater reduction in risk of insulin resistance (Whitaker et al. 2019).

CT also has mixed effects on insulin resistance in apparently healthy adults (AbouAssi et al. 2015; Brunelli et al. 2015; Timmons et al. 2018). Timmons et al. (2018) reported no change in glucose, insulin or HOMA-IR following 12 weeks of CT performed 3 times per week for 40 min in 84 adults >65 y (Timmons et al. 2018). However, Brunelli et al. (2015) showed a significant decrease in glucose, insulin and HOMA-IR after 24 weeks of CT performed 3 times per week for 1 h in 30 inactive obese males (49±1) (Brunelli et al. 2015). Acknowledging the difference in age and sex in these studies, the Brunelli et al. (2015) study was twice the duration

of the Timmons et al. (2018) study, which may influence the effect of exercise on insulin resistance (Lin et al. 2015). However, CT studies > 24 weeks in duration have not altered insulin resistance in inactive adults without pre-existing metabolic disease (AbouAssi et al. 2015; Stewart et al. 2005), and the meta-analysis by Lin et al. (2015) did not find an effect of exercise intervention duration on glucose or insulin responses (Lin et al. 2015). Regardless, another meta-analysis of randomised controlled trials has shown that exercise reduces HOMA-IR in individuals with type 2 diabetes (SMD=-0.5, 95%CI=-0.83,-0.17, P=0.003) and those without (SMD=-0.31, 95%CI=-0.49,-0.13, P<0.001) (Battista et al. 2021). Overall, these mixed findings highlight the need for further research into the effect of CT on insulin resistance.

Minimal literature regarding the effects of CT on insulin resistance in the desk-based workplace is available, and no studies have been conducted within academic populations. A meta-analysis reported a significant decrease in fasting glucose following interventions used to increase physical activity in the workplace (Conn et al. 2009). However, few studies measured glucose or insulin (n=6), supervised exercise was only used in 27% of studies and the independent effect of exercise on insulin resistance was not explored (Conn et al. 2009). Although this meta-analysis was published before 2010, no recent research investigating the effect of CT on insulin resistance in the desk-based workplace exists, including academics. Such research is needed given the low levels of physical activity experienced in the desk-based workplace may increase the risk of insulin resistance and future chronic disease (Fuezeki, Engeroff & Banzer 2017; Ruijgrok et al. 2018).

Concurrent Training for Systemic Inflammation in the Academic Workplace

A chronic increase in systemic levels of IL-6 or TNF-α is associated with increased risk of depression, type 2 diabetes, and CVD (Kaptoge et al. 2014; Liu et al. 2016; Osimo et al. 2020).

Physical activity has a negative correlation with both chronic systemic IL-6 and TNF-α (Elosua et al. 2005; Hamer et al. 2012), suggesting the potential of exercise to protect against systemic inflammation. A systematic review revealed mixed effects of resistance and endurance training on IL-6 and TNF-α, but no change in these inflammatory markers was evident following CT in inactive adults free of pre-existing metabolic disease (Cronin et al. 2017). However, only 2 CT studies were found, indicating the need for further research in this type of population. Libardi et al. (2012) reported no changes in IL-6 or TNF-α in 47 inactive males after 16 weeks of CT (Libardi et al. 2012). CT was performed three times per week and included equal duration of endurance and resistance training (Libardi et al. 2012). Comparatively, Stewart et al. (2007) showed that CT 3 times per week for 12-weeks did not change IL-6 or TNF-α in inactive younger (25±5 y, n=14) or older (71±4 y, n=17) adults. CT involved endurance training on a treadmill for 20min at 70-80% HR reserve, and 2 sets of 8 resistance exercises performed at 70-80% 1RM (Stewart et al. 2007). Although low-grade systemic inflammation can increase the risk of type 2 diabetes and CVD in females (Hu et al. 2004; Pai et al. 2004), most CT studies in apparently healthy adults have been conducted with males (Brunelli et al. 2015; Donges et al. 2013; Ihalainen et al. 2018; Langleite et al. 2016). More research into the effects of CT on systemic levels of IL-6 and TNF-α in both males and females is required.

In contrast to the limited effect of CT on IL-6 and TNF-α in apparently healthy adults, mixed results have been found in individuals with cardiometabolic disease (Balducci et al. 2010; Jorge et al. 2011). Balducci et al. (2010) reported a significant decrease in IL-6 and TNF-α following 12 months of CT in 82 individuals with type 2 diabetes (Balducci et al. 2010). CT involved endurance training for 40 min at 70-80% VO_{2max} and resistance training for 20 min at 80% 1RM (Balducci et al. 2010). In contrast, Jorge et al. (2011) found no differences in IL-6 or TNF-α after 12 weeks in 48 adults with type 2 diabetes (Jorge et al. 2011). Interestingly, a

meta-analysis reported a positive association between exercise volume and IL-6, wherein IL-6 levels decreased by -0.018 pg/ml (95%CI=-0.035,-0.002) and -0.13 pg/ml (95%CI=-20.24,-0.02) for every additional session or week of training in an exercise program, respectively (Hayashino et al. 2014). This may explain the results of the previous studies, where there was a 4-fold difference in CT duration (Balducci et al. 2010; Jorge et al. 2011). Overall, the effect of CT on IL-6 and TNF-α is equivocal, and further research is required within populations at high-risk of low-grade systemic inflammation and cardiometabolic disease due to low levels of physical activity, such as academics (Cooper & Barton 2016).

To our knowledge, the effect of CT on systemic levels of IL-6 and TNF-α has not been evaluated within desk-based workers or academics. Endurance training performed 4 times per week for 8 weeks did not change systemic levels of IL-6 or TNF-α in 12 apparently healthy inactive workers from a workplace in the UK (Hewitt et al. 2008). Besides the small sample size, the intervention duration may have been insufficient to elicit changes in systemic inflammation given the importance of exercise volume for changes in IL-6 (Hayashino et al. 2014). Although the study did not investigate the effect of CT on IL-6 or TNF-α, the findings indicate the potential effect of CT on inactive academics given the similar demographics of the participants. Regardless, a study to evaluate the effect of CT on systemic inflammation in inactive academics is warranted because of the low levels of physical activity and high stress experienced in the academic workplace (Fontinha, Easton & Van Laar 2019; Safi et al. 2021), which are positively associated with low-grade systemic inflammation (Phillips, Dillon & Perry 2017).

Concurrent Training for Stress in the Academic Workplace

There is a bidirectional relationship between physical activity and stress (Schultchen et al. 2019; Stults-Kolehmainen & Sinha 2014). Increasing physical activity may help to reduce stress in highly-stressed populations, which is important given that chronic stress can increase the risk of depression and MetS (Kuo et al. 2019; Rugulies, Aust & Madsen 2017). Chovanec et al. (2020) showed a significant decrease in general stress following 8-weeks of either endurance (n=18) or resistance (n=21) training ($P<0.001$) in 65 female students, with no differences between groups ($P>0.05$). Given evidence of a synergistic effect of combined endurance and resistance training on symptoms of depression and anxiety (Oftedal et al. 2019), a similar effect may be evident for stress, though this is currently speculative. Regardless, CT interventions in the workplace have resulted in significant improvements in general stress (Atlantis et al. 2004; Greco 2020). Atlantis et al. (2004) reported a decrease in general stress ($P=0.036$, d =-0.56) following 24-weeks of CT and behaviour modification in 44 inactive casino employees. Furthermore, Greco (2020) showed a decrease in general stress (≈27%) in 42 workers from mixed professions after CT was performed 3 times per week for 8-weeks (Greco 2020). However, desk-based workers experience lower physical activity compared to other workers (Prince et al. 2019), and may subsequently be at increased risk of chronic stress (Gerber et al. 2014).

Limited studies have investigated the impact of CT on stress in desk-based workers, and no such studies have been performed in academics, despite evidence of inadequate physical activity and high job stress (Cooper & Barton 2016; Fontinha, Easton & Van Laar 2019). Genin et al. (2018) reported no change in general stress following 10-months of CT in 224 office workers. However, CT was only performed twice per week for 45 min, and 55% of participants did not complete the whole intervention (Genin et al. 2018). Indeed, adherence and exposure

to CT appears to be important for stress reductions, as studies with ≥80% CT adherence have resulted in significant improvements in stress (Atlantis et al. 2004; Greco 2020). In comparison, Nurminen et al. (2002) showed that 8-months of CT did not change stress in 260 female laundry workers (Nurminen et al. 2002). However, training was conducted once per week, and only around 50% of participants took part in at least two-thirds of the sessions (Nurminen et al. 2002). Exercise adherence may be particularly challenging for highly stressed workers given the negative association between stress and physical activity (Stults-Kolehmainen & Sinha 2014). In turn, CT within the academic workplace should include onsite training and supervision, which has been shown to increase adherence compared to unsupervised and home-based training (Hunter et al. 2020; Jakobsen et al. 2015).

Concurrent Training for Depression in the Academic Workplace

Symptoms of depression are highly prevalent amongst desk-based workers (Kang et al. 2016), particularly those in academia, who have presented with higher psychological strain compared to other professionals (Winefield et al. 2003). A meta-analysis has shown that CT decreases symptoms of depression to a greater extent than endurance or resistance training alone (Rethorst, Wipfli & Landers 2009), justifying an evaluation of its efficacy within the academic workplace. Support for the anti-depressive effects of CT have been reported in other desk-based workplaces (Atlantis et al. 2004; Genin et al. 2018). The 24-week CT study by Atlantis et al. (2004) reported a significant decrease in symptoms of depression (P=0.048, *d*=0.16) in 44 inactive casino employees. Participants were prescribed 3 d/week endurance training for at least 20 min, which progressed from 50-60% age-predicted HR_{max} to ≥75% age-predicted HR_{max}. Resistance training was prescribed at least 2 d/week and involved whole body exercises progressing from 15RM to <8RM (Atlantis et al. 2004). In comparison, Genin et al. (2018) reported a decrease in symptoms of depression following 10 months of CT in 224 desk-based

workers. The onsite CT program involved at least 1 resistance training session per week using weight machines for 45 min, and a 45 min aerobic gym class at least once per week (Genin et al. 2018). Despite the difference in CT prescription, both studies resulted in a decrease in symptoms of depression, highlighting the potential benefits of CT for inactive academics.

Recent systematic reviews and meta-analyses reveal the dearth of studies into the effect of CT on depression. For example, a 2016 meta-analysis of randomised controlled trials that investigated the effect of exercise on individuals with depression found only 3 CT studies, compared to 19 endurance training studies (Schuch, Vancampfort, Richards, et al. 2016). Although studies with non-clinical individuals have reported significant improvements in symptoms of depression (Annesi, Gann & Westcott 2004; Hilyer et al. 1982), most were published before 2005 and few have been performed within the workplace. Despite research showing a large effect of CT on symptoms of depression (Rethorst, Wipfli & Landers 2009), evidence of the effectiveness of CT in high-risk, but currently disorder-free populations is lacking.

Concurrent Training for Anxiety in the Academic Workplace

Although the relationship between anxiety and physical activity is still equivocal (McDowell et al. 2019; Schuch et al. 2019), exercise interventions have been shown to decrease symptoms of anxiety (Jayakody, Gunadasa & Hosker 2014). However, in line with findings for depression, most studies have investigated the effect of endurance exercise on anxiety, with limited data available on CT interventions (Jayakody, Gunadasa & Hosker 2014; Wipfli, Rethorst & Landers 2008). Only 1 CT study was found in a 2015 systematic review of randomised controlled trials investigating the effect of exercise on anxiety in individuals with elevated anxiety symptoms or an anxiety disorders (Stonerock et al. 2015). Indeed, Hovland

(2013) reported a significant decrease in symptoms of anxiety following 12-weeks of CT in 36 adults with an anxiety disorder (Hovland et al. 2013). Given the current research landscape, more studies are needed to clarify the effect of CT on anxiety, particularly within apparently healthy adults at high-risk of anxiety due to low levels of physical activity.

Australian academics experience higher psychological strain compared to other university staff (Winefield et al. 2003), indicating the need to evaluate interventions that may reduce anxiety in this population. CT interventions in other workers with low levels of physical activity have reported mixed results for anxiety. The study by Atlantis et al. (2004) did not show a change in symptoms of anxiety following 24 weeks of CT ($P=0.23$) (Atlantis et al. 2004). Furthermore, Saavedra et al. (2021) did not report a change in anxiety symptoms after 12-weeks of CT in 47 desk-based workers ($P>0.05$) (Saavedra et al. 2021). However, the 10 month CT intervention by Genin et al. (2018) resulted in a significant decrease in symptoms of anxiety ($P<0.001$) (Genin et al. 2018). Lucibello et al. (2019) showed that endurance training only reduced anxiety in participants with elevated symptoms at baseline (Lucibello, Parker & Heisz 2019). However, this fails to explain the previous contrasting findings as participants had normal scores for anxiety symptoms at baseline in all studies (Atlantis et al. 2004; Genin et al. 2018; Saavedra et al. 2021). These mixed results justify further research into the effect of CT on symptoms of anxiety in inactive workers such as academics.

Summary of the Literature

The desk-based workplace involves lower amounts of physical activity compared to other workplaces (Prince et al. 2019). Physical activity is negatively correlated with risk factors for cardiometabolic and mental health disorders, including fat mass (Shibata et al. 2016), insulin resistance (Whitaker et al. 2019), systemic inflammation (Hamer et al. 2012) and components

of MetS. Further, physical activity is negatively associated with symptoms of depression (Dishman, McDowell & Herring 2021; Zhang et al. 2017), anxiety (Stubbs, Koyanagi, et al. 2017), and stress (Stults-Kolehmainen & Sinha 2014). However, physical activity is positively associated with protective factors including lean mass and aerobic capacity (Kim et al. 2018; Mundwiler et al. 2017). Desk-based workers participating in low levels of physical activity may be at increased risk of developing depression, CVD and type 2 diabetes compared to other, more active workers (Kang et al. 2016). Academics are a particularly high-risk population due to the long work hours and higher job stress compared to other desk-based workers (Fetherston et al. 2020; Fontinha, Easton & Van Laar 2019). These variables may have a compounding effect on risk of depression and cardiometabolic disease because they are associated with both decreased physical activity and increased symptoms of depression (Fransson et al. 2012; Kirk & Rhodes 2011; Rugulies, Aust & Madsen 2017; Virtanen et al. 2018). Although academics may be at high-risk of depression, type 2 diabetes and CVD, no studies have measured risk markers for these disorders in this population.

The long work hours and high levels of stress experienced by academics may represent barriers to increasing physical activity (Kirk & Rhodes 2011; Stults-Kolehmainen & Sinha 2014). Interventions aimed at increasing physical activity in this population will likely need to be easily accessible and conducted during work hours to facilitate adherence (Jakobsen et al. 2015). CT has been previously implemented within the workplace and provides concurrent adaptations to endurance and resistance training (Coffey & Hawley 2016; Hunter et al. 2020; Wilson et al. 2012), resulting in improvements in body composition (Schroeder et al. 2019), aerobic capacity (Slentz et al. 2011), components of MetS (Ostman et al. 2017) and symptoms of depression and stress (Atlantis et al. 2004). Consequently, individuals participating in regular CT have a reduced risk of both depression and type 2 diabetes (Bennie et al. 2019;

Grontved et al. 2012). A supervised CT program within the academic workplace may help to improve cardiometabolic and mental health risk factors, and subsequently decrease the risk of chronic disease in this high-risk population. However, limited research has investigated the effect of CT on a range of risk factors for mental and cardiometabolic disorders in academics, or the interrelationships between these risk factors in inactive populations.

Chapter 3

Study 1

The Cardiometabolic and Mental Health of Inactive Academics in an Australian University.

Abstract

Academics experience high job stress, which can increase the risk of both cardiometabolic and mental disorders, including depression and cardiovascular disease. This cross-sectional study describes the cardiometabolic and mental health of academics and investigates relationships between mental and cardiometabolic health variables, including stress, depression and metabolic syndrome (MetS). Full-time, inactive academics (n=59; n=17 male, n=42 female) were recruited from an Australian University and completed questionnaires to measure effort-reward imbalance (ERI) and symptoms of stress, anxiety, distress and depression. Cardiometabolic health was assessed via blood pressure, body composition (Dual Energy X-ray Absorptiometry [DEXA]), peak oxygen consumption (VO_{2peak}) and metabolic syndrome criteria. Comparisons were made between sex and academic level, respectively, by way of welch's one-way analysis of variance. Quantile regressions at the median were used to investigate associations between cardiometabolic and mental health risk factors. Results indicate that 20% of participants met the criteria for MetS and 48% were overweight or obese. 22% reported moderate to severe symptoms of anxiety, stress and/or depression. Further, lower ranking academics experienced greater feelings of distress, depression and stress compared to their more senior colleagues ($P<0.05$). There were no differences in mental health outcomes between males and females ($P>0.05$). Regression analyses showed ERI was positively associated with depression ($P=0.002$), and depression was positively associated with MetS ($P=0.037$). In conclusion, inactive academics present with mental and cardiometabolic health characteristics which are shown to relate to an increased risk of depression and MetS. Future research should investigate the efficacy of preventative strategies known to improve both mental and cardiometabolic health in academics.

Introduction

Occupations that involve high volumes of office-based work, such as university academics, are often associated with low levels of physical activity and high job-related stress (Cooper & Barton 2016; Dedele et al. 2019; Gillespie et al. 2001). The academic workplace is often desk-based and includes competing teaching, administrative and research demands that can contribute to long work hours, high sedentary time and job-related stress (Kinman 2016; Siegrist 1996). Such inactive and stressful working environments may increase the risk of negative cardiometabolic and mental health outcomes, including reduced aerobic capacity and a higher likelihood of obesity (Bradbury et al. 2017; Zeiher et al. 2019), metabolic syndrome (MetS) (Laaksonen et al. 2002), cardiovascular disease and depression (Rugulies, Aust & Madsen 2017; Sara et al. 2018). However, further insights of the consequences of inactivity and stress on the cardiometabolic and mental health of academics remain to be fully explored.

Currently, separate studies from China and the United Kingdom have investigated the cardiometabolic health of University academic staff. Using the International Activity Questionnaire, Cooper and Barton (2016) found less than 30% of academics engaged in high levels of physical activity, and over 20% reported low physical activity levels. Moreover, Alkhatib (2015) reported that academics were predominately overweight, with male academics presenting with higher Body Mass Index (BMI) and blood pressure compared to females. CheSerek et al. (2014) also reported that nearly 5% of academic staff from a Chinese university met the criteria for MetS (Cheserek et al. 2014). Notwithstanding, there is limited research reporting more detailed risk factors of chronic disease, such as aerobic capacity, fat mass and markers of MetS within academics, particularly within the Australian University environment. Furthermore, given that inactivity is associated with depression in employees (Kang et al.

2016), it is prudent to investigate both cardiometabolic and mental health within inactive academics.

In regard to the mental health of academics, University employees experience greater feelings of stress, anxiety and depression compared to the general population (Mark & Smith 2012). Further, full-time academics report higher psychological strain compared to other university staff, including administrative and technical staff (Winefield et al. 2003). The poorer mental health of academics has been attributed to the increased work hours and job demands (Kinman & Jones 2008; Tytherleigh et al. 2005). Indeed, a high effort output (e.g. heavy workload) with a low reward input (e.g. low recognition) is associated with an increased risk of depression in the workplace (Rugulies, Aust & Madsen 2017; Siegrist 1996), though evidence from academia is limited (Kinman 2019). Interestingly, preliminary findings show lower ranking academics (ie. Lecturers or Assistant Professors) report significantly higher stress compared to more senior colleagues (i.e. Professors) (Abouserie 1996; Gmelch, Wilke & Lovrich 1986). Furthermore, while female academics report similar stress levels to males (Abouserie 1996; Barkhuizen & Rothmann 2008; Mudrak et al. 2017), they experience significantly higher psychological strain (Akhtar Malik 2018; Catano et al. 2010; Hogan et al. 2015), indicating worse mental health. Regardless, higher job stress, or an increased effort-reward imbalance (ERI) can increase the risk of developing both mental and cardiometabolic disorders (Rugulies, Aust & Madsen 2017; Sara et al. 2018). Given the stressful and often inactive academic workplace, further research on the interrelationship of cardiometabolic and mental health of academics is warranted.

The primary aim of this study is to describe the cardiometabolic and mental health of inactive full-time academics within an Australian University and compare cardiometabolic and mental

health risk factors by sex and academic level. A secondary aim is to report relationships between risk factors of metabolic disease and depression in academics. It is hypothesised that females and lower ranking academics will experience higher levels of depression compared to males and higher-ranking academics, respectively. Additionally, a bidirectional relationship is expected between mental and cardiometabolic health markers.

Methods

Participants

This study reports baseline data from a larger research project aiming to investigate the impact of concurrent exercise training on the cardiometabolic and mental health of inactive academics, hence only inactive participants were recruited. Recruitment and testing commenced in June 2019 (before COVID-19) following university ethics approval (HREC ETH18-3093). Fifty-nine full-time academics from a single Australian University centrally based in a metropolitan city were recruited via local advertising and email to staff within all Science, Technology, Engineering, and Mathematics (STEM) and Humanities, Arts, and Social Sciences (HASS) disciplines. Participants attended a familiarisation session to provide verbal and written informed consent prior to completing a health pre-screening questionnaire (Exercise and Sport Science Australia adult pre-exercise screening tool). Inclusion criteria included; 1) Physically inactive (Active Australia criteria; verbal and questionnaire-based assessment of <150 min/week of weighted physical activity, where vigorous activity minutes are doubled); 2) aged between 35 and 65 years; and 3) working a minimum of 35 h per week at the university as an academic. Exclusion criteria included 1) pregnancy; 2) previous diagnoses of metabolic disease or severe musculoskeletal disorders; 3) anti-inflammatory and/or pharmacological treatment that may interfere with metabolic blood markers and mental health measures.

Overview

Eligible participants undertook a 60 min testing session for mental and cardiometabolic health parameters and a 2-week period of data collection on lifestyle related variables. Cardiometabolic and mental health testing was conducted in a climate-controlled exercise physiology laboratory in July and August 2019. Mental health data were collected and managed using Research Electronic Data Capture (REDCap, version 8.11.3) hosted at the University of Technology Sydney (Harris et al. 2009). After an overnight fast (10-12 h) participants arrived at the testing facility between 6:00 and 9:00 am. Participants were required to avoid consumption of alcohol and refrain from exercise in the previous 24 h, wear basic exercise attire, void their bladder, and remove jewellery and metal objects. Participants undertook a series of tests; 1) mental health questionnaires, resting heart rate (RHR) and blood pressure in a private room; 2) body composition measurements via a Dual Energy X-ray Absorptiometry (DEXA) scan; 3) venous blood sample collection, and; 3) aerobic capacity measured via a graded exercise test. Further, work hours and sociodemographic variables (research discipline, academic level, number of years employed as an academic, age, sex) were recorded by participants on their smartphones or electronic devices using a downloaded software application (MetricWire Inc. 2019).

Measures

Psychological Distress

Psychological distress was measured using the Kessler Scale (K10) (Kessler et al. 2002). Each response is scored on a 5-point scale ranging from 1 = “none of the time” through to 5 = “all of the time”, where the scores are summed to provide an overall score of distress experienced over the past four weeks (Kessler et al. 2002). Scores range from 10-50 with higher scores

indicative of greater levels of psychological distress. The K10 has previous evidence of strong psychometric properties (Cairney et al. 2007; Furukawa et al. 2003; Kessler et al. 2002).

Depression, Anxiety and Stress

The Depression, Anxiety and Stress Scales-21 (DASS-21; Lovibond & Lovibond, 1995) was used to measure depression, anxiety and stress. The questionnaire includes 21-items (7 items per dimension) measured on a 4-point scale ranging from 0 = "never" to 3 = "almost always". Scores are summed to provide a quantitative measure of severity of depression, anxiety and stress, and risk of further problems (Lovibond & Lovibond 1995). For the depression domain, scores of 0-4 are considered normal, 5-6 mild, 7-10 moderate, 11-13 severe, and >14 extremely severe. For anxiety, 0-3 is considered normal, 4-5 mild, 6-7 moderate, 8-9 severe, and >10 extremely severe. For stress, 0-7 is normal, 8-9 mild, 10-12 moderate, 13-16 severe, and >17 extremely severe. The psychometric properties of the DASS-21 have been comprehensively evaluated, and it has been found to be valid, consistent, and responsive to treatment within adults (Henry & Crawford 2005; LeBouthillier & Asmundson 2017; Sinclair et al. 2012).

Job Stress

Job stress was measured using the 16-item version of the ERI questionnaire (Siegrist 1996). Participants responded to items via a 4-point Likert scale ranging from 1 = "strongly disagree" to 4 = "strongly agree". The scores for overcommitment (6 items) were summed, and an ERI score was calculated from effort (3 items) and reward (7 items) items according to instructions (Siegrist, Li & Montano 2014). Previously, the ERI questionnaire has shown good internal consistency, discriminant validity and criterion validity for all scales and the ERI ratio (Leineweber et al. 2010; Siegrist, Li & Montano 2014).

Daily Work Hours

Daily work hours were reported via the MetricWire software application (MetricWire Inc. 2019). Participants responding to the item; "how many hours did you work from (work/home) today" before night-time sleep, every night for 2-weeks. To assist with compliance, alert notifications were programmed into the software application to remind participants to respond to the questions in the evening at 21:00, with a reminder notification 15 min later if the participant had still not completed the items. Participants were included in analysis if they responded on at least 4 weekdays. Hours worked from home and from the workplace between Monday and Friday (i.e. weekdays only) were then summed and averaged to indicate daily work hours.

Blood Pressure and Heart Rate

Blood pressure and RHR were measured using the automated office blood pressure method. This required participants to rest in a seated position for at least 10 min, alone in a quiet room (Armstrong et al. 2015). An automated blood pressure device (Omron 907, Omron Healthcare, Australia) measured blood pressure three times, at 1-min intervals (SPRINT Research Group et al. 2015). The mean of the three readings was recorded. Participants were blinded to the measurement result, thereby avoiding any acute stress responses to the measure (Muldoon et al. 1995).

Anthropometry and Dual Energy X-ray Absorptiometry

Height was recorded using a stadiometer (Seca Asia-Pacific, Kuala Lumpur, Malaysia) and body mass was measured using a calibrated electronic scale (A&D Weighing, Sydney,

Australia) in minimal clothing and footwear removed. The resulting measurements were used to calculate body mass index (BMI). Waist Circumference was measured from the top of the iliac crest, at the end of normal expiration (NHLBI Obesity Education Initiative 2000). Measurements were repeated twice. If the difference between the two measurements was greater than 1cm, the two measurements were repeated and the mean calculated (World Health Organization 2011).

Provided no x-ray or nuclear medicine scans were undertaken in the preceding 7 days, participants underwent a whole-body DEXA scan in the supine position (Lunar Prodigy, GE Healthcare, Madison, WI, USA) (Shiel et al. 2017). The DEXA scan was used to measure whole-body total fat mass and lean mass (Shiel et al. 2017). DEXA scans have previously been found to produce valid and reliable measures of fat mass and lean mass (Freda et al. 2009; Glickman et al. 2004; Norcross & Van Loan 2004; Tavoian et al. 2019). DEXA calibration was performed before each testing round according to the manufacturer's guidelines. Scanning mode was set to manufacturer defaults based on participant size, at a resolution of 4.8 x 13 mm.

Venous Blood Collection

Approximately 8 mL of fasting venous blood was collected in a serum separator tube (SST). Following clotting, tubes were centrifuged at 1300 g for 10 min at 18 °C. Serum was immediately stored at −80°C until further analysis of lipid profile, LDL-C and glucose were measured using the enzymatic colour test and hexokinase method, respectively (Beckman Coulter AU5800; Beckman Coulter Inc., Brea CA, USA). Cholesterol hazard ratio was calculated as the total cholesterol divided by high-density lipoprotein cholesterol (HDL-C).

Aerobic Capacity

Aerobic capacity was assessed via the measurement of peak oxygen consumption (VO_{2peak}) during a graded exercise test on a mechanically-braked cycle ergometer (Watt-bike Pro, Nottingham, United Kingdom). Participants commenced the test at 25 watts (W) and increased power output by 25 W each minute until volitional exhaustion. The mean of the highest three consecutive periods (10 s) of oxygen consumption was used to determine $VO_{2peak.}$ Oxygen consumption was determined by measuring O_2 and CO_2 concentrations with a metabolic gas analyser (Medgraphics Ultima System, Saint Paul, USA). The metabolic cart was calibrated according to the manufacturer's instructions, involving a pneumotachometer calibration via a 3 L syringe, analysis of ambient air, and gas calibration with a gravimetric gas mixture of known concentrations [CO_2 5 (0.02)%; O_2 12 (0.02)%].

Metabolic Syndrome Classification

Metabolic syndrome was defined according to recognised criteria (Alberti et al. 2009). MetS was identified if participants presented with at least 3 of the following 5 elements: 1) elevated waist circumference (Waist circumference; male ≥ 94 cm, female ≥ 80 cm); 2) elevated triglycerides (Triglycerides; ≥ 1.7 mmol/L); 3) reduced high density lipoprotein cholesterol (HDL-C; < 1.0 mmol/L in males; < 1.3 mmol/L in females); 4) elevated blood pressure (BP) (systolic ≥ 130 and/or diastolic ≥ 85 mm Hg) or 5) elevated fasting glucose (≥5.6 mmol/L).

Statistical Analysis

All data are reported as mean ± SD. Normality and equal variance of data was assessed using the Shapiro-Wilk and Levenes test, respectively. Participant mental and cardiometabolic health variables were calculated and categorised by sex (male or female) and separately by academic level; 1) A/Lecturer and Lecturer; 2) Senior Lecturer, and; 3) A/Professor (ie. "Reader") and Professor. Due to unequal sample size between groups and unequal variance of data a Welch's

one-way analysis of variance was used to detect a group effect between academic levels. If there was a significant group effect Games-Howell post-hoc test was used to identify differences between groups.

To assess the second aim, a quantile regression model at the median (q 0.5) determined the associations between mental health (stress, depression, anxiety, distress) as dependent variables with ERI, overcommitment, work hours, VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$), MetS (binary groups) and fat mass (%) as independent variables when adjusting for age, sex and VO_{2peak} (not included when independent variable was VO_{2peak}). Quantile regressions (q 0.5) were further conducted to assess the association between cardiometabolic health (VO_{2peak}, fat mass) as the dependent variables with ERI, stress, depression, anxiety and distress as independent variables when adjusting for age, sex and VO_{2peak}. Chi-square tests were used to compare categorical variables (MetS and BMI groupings) between males and females. Data are reported as a coefficient with 95% Confidence Interval (95%CI). Binary logistic regressions were used to measure relationships between participants without MetS and with MetS (reference group), with ERI, stress, depression, anxiety and distress as independent variables when adjusting for age, sex and VO_{2peak}. The Hosmer-Lemeshow test was used to assess the goodness of fit of the models. Data are reported as an odds ratio (OR) with 95%CI.

Analyses were performed using SPSS Software, version 26 (IBM Corporation, Armonk, NY) and missing data were treated as missing data in analyses. Significance was accepted as $p<0.05$ and confidence was set at the 95% interval. A priori sample size calculation was performed on G*Power software (Version 3.1.9.3) (Faul et al. 2007) using VO_{2max} because of its importance as a dependent, independent and confounding variable. Based on previously published data on differences in VO_{2max} between age groups and sex of inactive adults (Aspenes et al. 2011),

sample size calculation was performed with an effect size of 0.45, alpha error of 0.05, and a power of 0.80. It was determined that a sample size of 51 participants would be required.

Results

Population Characteristics

The participants (n=59) were 71% female (n=42) and 29% male (n=17) with a mean age of 49.1 ± 8.6 y and self-reported workday of 8.5 ± 1.7 h (Table 3.1). The mean duration of employment in academia was 11.2 ± 7.0 y. The sample included participants from all academic levels (Associate lecturer: 5%, Lecturer: 39%, Senior lecturer: 29%, Associate Professor: 8%, Professor: 19%) with comparable representation from STEM (n=27) and HASS (n = 28) disciplines. Overall, 48% of participants were overweight (n=18, 31%) or obese (n=10, 17%) and 20% (n = 12) met the criteria for MetS (Tables 3.1 and 3.2). Twenty-two percent (n=13) of participants indicated moderate to severe symptoms of depression (n=4), anxiety (n=4) and/or stress (n=11). In relation to job stress, the mean scores for effort-reward imbalance and overcommitment indicate more effort outputs for each reward input.

Table 3.1. Sociodemographic Variables, Fitness and Body Composition of Inactive Academics.

Variables	Pooled	Male	Female	P value	A/Lecturer & Lecturer	Senior Lecturer	A/Professor & Professor	P value
n	59	17	42	-	26, M=4, F=22	17, M=6, F=11	16, M=7, F=9	-
Age (years)	49.1±8.6	48.5±8.9	49.3±8.6	0.751	46.3± 8.5*	49.6±8.3	53.4±7.6	0.034
Daily work (hours)	8.4±1.6	8.6±1.5	8.45±1.7	0.685	8.4±1.7	7.9±1.3	9.1±1.5	0.101
Employed in academia (years)	11.2±6.9	11.6±8.7	11.1±6.2	0.822	9.9±6.3	12.56±6.7	11.9±8.3	0.411
VO_{2Peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	28.5 ±6.54	33.5±5.1	26.4±5.9	<0.001	28.13±6 .91	29.96±5.36	27.66±7.14	0.510
RHR (bpm)	68±8	64.6 ±8.2	70.1±7.4	0.024	71±7†	63±9	71±7†	0.017
BMI (kg/m^{-2})	25.78±5.10	24.81±4.22	26.18±5.41	0.356	25.90±5.81	24.18±3.63	27.31±4.99	0.127
WC (cm)	93.3±11.5	93.6±11.5	93.1±11.6	0.877	92±11.8	90.6±10.4	98.3±11.2	0.119
Fat mass (kg)	26.49±11.02	21.57±7.57	28.48±11.64	0.020	26.83±12.92	23.57±8.40	29.04±9.98	0.242
Fat mass (%)	34.7±8.6	26.7±5	38±7.6	<0.001	35.9±9.0	32.3±7.9	35.4±8.7	0.372
Lean mass (kg)	45.17±8.00	54.2±8	41.51±4.28	<0.001	42.52±5.16	45.50±8.43	49.13±9.92	0.049

Note. All data reported as mean ± SD. Abbreviations: VO_{2Peak}, peak volume of oxygen consumed during graded exercise test; RHR, resting heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; WC, waist circumference

* Significantly different from A/Professor & Professor (P<0.05)

† Significantly different from Senior Lecturer (P<0.05)

Table 3.2. Components of the Metabolic Syndrome in Inactive Academics.

Variables	Pooled	Males	Females	P value	A/Lecturer & Lecturer	Senior Lecturer	A/Professor & Professor	P value
MetS (n)	12	5	7	0.457	7	0	5	-
SBP (mmHg)	121±16	128±19	118±14	0.035	122±20	116±7	125±13	0.072
DBP (mmHg)	75±11	80±13	74±10	0.082	77±13	70±6*	79±10	0.006
Glucose (mmol/L)	5.25±0.52	5.28±0.54	5.23±0.52	0.744	5.16±0.63	5.33±0.41	5.31±0.42	0.585
Total cholesterol (mmol/L)	5.58±0.96	5.36±1.06	5.68±0.91	0.284	5.45±0.86	5.38±1.10	5.96±0.95	0.196
Triglycerides (mmol/L)	1.24±0.59	1.43±0.72	1.15±0.51	0.127	1.26±0.70	1.15±0.45	1.26±0.55	0.791
HDL-C (mmol/L)	1.47±0.30	1.27±0.19	1.56±0.31	<0.001	1.49±0.29	1.50±0.37	1.42±0.29	0.701
LDL-C (mmol/L)	3.54±0.85	3.44±0.93	3.58±0.82	0.578	3.37±0.86	3.35±0.89	3.95±0.70	0.050
C:HDL (mmol/L)	3.91±0.88	4.28±0.93	3.74±0.81	0.045	3.79±0.92	3.66±0.75	4.29±0.81	0.087

Note. All data reported as mean ± SD. Abbreviations: HDL-C, high density lipoprotein; LDL-C, low density lipoprotein; C:HDL, total cholesterol to HDL-C ratio.

* Significantly different from A/Professor & Professor ($P<0.05$).

Table 3.3. Mental Health Outcomes for Inactive Academics.

Variables	Pooled	Males	Females	P value	A/Lecturer & Lecturer	Senior Lecturer	A/Professor & Professor	P value
Effort	9.71±2	9.47±1.7	9.81±2.12	0.757	9.77±1.84	9.29±2.57	10.06±1.57	0.585
Reward	19.93±3.7	19±3.69	19.55±3.73	0.611	18±3.38*	19.53±3.26	21.5±3.78	0.018
ERI	1.22±0.40	1.23±0.42	1.22±0.4	0.933	1.33±0.43	1.15±0.42	1.13±0.29	0.184
Overcommitment	16.42±3.38	16.41±3.02	16.43±3.55	0.985	17.12±3.41	15.94±3.54	15.81±3.15	0.388
Distress	17.83±4.70	16.53±3.73	18.36±4.98	0.131	19.85±4.80*	16.65±4.76	15.81±3.15	0.008
Depression	2.59±2.80	2.59±3.32	2.6±2.61	0.443	3.50±3.57*	2.53±2.10	1.19±0.98	0.004
Anxiety	2.10±2.08	1.41±1.37	2.38±2.26	0.184	2.62±2.19	1.65±2.26	1.75±1.57	0.261
Stress	6.37±3.74	5.35±3.5	6.79±3.79	0.174	8.38±3.76*†	5.59±3.00	3.94±2.59	<0.001

Note. All data reported as mean ± SD. Abbreviations: ERI, effort reward imbalance.

* Significantly different from A/Professor & Professor ($P<0.05$)

† Significantly different from Senior Lecturer ($P<0.05$)

Sex Differences

There were no significant differences for the prevalence of overweight and obesity between males (41%) and females (50%; p=0.744). In regard to WC, over 85% (n=36) of females and 50% (n=9) of males were above the threshold for abdominal obesity based on MetS criteria, with no significant difference between males and females on prevalence of MetS (P=0.457). When compared to females, males had significantly lower HDL-C (P<0.001), RHR (P=0.024), fat mass (kg; P=0.02) and fat mass (%; P<0.001). However, females had a lower VO_{2peak} (P<0.001), lean mass (kg; P<0.001), total cholesterol to HDL-C ratio (P=0.045) and SBP (P=0.035) compared to males. Other metabolic variables, age, work hours, years employed in academia and BMI did not differ by sex (P>0.05). Additionally, there were no differences in the values for mental health outcomes between males and females (P>0.05; Table 3.3). Of note, 12% of males and 26% of females had moderate to severe levels of stress (n=2 male, n=9 females), anxiety (n=0 male, n=4 females), depression (n=1 male, n=3 females), and/or distress (n=1 male, n=3 females).

Academic Level Comparisons

A/Professors and Professors were significantly older than A/Lecturers and Lecturers (P=0.025), though work hours and years employed in academia were not significantly different between academic levels (P>0.05; Table 3.1). There were no significant differences between academic rank for measures of VO_{2peak}, lean mass and absolute (kg) and relative (%) fat mass (P>0.05). Senior Lecturers had a lower RHR compared to A/Lecturers and Lecturers (P=0.018) and A/Professors and Professors (P=0.033). Metabolic variables such as glucose, triglycerides and cholesterol did not significantly differ between academic levels (P>0.05; Table 3.2).

A/Lecturers and Lecturers reported greater feelings of distress (P=0.006) and depression (P=0.011), alongside lower reward (P=0.014) compared to A/Professors and Professors (Table

3.3). A/Lecturers and Lecturers were also significantly more stressed than Senior Lecturers (P=0.027) and A/Professors and Professors (P<0.001). There were no significant differences between groups in ERI, overcommitment, effort or anxiety between academic levels (P>0.05).

Relationships Between Cardiometabolic and Mental Health Outcomes

Results of the quantile regression analysis revealed that increased ERI was associated with increased stress (P=0.013) and depression (P=0.002), but not anxiety or distress (P>0.05; Table 3.4). Overcommitment was associated with increased stress (P=0.043) and distress (P=0.029), but not with anxiety or depression (P>0.05). VO_{2peak}, MetS and fat mass (%) were not associated with any dependent mental health variables. Anxiety was negatively associated with VO_{2peak} (P=0.017; Table 3.5), but ERI, depression, stress and distress had no association with VO_{2peak} or fat mass. The results of the binary logistic regressions showed that individuals with higher depression scores (P=0.037) and distress (P=0.016) were more likely to have MetS (Table 3.5). ERI, stress and anxiety were not associated with MetS (P>0.05).

Table 3.4. Cardiometabolic Risk Factors and Job Stress in Association with Mental Health Outcomes.

	Dependent Variables							
	Stress	**P**	**Depression**	**P**	**Anxiety**	**P**	**Distress**	**P**
ERI	3.65 (0.80,6.50)	0.013	2.616 (1.029,4.203)	0.002	0.280 (-1.077,1.637)	0.680	1.440 (-2.264,5.144)	0.439
Overcommitment	0.355 (0.012,0.699)	0.043	0.143 (-0.091,0.377)	0.226	0.054 (-0.098,0.206)	0.482	0.474 (0.051,0.897)	0.029
VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	0.086 (-0.144,0.317)	0.454	0.000 (-0.141,0.141)	1.000	-0.078 (-0.176,0.021)	0.120	-0.214 (-0.485, 0.057)	0.120
MetS	-3.418 (-7.656,0.820)	0.112	-1.000 (-3.042,1.042)	0.330	-1.137 (-2.682,0.407)	0.145	-0.704 (-4.479,3.071)	0.710
Fat Mass (%)	-0.005 (-0.221,0.212)	0.966	0.000 (-0.132,0.132)	1.000	0.020 (-0.077,0.118)	0.678	-0.035 (-0.290, 0.220)	0.785
Total work hours	-0.032 (-0.974,0.910)	0.946	0.000 (-0.650,0.650)	1.000	0.127 (-0.273,0.526)	0.527	-0.028 (-1.12,1.064)	0.959

Note. Quantile regressions are reported as coefficients (95% confidence intervals) at the median (q 0.5). Mental health outcomes are reported as dependent variables and independent variables are adjusted for age, sex and VO_{2peak}, while VO_{2peak} is adjusted for age and sex only. Final sample n=59

Table 3.5. Mental Health Variables in Association with Cardiometabolic Health Outcomes.

	VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	**P**	**Fat Mass (%)**	**P**	**MetS**	**Goodness of fit**	**P**
ERI	-0.362 (-5.044, 4.320)	0.877	-1.029 (-6.880, 4.823)	0.726	0.848 (0.115, 6.232)	0.009	0.871
Stress	0.008 (-0.500,0.517)	0.974	0.127 (-0.474, 0.728)	0.673	1.251 (0.959, 1.632)	0.679	0.098
Depression	0.095 (-0.551,0.740)	0.770	0.393 (-0.472,1.258)	0.366	1.406 (1.020, 1.938)	0.189	0.037
Anxiety	-1.062 (-1.927, -0.197)	0.017	0.333 (-0.757, 1.422)	0.543	1.555 (0.970, 2.492)	0.445	0.067
Distress	-0.124 (-0.509, 0.261)	0.521	0.380 (-0.169, 0.929)	0.171	1.634 (1.096, 2.436)	0.737	0.016

Note. Quantile regressions are reported as coefficients (95% confidence intervals) at the median (q 0.5). Cardiometabolic health outcomes are reported as dependent variables and independent variables are adjusted for age, sex and VO_{2peak}, while VO_{2peak} is adjusted for age and sex only. Final sample n=59.

Binary logistic regressions are reported as Odds Ratios (95% confidence intervals) and goodness of fit was determined by the Hosmer-Lemeshow test. MetS (reference group) is reported as the dependent variable and ERI, stress, depression, anxiety and distress as independent variables when adjusting for age, sex and VO_{2peak}. Final sample n=59.

Discussion

The main findings of this study reveal that 20% of inactive academics are classified as having MetS and nearly half are overweight or obese, whilst one in five reports experiencing moderate to severe symptoms of anxiety, stress and/or depression. In particular, lower ranking academics (A/Lecturers and Lecturers) experience significantly greater feelings of distress, depression and stress compared to their more senior colleagues. Furthermore, higher job stress was associated with higher depressive symptoms, and higher distress and depressive symptoms were associated with an increased likelihood of MetS. These results indicate that inactive academics experience poor cardiometabolic and mental health, with lower ranking academics reporting worse mental health compared to their higher ranked colleagues.

There were no significant sex differences in mean scores for job-specific and general stress, which supports previous research in academics from Universities in the United Kingdom (Abouserie 1996), Czech Republic (Mudrak et al. 2017), and South Africa (Barkhuizen & Rothmann 2008). Furthermore, A/Lecturers and Lecturers had similar ERI to higher ranking academics, which is surprising given the higher stress reported by A/Lecturers and Lecturers. Notwithstanding, ERI had a positive association with stress and depression, which concurs with a previous meta-analysis of prospective studies on workplace mental health in the US, Europe and Canada (Rugulies, Aust & Madsen 2017). In contrast, previous research within the academic population has reported limited support for a relationship between ERI and mental health as measured by the General Health Questionnaire (Kinman 2019). These contrasting results may be explained by the measurement scales used, as psychological strain measured by the General Health Questionnaire does not exclusively incorporate symptoms of depression (Goldberg 1988). Indeed, other components of mental health that are measured by the General Health Questionnaire such as anxiety and distress were not associated with ERI. Regardless,

inactive academics indicated more effort outputs for reward input, and this effort-reward imbalance was associated with greater feelings of depression.

We found no significant sex differences in mean scores for depression, anxiety or stress. These findings contrast with those from Irish, Finnish, Pakistani and Canadian Universities, in which female academics had poorer mental health compared to male academics (Akhtar Malik 2018; Catano et al. 2010; Hogan et al. 2015). Interestingly, in studies where academic and support staff have been pooled for analysis, mixed results for sex differences in mental health outcomes have been reported (Hogan, Carlson & Dua 2002; Tytherleigh et al. 2007; Winefield et al. 2003; Winefield & Jarrett 2001). This indicates that sex differences in mental health are contextual, being influenced by occupation (e.g. support vs academic staff) and work environment (e.g. socio-cultural setting) (Emslie et al. 2002). A/Lecturers and Lecturers reported more feelings of stress, depression and distress compared to higher ranking academics, which supports findings of lower ranked academics reporting higher self-reported stress at Universities in the United States (Gmelch, Wilke & Lovrich 1986) and United Kingdom (Abouserie 1996). The sources of stress that contribute to this disparity are still to be elucidated; however, frequently cited academic stressors include heavy workload, organisational structure, and administration and bureaucracy (Kinman 2001). Reducing job stress is important given the positive association between ERI and depression, and the finding of a bidirectional relationship between depression and MetS in a previous meta-analysis (Pan et al. 2012). Although participants were not clinically diagnosed with depression, the current study found higher symptoms of depression and distress were associated with increased likelihood of MetS. However, our hypothesis was only partially supported, as the relationship was not bidirectional. Notwithstanding, there are shared risk factors which may underlie the relationship between depression and MetS, including systemic inflammation (Dowlati et al. 2010; Wang et al. 2013),

low aerobic capacity and high adiposity (Alshehri et al. 2019; Laaksonen et al. 2002). These findings are novel given that associations between these cardiometabolic and mental health variables have not been previously explored in academics.

Consistent with previous studies, females had higher fat mass and lower lean mass and VO_{2peak} compared to males (Imboden, Swartz, et al. 2017; Imboden, Welch, et al. 2017; Kaminsky et al. 2017), but no differences were evident between academic levels. Previous research within academics has used BMI as measure of body composition, which is unable to differentiate fat and lean mass (Muller et al. 2012). Nonetheless, Alkhatib (2015) reported BMI values (26 kg/m^2) from 23 UK academics that are comparable to the present study. However, in contrast with our findings, the study reported a significantly higher BMI in male compared to female academics, and no sex-based differences in VO_{2peak} (Alkhatib 2015). The inactive status of the current cohort likely explains the high prevalence of overweight and obese classifications and may not be completely representative of the wider Academic cohort. Regardless, 48% of participants were overweight or obese and over 75% exceeded the WC threshold for abdominal obesity. These indicators of adiposity represent an increased risk of developing chronic diseases including type 2 diabetes and depression (Lee et al. 2009; Luppino et al. 2010).

Low physical activity and aerobic capacity and high adiposity are risk factors for both depression and MetS (Laaksonen et al. 2002; Schuch et al. 2018). Indeed, the current study found that 20% of academics met the MetS criteria, which contrasts with the 13% of individuals without diabetes diagnosed with MetS in the general Australian population (Cameron et al. 2007), and with the results from a large cross-sectional study of staff from a University in China, where 5% of academics were diagnosed with MetS (Cheserek et al. 2014). Furthermore, the mean distress scores place this cohort in the 75^{th} percentile of distress in Australian adults

(Slade, Grove & Burgess 2011). Despite the concomitant high scores of distress and prevalence of MetS, there was no relationship between depression and known cardiometabolic risk factors for MetS, such as low aerobic capacity or high adiposity. However, anxiety was negatively associated with $VO_{2peak,}$ which is contrary to previous cross-sectional and longitudinal research showing a negative association between aerobic capacity and depression, and no relationship between aerobic capacity and anxiety (Shigdel et al. 2019). Regardless, the association between symptoms of depression and MetS, and symptoms of anxiety and aerobic capacity, provide evidence of a unidirectional association between mental and cardiometabolic health risk factors.

Limitations

A limitation of this study is the generalizability of the findings, given the relatively low sample size and selective bias of only inactive academics from a single Australian University. Indeed, the mental and cardiometabolic health of academics may vary depending on the work environment and culture (Akhtar Malik 2018; Cheserek et al. 2014). However, recruitment of academics from a single university facilitated the more detailed and objective measurement of various cardiometabolic health markers alongside mental health. The cross-sectional nature of the study allows us to identify associations between mental and cardiometabolic health variables, but causation cannot be implied. Future longitudinal research with larger cohorts will help in understanding causation. Within the current cohort, the unequal distribution of males and females between academic levels may have influenced cardiometabolic health comparisons between groups given the effect of sex on fat mass, lean mass and aerobic capacity. Another general limitation of MetS and mental health research are the different diagnostic criteria's causing difficulties when comparing studies. Nevertheless, the quantitative

measurements utilised in the current study enabled a detailed analysis of the cardiometabolic and mental health of inactive academics, and the relationship between these variables.

Conclusions

We found evidence of a poor mental and cardiometabolic health profile among inactive academics. Lower ranking academics had worse mental health compared to higher ranking academics, though reasons for this remain equivocal (Kinman 2001). Our results indicate that inactive academics experience an ERI, and that increased ERI was associated with increased symptoms of depression. Further, increased symptoms of depression were associated with an increased likelihood of MetS. Given the absence of known metabolic disease, there is a high prevalence of MetS, overweight and obesity in currently healthy inactive academics. Future research should investigate the efficacy of preventative interventions such as exercise, which is known to improve mental and cardiometabolic health.

Chapter 4

Study 2

Effects of Concurrent Exercise Training on Body Composition, Systemic Inflammation and Components of Metabolic Syndrome in Inactive Tertiary Academics; a Randomised Controlled Trial.

Abstract

The low levels of physical activity in the academic workplace may increase the risk of cardiometabolic disease. This randomised controlled trial investigated the effect of 14-weeks of concurrent exercise training (CT) on components of metabolic syndrome, body composition, insulin resistance and markers of systemic inflammation in inactive full-time academics. Fifty-nine inactive academics from an Australian university were randomised into CT (n=29) or control (n=30) groups. CT performed supervised exercise training at an onsite facility 3 times per week for 14 weeks, whilst control maintained their normal lifestyle. Pre- and post the intervention period, Dual Energy X-ray Absorptiometry measured fat mass, lean mass and central adiposity. Fasting blood samples were analysed for interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), glucose, and lipid profile. Results showed a decrease in fat mass (%) in CT ($P<0.001$) but not in control ($P=0.937$). Android fat mass decreased in CT ($P=0.042$), without change in control ($P=0.105$). Visceral adipose tissue decreased in CT ($P=0.021$) but not in control ($P=0.199$). Waist circumference increased in control ($P=0.001$) but did not change in CT ($P=0.474$). Lean mass increased in CT ($P<0.001$) and did not change in control ($P=0.413$). Aerobic capacity also increased in CT ($P<0.001$) but not in control ($P=0.769$). There were no changes in IL-6, TNF-a, HOMA-IR, glucose or lipid profile in CT or control groups ($P>0.05$). Changes in insulin resistance were positively associated with interleukin-6 in the control group only. In conclusion, CT is effective in improving aerobic capacity, lean mass and total and central fat mass in the academic workplace, thereby improving some of the risk factors associated with low levels of physical activity.

Introduction

Tertiary academia is a predominantly desk-based workplace, wherein over 66% of academics report low-moderate levels of physical activity (Cooper & Barton 2016). Low levels of physical activity can increase risk-factors associated with cardiometabolic disease, such as increased fat mass (Leskinen et al. 2009; Shibata et al. 2016), chronic systemic inflammation (Hamer et al. 2012) and insulin resistance (Tsenkova 2017), whilst reducing protective factors such as lean mass and aerobic capacity (Aspenes et al. 2011; Fukumoto et al. 2018; Shephard et al. 2013). Furthermore, there appears to be an underlying association between risk factors, whereby markers of chronic systemic inflammation such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) have been associated with increased insulin resistance and fat mass (Hivert et al. 2008; Park, Park & Yu 2005), and decreased muscle mass (Tuttle, Thang & Maier 2020). Accordingly, increasing physical activity in inactive academics may decrease the risk of MetS (Zhang et al. 2017) and the onset of cardiometabolic disease (Kraus et al. 2019; Smith et al. 2016b).

Many workplaces assist employees to counter inactive lifestyles via exercise interventions to increase moderate to vigorous physical activity and improve aerobic capacity (Prieske et al. 2019), body composition (de Sevilla et al. 2021) and components of MetS (Cuddy, Ramos & Dalleck 2019). Onsite exercise interventions may be particularly effective within the academic workplace, where the engagement in moderate to vigorous physical activity is minimal (Safi et al. 2021), and long work hours can limit the leisure-time available for exercise (Fetherston et al. 2020; Kirk & Rhodes 2011). However, despite the health consequences of low physical activity, the effectiveness of exercise training programs within tertiary academic populations remains to be fully explored.

Workplace exercise interventions often consist of endurance or resistance exercise, that result in distinct physiological benefits (Fyfe, Bishop & Stepto 2014; Grgic et al. 2019). Combining the modes as concurrent training (CT) can provide combined health benefits within previously inactive adults (Willis et al. 2012). Indeed, CT increases aerobic capacity and muscle strength (Donges et al. 2013), and decreases body fat (Timmons et al. 2018), total cholesterol and triglycerides within inactive adults (Libardi et al. 2012). However, there are conflicting results on the impact of CT on systemic inflammation in healthy adults (Donges et al. 2013; Ihalainen et al. 2018; Libardi et al. 2012), whereby only individuals with higher chronic systemic inflammation at baseline have significant reductions in response to exercise (Lakka et al. 2005). Regardless, CT is known to improve insulin resistance and body composition (Slentz et al. 2011), warranting an investigation into the association between changes in these variables and alterations in IL-6 and TNF-α. Whilst CT has been shown to increase VO_{2peak} and strength, and decrease fat mass in university staff (e.g. academics, technical and professional staff) (Hunter et al. 2020); the protective effects of a CT intervention within the academic workplace remain to be explored in more detail.

The primary aim of this study is to determine the effect of a 14-week concurrent exercise training program on components of MetS, insulin resistance, body composition and markers of systemic inflammation in inactive full-time academics from an Australian University. A secondary aim is to investigate associations between changes in systemic inflammation with changes in insulin resistance and body composition. We hypothesised that body composition, insulin resistance, systemic inflammation and components of MetS will improve with CT compared to control. Furthermore, positive associations are expected between changes in inflammatory cytokines with changes in body composition and insulin resistance.

Methods

Participants and study design

Participants from an Australian metropolitan university were recruited via local advertising and email to all academic staff. Potential participants attended a familiarisation session to provide verbal and written informed consent prior to completing a health pre-screening questionnaire (Exercise and Sport Science Australia adult pre-exercise screening tool). Inclusion criteria included 1) Physically inactive (Active Australia criteria; verbal and questionnaire-based assessment of <150 min/week of weighted physical activity); 2) aged between 35 and 65 years; and 3) working a minimum of 35 h per week at the university as an academic. Exclusion criteria included 1) pregnancy; 2) previous diagnoses of metabolic disease or musculoskeletal disorders; 3) pharmacological treatment for depression, diabetes, cardiovascular disease or inflammation; and 4) contraindications to exercise as identified in the health pre-screening.

Participants (n=59) were stratified by age, gender and peak oxygen consumption (VO_{2peak}), and matched to the nearest neighbour. Matched participants were randomised in parallel groups of CT (n=29), or non-exercise control (n=30) at a 1:1 ratio. An independent third party generated a series of numbers via a computerized random number generator and another third party allocated matched participant codes according to the random number sequence (Urbaniak & Plous 2019). The study was approved by the Human Research Ethics Committee at the University of Technology Sydney (HREC REF: ETH18-3093) and registered with the Australian New Zealand Clinical Trials Registry (ACTRN12619000608167). Recruitment and testing commenced in June 2019 and was completed in December 2019. Schematic diagram of recruitment, retention and follow-up is shown in Figure 4.1.

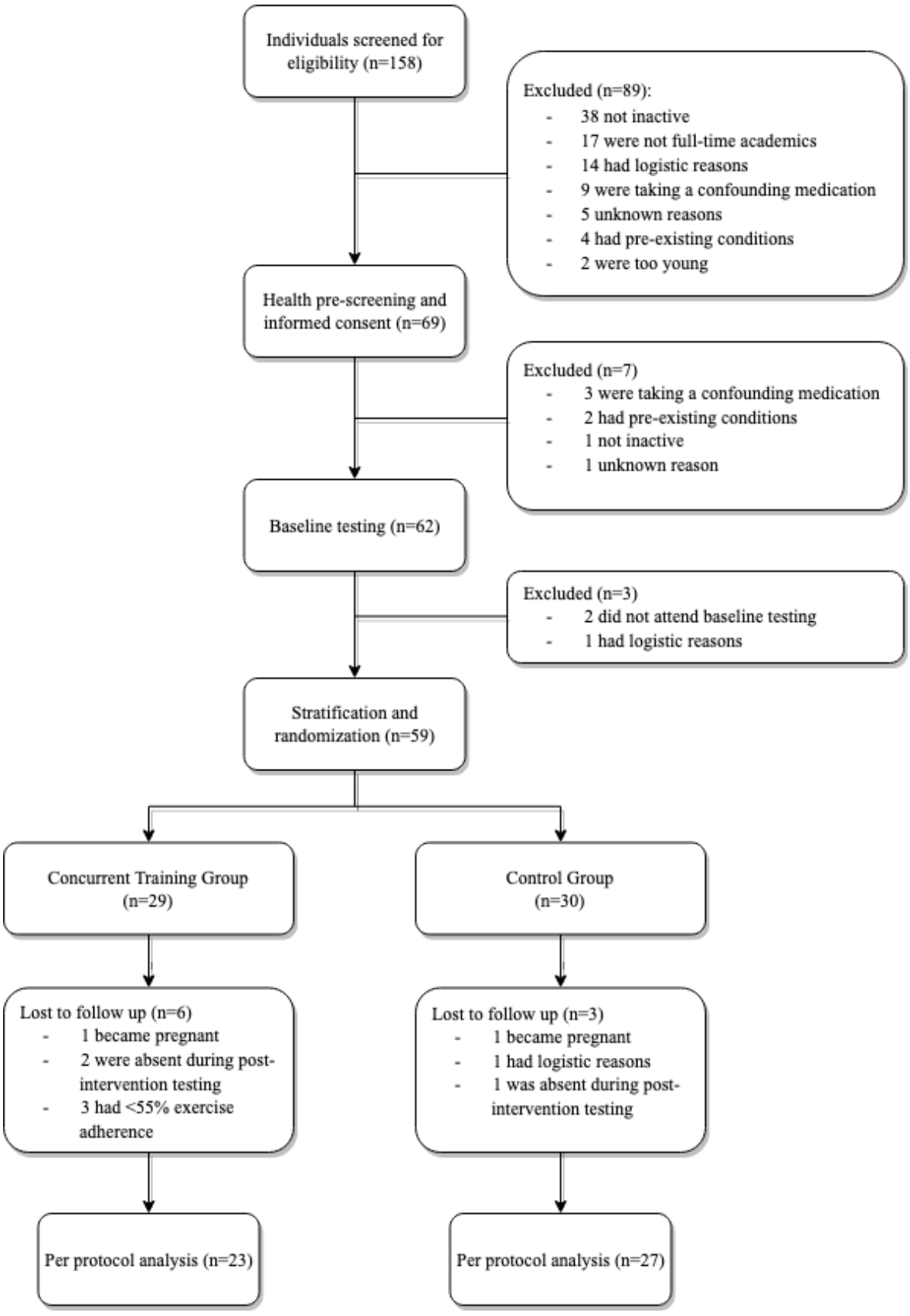


Figure 4.1 Consolidated Standards of Reporting Trials (CONSORT) Flow Diagram

Overview

Participants undertook a 60 min testing session for cardiometabolic health parameters and a 2-week period of data collection on lifestyle related variables before (July and August 2019) and after (November 2019) the 14-week intervention. Testing was conducted in a climate-controlled exercise physiology laboratory and outside of the primary teaching session. All assessors who measured key outcomes were blinded to group allocation. Participants arrived in a fasted state (10-12 h) at the testing facility between 6:00 and 9:00 am. Participants were required to avoid consumption of alcohol and refrain from exercise in the previous 24 h, wear basic exercise attire, void their bladder, and remove jewellery and metal objects. Participants then performed a series of tests, including 1) self-reported physical activity, blood pressure and resting heart rate (RHR); 2) body composition via a Dual Energy X-ray Absorptiometry (DEXA) scan and anthropometry; 3) fasting venous blood sample collection, and; 4) aerobic capacity measured via a graded exercise test (GXT). Further, sociodemographic variables (research discipline, academic level, number of years employed as an academic, age, sex) were completed by participants on their smartphones or electronic devices using a downloaded software application (MetricWire Inc. 2019).

Procedures

Leisure-time Physical Activity

Leisure-time physical activity (including the CT sessions) was measured using the Godin Leisure-Time Exercise Questionnaire (GLTEQ), which is reported to have appropriate validity and reliability (Godin & Shephard 1997). The GLTEQ includes 3-items used to measure the frequency of mild, moderate, and strenuous exercise during a normal 7-day period. Each exercise intensity is weighted and multiplied by how often it is performed and then scores are summed to provide a total weekly leisure activity score.

Blood Pressure and Heart Rate

Participants rested in isolation in a seated position for at least 10 min (Armstrong et al. 2015). An automated blood pressure device (Omron 907, Omron Healthcare, Australia) then measured the respective means of RHR and blood pressure from 3 separate measures recorded at 1-min intervals (SPRINT Research Group et al. 2015). Participants remained blind to the measurement result, thereby avoiding any acute stress responses to the measure.

Anthropometry and Dual Energy X-ray Absorptiometry

Height was recorded using a stadiometer (Seca Asia-Pacific, Kuala Lumpur, Malaysia) and body mass was measured using a calibrated electronic scale (A&D Weighing, Sydney, Australia) in minimal clothing and without footwear. The resulting measurements were used to calculate body mass index (BMI). Waist Circumference (WC) was measured from the top of the iliac crest, at the end of normal expiration (NHLBI Obesity Education Initiative 2000), and repeated twice. If the difference between the two measurements was greater than 1 cm, the two measurements were repeated and the mean calculated (World Health Organization 2011).

Provided no x-ray or nuclear medicine scans were undertaken in the preceding 7 days, participants underwent a whole-body DEXA scan in the supine position (Lunar Prodigy, GE Healthcare, Madison, WI, USA) (Shiel et al. 2017). The DEXA scan is a valid and reliable measure (Glickman et al. 2004; Norcross & Van Loan 2004), and was used to report absolute (kg) and relative (%) total body fat mass, android and gynoid fat mass and absolute (kg) total-body lean mass. Standardized body landmarks were used for reference and scans were analysed using enCORE software version 16 (GE Healthcare, Milwaukee, USA). Specifically, the android region of interest was set to 20% of the distance from the iliac crest to the base of the

skull (Olarescu et al. 2014). VAT volume (cm^3) was estimated by manufacturer software as previously described (Olarescu et al. 2014). DEXA calibration was performed before each testing round according to the manufacturer's guidelines. Scanning mode was set to manufacturer defaults based on participant size, at a resolution of 4.8 x 13 mm.

Venous Blood Collection

Approximately 16 mL of fasting venous blood was collected in a serum separator tube (SST) and ethylenediaminetetraacetic acid (EDTA) tube. EDTA tubes were immediately centrifuged at 1300 g for 10 min at 18 °C whilst SST tubes clotted for 30 min before being centrifuged in the same manner. Serum and plasma were immediately stored at -80°C until analysis. Serum was used to measure lipid profile, including total cholesterol, HDL-C, Non-HDL-C, low-density lipoprotein cholesterol (LDL-C) and triglycerides via the enzymatic colour test (Beckman Coulter AU5800; Beckman Coulter Inc., Brea CA, USA). Cholesterol hazard ratio was calculated as the total cholesterol divided by HDL-C. Glucose was measured using the hexokinase method (Beckman Coulter AU5800; Beckman Coulter Inc., Brea CA, USA). Plasma concentrations of IL-6, TNF-α and insulin were measured with chemiluminescent immunoassay (Magpix, Luminex Corporation, Texas, USA). For quality assurance, samples used for insulin, IL-6 and TNF-α measurement were analysed in duplicate with the derived mean used as the index value. Quality controls 1 and 2 were within the range of manufacturer recommendations. Insulin resistance was assessed via the Homeostatic Model Assessment (HOMA-IR) model-1 (Matthews et al. 1985).

Aerobic Capacity

Aerobic capacity was assessed via the measurement of peak oxygen consumption (VO_{2peak}) during a graded exercise test (GXT) on a mechanically-braked cycle ergometer (Watt-bike Pro,

Nottingham, United Kingdom). Participants commenced the test at 25 watts (W) and increased power output by 25 W each minute until volitional exhaustion. The average power output (W) was recorded at the completion of each 25W increment to determine peak power output (PPO). The mean of the highest three consecutive periods (10 s) of oxygen consumption was used to determine $VO_{2peak.}$ Oxygen consumption was determined by measuring O_2 and CO_2 concentrations with a metabolic gas analyser (Medgraphics Ultima System, Saint Paul, USA). The metabolic cart was calibrated according to the manufacturer's instructions, involving a pneumotachometer calibration via a 3 L syringe, analysis of ambient air, and gas calibration with a gravimetric gas mixture of known concentrations [CO_2 5.0 (0.02)%; O_2 12.0 (0.02)%].

Metabolic Syndrome classification

Metabolic syndrome was defined according to recognised criteria (Alberti et al. 2009). MetS was defined if participants present with 3 or more of the following 5 elements: 1) elevated WC (male ≥ 94 cm, female ≥ 80 cm); 2) elevated triglycerides (≥ 1.7 mmol/L); 3) reduced HDL-C (HDL-C; < 1.0 mmol/L in males; < 1.3 mmol/L in females); 4) elevated BP (systolic ≥ 130 and/or diastolic ≥ 85 mm Hg) or 5) elevated fasting glucose (≥5.6 mmol/L).

Training and control conditions

The CT group trained for 60 min, three times per week for 14-weeks, with options of training before (6-9 am), during (11-1 pm) and after (4-7 pm) working hours. Training was conducted in small groups (2-6 participants) within a private, climate-controlled exercise facility at the University campus and was performed under supervision by trained non-academic instructors. The control group were instructed to maintain their normal lifestyle as determined using the GLTEQ (Godin & Shephard 1997).

Exercise was prescribed in line with CT programs that have previously resulted in improvements in mental and cardiometabolic health. These included progressive overload of compound resistance exercises of the upper and lower body, and continuous moderate intensity endurance exercise (AbouAssi et al. 2015; Atlantis et al. 2004). The first week of training educated participants on the correct technique when completing exercises and familiarised participants with the training facility. Table 4.1 shows the concurrent exercise training program including resistance and aerobic portions. Resistance training progressed to involve 3 sets of 8-12 repetitions, and load was increased once a participant could complete the required number of repetitions with the correct technique on all sets over two consecutive training sessions. Rest periods and repetition velocity were self-determined with consultation from training instructors. Training data (resistance training; sets, repetitions, weight. Endurance training; time, distance, power) were recorded in a customised training diary to monitor progressive overload. All training sessions started with a 5-7 min warm-up involving 3 min of low to moderate intensity aerobic exercise on rower and cycle ergometers, and resistance exercises at 50% working weight. After each session, static stretching of the primary muscle groups (15 s per muscle group) was undertaken. Importantly, resistance exercise was completed prior to endurance exercise to minimise any potential interference effects, and maximise training adaptations (Eddens, van Someren & Howatson 2017).

Table 4.1. Concurrent Training Program.

	Week 1	Week 2	Week 3	Weeks 4 to 7	Weeks 8 to 14	Variables used to monitor progressive overload
Resistance exercises	2 sessions x 1 set x 8-12 reps: Leg press Split squat Seated hamstring curl Chest press Lat pulldown	2 sessions x 2 sets x 8-12 reps: Leg press Split squat Seated hamstring curl Chest press Lat pulldown	3 sessions x 2 sets x 8-12 reps: Leg press Split squat Seated hamstring curl Chest press Lat pulldown	3 sessions x 3 sets x 8-12 reps: Leg press Split squat Seated hamstring curl Chest press Lat pulldown	3 sessions x 3 sets x 8-12 reps: Leg press Split squat Hip thrust Chest press Cable row	Training volume = session frequency x sets x reps x weight (kg)
Resistance Exercise Volume *	8653 ± 3770	46389 ± 2436	77612 ± 40467	Week 4; 217562 ± 106421 Week 7; 304189 ± 124982	Week 8; 223072 ± 118699 Week 14; 244459 ± 115950	
Resistance Exercise Weight (kg) *†	15 ± 7	19 ± 9	23 ± 11	Week 4; 28 ± 14 Week 7; 39 ± 15	Week 8; 28 ± 15 Week 14; 39 ± 11	
Endurance exercise	7.5 min each: Row ergometer Cycle ergometer	7.5min each: Row ergometer Cycle ergometer	7.5min each: Row ergometer Cycle ergometer	8 to 9min each: Row ergometer Cycle ergometer	9 to 11min each: Row ergometer Cycle ergometer	Duration, distance (km) and average power output (W)
Row Distance (km) *	2514 ± 522	2817 ± 474	4387 ± 660	Week 4; 4698 ± 741 Week 7; 5390 ± 729	Week 8; 5403 ± 741 Week 14; 4814 ± 1587	
Row Power (W) *	67 ± 42	90 ± 46	99 ± 45	Week 4; 106 ± 44 Week 7; 110 ± 42	Week 8; 115 ± 42 Week 14; 116 ± 33	
Bike Distance (km) *	5.7 ± 0.9	6.2 ± 0.9	9.3 ± 1.2	Week 4; 11.4 ± 6.4 Week 7; 11.0 ± 1.4	Week 8; 10.7 ± 1.5 Week 14; 8.8 ± 2.6	

All data reported as mean ± SD.

* Week 7 significantly higher than week 1 ($p<0.001$)

† Week 14 significantly higher than week 8 ($p<0.05$)

Statistical analysis

A per-protocol analysis was performed, whereby participants were excluded if their exercise adherence was more than 1SD below the mean (<55%). All normally distributed data are reported as mean ± standard deviation (SD) and skewed data are reported as median (interquartile range, IQR; difference between the third and first quartile). Normality and equal variance of data was assessed using the Shapiro-Wilk and Levenes test, respectively.

Non-parametric analysis was completed on skewed variables (insulin, HOMA-IR, IL-6, TNF-α, android fat mass, VAT, total weekly leisure activity, SBP, and RHR) and parametric analysis was completed on log transformed (PPO, DBP, BMI, total fat mass (kg), total lean mass (kg), triglycerides, Non HDL-C and LDL-C) and all remaining normally distributed variables. Parametric analysis included a 2-way (time * group) repeated measures analysis of variance (ANOVA). If a significant time * group interaction effect was identified, paired t-tests were performed to determine within-group changes. Non-parametric analysis included a Mann-Whitney U test to assess between-group differences in change data, and the Wilcoxon signed-rank test analysed within-group differences. Effect sizes (ES) were determined using partial eta square for parametric analysis (0.01 = small; 0.06 = moderate; 0.14 = large), and a standardised effect size for nonparametric analysis using $Z/\sqrt{N}$ (0.1 = small; 0.3 = moderate; 0.5 = large).

For the secondary aim, quantile regressions were used due to the non-normal distribution of the residuals in an ordinary least squares linear regression model. Quantile regressions at the median (q 0.5) were used to identify associations between body composition and insulin resistance as independent variables, and markers of systemic inflammation as dependent variables. Model 1 was adjusted for age, sex, height, group and independent variable * group

interaction. Model 2 was further adjusted for fat mass (kg). Regression models were conducted within each intervention group when there was a significant group interaction effect. Data are presented as a coefficient with 95% confidence interval (95% CI) and significance was accepted at $P<0.05$.

Analyses were performed using SPSS Software, version 26 (IBM Corporation, Armonk, NY) and missing data were treated as missing in analyses. A priori sample size calculation was based on the smallest effect size of interest and performed using G*Power software (Version 3.1.9.3) (Faul et al. 2007). A small effect of a 24-week CT intervention on TNF-α in apparently healthy adults has been previously shown (Ihalainen et al. 2018). Therefore, 45 participants per group were required to detect effect size f of 0.15, alpha error of 0.05, and a power of 0.80. However, given resource constraints and a finite recruitment period, 59 participants were recruited.

Results

Participant and Training Characteristics

Participants (n=50) were 66% female (n=18) and 33% male (n=9) in control and 70% female (n=16) and 30% male (n=7) in CT. The age of participants in control and CT were 49.8 ± 7.9 y and 48.7 ± 9.1 y. CT participants completed a mean of 32 ± 10 of the 40 training sessions (79 ± 24%), and 3 participants were excluded from analysis due to non-adherence. There was a significant interaction effect for total weekly leisure activity (P=0.024, ES=-0.326), showing an increase in CT (P<0.001) and no change in control (P=0.096).

Metabolic Syndrome, Insulin Resistance and Systemic Inflammation

There were 5 participants with MetS in CT (22%) and control (19%) at baseline, and 3 in CT (13%) and 6 in control (22%) following the intervention. Overall, there was a significant interaction effect for non-HDL-C (P=0.013, ES=0.138), C:HDL (P=0.013, ES=0.139) and glucose (P=0.047, ES=0.091). However, post-hoc analysis reported no within-group changes for non-HDL-C (CT P=0.099; control P=0.067), C:HDL (CT P=0.094; control P=0.071), and glucose (CT P=0.120; control P=0.157). There was a significant interaction effect for WC (P=0.002, ES=0.184), which showed an increase in control (P=0.001) and no change in CT (P=0.474). No significant interaction effects were reported for HOMA-IR, insulin, IL-6, TNF-α, triglycerides, total cholesterol, HDL-C, LDL-C, DBP or SBP (Table 4.2, P>0.05).

Table 4.2. Components of the Metabolic Syndrome, Systemic Inflammation and Insulin Resistance Before and After the Exercise Intervention.

Variables	**Concurrent Training**				**Control**				**Time by Group**
	n	**Pre**	**Post**	**Change**	**n**	**Pre**	**Post**	**Change**	**P value (Effect Size)**
MetS, n (%)	23	5 (22)	3 (13)	-2 (9)	27	5 (19)	6 (22)	1 (4)	
SBP (mmHg)	23	121 (15)	114 (14)	-3 (9)	27	117 (16)	113 (22)	-4 (8)	0.891 (-0.019)
DBP (mmHg)	23	74 (10)	70 (14)	-3 (7)	27	70 (17)	72 (12)	-1 (6)	0.155 (0.042)
WC (cm)	23	92.7 ± 9.9	92.3 ± 10.2	-0.3 ± 2.2	27	93.8 ± 12.2	95.7 ± 12.3	1.8 ± 2.4	**0.002 (0.184)**[†]
Glucose (mmol/L)	19	5.27 ± 0.46	5.17 ± 0.37	-0.10 ± 0.27	25	5.13 ± 0.41	5.24 ± 0.40	0.12 ± 0.40	**0.047 (0.091)**
Triglycerides (mmol/L)	19	1.2 (0.6)	1.1 (0.5)	0.0 (0.4)	25	1.1 (0.6)	1.1 (0.9)	0.0 (0.6)	0.587 (0.007)
HDL-C (mmol/L)	19	1.53 ± 0.31	1.58 ± 0.38	0.05 ± 0.21	25	1.44 ± 0.32	1.44 ± 0.29	-0.01 ± 0.16	0.322 (0.023)
Total Cholesterol (mmol/L)	19	5.78 ± 0.78	5.64 ± 0.83	-0.14 ± 0.52	25	5.35 ± 1.15	5.49 ± 1.03	0.14 ± 0.48	0.070 (0.076)
Non-HDL-C (mmol/L)	19	4.1 (1.2)	4.1 (1.0)	-0.1 (0.6)	25	3.8 (2.0)	4.0 (1.8)	0.1 (0.5)	**0.013 (0.138)**
LDL-C (mmol/L)	19	3.5 (1.1)	3.4 (0.7)	-0.1 (0.6)	25	3.2 (1.5)	3.4 (1.5)	0.1 (0.5)	0.051 (0.088)
C:HDL (mmol/L)	19	3.90 ± 0.86	3.73 ± 0.92	-0.17 ± 0.43	25	3.81 ± 0.89	3.95 ± 1.01	0.14 ± 0.36	**0.013 (0.139)**
Insulin (uIU/ml)	18	5.18 (6.31)	4.05 (6.57)	-0.95 (1.92)	25	5.29 (10.42)	5.20 (14.02)	-0.28 (3.11)	0.375 (0.135)
HOMA-IR	18	1.29 (1.69)	0.95 (1.61)	-0.23 (0.56)	25	1.20 (2.39)	1.15 (3.34)	0.00 (0.85)	0.115 (0.240)
IL-6 (pg/ml)	15	0.77 (14.24)	1.28 (14.27)	0.05 (1.37)	22	5.30 (16.54)	4.82 (24.35)	-0.30 (4.93)	0.143 (-0.244)
TNF-α (pg/ml)	18	1.57 (1.31)	1.74 (1.55)	0.02 (0.29)	25	1.93 (1.04)	1.67 (0.93)	-0.04 (0.58)	0.796 (-0.039)

Data are reported as median (IQR) or mean ± SD. Abbreviations: MetS, metabolic syndrome; SBP, systolic blood pressure; DBP, diastolic blood pressure; WC, waist circumference; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; C:HDL, cholesterol hazard ratio; HOMA-IR, homeostatic model assessment of insulin resistance; IL-6, Interleukin-6; TNF-α, tumor necrosis factor-alpha.

[†] Higher in control compared to intervention

Body Composition and Aerobic Fitness

Body composition and aerobic capacity results are shown in Table 4.3. In response to CT, there was a significant interaction effect for absolute (P=0.019, ES=0.109) and relative total fat mass (P=0.001, ES=0.218) with a decrease in CT (kg P=0.008, % P=<0.001) and no change in control (kg P=0.765, % P=0.937). A significant interaction effect was shown for android fat mass (kg; P=0.017, ES=0.337; % P=0.032, ES=0.093), whereby a within-group decrease in absolute android fat mass was found for CT (kg P=0.042, % P=0.075), without change in control (kg P=0.105, % P=0.229). There was an interaction effect for VAT (P=0.009, ES=0.369) which decreased in CT (P=0.021) and did not change in control (P=0.199). There was also an interaction effect for lean mass (P=0.002, ES=0.185) which increased in CT (P<0.001) and did not change in control (P=0.413). There were no significant interaction effects for gynoid fat mass or BMI following the intervention (P>0.05).

A significant interaction effect was evident for RHR (P=0.042, ES=0.294), with a decrease in CT (P=0.002) and no change in control (P=0.302). An interaction effect was also found for PPO (P<0.001, ES=0.433) with an increase in CT (P<0.001) and no change in control (P=0.737). An interaction effect was evident for VO_{2peak} (P<0.001, ES=0.296), which increased in CT (P<0.001) and did not change in control (P=0.769).

Table 4.3. Body Composition, Aerobic Capacity and Physical Activity Measures Before and After the Intervention.

Variables	Concurrent Training				Control				Time by Group
	n	Pre	Post	Change	n	Pre	Post	Change	P value (Effect Size)
BMI (kg/m^2)	23	24.36 (3.46)	24.72 (3.45)	0.12 (0.69)	27	26.08 (5.24)	25.57 (5.79)	0.12 (0.80)	0.874 (0.001)
Height (cm)	23	170.73 ± 8.46	170.75 ± 8.53	0.02 ± 0.74	27	170.60 ± 7.40	170.39 ± 7.32	-0.21 ± 0.63	0.241 (0.028)
Weight (kg)	23	73.09 ± 14.68	73.56 ± 14.80	0.46 ± 1.44	27	74.94 ± 14.71	75.19 ± 14.35	0.25 ± 1.77	0.646 (0.004)
Total Fat Mass (kg)	23	24.00 (8.35)	22.53 (9.14)	-0.63 (1.27)	27	25.70 (14.74)	26.01 (14.83)	0.18 (1.25)	**0.019 (0.109)**†
Total Lean Mass (kg)	23	41.38 (11.00)	42.86 (12.41)	1.35 (1.86)	27	44.28 (8.17)	44.63 (8.05)	0.17 (1.81)	**0.002 (0.185)***
Total fat mass (%)	23	34.3 ± 7.6	33.0 ± 8.1	-1.3 ± 1.4	27	34.4 ± 9.1	34.4 ± 9.3	0.0 ± 1.1	**0.001 (0.218)**†
Android (kg)	23	1.97 (0.69)	1.80 (0.92)	-0.06 (0.27)	27	2.14 (1.38)	1.93 (1.44)	0.04 (0.17)	**0.017 (0.337)**†
Android (%)	23	7.7 ± 1.8	7.5 ± 1.8	-0.2 ± 0.4	27	8.2 ± 1.9	8.3 ± 1.9	-0.1 ± 0.4	**0.032 (0.093)**
Gynoid (kg)	23	4.58 ± 1.59	4.49 ± 1.63	-0.10 ± 0.27	27	4.68 ± 2.24	4.65 ± 2.15	-0.03 ± 0.27	0.36 (0.017)
Gynoid (%)	23	18.3 ± 3.3	18.4 ± 3.4	0.1 ± 0.5	27	17.4 ± 2.8	17.4 ± 2.7	0.0 ± 0.6	0.367 (0.017)
VAT volume (cm^3)	23	663 (685)	553 (715)	-66 (110)	27	779 (761)	759 (1093)	37 (167)	**0.009 (0.369)**†
VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	22	28.9 ± 5.7	32.9 ± 6.9	4.0 ± 3.1	25	29.5 ± 6.1	29.3 ± 5.6	-0.2 ± 3.4	**<0.001 (0.296)***
PPO (watts)	23	151 (72)	174 (97)	22 (31)	25	153 (49)	154 (54)	-1 (8)	**<0.001 (0.433)***
RHR (bpm)	23	69 (10)	64 (12)	-5 (9)	25	67 (9)	65 (12)	0 (10)	**0.042 (0.294)**†
Total weekly leisure activity	22	17 (27)	41 (20)	21(19)	26	21 (22)	24 (40)	4 (28)	**0.024 (-0.326)***

Data are reported as median (IQR) or mean ± SD. Abbreviations: BMI, body mass index; VAT, visceral adipose tissue; VO_{2Peak}, peak volume of oxygen consumed during graded exercise test; PPO, peak power output; RHR, resting heart rate.

* Higher in intervention compared to control

† Lower in intervention compared to control

Associations between Body Composition, Insulin Resistance and Systemic Inflammation

Regression models showed a significant group interaction effect for changes in HOMA-IR (P=0.006) and fasting insulin (P=0.006) in association with IL-6 (Table 4.4). Post-hoc analysis showed that changes in HOMA-IR and fasting insulin had a significant positive association with IL-6 in the control group (P<0.001) and this association remained following adjustment for changes in fat mass (P<0.001, Table 4.4). No significant associations or group interaction effects (P>0.05) were evident between change in body composition variables and change in markers of systemic inflammation.

Table 4.4. Associations Between Changes in Insulin Resistance and Body Composition and Changes in Systemic Inflammation.

	Dependent Variables							
	Model 1				**Model 2**			
	Δ IL-6 (pg/ml)	**P**	**Δ TNF-α (pg/ml)**	**P**	**Δ IL-6 (pg/ml)**	**P**	**Δ TNF-α (pg/ml)**	**P**
Δ Fat Mass (kg)	0.997 (-4.045, 6.038)	0.689	-0.283 (-0.727, 0.161)	0.204	-	-	-	-
Δ Lean mass (kg)	0.097 (-0.229, 0.423)	0.549	0.340 (-5.167, 5.846)	0.901	0.652 (-5.658, 6.962)	0.834	0.167 (-0.183, 0.517)	0.340
Δ Android Mass (kg)	2.165 (-28.597, 32.927)	0.887	-1.637 (-4.302, 1.027)	0.221	1.953 (-26.927, 30.832)	0.891	-3.433 (-6.922, 0.056)	0.054
Δ Gynoid Mass (kg)	3.237 (-20.226, 26.699)	0.780	-0.727 (-2.867, 1.412)	0.495	1.169 (-18.547, 20.884)	0.904	-1.543 (-3.790, 0.705)	0.172
Δ VAT Volume (cm^3)	-0.004 (-0.051, 0.043)	0.863	-0.002 (-0.005, 0.002)	0.345	0.003 (-0.040, 0.045)	0.898	-0.001 (-0.006, 0.003)	0.620
Δ HOMA-IR	-7.957 (-17.157, 1.243)	0.088*	0.085 (-0.653, 0.822)	0.817	-4.955 (-13.173, 3.264)	0.227*	0.304 (-0.632, 1.239)	0.515
Intervention	-0.650 (-7.521, 6.222)	0.837	-	-	-0.114 (-8.373, 8.145)	0.976	-	-
Control	6.604 (4.150, 9.058)	<0.001	-	-	5.957 (2.961, 8.953)	<0.001	-	-
Δ Fasting Glucose (mmol/L)	-0.763 (-22.644, 21.119)	0.944	0.418 (-0.956, 1.791)	0.541	1.618 (-14.404, 17.641)	0.838	1.052 (-0.192, 2.295)	0.095
Δ Fasting Insulin (uIU/ml)	-1.262 (-3.192, 0.667)	0.192*	-0.028 (-0.217, 0.162)	0.769	-1.090 (-2.955, 0.775)	0.242*	-0.024 (-0.219, 0.171)	0.804
Intervention	0.115 (-2.227, 2.457)	0.915	-	-	0.619 (-1.896, 3.134)	0.591	-	-
Control	1.926 (1.378, 2.473)	<0.001	-	-	1.787 (1.137, 2.437)	<0.001	-	-

Quantile regressions are reported as coefficients (95% confidence intervals, CI) at the median (q 0.5)

Model 1: adjusted for age, sex, height, group and group interaction

Model 2: adjusted for age, sex, height, fat mass (kg), group and group interaction.

* Interaction effect for group

Final sample n=43.

Discussion

Our findings support the use of CT to improve various cardiometabolic risk factors within inactive academic employees. Specifically, 14-weeks of CT decreased central adiposity and increased lean muscle mass and aerobic capacity. However, there were no changes in systemic inflammation or insulin resistance. Although there were no associations between changes in fat mass and changes in systemic inflammation, there was a positive association between changes in insulin resistance and changes in IL-6 in the control, but not the training group. Given the adherence (79%) to the intervention, our results indicate that an onsite CT program is an effective method to combat inactivity within the academic workplace and reduce some of the risk factors associated with the development of type 2 diabetes and cardiovascular disease.

To our knowledge, this is the first study to investigate the impact of CT on the cardiometabolic health of inactive academics. Despite the observed reduction in the number of participants with MetS in the CT group, the sample size was too small to statistically compare effects between groups. Furthermore, despite an interaction effect for components of MetS (ie. fasting glucose, non HDL-C and C:HDL), there were no significant within-group changes in these risk markers, likely due to the limited study power. Comparative data on exercise training in academics is minimal, but other CT interventions within similar inactive adults have shown no changes in fasting glucose or lipid profile (Azarbayjani et al. 2014; Ho et al. 2012; Langleite et al. 2016; Schroeder et al. 2019). HOMA-IR also remained unchanged in the current academic cohort, whilst other studies in adults without pre-existing diabetes have reported mixed results (AbouAssi et al. 2015; Brunelli et al. 2015; Jamka et al. 2021). It is suggested that these outcomes may be influenced by exercise adherence, intensity and intervention duration, but the training variables that have the largest effect remain equivocal (Conn et al. 2014; Kim, Kim, et al. 2019). Furthermore, given our participants had not been previously diagnosed with

metabolic disease, there may have also been a ceiling effect on improvements to metabolic blood markers. Indeed, exercise has been shown to have a larger effect on insulin sensitivity, LDL-C and total cholesterol in individuals with pre-existing metabolic conditions (Battista et al. 2021; Lin et al. 2015). Regardless, the interaction effects we report in fasting glucose and the lipid profile prompt further research with larger samples into the impact of CT on components of MetS in inactive academics.

Previous prospective research has reported that regular CT reduces the risk of developing MetS (Bakker et al. 2017). Our results highlight the potential of CT to protect against risk factors of MetS through a decrease in total and central adiposity. Other workplace studies have reported significant improvements in total body fat mass following CT (Hunter et al. 2020; Karatrantou et al. 2020; Pedersen et al. 2009), but few have reported changes in regional body fat distribution. The decrease in central adiposity (VAT and android fat mass) is particularly important given its strong association with proinflammatory cytokine activity and insulin resistance (Pou et al. 2007; Preis et al. 2010). Further, we found large increases in lean mass alongside increases in aerobic capacity, indicating concurrent adaptations to both endurance and resistance training (Coffey & Hawley 2016). Though research within academics is limited, CT studies in other untrained populations have reported mixed results for a change in lean mass (Donges et al. 2013; Schroeder et al. 2019), which may be due to low statistical power given the small group sizes. Regardless, BMI did not change, likely owing to the contrasting changes in fat mass and lean mass, emphasising the limitation of BMI to differentiate between these variables (Lee et al. 2018). Overall, we show that CT is effective in countering the detrimental effects of low physical activity on body composition and fat mass distribution in the academic workplace. These adaptations are vital for reducing the risk of MetS and type 2 diabetes, which have detrimental impacts on workplace productivity (Magliano et al. 2018; Schultz & Edington

2009). In turn, our findings may have important implications for the tertiary education sector given the crucial teaching and research roles performed by academics in universities.

Systemic inflammation did not change in response to CT, which is similar to previous studies completed in inactive apparently healthy adults (Donges et al. 2013; Libardi et al. 2012). This lack of change may be due to participants being free of pre-existing cardiometabolic disease at baseline. Indeed, exercise decreases IL-6 in individuals with type 2 diabetes (Hayashino et al. 2014), but has mixed effects on IL-6 and no effect on TNF-α in apparently healthy inactive adults (Cronin et al. 2017). Notwithstanding, previous findings show a positive association between fat mass and IL-6 and TNF-α (Park, Park & Yu 2005). Thus, regular CT may prevent inactive academics from low-grade chronic systemic inflammation and concomitant risk of metabolic disease through modulation of fat mass (Kaptoge et al. 2014; Spranger et al. 2003).

There were no relationships between changes in body composition and markers of systemic inflammation. This is surprising given that CT decreased fat mass and VAT, which are primary sources of IL-6 and TNF-α production (Fain et al. 2004; Fontana et al. 2007; Winkler et al. 2003). Regardless, other CT research has also reported decreases in measures of fat mass without concomitant decreases in IL-6 and TNF-α (Ihalainen et al. 2018; Langleite et al. 2016). However, prospective studies have found that measures of fat mass at least partially account for the positive association between IL-6 and TNF-α and metabolic disease (Kaptoge et al. 2014; Spranger et al. 2003; Wang et al. 2013). It is also likely that changes in other variables, such as adipose tissue macrophage phenotype, adipose tissue type, and insulin resistance are associated with changes in IL-6 and TNF-α (Hotamisligil 2017b; Villarroya et al. 2018). Indeed, we found that changes in fasting insulin and HOMA-IR were positively associated with IL-6 in the control group, which was independent of fat mass. Whilst this independent

relationship has been found in other inactive populations (Abbatecola et al. 2004; Kern et al. 2001), it was not evident in our CT group, indicating that CT may attenuate the association between insulin resistance and IL-6. Indeed, IL-6 is a complex cytokine with various effects dependent on the location of its release and mode of action (Hunter & Jones 2015), which can be influenced by exercise (Pedersen 2011). Although we did not investigate the reasons for the lack of association in CT, our findings prompt further investigation into how exercise can influence the association between insulin resistance and IL-6.

Limitations

This study shows the benefits of CT for apparently healthy inactive academics but limits the generalisability of our findings to other inactive workplaces and the wider academic population. Indeed, exercise has a greater impact on systemic inflammation, insulin resistance and other metabolic blood markers in individuals with pre-existing metabolic conditions, which may also clarify associations between changes in these variables. Multiple testing may have increased the risk of type I error, and our sample size was underpowered to detect changes in inflammatory markers, though they were the smallest effect sizes of interest. Future research should utilise a larger multicentre longitudinal design and investigate the impact of CT on academics with and without metabolic disease.

Conclusions

This study reports that a 14-week CT program with strong adherence (79%) is effective in improving fat mass, fat distribution, lean mass and aerobic capacity in inactive academics. However, there were no changes to insulin resistance or systemic inflammation in this apparently healthy cohort. The study also prompts further research into the relationship between insulin resistance and IL-6 given the positive association evident in the control group,

but not CT. Overall, this study conveys the effectiveness of combined endurance and resistance training in reducing the risk factors associated with low levels of physical activity in the academic workplace.

Chapter 5

Study 3

Effect of Concurrent Exercise Training on Stress, Depression and Anxiety in Inactive Academics

Abstract

The high job stress and low levels of physical activity experienced by academics may increase their risk of depression and other mental disorders. This randomised controlled trial investigated the effect of concurrent training (CT) on the mental health of inactive academics and examined associations between changes in stress, depressive symptoms and systemic inflammation. Inactive academics from an Australian university (n=59) were randomly assigned to a CT (n=29) or control (non-exercise) group (n=30). CT performed supervised group training at an onsite facility 3 times per week for 14-weeks. Symptoms of depression, anxiety, and stress (job specific and general), and systemic inflammation (Interleukin-6 and Tumor necrosis factor-α) were measured pre and post intervention, and ecological momentary assessment of wellness measures was conducted before and during the last 2-weeks of the intervention. Results showed an effort-reward imbalance was evident before (CT, 1.26 ± 0.37; control; 1.22 ± 0.47) and after (CT, 1.16±0.31; control; 1.21±0.35) training, with no interaction effect (P>0.05). Following CT, there was a significant decrease in symptoms of depression in the CT group (P=0.009) and no change in control (P=0.463). There were no changes in stress, anxiety, daily wellness measures or systemic inflammation (P>0.05). There were no significant associations between changes in stress and changes in depressive symptoms or systemic inflammation (P>0.05). CT can decrease symptoms of depression in inactive academics despite the continued presence of an effort-reward imbalance. These findings may be important for universities aiming to improve the mental health of currently inactive academics via onsite exercise programs.

Introduction

Academia is an occupation combining high-stress with low physical activity (Cooper & Barton 2016; Gillespie et al. 2001), which may increase the risk of common mental disorders such as depression and anxiety (Schuch et al. 2019; Schuch et al. 2018). Academics experience higher job stress and psychological strain compared to other professions (Fontinha, Easton & Van Laar 2019; Winefield et al. 2003). This increased job stress may be due to an imbalance in effort output (e.g. work demands and obligations) and reward input (e.g. salary and job security) from academic work (Siegrist 1996). Workers with high effort-reward imbalance (ERI) have a 1.5-fold increased risk of developing depression compared to those with a low ERI (Rugulies, Aust & Madsen 2017), though there is currently limited evidence of this relationship within academia (Kinman 2019). Notwithstanding, the effectiveness of interventions known to reduce stress should be assessed within the academic workplace.

Like job stress, low levels of physical activity increase the risk of incident depression and anxiety (Schuch et al. 2019; Schuch et al. 2018). Low physical activity is associated with increased stress and is often evident in desk-based occupations such as academia (Prince et al. 2019; Stults-Kolehmainen & Sinha 2014), wherein long work hours and periods of sitting can reduce physical activity and increase the likelihood of symptoms of anxiety and depression (Hallgren et al. 2020; Kirk & Rhodes 2011). Increasing exercise engagement can reduce symptoms of stress and depression within previously inactive workplaces (Atlantis et al. 2004; Norvell & Belles 1993). However, results for symptoms of anxiety are mixed (Atlantis et al. 2004; Norvell & Belles 1993), with larger improvements reported in individuals with higher baseline anxiety (Lucibello, Parker & Heisz 2019). Given the combination of high-stress and low physical activity in the academic workplace, investigations into the impact of exercise interventions on improving the mental health of academics is warranted.

Resistance and endurance training have been shown to respectively decrease symptoms of depression and anxiety in healthy populations (Gordon et al. 2018; Gordon et al. 2017; Norris, Carroll & Cochrane 1990). However, preliminary observational research reports that adults participating in concurrent training (CT), ie. combined resistance and endurance training, have the lowest prevalence of depressive symptoms (Bennie et al. 2019). Although studies of CT within workplace environments are limited, Atlantis et al. (2004) report a decrease in symptoms of stress and depression, but not anxiety, in response to 24 weeks of CT and behaviour modification on inactive casino employees (Atlantis et al. 2004). Further exploratory research on the independent impact of CT on mental health is required, with specific focus on the academic workplace given the low physical activity and high stress in this population.

There is preliminary evidence of a relationship between chronic stress, systemic inflammation and depression (Lee. 2020). Chronic stress is associated with an increase in circulating cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) (Rohleder 2019), and individuals with depression present with higher levels of both markers (Dowlati et al. 2010). Chronic systemic inflammation is also associated with increased risk of developing cardiovascular disease and type 2 diabetes (Kaptoge et al. 2014; Wang et al. 2013), which may partly explain why individuals with depression are at greater risk of these metabolic disorders (Golden et al. 2008). However, the relationship between systemic inflammation, stress and depression remains equivocal and requires further investigation (Slavich & Irwin 2014). Given that CT has mixed effects on systemic inflammation (Donges et al. 2013; Ihalainen et al. 2018), but can improve stress and depression within healthy inactive workers (Atlantis et al. 2004), further investigation is required into the relationship between stress, inflammation, and depression following exercise training.

The primary aim of this study was to determine the effect of a 14-week CT program on symptoms of depression, stress and anxiety in healthy inactive full-time academics within an Australian University. A secondary aim is to investigate the associations between changes in stress, depression and systemic inflammation. We hypothesise that the CT intervention will improve symptoms of depression, anxiety and stress relative to control, and that the improvements in stress will be associated with a reduction in markers of chronic systemic inflammation and symptoms of depression.

Methods

Participants and study design

This is a secondary analysis of a 14-week randomised (1:1), parallel-group, stratified (VO_{2peak}, age, sex) and matched superiority trial comparing CT to a control group. The study was approved by the Human Research Ethics Committee at the University of Technology Sydney (HREC REF: ETH18-3093) and registered with the Australian New Zealand Clinical Trials Registry (ACTRN12619000608167). Recruitment and testing commenced in June 2019 and was completed in December 2019. Schematic diagram of recruitment, retention and follow-up is shown in Figure 4.1 (pg 94).

Participants from a single Australian university based in a metropolitan city were recruited via local advertising and email to all academic staff. Potential participants attended a familiarisation session to provide verbal and written informed consent prior to completing a health pre-screening questionnaire (Exercise and Sport Science Australia adult pre-exercise screening tool). Inclusion criteria included 1) Physically inactive (Active Australia criteria; verbal and questionnaire-based assessment of <150 min/wk of weighted physical activity); 2)

aged between 35 and 65 years; and 3) working a minimum of 35 h per week at the university as an academic. Exclusion criteria included 1) pregnancy; 2) previous diagnoses of metabolic disease or severe musculoskeletal disorders; 3) pharmacological treatment for depression, diabetes, cardiovascular disease, or inflammation; and 4) contraindications to exercise as identified in the health pre-screening. Eligible participants undertook baseline testing and fifty-nine were then stratified (age, sex, VO_{2peak},) and matched to the nearest neighbour. An independent third party generated a series of random numbers via a computerized random number generator and another third party allocated matched participant codes using a 1:1 ratio into either a concurrent training (CT) group (n=29), or non-exercise control group (n=30), according to the random number sequence (Urbaniak & Plous 2019).

Overview

Eligible participants undertook a 60 min testing session for cardiometabolic and mental health parameters and a 2-week period of data collection on lifestyle related variables before and after the training intervention. Testing was conducted in a climate-controlled exercise physiology laboratory before (July and August 2019) and after (November 2019) the 14-week intervention, and outside of the primary teaching session. Mental health assessments were collected and managed using Research Electronic Data Capture (REDCap, version 8.11.3) hosted at the University of Technology Sydney (Harris et al. 2009). Participants arrived at the testing facility between 6:00 and 9:00 am after an overnight fast (10-12 h) and 24 h of no alcohol consumption or exercise. Further, over a 2-week period daily wellness measures and sociodemographic variables (research discipline, academic level, age, sex) were completed by participants on their smartphones or electronic devices using a downloaded software application (MetricWire Inc. 2019).

Procedures

Psychological Distress

Psychological distress was measured using the Kessler Scale (K10) (Kessler et al. 2002). Each response is scored on a 5-point scale ranging from 1 = "none of the time" through to 5 = "all of the time", where the scores are summed to provide an overall score of distress experienced over the past four weeks (Kessler et al. 2002). Scores range from 10-50 with higher scores indicative of greater levels of psychological distress. The K10 has previous evidence of strong psychometric properties (Cairney et al. 2007; Furukawa et al. 2003; Kessler et al. 2002).

Depression, Anxiety and Stress

The Depression, Anxiety and Stress Scales-21 (DASS-21; Lovibond & Lovibond, 1995) was used to measure depression, anxiety and stress. The questionnaire includes 21-items (7 items per dimension) measured on a 4-point scale ranging from 0 = "never" to 3 = "almost always". Scores are summed to provide a quantitative measure of severity of depression, anxiety and general stress, and risk of further problems (Lovibond & Lovibond 1995). For the depression domain, scores of 0-4 are considered normal, 5-6 mild, 7-10 moderate, 11-13 severe, and ≥14 extremely severe. For anxiety, 0-3 is considered normal, 4-5 mild, 6-7 moderate, 8-9 severe, and ≥10 extremely severe. For general stress, 0-7 is normal, 8-9 mild, 10-12 moderate, 13-16 severe, and ≥17 extremely severe. The psychometric properties of the DASS-21 have been comprehensively evaluated, and it has been found to be valid, consistent, and responsive to treatment within adults (Henry & Crawford 2005; LeBouthillier & Asmundson 2017; Sinclair et al. 2012).

Job Stress

Job stress was measured using the 16-item version of the ERI questionnaire (Siegrist 1996). Participants responded to items via a 4-point Likert scale ranging from 1 = "strongly disagree" to 4 = "strongly agree". The scores for overcommitment (6 items) were summed, and an ERI score was calculated from effort (3 items) and reward (7 items) items according to instructions (Siegrist, Li & Montano 2014). Previously, the ERI questionnaire has shown good internal consistency, discriminant validity and criterion validity for all scales and the ERI ratio (Leineweber et al. 2010; Siegrist, Li & Montano 2014).

Daily Wellness Measures and Work Hours

The MetricWire software application was used to attain Ecological Momentary Assessment (EMA) of daily wellness measures in the 2-weeks following the initial testing session (but before training commenced), and during the final 2-weeks of the intervention period. Participants responded once-daily in the morning to a 6-item questionnaire assessing sleep duration, fatigue, sleep quality, stress and mood. Participants also responded to three items regarding work hours and perceived workload once-daily before night-time sleep. To assist with compliance, alert notifications were programmed into the software application to remind participants to respond to the questionnaire in the morning at 07:00 and evening at 21:00, with a reminder notification 15-min later if the participant had still not completed the items. Additionally, questions were presented in random order to avoid ordering effects (Groves et al. 2011).

The fatigue and mood items were adapted from the profile of mood states (POMS) questionnaire (McNair, Loor & Droppleman 1981). Participants responded to the question: "How fatigued [unhappy] do you feel right now?", using a 5-point scale ranging from 1 ('not

at all') to 5 ('extremely'). The sleep quality item from the consensus sleep diary was used to assess sleep quality (Carney et al. 2012), with responses ranging from 1 ('very poor') to 5 ('very good). Additionally, total sleep time was estimated based on the difference in the two items adapted from the consensus sleep diary; 1) "What time did you try to go to sleep last night?", and 2) "What time did you get out of bed for the day?" (Carney et al. 2012). Daily stress was measured through a single item; "What is your current level of stress (i.e. feeling of being overwhelmed or out of control)". The brief definition of stress was based on previous recommendations to define stress as a context where predictability and controllability are in question (Koolhaas et al. 2011). Response options were those previously used in a large cohort study; low=1, medium=2, high=3, extremely high=4 (Iso et al. 2002).

For work hours, participants responded to the item; "how many hours did you work from (work/home) today". Hours worked from home and from the workplace between Monday and Friday (i.e. weekdays only) were summed and averaged to indicate daily work hours. Perceived daily workload was measured on a response scale from 1 ('much lighter than normal') to 5 ('much heavier than normal'). Perceptual scales were quantified by weighting responses on a 4 (e.g. stress) or 5-point (e.g. mood/fatigue) scale. These values were then summed and averaged, with higher values representing higher perception of the variable.

Aerobic Capacity

Aerobic capacity was assessed via the measurement of peak oxygen consumption (VO_{2peak}) during a graded exercise test (GXT) on a mechanically-braked cycle ergometer (Watt-bike Pro, Nottingham, United Kingdom). Participants commenced the test at 25 watts (W) and increased power output by 25 W each minute until volitional exhaustion. The mean of the highest three consecutive periods (10 s) of oxygen consumption was used to determine $VO_{2peak.}$ Oxygen

consumption was determined by measuring O_2 and CO_2 concentrations with a metabolic gas analyser (Medgraphics Ultima System, Saint Paul, USA). The metabolic cart was calibrated according to the manufacturer's instructions, involving a pneumotachometer calibration via a 3 L syringe, analysis of ambient air, and gas calibration with a gravimetric gas mixture of known concentrations [CO_2 5 (0.02)%; O_2 12 (0.02)%].

Leisure-time Physical Activity and Body Mass Index

The Godin Leisure-Time Exercise Questionnaire (GLTEQ) was used to assess leisure-time physical activity (including the CT sessions) (Godin & Shephard 1997). 3-items measure the frequency of mild, moderate, and strenuous exercise during a standard 7-day period. Each exercise intensity is weighted and then multiplied by its frequency. The individual scores are then summed to provide a total weekly leisure activity score.

Weight (kg) was measured using a calibrated electronic scale (A&D Weighing, Sydney, Australia) and height (m) using a stadiometer (Seca Asia-Pacific, Kuala Lumpur, Malaysia), wearing minimal clothing and no footwear. Body mass index (BMI) was calculated via the formula kg/m^2.

Venous Blood Collection

Fasting (10-12 h) venous blood (~16 mL) was collected in an ethylenediaminetetraacetic acid (EDTA) tube, immediately centrifuged at 1300 g for 10 min at 18 °C and stored at -80°C until analysis. Concentrations of IL-6 and TNF-α were quantified via chemiluminescent immunoassay (Magpix, Luminex Corporation, Texas, USA) according to manufacturer instructions.

Training and control conditions

The intervention was designed to be adaptable, easily implementable and low cost. The CT group trained for 60 min, three times per week for 14-weeks, with options of training before (6-9am), during (11-1pm) and after (4-7pm) working hours. Training was conducted in small groups (2-6 participants) within a private climate-controlled exercise facility at the University campus and was performed under supervision by trained instructors with a typical instructor:participant ratio of 1:2. The control group were instructed to maintained their normal exercise behaviour as determined by the Godin Leisure-Time Exercise Questionnaire (GLTEQ) (Godin & Shephard 1997), and were offered the CT program following the study to encourage compliance.

The first week of training was used to instruct participants on the proper technique when completing exercises and familiarised participants with the training facility. As shown in Table 4.1 (pg. 100), resistance training progressed to involve 3 sets of 8-12 repetitions, and load was increased once a participant could complete the required number of repetitions with proper technique on all sets over two consecutive training sessions. Rest periods and repetition velocity were self-determined with consultation from training instructors. Exercise intensity was not directly measured to increase the ease of implementation. However, verbal encouragement was provided to each participant and training data were recorded in a customised training diary to monitor progressive overload, and included sets, repetitions and weight for resistance exercises, and duration, distance and power for endurance exercises.

All training sessions started with a 5-7 min warm-up involving 3 mins of low to moderate intensity aerobic exercise on rower and cycle ergometers, and resistance exercises at 50% working weight. After each session, static stretching of the primary muscle groups (15 s per

muscle group) was undertaken. Importantly, resistance exercise was completed prior to endurance exercise to avoid any potential interference effects, and maximise training adaptations (Eddens, van Someren & Howatson 2017).

Statistical analysis

A per-protocol analysis was performed, whereby participants were excluded if their exercise adherence was below 1SD below the mean (< 55%). Additionally, participants were only included in the EMA analysis if they responded to items on at least 4 weekdays. All normally distributed data are reported as mean ± standard deviation (SD) and skewed data are reported as median (interquartile range, IQR; difference between the third and first quartile). Normality and equal variance of data was assessed using the Shapiro-Wilk and Levenes test, respectively. Skewed variables included distress, depression, anxiety, stress, overcommitment, IL-6, TNF-α, BMI, daily sleep quality, daily fatigue, daily mood, total work hours, and total weekly leisure activity. Distress and BMI were the only skewed variables that were successfully log transformed. A 2-way (time * group) repeated measures analysis of variance (ANOVA) was used to assess interaction effects for all normally distributed outcome variables. If a significant time * group interaction effect was identified, paired samples t-tests were performed to determine within-group changes. Non-parametric analysis was performed on skewed data that could not to be transformed. The Mann-Whitney U test was used to assess between-group differences in change data, and the Wilcoxon signed-rank test analysed within-group differences.

For the second aim, quantile regressions at the median (q 0.5) were conducted due to the non-normal distribution of the residuals in an ordinary least squared linear regression model. Measures of general stress, daily stress and ERI were regressed against the following dependent

variables: IL6, TNF-α, depression, unhappy score and K10. All models were adjusted for age, sex, group and stress (general, daily or ERI) * group interaction. Data are presented as a coefficient with 95% confidence interval (95% CI).

Analysis was performed using SPSS Software, version 26 (IBM Corporation, Armonk, NY) and missing data were treated as missing in analyses. Significance was accepted as $p<0.05$. Effect sizes (ES) were determined using partial eta square for parametric analysis (0.01 = small; 0.06 = moderate; 0.14 = large), and a correlation coefficient (r) for nonparametric analysis using the formula; $Z/\sqrt{N}$ (0.1 = small; 0.3 = moderate; 0.5 = large) (Fritz, Morris & Richler 2012). This study is a secondary analysis of a randomised controlled trial and a retrospective sample size calculation was performed using G*Power software (Version 3.1.9.3) (Faul et al. 2007). Based on previously published data on the effect of concurrent exercise training on stress in apparently healthy adults (Atlantis et al. 2004), sample size calculation was performed with an effect size f of 0.4, alpha error of 0.05, and a power of 0.80. It was determined that a minimum sample size of 20 participants per group would be required.

Results

Participant and Training Characteristics

Baseline characteristics are reported in Table 5.1, and most participants were within normal ranges for BMI, distress, depression, stress and anxiety. The mean baseline scores for ERI were 1.26 ± 0.37 and 1.22 ± 0.47 for CT and control, indicating more effort outputs for each reward input. Adherence to CT was 79 ± 24% with a mean of 32 ± 10 of the 40 training sessions attended.

Depression, Anxiety, Stress and Daily Wellness Measures

Table 5.2 shows the results for symptoms of depression, anxiety and stress. There was a significant interaction effect for depression (P=0.021, ES=0.33), which decreased in CT (P=0.009) and did not change in control (P=0.463). There were no significant interaction effects for anxiety, distress, general stress or job stress (P>0.05). Daily wellness measures are shown in Table 5.3. There were no significant interaction effects for total sleep time, sleep quality, fatigue, daily stress, mood, work hours or perceived workload (P>0.05).

Cardiometabolic Health Measures

There were no significant interaction effects for BMI, IL-6 or TNF-α (P>0.05; Table 5.2). There was an interaction effect for VO_{2peak} (P<0.001, ES=0.296) which increased in CT (P<0.001) and did not change in control (P=0.769).

Regressions

Regression analysis between stress, depression and inflammation markers are shown in Table 5.4. Quantile regression results indicated no significant association between changes in stress and systemic inflammation, or changes in stress and symptoms of depression (P>0.05).

Table 5.1. Baseline Characteristics of Participants in Intervention and Control Groups.

Characteristics	Intervention (n=23)	Control (n=27)
Age (years), mean ± SD	49 ± 9	50 ± 8
Female Sex, n (%)	16 (70)	18 (66)
VO_{2peak}, mean ± SD	28.9 ± 5.7	29.5 ± 6.1
Leisure-Time Physical Activity Score, median (IQR)*	17 (27)	21 (22)
Body Mass Index (kg/m^2), n (%)		
Underweight (<18.5)	1 (4)	1 (4)
Normal (18.5-24.9)	13 (57)	12 (44)
Overweight (25.0-29.9)	7 (30)	9 (33)
Obese (≥30)	2 (9)	5 (19)
Academic Discipline, n (%)		
HASS	13 (56)	16 (59)
STEM	10 (44)	11 (41)
Academic Level, n (%)		
Associate Lecturer	1 (4)	1 (4)
Lecturer	9 (39)	12 (44)
Senior Lecturer	8 (35)	7 (26)
Associate Professor (Reader)	1 (4)	2 (7)
Professor	4 (17)	5 (19)
Daily Work Hours, median (IQR)	8.8 (1.2)	8.7 (2.1)
ERI, Mean ± SD	1.26 ± 0.37	1.22 ± 0.47
Overcommitment, median (IQR)	17 (7)	16 (2)
DASS Depression Domain, n (%)		
Normal (0-4)	18 (78)	21 (78)
Mild (5-6)	3 (13)	5 (19)
Moderate (7-10)	0 (0)	1 (4)
Severe (11-13)	1 (4)	0 (0)
Extremely Severe (≥14)	1 (4)	0 (0)
DASS Anxiety Domain, n (%)		
Normal (0-3)	19 (83)	25 (93)
Mild (4-5)	1 (4)	2 (7)
Moderate (6-7)	2 (9)	0 (0)
Severe (8-9)	1 (4)	0 (0)
Extremely Severe (≥10)	0 (0)	0 (0)
DASS Stress Domain, n (%)		
Normal (0-7)	15 (65)	17 (63)
Mild (8-9)	3 (13)	5 (19)
Moderate (10-12)	3 (3)	3 (11)
Severe (13-16)	2 (9)	2 (7)
Extremely Severe (≥17)	0 (0)	0 (0)
K10 Distress, n (%)		
Normal (<20)	15 (65)	20 (74)
Mild (20-24)	5 (22)	7 (26)
Moderate (25-29)	3 (13)	0 (0)
Severe (≥30)	0 (0)	0 (0)

Abbreviation: VO_{2Peak}, peak volume of oxygen consumed during graded exercise test; HASS; Humanities, Arts, and Social Sciences; STEM, Science, Technology, Engineering, and Mathematics; ERI, Effort Reward Imbalance; DASS-21, Depression, Anxiety and Stress Scales-21; K10, Kessler Scale

* Measured using the GLTEQ

Table 5.2. Depression, Anxiety, Stress, VO2peak, BMI and Inflammation Before and After the Intervention.

Variables	CT			CON			Time by Group P value (ES)
	Pre	Post	Change	Pre	Post	Change	
Depression	2 (3)	1 (2)	-1 (3)	2 (3)	1 (4)	0 (1)	**0.021 (0.327)**[*]
Anxiety	2 (1)	1 (3)	-1 (3)	1 (3)	1 (3)	0 (2)	0.123 (0.218)
Stress	6 (6)	4 ± (5)	-2 (4)	6 (4)	5 (6)	0 (6)	0.328 (0.138)
Distress	18 (9)	15 (3)	-2 (5)	16 (6)	15 (4)	-1 (3)	0.144 (0.044)
ERI	1.26 ± 0.37	1.16 ± 0.31	-0.10 ± 0.41	1.22 ± 0.47	1.21 ± 0.35	-0.01 ± 0.39	0.416 (0.014)
Overcommitment	17 (7)	16 (5)	-1 (2)	16 (2)	16 (3)	-1 (3)	0.473 (0.102)
Total weekly leisure activity	17 (27)	41 (20)	21(19)	21 (22)	24 (40)	4 (28)	**0.024 (-0.326)**[†]
VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	28.9 ± 5.7	32.9 ± 6.9	4.0 ± 3.1	29.5 ± 6.1	29.3 ± 5.6	-0.2 ± 3.4	**<0.001 (0.296)**[†]
BMI (kg/m^2)	24.36 (3.46)	24.72 (3.45)	0.12 (0.69)	26.08 (5.24)	25.57 (5.79)	0.12 (0.80)	0.874 (0.001)
IL-6 (pg/ml)	0.77 (14.24)	1.28 (14.27)	0.05 (1.37)	5.30 (16.54)	4.82 (24.35)	-0.30 (4.93)	0.143 (-0.244)
TNF-α (pg/ml)	1.57 (1.31)	1.74 (1.55)	0.02 (0.29)	1.93 (1.04)	1.67 (0.93)	-0.04 (0.58)	0.796 (-0.039)

Data are reported as median (IQR) or mean ± SD. Abbreviations: ERI, effort-reward imbalance; BMI; body mass index; VO_{2Peak}, peak volume of oxygen consumed during graded exercise test; IL-6, Interleukin-6; TNF-α, tumor necrosis factor-alpha.

All mental health variables and BMI report at n = 23 for CT and n = 27 for control. VO_{2Peak} reports at n = 22 for CT and 25 for control. IL-6 reports at n = 15 for CT and n = 22 for control. TNF-α reports at n = 18 for CT and n = 25 for control.

[*] Decrease in intervention compared to control

[†] Increase in intervention compared to control

Table 5.3. Daily Wellness Measures Before and During the Intervention.

Variables	CT			CON			
	Pre	During	Change	Pre	During	Change	Time by Group P value (ES)
Total Sleep Time (hours)	7:47 ± 0:43	7:35 ± 0:38	-0:11 ± 0:33	8:08 ± 0:49	8:01 ± 0:38	-0:06 ± 0:34	0.641 (0.006)
Sleep Quality	3.2 (0.4)	3.2 (0.7)	0.1 (0.6)	3.1 (1.3)	3.0 (1.1)	-0.1 (0.9)	0.097 (-0.259)
Fatigue	2.3 (0.7)	2.1 (0.8)	-0.1 (0.4)	2.2 (0.9)	2.3 (1.3)	-0.0 (0.6)	0.601 (0.082)
Daily Stress	1.7 ± 0.5	1.7 ± 0.5	0.0 ± 0.6	1.7 ± 0.5	1.8 ± 0.6	0.1 ± 0.6	0.679 (0.004)
Mood (Unhappy)	1.8 (0.9)	1.5 (0.6)	-0.4 (0.7)	1.6 (0.9)	1.7 (1.1)	0.1 (1.0)	0.099 (0.257)
Total Work Hours	8.8 (1.2)	8.3 (2.7)	-0.1 (2.4)	8.7 (2.1)	7.5 (1.0)	-1.0 (1.4)	0.062 (0.010)
Perceived Workload	3.0 ± 0.6	3.2 ± 0.7	0.1 ± 0.6	3.2 ± 0.5	3.0 ± 0.7	-0.1 ± 0.9	0.295 (0.026)

Data are reported as median (IQR) or mean ± SD. All daily wellness measures report at n = 22 for CT and n = 19 for control

Table 5.4. Associations Between Changes in Stress with Changes in Depression and Systemic Inflammation.

	Dependent Variables									
	Δ IL-6 (pg/ml)	**P**	**Δ TNF-α (pg/ml)**	**P**	**Δ Depression**	**P**	**Δ Daily Mood**	**P**	**Δ K10**	**P**
Δ Stress	0.027 (-1.804, 1.857)	0.976	-0.062 (-0.185, 0.062)	0.317	0.250 (-0.235, 0.735)	0.305	0.069 (-0.113, 0.250)	0.448	0.500 (-0.277, 1.277)	0.201
Δ Daily Stress	3.397 (-7.715, 14.509)	0.533	-0.378 (-1.207, 0.451)	0.358	0.608 (-3.794, 5.009)	0.781	0.205 (-0.656, 1.066)	0.632	4.313 (-1.498, 10.124)	0.141
Δ ERI	-4.662 (-17.521, 8.198)	0.465	-0.191 (-1.239, 0.857)	0.714	5.031 (-0.910, 10.973)	0.095	-1.082 (-3.094, 0.929)	0.282	6.345 (-3.228, 15.918)	0.188

Quantile regressions are reported as coefficients (95% confidence intervals, CI) at the median (q 0.5)

The model has been adjusted for age, sex, group and stress (general, daily or ERI) * group interaction. No group interaction effects were evident p>0.05.

Final sample n=43.

Discussion

This study reports a decrease in symptoms of depression within previously inactive academics following 14-weeks of CT. However, no changes in anxiety, stress or daily wellness measures were evident following the training program. Additionally, there were no associations between changes in stress and changes in systemic inflammation or symptoms of depression. Our results show that despite continued high job stress, represented by an effort-reward imbalance, CT can decrease symptoms of depression in inactive academics.

To our knowledge, this is the first study to investigate the effects of CT on the mental health of inactive academics. CT significantly improved symptoms of depression without altering anxiety (as assessed by the DASS-21), consistent with studies of CT in other inactive workers (Atlantis et al. 2004). Whilst previous research combined CT with a behavioural intervention, confounding the explicit effect of CT on mental health (Atlantis et al. 2004), we highlight the independent and moderate effect of CT on symptoms of depression. The lack of change in symptoms of anxiety is unsurprising given the low levels at baseline, which has also been shown in previous studies (Lucibello, Parker & Heisz 2019). Regardless, increased physical activity can protect against incident depression and anxiety (Harvey et al. 2018; Schuch et al. 2019), indicating that CT may help to maintain the mental health of currently healthy inactive academics. Moreover, our results show that CT improves symptoms of depression, without change in ERI, which is notable given the ERI experienced in the current academic cohort has been previously shown to increase the risk of depression (Rugulies, Aust & Madsen 2017). This may have implications for the university sector, given previous research showing a decrease in productivity in workers with higher depressive symptoms (McTernan, Dollard & LaMontagne 2013).

The CT intervention did not affect general stress, daily stress or job stress within academics. This contrasts with previous findings of a decrease in general stress after CT within inactive workers, which may be explained by differences in baseline stress levels (Atlantis et al. 2004). Indeed, in the study by Atlantis et al. (2004), "moderate" stress (via DASS-21) was reported at baseline compared to a "normal" stress level for the current sample (Lovibond & Lovibond 1995). As with symptoms of depression and anxiety (Lucibello, Parker & Heisz 2019; Rethorst, Wipfli & Landers 2009), higher baseline symptoms of stress are associated with greater improvements following exercise interventions (Atlantis et al. 2004; King, Taylor & Haskell 1993). The above findings may also be explained by the lack of change in daily stress as measured via EMA, suggesting a consistency in perceived stress throughout the study that was not abated by exercise. Whilst previous EMA research has revealed that increased self-reported physical activity is associated with an acute decrease in subsequent stress (Schultchen et al. 2019), the type and timing of measures differs between studies. The current study did not measure stress directly after training sessions, and any acute, transient changes in perceived stress following exercise were not evident in the daily morning questionnaire during the CT intervention. Regardless, whilst other EMA research has investigated the impact of habitual daily physical activity on stress (Schultchen et al. 2019), our pre-post exercise intervention comparison offers a novel understanding of the impact of an exercise program on daily stress.

There was no change in the job stress measures of ERI and overcommitment following CT. Whilst other studies on the effect of CT on ERI and overcommitment are limited, Michishita et al. (2017) reported improvements in certain aspects of job stress (as measured by the brief job stress questionnaire) after an exercise intervention within various white- and blue-collar workplaces (Michishita et al. 2017). However, the different assessments and definitions of job stress can significantly influence results and are important to consider when interpreting

findings (Hassard et al. 2018; Houdmont, Cox & Griffiths 2010). Within academia, increases in promotion prospects and decreases in workload are suggested to improve ERI and overcommitment (Kinman 2016). Accordingly, the nature of job stress indicates that effort-reward imbalances may be meaningfully impacted by changes to the work environment, rather than external exercise interventions.

There was no change to perceived sleep quality or self-reported total sleep time during CT, which supports other research of CT within active, healthy adults (Jurado-Fasoli et al. 2020; Kuusmaa-Schildt et al. 2019) and inactive, obese adults (Leonel et al. 2020). Cross-sectional research reports that individuals meeting both endurance and resistance training guidelines are less likely to have poor sleep quality, alongside short (4 to 6 h) or long (10 to 12 h) sleep durations (Bennie, De Cocker & Duncan 2021). The current cohort were already within the 7-9 h of recommended sleep at baseline (Hirshkowitz et al. 2015), potentially resulting in a ceiling effect for further changes in self-reported sleep duration when there was no specific focus on sleep behaviour. Given symptoms of depression have been previously associated with sleep health (Bowman et al. 2021), our results indicate that despite decreasing depressive symptoms, CT does not have an impact on self-reported sleep duration or quality in inactive academics already meeting sleep duration guidelines.

We also found no evidence of an effect of CT on daily perception of unhappy mood and fatigue. Similar to daily stress, previous research has reported improvements in mood following acute exercise, but the effects are transient, peaking shortly after exercise and declining thereafter (Reed & Ones 2006; Wichers et al. 2012). The current study may have been unable to detect any acute, post-exercise improvements in mood because it was not assessed immediately following training sessions. Other studies investigating the acute effect of exercise on

perceived fatigue have reported mixed results (Gauvin, Rejeski & Reboussin 2000; Thogersen-Ntoumani et al. 2015; Vetrovsky et al. 2021). These may be due to the high heterogeneity between exercise studies assessing the acute effects of exercise, wherein differences in population (clinical vs non clinical), exercise intensities (walking vs running) and assessment tools can have a significant influence on mental health outcomes (Reed & Ones 2006) and make study comparisons difficult.

There were no associations between changes in stress and changes in systemic inflammation or depression, despite previous cross-sectional studies reporting positive associations (Fan et al. 2015; Gouin et al. 2012; Howren, Lamkin & Suls 2009). There is a theoretical pathway from stress to inflammation to depression (Slavich & Irwin 2014), though recent studies have reported mixed support for this hypothesis, and investigations into the relationship between changes in these variables is lacking (Lee. 2020; Piantella et al. 2021). Paolucci et al. (2018) reported a concurrent decrease in perceived stress, depressive symptoms and TNF-α following 6-weeks of moderate intensity endurance training in 55 healthy adults (Paolucci et al. 2018). However, associations between these improvements were not formally analysed. Hartmann et al. (2021) showed a positive correlation between TNF-α and general stress following 6-weeks of endurance training in inactive adults with a mental illness (n=13) and without (n=13), but no association with depression was evident (Hartmann et al. 2021). Given the numerous types of perceived stress (e.g. job, general and daily) and depressive symptoms (e.g. general and daily) measured in the current study, our findings justify further research to clarify these associations and develop targeted interventions to improve these risk factors.

Limitations

The study included healthy inactive academics from a single Australian university, with access to supervised training at an onsite facility. In turn, the findings may be hard to generalise to the broader academic population and other inactive workplaces. Future studies should investigate the impact of CT on a diverse sample of academics from multiple universities. Furthermore, though most EMA items were sourced from previously validated questionnaires, the ability to measure mental health may be limited given they were only single items. Notwithstanding, EMA provides a unique insight into the day-to-day perception of mental health variables and may reduce the bias associated with recall-based mental health questionnaires (Scollon, Prieto & Diener 2009). The complexity of stress provides another limitation, particularly when comparing research. Indeed, there are many ways to characterise stress, for example, acute or chronic (Rohleder 2019), physical or perceived (Koolhaas et al. 2011), and job specific or general (Bergmann, Gyntelberg & Faber 2014), and each type of stress may respond differently to exercise interventions. However, this is also a strength of the current study, wherein measurements of various types of stress enabled more comprehensive results and comparisons with systemic inflammation and symptoms of depression.

Conclusions

This study reports a significant decrease in symptoms of depression after 14-weeks of CT in inactive academics. This emphasises the benefits of regular CT for non-clinical populations at higher risk of mental disorders. However, due to the low baseline values, a ceiling effect may have been present for symptoms of anxiety and stress. Further, CT did not affect ERI or work hours. No associations were found between changes in stress and changes in systemic inflammation or depressive symptoms, highlighting that CT can decrease symptoms of depression without affecting the effort-reward imbalance experienced by the current cohort.

This may have implications for universities wanting to decrease the risk of depression in inactive academics.

Chapter 6

Discussion

Overview, Aims and Key Findings

The desk-based workplace, long workhours and high job stress are associated with lower levels of physical activity, and may at least partly explain why 66% of academics report low to moderate levels of physical activity (Cooper & Barton 2016; Kirk & Rhodes 2011; Prince et al. 2019). Competing teaching, administrative and research demands may underlie the higher job stress and psychological strain experienced by academics compared to other professionals (Fontinha, Easton & Van Laar 2019; Kinman 2016; Siegrist 1996; Winefield et al. 2003). Prolonged high stress and low levels of physical activity are both associated with depression and MetS (Chandola, Brunner & Marmot 2006; Hammen et al. 2009; Schuch et al. 2018; Zhang et al. 2017). Furthermore, mental and cardiometabolic health may be interrelated via shared risk factors, including low grade systemic inflammation (Moazzami et al. 2019), increased fat mass and insulin resistance (Kan et al. 2013; Lee et al. 2018; Speed et al. 2019). Interventions that can improve these risk factors, increase physical activity, and decrease stress in the academic workplace are warranted. Separately, CT has been shown to improve cardiometabolic risk factors and symptoms of stress and depression within other inactive workplaces (Atlantis et al. 2004; Karatrantou et al. 2020); however, the effectiveness of CT on systemic inflammation, insulin resistance, stress and depression within academics has not been assessed.

Given that high stress and low levels of physical activity are associated with mental and cardiometabolic health disorders (Kraus et al. 2019; Rugulies, Aust & Madsen 2017), this thesis firstly aimed to describe the cardiometabolic and mental health of inactive full-time academics within an Australian University and compare cardiometabolic and mental health risk factors by sex and academic level (study 1). Secondly, this thesis aimed to determine the effect of a 14-week CT program on components of the metabolic syndrome (MetS), insulin

resistance, body composition, aerobic capacity and markers of systemic inflammation in inactive full-time academics from an Australian University (study 2). Thirdly, this thesis aimed to evaluate the effect of 14-weeks of CT on symptoms of depression, stress and anxiety in inactive full-time academics within an Australian University (study 3). Lastly, this thesis aimed to investigate the relationships between metabolic risk factors (e.g. fat mass, insulin resistance and systemic inflammation), stress and symptoms of depression (study 1, 2 and 3).

Study 1 reported that one in five inactive academics had MetS and nearly half (48%) were overweight or obese. 22% experienced moderate to severe symptoms of anxiety, stress and/or depression and lower ranking academics (A/Lecturers and Lecturers) experienced significantly greater feelings of distress, depression and stress compared to their more senior colleagues. There were no differences in mental health variables between males and females. Regression analyses revealed that higher job stress (ERI) was associated with increased symptoms of depression and higher anxiety was associated with lower aerobic capacity. There was a relationship between mental and cardiometabolic health, whereby higher distress and depressive symptoms were associated with an increased likelihood of MetS.

Study 2 showed a decrease in total body and central adiposity, alongside increases in aerobic capacity and lean mass following 14 weeks of CT, which indicates concurrent adaptations to both endurance and resistance training. However, no changes in systemic inflammation or insulin resistance were evident. Overall, there was a decrease in the number of participants with MetS in CT (pre=5, post=3) compared to an increase in control (pre=5, post=6), though adequate power to statistically compare the groups achieved. A positive association was found between changes in insulin resistance (fasting insulin/HOMA-IR) and changes in IL-6 in the control group.

Study 3 reported a significant decrease in symptoms of depression after 14 weeks of CT, despite a consistent high level of job stress (ERI). However, there were no changes observed in anxiety, general stress or daily wellness measures. Furthermore, no associations were found between changes in stress and changes in systemic inflammation or symptoms of depression.

Cardiometabolic Health of Inactive Academics and the Effect of Concurrent Training

State of Cardiometabolic Health in Inactive Academics

Study 1 found that 20% of the inactive academics in our sample met the MetS criteria, in comparison to 13% of non-diabetic individuals in the general Australian population (Cameron et al. 2007). Our results contrast with findings from a large cross-sectional study of staff from a University in China, where 5% of academics met the criteria for MetS (Cheserek et al. 2014). Acknowledging MetS calculations vary between studies, the relatively high prevalence of MetS in the current cohort is likely associated with their low levels of physical activity, given previous findings of a positive association between low physical activity and MetS (Zhang et al. 2017). In turn, these descriptive findings support the importance of increasing physical activity in inactive academics to improve components of MetS and reduce the risk of subsequent cardiometabolic disease (Pattyn et al. 2013).

The prevalence of MetS in our cohort may partly be explained by the observation that 75% exceeded the WC threshold for abdominal obesity, which is a key criterion for MetS. Further, in our study females had higher fat mass and lower lean mass compared to males, which is commonly observed in cross-sectional studies in adult populations (Imboden, Swartz, et al. 2017; Imboden, Welch, et al. 2017). Despite the age difference (≈7 years), A/Professors and Professors had similar lean mass and body fat compared to A/Lecturers and Lecturers. This

could be explained by a higher proportion of females in the lower ranking academic group, and sex-based differences outlined above that may have countered the contrasting effects of age on body composition (Imboden, Swartz, et al. 2017; Imboden, Welch, et al. 2017). Whilst other research reporting fat mass and lean mass in academics is limited, BMI has been reported as a surrogate of body composition. Alkhatib (2015) reported comparable mean BMI values from 23 UK academics (26±4 kg/m^2 vs 26±5 kg/m^2 in our study), but in contrast to our findings, the study also reported a significantly higher BMI in male compared to female academics (Alkhatib 2015). Collectively, the current data highlight the high prevalence of overweight and obesity in inactive academics, which is known to increase the risk of developing metabolic and mental disorders (Lee et al. 2009; Luppino et al. 2010), thus warranting investigation into preventive strategies.

Despite the high prevalence of abdominal obesity, mean measures of other individual components of MetS including blood pressure, glucose, HDL-C and triglycerides were below MetS cut-off values (Alberti et al. 2009). This was to be expected given the participants had not been previously diagnosed with metabolic disease. Our findings compare to research within the broader Australian adult population, which reported mean values for SBP (129 mmHg vs 121 mmHg in our study), DBP (70 mmHg vs 75 mmHg in our study), HDL-C (1.42 mmol/L vs 1.47 mmol/L in our study) and triglycerides (1.28 mmol/L vs 1.24 mmol/L in our study) (Barr et al. 2007). Studies within academic populations have also reported normotensive values for SBP (120±18 mmHg) and DBP (75±13 mmHg) (Alkhatib 2015). However, comparisons must be made with caution given the current cohort was inactive, yet free of known metabolic diseases and is not completely representative of the wider academic or Australian population. Regardless, our cohort exhibits low levels of physical activity and a high prevalence of

overweight and obesity (48%), which have been associated with increased risk of future onset of cardiometabolic diseases (Kraus et al. 2019; Smith et al. 2016a).

Aerobic capacity has also been positively associated with physical activity (Zeiher et al. 2019), and negatively associated with cardiovascular disease (Kodama et al. 2009). The mean VO_{2peak} in the current cohort was 34±5 $mL \cdot kg^{-1} \cdot min^{-1}$ for males and 26±6 $mL \cdot kg^{-1} \cdot min^{-1}$ for females. Larger cross-sectional research testing VO_{2peak} on a cycle ergometer reported a VO_{2peak} of 20±5 $mL \cdot kg^{-1} \cdot min^{-1}$ in females and 28±7 $mL \cdot kg^{-1} \cdot min^{-1}$ in males aged 40-49 y, though the cohort was not grouped by physical activity level (Kaminsky et al. 2017). VO_{2peak} can be affected by age, gender and testing methodology, making it challenging to compare studies (Aspenes et al. 2011; Kaminsky et al. 2017). Notwithstanding, our results are comparable to UK academics, wherein VO_{2peak} was 33±5 $mL \cdot kg^{-1} \cdot min^{-1}$ in males and 32±9 $mL \cdot kg^{-1} \cdot min^{-1}$ in females (Alkhatib 2015). However, Alkhatib reported VO_{2peak} did not differ by sex, which is contrary to our findings which support larger cross-sectional studies showing larger aerobic capacity in males compared to females (Kaminsky et al. 2017). Regardless, there were no differences observed in VO_{2peak} between academic levels. Like fat mass and lean mass, this is likely due to the nullification of the respective effects of age and sex on VO_{2peak} given the differences between groups (Kaminsky et al. 2017). Increasing aerobic capacity can improve components of MetS and decrease subsequent risk of cardiometabolic disease (Chow et al. 2016; Knaeps et al. 2018; Kodama et al. 2009), which may have implications for inactive academics given the high prevalence of MetS.

The low levels of physical activity, and high prevalence of MetS and overweight and obesity are of concern given their association with increased risk of cardiometablic diseases and mental disorders (Cleven et al. 2020; Lee et al. 2009; Luppino et al. 2010; Schuch et al. 2018).

Accordingly, the findings of study 1 provide justification to investigate interventions known to improve cardiometabolic risk factors, such as exercise training (de Sevilla et al. 2021) within academics participating in low levels of physical activity.

The Effect of Concurrent Training on Aerobic Capacity

The aforementioned section outlines the predominance of various cardiometabolic risk factors associated with low physical activity in inactive academics (Bradbury et al. 2017; Knaeps et al. 2018). CT has previously resulted in improvements to body composition, components of MetS and aerobic capacity in untrained adults (Brunelli et al. 2015; Coffey & Hawley 2016), justifying a trial to determine its effectiveness within inactive academics. Following the 14-week CT intervention, an increased VO_{2peak} was evident (≈14%), supporting previous research within both university staff and the general population (Hunter et al. 2020; Ihalainen et al. 2018). For example, Hunter et al. (2020) reported a 10±11% increase in VO_{2peak} following a 16-week CT intervention in university staff (47% full-time academic staff), though specific effects on the academic participants were not reported. Despite the benefits of resistance training for body composition and cardiometabolic risk factors (Strasser, Siebert & Schobersberger 2010), the improvements in aerobic capacity were likely due to the endurance component of CT. Studies have found greater improvements in aerobic capacity following CT and endurance training, compared to resistance training alone (AbouAssi et al. 2015; Schroeder et al. 2019). Regardless, greater aerobic capacity is associated with a decreased risk of developing type 2 diabetes and cardiovascular disease (Kodama et al. 2009; Lee et al. 2009), indicating the importance of regular CT for inactive academics at risk of cardiometabolic disorders.

The relatively high training adherence (79±24%, range 23-100%) reported in this study may also explain the improved aerobic capacity, with previous evidence reporting a dose-response relationship between exercise and aerobic capacity (Bonafiglia et al. 2021). Other research has reported between 73-80% adherence to supervised CT within workers without pre-existing cardiometabolic conditions (Atlantis et al. 2004; Nurminen et al. 2002). However, a strength of the current study is that it involved workplace-based supervised training, which has been shown to increase adherence compared to home-based, and unsupervised training (Hunter et al. 2020; Jakobsen et al. 2015). Overall, our results indicate that supervised work-based CT is an effective method to increase moderate to vigorous physical activity and therefore aerobic capacity in the inactive academic workplace. Increased aerobic capacity is associated with a decreased risk of developing MetS and type 2 diabetes (Chow et al. 2016; Lee 2020), which have been shown to have detrimental impacts on workplace productivity (Magliano et al. 2018; Schultz & Edington 2009). Accordingly, CT may have positive workplace related implications beyond the reported health improvements. Regardless, our findings support an onsite CT program to improve aerobic capacity of inactive academics and show cause for future integration into workplace wellness programs.

The Effect of Concurrent Training on Body Composition

Alongside an improvement in aerobic capacity, there was an increase in lean mass (≈3%), suggesting concomitant adaptations to both endurance and resistance exercise. Though research in academic populations is limited, our results contrast with studies in other inactive populations reporting mixed effects of CT on lean mass (Amaro-Gahete et al. 2021; Donges et al. 2013; Schroeder et al. 2019; Stewart et al. 2005). Indeed, Donges et al. (2013) found significant improvements in aerobic capacity, but not lean mass in response to 12-weeks of CT in 47 inactive males (Donges et al. 2013). In comparison, Schroeder et al. (2019) reported

concurrent increases in aerobic capacity and lean mass in response to 8-weeks of CT in 69 inactive adults (Schroeder et al. 2019). However, the mixed results may be due to the small samples sizes with different training program duration and stimuli apparent in these studies.

Muscle hypertrophy and consequent increases in lean mass are primarily due to the resistance training component of CT given the divergent molecular pathways stimulated by endurance and resistance exercise (Coffey & Hawley 2016; Grgic et al. 2019). Resistance training volume is particularly important as there is a dose-response effect on muscle hypertrophy (Figueiredo, de Salles & Trajano 2018). In turn, methods used to progressively increase resistance training volume within CT studies may significantly influence outcomes for lean mass. Donges et al. (2013) trained participants 3 times per week for 12 weeks and initially performed 1.5 sets of 10 repetitions of 9 resistance exercises at 75% 1RM in weeks 1 to 4, which progressed to 2 sets of 8 repetitions at 80% 1RM in weeks 5 to 12. However, Schroeder et al. (2019) trained participants 3 times per week for 8 weeks, performing 2 sets of 8 resistance exercises until repetition failure. Other CT studies have also increased resistance training volume subjectively through repetition failure (Brunelli et al. 2015; Langleite et al. 2016; Libardi et al. 2012) or relative to 1RM (Krasilshchikov, Shaw & Shaw 2009). Indeed, previous research suggest lifting to failure is an important principle in hypertrophy training (Mitchell et al. 2012), though this may not be an appropriate stimulus for inactive populations. Our exercise prescription method was similar to that used in the STRRIDE studies (AbouAssi et al. 2015; Bateman et al. 2011; Slentz et al. 2011), wherein resistance was increased when a participant could perform 12 repetitions with correct technique for all sets during 2 consecutive training sessions. This method of progressive overload is easily implementable and ensures progressions are individualised and volume is increased regularly without safety or technique concerns. Regardless, assuming a sufficient training stimulus was provided, the observed increases in

lean mass may have important implications for inactive academics, due to its relationship with a reduced risk of developing MetS (Kim et al. 2018).

CT resulted in decreases in total fat mass, android fat mass and VAT, supporting other workplace study findings of significant improvements in fat mass following CT (Hunter et al. 2020; Karatrantou et al. 2020; Pedersen et al. 2009). Indeed, Karatrantou (2020) reported a significant decrease in whole body fat mass (≈ 8%) following 6 months of CT in 36 inactive office workers, wherein CT was performed for 15 to 20 min twice per day for 5 days each week. Furthermore, Pedersen et al. (2009) showed a decrease in fat mass (%) in CT following 6 months of CT in 549 office employees, with training being conducted 3 times per week for 20 min (Pedersen et al. 2009). Within the current study, reductions in fat mass are likely due to adaptations to the endurance component of CT. Indeed, endurance training results in significantly larger improvements in fat mass compared to resistance training (Schwingshackl et al. 2013), highlighting the importance of combining resistance and endurance training for dual body composition benefits. Regardless, the effect of CT on fat mass in academics has not been investigated, and few studies have measured the impact of CT on fat distribution within inactive workers. The reduction in central adiposity (android fat mass and VAT) in the current cohort is particularly important given its positive association with proinflammatory cytokine activity and insulin resistance (Pou et al. 2007; Preis et al. 2010). Indeed, for every kilogram increase in VAT the risk of T2DM is doubled in males and quadrupled in females (Gupta et al. 2019). In turn, the decrease in total body and central adiposity indicates the potential for CT to help protect against the onset of cardiometabolic disease in inactive academics, though further research is required.

Previous prospective research has reported that participating in regular CT can significantly lower the risk of developing MetS (Bakker et al. 2017). The potential of CT to protect against cardiometabolic disease was also highlighted in the interaction effect for WC, which was unchanged in CT but increased in the control group. Despite being a less sensitive measure of central adiposity compared to VAT, increases in WC are associated with increased risk of incident type 2 diabetes (Vazquez et al. 2007), indicating the importance of CT for preventing a further increase in central obesity. CT interventions in other inactive populations have resulted in significant reductions in WC (Stewart et al. 2005; Tseng et al. 2013), although, research within academics is limited. For example, Tseng et al. (2013) reported a decrease in WC (≈9%) in the training group following 12-weeks of CT in 40 obese male adults (Tseng et al. 2013). Additionally, Stewart et al. (2005) showed a significant decrease in WC (≈3%) in the CT following 6 months of training in 104 inactive older adults (Stewart et al. 2005). Interestingly, despite significant decreases in fat mass, there was no change in BMI in the current study, again highlighting the inability of BMI to differentiate between lean or fat mass (Lee et al. 2018). Regardless, CT can improve lean mass, total fat mass and central adiposity in inactive academics, which is important given the high prevalence of overweight and obesity reported in study 1 and ensuing risk of MetS (Atlantis et al. 2009; Kwon, Kim & Kim 2017; Lee 2020). These findings support a work-based CT program for inactive academics to improve cardiometabolic risk markers associated with low levels of physical activity.

The Effect of Concurrent Training on Lipid Profile, Insulin Resistance and Inflammation

Fasting lipid profile is an important component of MetS and an indicator of cardiovascular disease risk (Alberti et al. 2009; Virani et al. 2021). Following CT, there was a significant interaction effect for non HDL-C and C:HDL, but no within-group changes. Further, CT did not alter triglycerides, total cholesterol, HDL-C or LDL-C. Though research within academics

is limited, CT interventions within other apparently healthy inactive adults have also not altered lipid profiles (Azarbayjani et al. 2014; Ho et al. 2012; Langleite et al. 2016; Schroeder et al. 2019; Stewart et al. 2005). For example, Ho et al. (2012) reported no changes in lipid profile after 12 weeks of CT in 64 inactive, overweight or obese adults (Ho et al. 2012). Results from meta-analyses suggest that lipid outcomes may be influenced by exercise adherence, intensity and intervention duration, but further research is required (Kim, Kim, et al. 2019). Indeed, we showed no changes in lipid profile, despite 79% adherence to the 14-week CT intervention, and implementation of various methods to maintain training intensity (e.g., exercise progression protocols and training load monitoring). Irrespective of the limitations of our sample size, the results may also be due to a ceiling effect on improvements given the current cohort were free of known pre-existing cardiometabolic disease and below lipid thresholds according to the MetS criteria (Alberti et al. 2009). Indeed, exercise results in larger improvements to lipid profile in individuals with pre-existing metabolic conditions (Lin et al. 2015). Subgroup analysis within the meta-analysis by Lin et al. (2015) reported that exercise improves total cholesterol and LDL-C in individuals with at least one cardiometabolic abnormality (type 2 diabetes, hypertension, hyperlipidaemia or MetS), but has no effect in individuals with none of those conditions (Lin et al. 2015). Regardless, the interaction effects we report for non HDL-C and C:HDL prompt further research into the impact of CT on lipid profile using larger cohorts of academics.

Fasting glucose and insulin, and HOMA-IR indicate risk of MetS and type 2 diabetes (Gayoso-Diz et al. 2013; Ruijgrok et al. 2018). We showed an interaction effect for fasting glucose following CT, but no within-group changes. Furthermore, CT had no effect on fasting insulin and HOMA-IR. Interestingly, other CT interventions in inactive adults with no known cardiometabolic disease report no changes to fasting glucose, but mixed effects for insulin and

HOMA-IR (AbouAssi et al. 2015; Azarbayjani et al. 2014; Brunelli et al. 2015; Stewart et al. 2005). Indeed, AbouAssi et al. (2015) reported a significant decrease in fasting insulin, but no change in glucose or HOMA-IR following 8 months of CT in 88 inactive with overweight/obese adults and mild to moderate dyslipidaemia (AbouAssi et al. 2015). In comparison, Stewart et al. (2005) reported no differences in measures of insulin resistance between intervention and control groups following 6 months of CT in 104 inactive older adults (Stewart et al. 2005). These mixed findings may be due to variance in CT characteristics and exercise adherence, but further research is required to determine which training factors are most effective in improving insulin resistance (Conn et al. 2014). Indeed, compared to the 79±24% adherence to our CT program, AbouAssi et al. (2015) reported 79±18% and Stewart et al. (2005) reported 88±10% adherence to their interventions (AbouAssi et al. 2015). Other CT studies in adults without pre-existing conditions have shown no changes in measures of insulin resistance with adherence between 67-91% (Ho et al. 2012; Jamka et al. 2021; Langleite et al. 2016). Additionally, meta-analyses have reported that exercise intervention duration does not affect fasting insulin or glucose (Lin et al. 2015). Whilst the type and distribution of endurance and resistance training within CT may have an impact on insulin resistance (AbouAssi et al. 2015; Jorge et al. 2011), the effect of key CT characteristics on insulin resistance are equivocal and require further research. Regardless, the current cohort may have also experienced a ceiling effect for improvement given exercise has a larger effect on insulin resistance within individuals with pre-existing conditions (Battista et al. 2021; Lin et al. 2015). Indeed, the meta-analysis by Lin et al. (2015) reported that exercise significantly deceased fasting insulin in individuals with at least one of type 2 diabetes, hypertension, hyperlipidaemia, or MetS, but not in individuals with none of these conditions (Lin et al. 2015). Notwithstanding, increased physical activity reduces the risk of developing type 2 diabetes

(Smith et al. 2016a), indicating the importance of work-based CT for inactive academics with high prevalence of MetS (study 1).

Systemic inflammation has been positively associated with insulin resistance (Hivert et al. 2008; Kern et al. 2001), and IL-6 and TNF-α are cytokines of particular interest due to their contribution to a low-grade chronic systemic inflammatory state that is evident with obesity and MetS (Park, Park & Yu 2005; Zafar et al. 2019). There were no changes to IL-6 and TNF-α following CT, which is comparable to previous research in healthy inactive adults (Donges et al. 2013; Libardi et al. 2012). For example, Libardi et al. (2012) found no changes in IL-6 (0.73 pg/ml vs 0.77 pg/ml in our study at baseline) or TNF-α (2.94 pg/ml vs 1.57 pg/ml in our study at baseline) following 16 weeks of CT in 47 inactive males (Libardi et al. 2012). Brunelli et al. (2015) also showed no changes in IL-6 (< 2pg/mL at baseline) or TNF-α (<2.5 pg/ml at baseline) after 24 weeks of CT in 30 inactive obese males (Brunelli et al. 2015). However, most studies investigating the effect of CT on IL-6 and TNF-α in apparently healthy participants were performed in males only (Donges et al. 2013; Ihalainen et al. 2018; Langleite et al. 2016), despite the detrimental impact that low-grade systemic inflammation can have on females (Hu et al. 2004; Pai et al. 2004). Furthermore, our study is the first in inactive academics, who may be at greater risk of low-grade systemic inflammation due to the low physical activity, high effort-reward imbalance and high prevalence of MetS reported in study 1 (Almadi, Cathers & Chow 2013; Gouin et al. 2012; Moazzami et al. 2019). Regardless, whilst CT studies are often underpowered to detect small changes in inflammatory markers, meta-analyses have reported no change in IL-6 and TNF-α in individuals with CVD (Swardfager et al. 2012), and significant decreases in IL-6 in individuals with type 2 diabetes following aerobic exercise (Hayashino et al. 2014). However, Cronin et al. (2017) reviewed the effects of aerobic, resistance and concurrent training on systemic inflammation in healthy, inactive individuals

and reported no alterations in TNF-α for any exercise type, but mixed results for only aerobic, or resistance exercise on IL-6 (Cronin et al. 2017). Overall, it appears that exercise predominantly improves systemic inflammation in individuals with high baseline concentrations (Lakka et al. 2005). Consequently, given the absence of cardiometabolic diseases in the current cohort, improvements in IL-6 and TNF-α may have been limited.

Summary of Effects of Concurrent Training on Cardiometabolic Health

In summary, CT resulted in improvements in aerobic capacity, lean mass, total body fat mass and central adiposity, despite no change in systemic inflammation or insulin resistance in inactive academics. Given the prevalence of MetS and overweight and obesity found in study 1, these findings have important implications for inactive academics. Indeed, increases in lean mass and aerobic capacity are associated with a reduced risk of developing MetS (Kim et al. 2018; Lee 2020), whilst decreased fat mass and central adiposity are associated with a lower risk of incident MetS (Kwon, Kim & Kim 2017). Given the relatively high adherence, the current workplace CT program was an effective intervention to improve cardiometabolic risk factors that exist in academics participating in low levels of physical activity.

Mental Health of Inactive Academics and the Effect of Concurrent Training

State of Mental Health in Inactive Academics

University staff are reported to have worse mental health compared to the general population (Mark & Smith 2012). Furthermore, academics experience worse mental health than other university staff, indicating they may be at an increased risk of mental illness (Winefield et al. 2003). Given low levels of physical activity are also associated with poor mental health in the general population and within employees (Dishman, McDowell & Herring 2021; Kang et al. 2016), an investigation into the mental health status of inactive academics was warranted.

Study 1 assessed the mental health status of inactive academics and reported an ERI score of 1.2±0.4 in the present cohort, indicating that these inactive academics experience more effort output than reward input. This finding contrasts with Kinman (2019) who reported an ERI of 0.8±0.6 in a sample of 458 academics from universities in the UK (Kinman 2019). However, job stress differs by occupation and country (Siegrist, Li & Montano 2014), and comparisons must consider differences in sample size and the type of ERI questionnaire used (i.e. long vs short version). Though not a clinical threshold, an ERI score >1.0 theoretically represents a failure in social reciprocity at work, leading to stress and negative feelings (Siegrist 2012; Siegrist, Li & Montano 2014). Whilst we did not investigate the reasons for the imbalance in effort and reward, commonly cited sources of job stress in Australian academics include high workload and responsibility, alongside a lack of funding, support services, leadership, promotion and recognition (Gillespie et al. 2001).

Within the current cohort, A/Lecturers and Lecturers reported similar ERI values, but higher general stress compared to higher ranking academics, which contrasts with other research reporting inconsistent differences in general stress between academic levels (Abouserie 1996; Darabi, Macaskill & Reidy 2017; Gmelch, Wilke & Lovrich 1986). Notwithstanding, lower ranking academics may experience greater exposure to stressors related to workload, work relationships, bureaucracy, social recognition and status (Slišković & Seršić 2011), which may increase general stress, though such associations do not indicate cause and effect. In regard to sex, there were no differences in mean scores for job-specific and general stress, in line with previous research in academics from universities in the UK (Abouserie 1996; Darabi, Macaskill & Reidy 2017), Czech Republic (Mudrak et al. 2017), and South Africa (Barkhuizen & Rothmann 2008). Given previous research has shown that higher ERI and stress are

associated with greater risk of developing depression (Hammen et al. 2009; Rugulies, Aust & Madsen 2017), it is pertinent to investigate strategies to minimise stress in inactive academics.

Despite mean mental health scores in the "normal" range according to DASS-21 and K10 definitions, 22% of inactive academics had moderate to severe symptoms of stress, anxiety or depression. Furthermore, the mean distress score places this cohort in the 75th percentile of distress in Australian adults (Slade, Grove & Burgess 2011). Similarly, Mark & Smith (2012) reported increased feelings of anxiety and depression in university staff compared to the general population, and Winefield et al. (2003) found that within university staff, academics had higher psychological strain compared to other employees (e.g. administrative and technical staff) (Winefield et al. 2003). This suggests that inactive academics may be at greater risk of mental disorders compared to other populations.

In the current study, we found no significant sex differences in mean scores for depression or anxiety, which is in line with findings from a sample of UK academics (Darabi, Macaskill & Reidy 2017), but contrasts with research from Irish, Finnish, Pakistani and Canadian Universities, wherein female academics had poorer mental health compared to male academics (Akhtar Malik 2018; Catano et al. 2010; Hogan et al. 2015). However, sex differences in mental health outcomes are likely influenced by occupation (e.g. support vs academic staff) and work environment (e.g. socio-cultural setting) (Emslie et al. 2002), which must be considered when comparing research. Although we did not investigate specific causes of anxiety and depression, the association between ERI and depression highlights that the workplace characteristics that affect effort and reward may also influence other mental health outcomes. Regardless, previous research has reported a positive association between stress and symptoms of depression (Fan et al. 2015; Hammen et al. 2009). Our study shows that A/Lecturers and Lecturers reported

more feelings of depression and distress compared to higher ranking academics, which may explain the higher levels of general stress experienced by A/Lecturers and Lecturers. Overall, these results indicate that inactive academics experience increased symptoms of distress, with greater feelings of distress and depression in lower ranking academics. Accordingly, the efficacy of interventions known to improve symptoms of distress and depression, such as exercise (Bellón et al. 2021), should be assessed within the inactive academic workplace.

In summary, study 1 provides evidence of poor mental health within an inactive Australian academic cohort. Specifically, 1 in 5 individuals in our cohort experienced moderate to severe symptoms of stress, anxiety or depression, and the mean ERI of 1.2 indicated an imbalance between effort input and reward output. In turn, higher stress and low physical activity have previously shown to increase the risk of developing mental disorders such as depression (Hammen et al. 2009; Rugulies, Aust & Madsen 2017; Schuch et al. 2018). Given that exercise has been shown to decrease symptoms of depression and stress within other inactive workplaces (Atlantis et al. 2004), an investigation into the impact of exercise on mental health in the inactive academic workplace was warranted.

The Effect of Concurrent Training on Depression and Anxiety

Due to the prevalence of poor mental health in inactive academics shown in study 1, we examined the effect of a 14-week CT intervention on symptoms of depression, anxiety and stress in this population. CT resulted in significant improvements in symptoms of depression (as assessed by the DASS-21). Previous studies in academics are lacking, Atlantis et al. (2004) reported a decrease in symptoms of depression (via DASS-21) following 24 weeks of CT and behaviour modification in inactive casino employees (Atlantis et al. 2004), though independent effects of CT were not assessed. Although CT adherence was similar between studies (80% vs

79% in our study), our intervention resulted in a moderate effect size for improvements in depression compared to the small effect size in the study by Atlantis et al. (2004). A larger effect may have been expected in the Atlantis et al. (2004) study as the mean depression score (via DASS-21) at baseline was "moderate" compared to the median of "normal" in ours, and higher baseline scores of depression are associated with larger improvements following exercise (Atlantis et al. 2004; King, Taylor & Haskell 1993; Rethorst, Wipfli & Landers 2009). These collective findings highlight the impact that CT can have on symptom of depression, independent of other behavioural interventions. The importance of combined endurance and resistance training for depressive symptoms has also been emphasised in cross-sectional research, wherein the lowest prevalence of depressive symptoms were found in adults participating in regular endurance and resistance training, in contrast to either exercise mode alone, though analysis was not adjusted for total weekly exercise volume (Bennie et al. 2019). Consequently, the moderate effect that CT had on symptoms of depression may have implications for the future mental health of inactive academics, particularly given that increasing physical activity has been associated with a decreased risk of developing depression (Harvey et al. 2018).

Increased physical activity has also been shown to decrease anxiety by a small effect in non-clinical populations (Rebar et al. 2015). However, our CT intervention did not alter symptoms of anxiety, which may be unsurprising given the low levels at baseline. While limited research has been conducted in academics, CT interventions within other inactive workplaces have also reported no changes in anxiety when baseline anxiety has been within normal ranges (as measured by the DASS-21) (Atlantis et al. 2004). Lucibello et al. (2019) showed that 9-weeks of endurance exercise reduced state anxiety in participants with high, but not low baseline anxiety (Lucibello, Parker & Heisz 2019). This highlights the ceiling effect on improvements

for individuals with low baseline anxiety, whilst reaffirming that exercise may still protect against an increase in anxiety. Increased physical activity has been shown to reduce the risk of incident anxiety disorders (Schuch et al. 2019), indicating a role of CT in maintaining the mental health of inactive academics.

Overall, CT was effective in decreasing symptoms of depression in inactive academics, despite no effect on anxiety. This is important given the prevalence of moderate to severe symptoms of depression, anxiety or stress reported in study 1. These results indicate that CT may counter the increased risk of depression associated with the effort-reward imbalance evident in the current cohort (Rugulies, Aust & Madsen 2017). Such a decrease in depressive symptoms may not only be relevant to inactive academics, but also the university sector given previous research has shown a significant decrease in productivity in workers with higher depressive symptoms (McTernan, Dollard & LaMontagne 2013), however, research into the impact of CT on productivity in inactive academics is required.

The Effect of Concurrent Training on Stress

Perceived stress is an important risk factor for depression (Hammen et al. 2009), and has previously shown to be higher in academics compared to other workers (Fontinha, Easton & Van Laar 2019). In our study, CT did not affect general stress, which contrasts with other research within inactive workplaces that report a significant decrease in stress (via DASS-21) following CT (Atlantis et al. 2004). However, Atlantis et al. (2012) reported a "moderate" level of stress at baseline, compared to the "normal" scores in the current cohort. As with symptoms of depression and anxiety (Lucibello, Parker & Heisz 2019; Rethorst, Wipfli & Landers 2009), higher baseline symptoms of stress are associated with greater decreases following exercise interventions (Atlantis et al. 2004; King, Taylor & Haskell 1993), and must be considered when

comparing post-training results. Regardless, increased physical activity is associated with decreased stress (Burg et al. 2017; Ng & Jeffery 2003), which is important given the association between stress and depression reported in study 1 and other cross-sectional research (Fan et al. 2015; Hammen et al. 2009). Hence, increasing moderate to vigorous physical activity via CT may have important implications for managing stress in inactive academics, despite the lack of change observed here following exercise training.

Separate from recall-based measures of stress (e.g. via DASS-21), the daily reporting of stress (via EMA) can provide a unique insight into the day-to-day fluctuations in stress (Scollon, Prieto & Diener 2009). The CT intervention did not affect daily stress within academics, which may explain why general stress questionnaire responses were not significantly different following training. Previously, a 7-day study employing EMA found that self-reported physical activity was associated with a decrease in acute stress over the following several hours (Schultchen et al. 2019). Moreover, Burg et al. (2017) reported a significant negative association between perceived end-of-day stress and a 30-min bout of objectively measured physical activity during the day (Burg et al. 2017). However, there were substantial individual differences in responses, with no relationship between stress and physical activity reported within most individuals (Burg et al. 2017). Regardless, the type and timing of stress measures differs between studies and must be considered when inferring conclusions. For example, Schultchen et al. (2019) measured stress 6 times per day using 2 items from the perceived stress scale (Schultchen et al. 2019), whilst Burg et al. (2017) measured stress once in the evening with a single arbitrary item (Burg et al. 2017). In the current study, stress was not measured directly after exercise sessions, and any acute or transient changes in perceived stress following exercise were not apparent in the daily morning questionnaire during the CT intervention.

Study 1 and other research within academics have reported high stress and poor mental health within the profession (Winefield et al. 2003), and study 3 is the first to assess the impact of an exercise intervention on ERI and overcommitment. In turn, our results indicate the limited impact exercise had on job stress. Previous research has shown that exercise can influence the perception of general stress (Atlantis et al. 2004), but variables such as workload, job-specific work outcomes, support services and promotion prospects are more likely to have a meaningful impact on job stress given its job-specific nature (Gillespie et al. 2001). Research in other workplaces has reported improvements in certain aspects of job stress (as measured by the brief job stress questionnaire) following 8 weeks of CT within various white- and blue-collar workplaces (Michishita et al. 2017). However, the different assessments and definitions of job stress may significantly influence results and are important to consider when interpreting findings (Hassard et al. 2018; Houdmont, Cox & Griffiths 2010). For example, the brief job stress questionnaire used in the study by Michishita et al. (2017) identifies job-related stress via various job stressors, including job demands and control (Shimomitsu 2000), suggesting a unique definition and measurement of job stress compared to the ERI questionnaire. Furthermore, a review of 18 nationally representative surveys suggested that case definitions affect job stress outcomes (Houdmont, Cox & Griffiths 2010). Notwithstanding, the association of ERI with depression (Rugulies, Aust & Madsen 2017), and the imbalance in effort and rewards found in study 1, highlights the importance to investigate strategies other than exercise to decrease ERI in inactive academics.

The Effect of Concurrent Training on Daily Wellness Measures

Given the various biases associated with recall based questionnaires (Choi & Pak 2005), EMA provides a more sensitive measure of mental health indices (Solhan et al. 2009). In turn, EMA was used to measure daily perceptions of fatigue, stress, mood and workload, alongside sleep

quality and duration in study 3. Previously, the poor mental health experienced by academics compared to other professions has been associated with sleep disturbances (Winefield et al. 2002), and the decreases in symptoms of depression in the current study may have been associated with improvements in sleep (Bowman et al. 2021). However, we found no changes in daily measures of perceived sleep quality or self-reported total sleep duration in response to CT, which is in line with other CT intervention studies within inactive obese (Leonel et al. 2020), and apparently healthy adults (Jurado-Fasoli et al. 2020; Kuusmaa-Schildt et al. 2019). For example, Leonel et al. (2020) reported no changes in subjective measures of sleep quality and duration following 16 weeks of CT in inactive obese adults (Leonel et al. 2020). Additionally, Jurado-Fasoli et al. (2020) found no interaction effects for perceived sleep quality or objectively measured total sleep time between CT and control groups following a 12-week intervention in inactive healthy adults (Jurado-Fasoli et al. 2020). Though unable to determine causality, cross-sectional research has reported that individuals adhering to both endurance and resistance training guidelines are less likely to have poor sleep quality or short (4 to 6 h) or long (10 to 12 h) sleep duration (Bennie, De Cocker & Duncan 2021). However, a meta-analysis found that exercise-induced changes in sleep quality and quantity were predominantly reported in older populations, or those with pre-existing conditions (Kovacevic et al. 2018). The current academic cohort were free of known pre-existing conditions and within the recommended 7-9 h of sleep at baseline according to self-report data (Hirshkowitz et al. 2015), which may have resulted in a ceiling effect on any improvements in sleep quality and duration. Notwithstanding, our research provides a novel assessment of perceived sleep quality within academia and shows that CT did not have an impact on subjective measures of sleep despite decreases in depression in our sample.

No changes in daily mood were evident during CT despite a decrease in symptoms of depression (via DASS-21), highlighting the low agreement often apparent between EMA and retrospective assessments (Solhan et al. 2009). Although exercise research in academics is lacking, other studies have found improvements in mood after acute exercise, but the impact is transient, peaking shortly after exercise and returning to baseline thereafter (Reed & Ones 2006; Wichers et al. 2012). Wichers et al. (2012) found that positive affect significantly increased for up to 3 h following usual physical activity in 474 female adults, however, negative affect did not change (Wichers et al. 2012). The current study may have missed any acute, post-exercise improvements in mood because it was not assessed immediately following training sessions. Furthermore, we measured mood via a single item representing negative affect, for which the effect of exercise is mixed (Liao, Shonkoff & Dunton 2015). Nevertheless, our research indicates that despite improving recall-based measurement of depressive symptoms, the daily measurement of mood was not influenced by CT.

Despite previous research reporting a positive association between depression and fatigue (Lim et al. 2005), we found that CT significantly improved symptoms of depression with no changes in perceived fatigue. Although research in academics is limited, other studies investigating the effect of exercise on perceived fatigue have reported mixed results (Gauvin, Rejeski & Reboussin 2000; Thogersen-Ntoumani et al. 2015; Vetrovsky et al. 2021). The study by Gauvin, Rejeski and Reboussin (2000) reported no effect of physical activity on self-reported fatigue in 84 females (Gauvin, Rejeski & Reboussin 2000). However, Vetrovsky et al. (2021) found that exercise was associated with a significant decrease in acute perceptions of fatigue the following morning during a 3-week study (Vetrovsky et al. 2021). The variance in results may be due to the high heterogeneity between exercise studies, wherein differences in population (clinical vs non clinical), exercise intensities (walking vs running) and assessment

tools can have a significant influence on perceptual mental health outcomes (Reed & Ones 2006), making study comparisons difficult. Despite no significant effect of CT on fatigue in the current study, fatigue can significantly influence productivity within the workplace (Ricci et al. 2007) and should be managed in academics given their vital role in the tertiary education system (Marginson 2007; Taylor 2001).

Overall, 14-weeks of CT resulted in a significant decrease in symptoms of depression in inactive academics, without changes to stress, anxiety or daily wellness measures. Despite the "normal" baseline scores for symptoms of stress, anxiety and depression in the current cohort, CT may counter the mental health risks associated with the low levels of physical activity and high job stress in the inactive academic workplace. Furthermore, the relatively high adherence to CT provides evidence of its feasibility in the academic workplace, and our findings warrant further research into the impact of CT on productivity within tertiary academics.

The Interrelationships Between Risk Factors for Cardiometabolic and Mental Health

Associations Between Stress, Depression, and Inflammation

The inter-relationship of physical and mental health is of growing interest, with previous cross-sectional research reporting positive associations between stress, systemic inflammation and symptoms of depression (Fan et al. 2015; Gouin et al. 2012; Howren, Lamkin & Suls 2009). However, few studies report inter-related changes over time, which is important to facilitate the prescription of more targeted and effective interventions to improve these risk factors. Previous research has shown concomitant improvements in stress and depressive symptoms following CT (Atlantis et al. 2004), but mixed effects on systemic inflammation in apparently healthy populations (Donges et al. 2013; Ihalainen et al. 2018). Accordingly, further investigation into the association between these risk factors was warranted.

The cross-sectional analysis in study 1 reported that ERI had a positive association with stress and depression, which concurs with a previous meta-analysis of prospective studies on workplace mental health in the US, Europe and Canada (Rugulies, Aust & Madsen 2017). Indeed, Rugulies, Aust & Madsen (2017) showed that a greater ERI was associated with a 1.5-fold increased risk of depression (Rugulies, Aust & Madsen 2017). In contrast, Kinman (2019) reported limited evidence for a relationship between ERI and mental health as measured by the General Health Questionnaire in academics. The study found a positive correlation between ERI and mental ill health, but subsequent regression analysis found the association only existed for certain types of reward within the ERI ratio (e.g. esteem rewards) (Kinman 2019). These results may contrast with ours due to the measurement scales used, as psychological strain measured by the General Health Questionnaire not only incorporates symptoms of depression, but also anxiety and distress (Goldberg 1988), which were not associated with ERI in the current study. Regardless, the association between ERI and depression in study 1 prompted further investigation into this relationship in study 3. Indeed, previous research has reported a decrease in symptoms of depression following CT in inactive workers (Atlantis et al. 2004), and we wanted to investigate whether such improvements were associated with changes in ERI.

Despite a significant decrease in symptoms of depression, there was no change in ERI and no association between changes in either variable following the CT intervention (study 3). This contrasts with the cross-sectional results in study 1 and from prospective research indicating a positive association between ERI and depression (Rugulies, Aust & Madsen 2017). However, the lack of significant changes in ERI in the current study may have limited the power of the regression analysis, as there was minimal variation in the independent variable. There was no interaction effect of group, indicating that allocation to the training or control group did not

influence the association between ERI and symptoms of depression. In turn, our results suggest that while CT can decrease symptoms of depression, this occurs without concomitant changes in job stress. Consequently, for universities wanting to improve the mental health of inactive academics, CT offers an effective alternative to other, potentially more costly methods that target depressive symptoms through improvements in ERI i.e. reductions in workload or increases in wages. However, our results must be interpreted in relation to the sample size of the current study which is significantly smaller than longitudinal studies and thus has less statistical power to detect associations between variables.

Study 1 found that higher symptoms of depression and distress were associated with greater likelihood of MetS, though the relationship was not bidirectional. In comparison, a previous meta-analysis found evidence of a bidirectional association between depression and MetS (Pan et al. 2012), wherein MetS significantly predicted incident depression (OR=1.49, 95%CI=1.19,1.89), and vice versa (OR=1.52, 95%CI=1.20,1.91). This relationship between cardiometabolic and mental health may be founded on the similar risk factors that underlie the development of both cardiometabolic disease and mental illness. Indeed, stress and low-grade systemic inflammation are positively associated with both depression and MetS (Dowlati et al. 2010; Esser et al. 2014; Hammen et al. 2009; Kuo et al. 2019). Furthermore, chronic stress is associated with increased systemic inflammatory markers, such as IL-6 and TNF-α (Rohleder 2019), and thus a theoretical pathway has been suggested to exist between stress to inflammation and in turn depression (Slavich & Irwin 2014). However, to date this relationship has received mixed support (Lee. 2020; Piantella et al. 2021), and further exploration is required.

Given that stress has been previously associated with depression (Hammen et al. 2009), and the inflammatory markers IL-6 and TNF-α (Gouin et al. 2012; Rohleder 2019), we investigated whether changes in stress would be associated with changes in systemic inflammation or depression following CT. However, there was no association between changes in any type of stress and changes in depression with systemic inflammation. Previously, Paolucci et al. (2018) reported concomitant improvements in stress, depression and TNF-α following 6-weeks of moderate intensity endurance training in 55 healthy adults (Paolucci et al. 2018). However, analysis of the relationship between changes in these variables was not performed. Regardless, Hartmann et al. (2021) found a positive correlation between TNF-α and general stress (r=0.44, P=0.026), but not depression, following 6-weeks of endurance training (Hartmann et al. 2021). Lee et al. (2020) reported an association (*B*=0.11, 95% CI=0.10, 0.13, n=941) between general stress and symptoms of depression from longitudinal data (6 years), but no cross-sectional association between general stress and IL-6 (Lee. 2020). This contrasts with a cross-sectional study of 2,528 adults that reported job stress and depressive symptoms were positively associated with IL-6 in females only, and job stress was positively associated with symptoms of depression (Piantella et al. 2021). These results allude to the complexity of stress and its relationship with mental and physical health (Koolhaas et al. 2011), and indicate the need for further research into the associations between these variables.

Overall, our results reveal that despite a positive cross-sectional association between job stress and symptoms of depression (study 1), changes in depressive symptoms following CT were not associated with changes in ERI (study 3). Furthermore, changes in general, daily, and job-specific stress were not associated with changes in symptoms of depression or systemic inflammation (study 3), suggesting that CT decreases symptoms of depression without concomitant changes in stress or systemic inflammation. Acknowledging the limitations of our

low sample size and small variations in the predictor variable, our analysis of change data provides a unique perspective from cross-sectional studies on the association between mental and physical health in an academic cohort.

Associations Between Body Composition, Insulin Resistance and Systemic Inflammation

The positive association between systemic inflammation and mental and cardiometabolic disorders such as depression and type 2 diabetes (Dowlati et al. 2010; Spranger et al. 2003; Wang et al. 2013), highlights the importance in investigating relationships between systemic inflammation and other risk markers of these disorders. Indeed, IL-6 and TNF-α have been positively associated with other metabolic risk factors including fat mass and insulin resistance (Kunz et al. 2021). Given exercise is known to improve body composition and insulin resistance (Battista et al. 2021), study 2 reports the associations between changes in these variables and changes in systemic inflammation. Despite significant reductions in fat mass, there were no concomitant decreases in systemic inflammation following CT. Furthermore, regression analyses did not find an association between changes in fat mass and changes in IL-6 or TNF-α, which is surprising because VAT and fat mass are primary sources of IL-6 and TNF-α production (Fain et al. 2004; Fontana et al. 2007; Winkler et al. 2003). Other exercise interventions have also resulted in decreases in measures of fat mass without alterations in IL-6 and TNF-α (Ihalainen et al. 2018; Langleite et al. 2016). Alternatively, prospective studies have found that measures of fat mass at least partially account for the positive association between IL-6 and TNF-α and cardiometabolic disease (Kaptoge et al. 2014; Spranger et al. 2003; Wang et al. 2013), indicating an association between fat mass and systemic inflammation. There is complexity surrounding the production and effects of cytokines and it

is likely that changes in other variables such as adipose tissue macrophage phenotype, adipose tissue type, and insulin resistance are associated with changes in IL-6 and TNF-α (Hotamisligil 2017b; Villarroya et al. 2018).

Previous cross-sectional research has reported a positive association between insulin resistance and systemic inflammation, independent of fat mass (Hivert et al. 2010). However, few studies have assessed whether a change in insulin resistance is associated with a change in markers of systemic inflammation. We show changes in fasting insulin and HOMA-IR were positively associated with IL-6 in the control group and remained significant even after adjustment for fat mass. However, no such association existed in the CT group, suggesting that CT may attenuate the relationship between systemic IL-6 and insulin resistance. Indeed, IL-6 can have varied effects depending on location of release and mode of action (Hunter & Jones 2015), which can be influenced by exercise (Pedersen 2011). For example, acute increases in IL-6 release from muscle tissue following exercise can result in insulin sensitising effects, whilst chronic expression of IL-6 from adipose tissue can induce insulin resistance (Kunz et al. 2021; Pedersen 2017). However, the lack of association between insulin resistance and IL-6 in the CT group of the current study remains to be explained and requires further research. Regardless, our findings in the control group support other research conveying a positive association between IL-6 and insulin resistance, independent of adiposity (Abbatecola et al. 2004; Kern et al. 2001). Though we did not explore the underlying causes for the lack of association in the training group, our findings prompt further research into the effect that CT has on the relationship between insulin resistance and systemic inflammation.

Limitations

Despite our study being the first to evaluate the impact of CT on cardiometabolic and mental health in inactive academics, there are limitations that need to be recognised. We recruited inactive, apparently healthy academics from a single Australian university, with access to supervised training at an onsite facility. Therefore, results are difficult to generalise to the broader academic population and other inactive workplaces. Indeed, the mental and cardiometabolic health of academics may differ by country and demographics (Akhtar Malik 2018; Cheserek et al. 2014), and universities may vary in regard to workplace culture and support services. Furthermore, exercise has a more pronounced effect on cardiometabolic (e.g. insulin resistance and cholesterol) and mental (e.g. symptoms depression and anxiety) health in participants with pre-existing conditions (Lin et al. 2015; Rethorst, Wipfli & Landers 2009) and it is recognised such participants were excluded from the current studies. Future research should employ a multicentre longitudinal design and investigate the impact of CT on the mental and cardiometabolic health of academics with and without pre-existing conditions. However, the obvious resource constraints associated with such research make it difficult to collect the detailed and objective measurements of cardiometabolic and mental health in the current study.

The complexity of some of the mental and cardiometabolic health variables measured in the research is another limitation. For example, the prevalence of MetS can differ depending on the defining criteria, which makes study comparisons difficult (Cameron et al. 2007). This issue is also found in stress research, wherein stress can be characterised as acute or chronic (Rohleder 2019), physical or perceived (Koolhaas et al. 2011), and job specific or general (Bergmann, Gyntelberg & Faber 2014), and each type may respond differently to exercise interventions. In turn, various types of stress were measured in the current study to enable more comprehensive conclusions and comparisons to be made within inactive academics.

There were also more specific limitations within each study. Regarding study 1, though associations between mental and cardiometabolic health variables were evident, its cross-sectional nature does not allow causation to be determined. Furthermore, the unequal distribution of females and males between academic levels may have influenced between-group comparisons especially the effects of sex on fat mass, lean mass and aerobic capacity. In study 2 and 3, the sample size was inadequate to detect small changes in systemic inflammation, and thus results should be interpreted with caution. Furthermore, the number of participants with MetS was too small to statistically compare between groups in study 1 and 2, despite a decrease in the number of participants with MetS in the CT group in study 2. A limitation of study 3 was the single items used to measure complex variables such as stress and fatigue during daily EMA. Although sourced from previously validated questionnaires, these items are often amalgamated with others to more thoroughly assess mental health (McNair, Loor & Droppleman 1981). Notwithstanding, the use of EMA provided a unique insight into the day-to-day perceptions of inactive academics, and was an important complementary measure of mental health given the biases associated with recall-based questionnaires (Scollon, Prieto & Diener 2009).

Chapter 7

Summary, Practical Applications and Future Directions

Summary and Conclusions

This thesis examined the mental and cardiometabolic health status of inactive academics (study 1), and then assessed the effectiveness CT on risk factors for cardiometabolic and mental disorders in inactive academics (study 2 and 3). More specifically, the primary aims were to:

1. Describe the cardiometabolic and mental health of inactive full-time academics within an Australian university and compare cardiometabolic and mental health risk factors by sex and academic level (study 1).
2. Evaluate the effect of 14-weeks of CT on insulin resistance, body composition, body fat distribution, markers of systemic inflammation and components of MetS in inactive full-time academics from an Australian university (study 2).
3. Determine the effect of a 14-week CT program on symptoms of depression, stress and anxiety in inactive full-time academics from an Australian university (study 3).

A secondary aim of the thesis was to investigate relationships between:

- Risk markers of mental (e.g. ERI, depressive symptoms) and cardiometabolic (VO_{2peak}, MetS) disorders (study 1).
- Changes in systemic inflammation and changes in insulin resistance and body composition (study 2).
- Changes in different types of stress (job specific, general, daily) and changes in symptoms of depression and systemic inflammation (study 3).

Key Findings

Study 1:

- 20% (n=12) of inactive academics met the criteria for MetS.
- 48% of inactive academics were overweight (n=18, 31%) or obese (n=10, 17%).

- 22% (n=13) of inactive academics had moderate to severe symptoms of depression (n=4), anxiety (n=4) and/or stress (n=11).
- Inactive academics had a mean ERI score of 1.22 ±0.40 indicating more effort outputs for each reward input.
- Mental health outcomes did not differ between males and females.
- A/Lecturers and Lecturers reported greater feelings of distress and depression compared to A/Professors and Professors and were significantly more stressed than Senior Lecturers and A/Professors and Professors.
- Job stress (ERI) was positively associated with depressive symptoms, and higher depressive symptoms and distress were associated with an increased likelihood of MetS.

Study 2:

- There were significant increases in lean mass and aerobic capacity in CT compared to control.
- There were significant decreases in fat mass and central adiposity (VAT and android fat mass) in CT compared to control.
- CT did not affect HOMA-IR, insulin, systemic inflammation, triglycerides, total cholesterol, HDL-C or LDL-C.
- Changes in insulin resistance were positively associated with changes in IL-6 in the control group, but not in CT.

Study 3:

- There was a significant decrease in symptoms of depression in CT compared to control.
- CT did not affect anxiety, distress, general stress, job stress or daily wellness measures.

- There were no associations between changes in stress and changes in depressive symptoms or systemic inflammation.

We found evidence of poor mental and cardiometabolic health in inactive academics. However, CT was effective in countering the negative effects of high stress and low levels of physical activity on body composition, aerobic capacity, and symptoms of depression in the inactive academic workplace. Our findings also emphasise the benefits of CT for non-clinical populations at higher risk of mental and cardiometabolic health disorders. Given the detrimental impact that chronic conditions like depression and cardiometabolic diseases can have on health and productivity, our findings may have important implications for both inactive academics and the broader university sector.

Practical Applications

Based on the key findings of this thesis, there are subsequent practical applications for both the university sector and exercise professionals:

- For the university sector, there is a need to attend to the cardiometabolic and mental health of inactive academics. This is evident by the high prevalence of MetS, rates of moderate to severe levels of stress, anxiety and/or depression, and experience of an effort-reward imbalance.
- Lower ranking academics experience worse mental health compared to their more senior colleagues. In turn, interventions to improve mental health should place a particular emphasis on this sub-group of inactive academics.
- For the university sector, embedding a concurrent exercise training program into the inactive academic workplace may counter the detrimental impact of low amounts of

physical activity and an effort-reward imbalance on mental and cardiometabolic health, without altering effort-reward imbalance.

- Given the positive cross-sectional association between ERI and depression, and depression and MetS, it is important to consider both mental and cardiometabolic health outcomes when developing interventions to improve one of these variables.
- For exercise professionals, CT is an effective exercise mode to provide concomitant improvements in aerobic capacity, fat mass and lean mass in untrained populations.
- Despite the absence of pre-existing conditions, CT can still improve the mental and cardiometabolic health of inactive academics and reduce the risk factors associated with future onset of cardiometabolic diseases and mental disorders.

Directions for Future Research

There are multiple recommendations for future research based on the results and limitations of the current thesis:

- The current cohort were apparently healthy inactive academics from a single Australian university. This makes it difficult to generalise findings to the broader academic population, and those with pre-existing conditions. Future research should be multi-centred and investigate the impact of exercise (CT or otherwise) on academics with and without pre-existing conditions.
- Various types of CT interventions have been used within inactive adults, and future research should investigate which components of a CT intervention have the largest impact on cardiometabolic and mental health outcomes. These may include the types and ratio of endurance and resistance training, progressive overload method, and duration, frequency and intensity of training.

- Despite previous cross-sectional research showing a positive association between fat mass and systemic inflammation, we did not find that change in fat mass was associated with alterations in systemic inflammation. Furthermore, we show a positive association between changes in insulin resistance and IL-6 in the control group, with no relationship evident in the CT group. In turn, further research is required to clarify associations between fat mass, insulin resistance and inflammation, and explain the impact of CT on any of these relationships.
- Despite no association between changes in stress (daily, general or job-specific) and changes in systemic inflammation or depressive symptoms, these relationships have been reported previously. Evidently, further research into the association between different types of stress, inflammatory markers and symptoms of depression is warranted.

References

Abbatecola, A.M., Ferrucci, L., Grella, R., Bandinelli, S., Bonafe, M., Barbieri, M., Corsi, A.M., Lauretani, F., Franceschi, C. & Paolisso, G. 2004, 'Diverse effect of inflammatory markers on insulin resistance and insulin-resistance syndrome in the elderly', *J Am Geriatr Soc*, vol. 52, no. 3, pp. 399-404.

AbouAssi, H., Slentz, C.A., Mikus, C.R., Tanner, C.J., Bateman, L.A., Willis, L.H., Shields, A.T., Piner, L.W., Penry, L.E., Kraus, E.A., Huffman, K.M., Bales, C.W., Houmard, J.A. & Kraus, W.E. 2015, 'The effects of aerobic, resistance, and combination training on insulin sensitivity and secretion in overweight adults from STRRIDE AT/RT: a randomized trial', *J Appl Physiol (1985)*, vol. 118, no. 12, pp. 1474-82.

Abouserie, R. 1996, 'Stress, Coping Strategies and Job Satisfaction in University Academic Staff', *Educational Psychology*, vol. 16, no. 1, pp. 49-56.

Akhtar Malik, N. 2018, 'Occupational Stress and Mental and Musculoskeletal Health among University Teachers', *Eurasian Journal of Medical Investigation*, vol. 2, no. 3, pp. 139-47.

Alberti, K.G., Eckel, R.H., Grundy, S.M., Zimmet, P.Z., Cleeman, J.I., Donato, K.A., Fruchart, J.C., James, W.P., Loria, C.M., Smith, S.C., Jr., International Diabetes Federation Task Force on, E., Prevention, Hational Heart, L., Blood, I., American Heart, A., World Heart, F., International Atherosclerosis, S. & International Association for the Study of, O. 2009, 'Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity', *Circulation*, vol. 120, no. 16, pp. 1640-5.

Alkhatib, A. 2015, 'High prevalence of sedentary risk factors amongst university employees and potential health benefits of campus workplace exercise intervention', *Work*, vol. 52, no. 3, pp. 589-95.

Almadi, T., Cathers, I. & Chow, C.M. 2013, 'Associations among work-related stress, cortisol, inflammation, and metabolic syndrome', *Psychophysiology*, vol. 50, no. 9, pp. 821-30.

Alshehri, T., Boone, S., de Mutsert, R., Penninx, B., Rosendaal, F., le Cessie, S., Milaneschi, Y. & Mook-Kanamori, D. 2019, 'The association between overall and abdominal adiposity and depressive mood: A cross-sectional analysis in 6459 participants', *Psychoneuroendocrinology*, vol. 110, p. 104429.

Amagasa, S., Machida, M., Fukushima, N., Kikuchi, H., Takamiya, T., Odagiri, Y. & Inoue, S. 2018, 'Is objectively measured light-intensity physical activity associated with health outcomes after adjustment for moderate-to-vigorous physical activity in adults? A systematic review', *International Journal of Behavioral Nutrition and Physical Activity*, vol. 15, no. 1, pp. 1-13.

Amaro-Gahete, F.J., De-la, O.A., Jurado-Fasoli, L., Dote-Montero, M., Gutierrez, A., Ruiz, J.R. & Castillo, M.J. 2019, 'Changes in Physical Fitness After 12 Weeks of Structured Concurrent Exercise Training, High Intensity Interval Training, or Whole-Body Electromyostimulation Training in Sedentary Middle-Aged Adults: A Randomized Controlled Trial', *Front Physiol*, vol. 10, p. 451.

Amaro-Gahete, F.J., Ponce-Gonzalez, J.G., Corral-Perez, J., Velazquez-Diaz, D., Lavie, C.J. & Jimenez-Pavon, D. 2021, 'Effect of a 12-Week Concurrent Training Intervention on Cardiometabolic Health in Obese Men: A Pilot Study', *Front Physiol*, vol. 12, p. 630831.

American Diabetes Association 2021, '2. Classification and diagnosis of diabetes: Standards of Medical Care in Diabetes—2021', *Diabetes Care*, vol. 44, no. Supplement 1, pp. S15-S33.

Annesi, J.J., Gann, S. & Westcott, W.W. 2004, 'Preliminary evaluation of a 10-wk. resistance and cardiovascular exercise protocol on physiological and psychological measures for a sample of older women', *Percept Mot Skills*, vol. 98, no. 1, pp. 163-70.

Armstrong, D., Matangi, M., Brouillard, D. & Myers, M.G. 2015, 'Automated office blood pressure - being alone and not location is what matters most', *Blood Press Monit*, vol. 20, no. 4, pp. 204-8.

Aspenes, S.T., Nilsen, T.I., Skaug, E.A., Bertheussen, G.F., Ellingsen, O., Vatten, L. & Wisloff, U. 2011, 'Peak oxygen uptake and cardiovascular risk factors in 4631 healthy women and men', *Med Sci Sports Exerc*, vol. 43, no. 8, pp. 1465-73.

Assah, F., Brage, S., Ekelund, U. & Wareham, N. 2008, 'The association of intensity and overall level of physical activity energy expenditure with a marker of insulin resistance', *Diabetologia*, vol. 51, no. 8, pp. 1399-407.

Atlantis, E., Chow, C.M., Kirby, A. & Singh, M.F. 2004, 'An effective exercise-based intervention for improving mental health and quality of life measures: a randomized controlled trial', *Prev Med*, vol. 39, no. 2, pp. 424-34.

Atlantis, E., Martin, S.A., Haren, M.T., Taylor, A.W. & Wittert, G.A. 2009, 'Inverse associations between muscle mass, strength, and the metabolic syndrome', *Metabolism*, vol. 58, no. 7, pp. 1013-22.

Australian Bureau of Statistics. 2018, 'National Health Survey: First Results, 2017-18', Series National Health Survey: First Results, 2017-18 Canberra, <https://www.abs.gov.au/statistics/health/health-conditions-and-risks/national-health-survey-first-results/latest-release>.

Azarbayjani, M.A., Abedi, B., Peeri, M., Rasaee, M.J. & Stannard, S.R. 2014, 'Effects of combined aerobic and resistant training on lipid profile and glycemic control in sedentary men', *Int Med J*, vol. 21, no. 2, pp. 132-6.

Bakker, E.A., Lee, D.-c., Sui, X., Artero, E.G., Ruiz, J.R., Eijsvogels, T.M., Lavie, C.J. & Blair, S.N. 2017, 'Association of resistance exercise, independent of and combined with aerobic exercise, with the incidence of metabolic syndrome', vol. 92, Elsevier, pp. 1214-22.

Balducci, S., Zanuso, S., Nicolucci, A., Fernando, F., Cavallo, S., Cardelli, P., Fallucca, S., Alessi, E., Letizia, C. & Jimenez, A. 2010, 'Anti-inflammatory effect of exercise training in subjects with type 2 diabetes and the metabolic syndrome is dependent on exercise modalities and independent of weight loss', *Nutrition, Metabolism and Cardiovascular Diseases*, vol. 20, no. 8, pp. 608-17.

Barkhuizen, N. & Rothmann, S. 2008, 'Occupational stress of academic staff in South African higher education institutions', *South African journal of psychology*, vol. 38, no. 2, pp. 321-36.

Barr, E.L., Zimmet, P.Z., Welborn, T.A., Jolley, D., Magliano, D.J., Dunstan, D.W., Cameron, A.J., Dwyer, T., Taylor, H.R., Tonkin, A.M., Wong, T.Y., McNeil, J. & Shaw, J.E. 2007, 'Risk of cardiovascular and all-cause mortality in individuals with diabetes mellitus, impaired fasting glucose, and impaired glucose tolerance: the Australian Diabetes, Obesity, and Lifestyle Study (AusDiab)', *Circulation*, vol. 116, no. 2, pp. 151-7.

Batelaan, N.M., Seldenrijk, A., Bot, M., van Balkom, A.J. & Penninx, B.W. 2016, 'Anxiety and new onset of cardiovascular disease: critical review and meta-analysis', *Br J Psychiatry*, vol. 208, no. 3, pp. 223-31.

Bateman, L.A., Slentz, C.A., Willis, L.H., Shields, A.T., Piner, L.W., Bales, C.W., Houmard, J.A. & Kraus, W.E. 2011, 'Comparison of aerobic versus resistance exercise training effects on metabolic syndrome (from the Studies of a Targeted Risk Reduction Intervention Through Defined Exercise-STRRIDE-AT/RT)', *The American Journal of Cardiology*, vol. 108, no. 6, pp. 838-44.

Battista, F., Ermolao, A., van Baak, M.A., Beaulieu, K., Blundell, J.E., Busetto, L., Carraca, E.V., Encantado, J., Dicker, D., Farpour-Lambert, N., Pramono, A., Bellicha, A. & Oppert, J.M. 2021, 'Effect of exercise on cardiometabolic health of adults with overweight or obesity: Focus on blood pressure, insulin resistance, and intrahepatic fat-A systematic review and meta-analysis', *Obes Rev*, vol. 22 Suppl 4, p. e13269.

Baumann, S., Guertler, D., Weymar, F., Bahls, M., Dörr, M., van den Berg, N., John, U. & Ulbricht, S. 2020, 'Do accelerometer-based physical activity patterns differentially affect cardiorespiratory fitness? A growth mixture modeling approach', *Journal of Behavioral Medicine*, vol. 43, no. 1, pp. 99-107.

Becofsky, K.M., Sui, X., Lee, D.C., Wilcox, S., Zhang, J. & Blair, S.N. 2015, 'A prospective study of fitness, fatness, and depressive symptoms', *Am J Epidemiol*, vol. 181, no. 5, pp. 311-20.

Bell, A.S., Rajendran, D. & Theiler, S. 2012, 'Job Stress, Wellbeing, Work-Life Balance and Work-Life Conflict Among Australian Academics', *E-Journal of Applied Psychology*, vol. 8, no. 1.

Bellón, J.Á., Conejo-Cerón, S., Sánchez-Calderón, A., Rodríguez-Martín, B., Bellón, D., Rodríguez-Sánchez, E., Mendive, J.M., Ara, I. & Moreno-Peral, P. 2021, 'Effectiveness of exercise-based interventions in reducing depressive symptoms in people without clinical depression: systematic review and meta-analysis of randomised controlled trials', *The British Journal of Psychiatry*, pp. 1-10.

Bennie, J.A., De Cocker, K., Biddle, S.J. & Teychenne, M.J. 2020, 'Joint and dose-dependent associations between aerobic and muscle-strengthening activity with depression: A cross-sectional study of 1.48 million adults between 2011 and 2017', *Depression and Anxiety*, vol. 37, no. 2, pp. 166-78.

Bennie, J.A., De Cocker, K. & Duncan, M.J. 2021, 'Associations of muscle-strengthening and aerobic exercise with self-reported components of sleep health among a nationally representative sample of 47,564 US adults', *Sleep Health*, vol. 7, no. 2, pp. 281-8.

Bennie, J.A., Pedisic, Z., Timperio, A., Crawford, D., Dunstan, D., Bauman, A., van Uffelen, J. & Salmon, J. 2015, 'Total and domain-specific sitting time among employees in desk-based work settings in Australia', *Australian and New Zealand Journal of Public Health*, vol. 39, no. 3, pp. 237-42.

Bennie, J.A., Teychenne, M.J., De Cocker, K. & Biddle, S.J. 2019, 'Associations between aerobic and muscle-strengthening exercise with depressive symptom severity among 17,839 US adults', *Preventive Medicine*, vol. 121, pp. 121-7.

Benson, S., Engler, H., Wegner, A., Rebernik, L., Spreitzer, I., Schedlowski, M. & Elsenbruch, S. 2017, 'What makes you feel sick after inflammation? Predictors of acute and persisting physical sickness symptoms induced by experimental endotoxemia', *Clinical Pharmacology & Therapeutics*, vol. 102, no. 1, pp. 141-51.

Bergmann, N., Gyntelberg, F. & Faber, J. 2014, 'The appraisal of chronic stress and the development of the metabolic syndrome: a systematic review of prospective cohort studies', *Endocr Connect*, vol. 3, no. 2, pp. R55-80.

Bonafiglia, J.T., Preobrazenski, N., Islam, H., Walsh, J.J., Ross, R., Johannsen, N.M., Martin, C.K., Church, T.S., Slentz, C.A., Ross, L.M., Kraus, W.E., Kenny, G.P., Goldfield, G.S., Prud'homme, D., Sigal, R.J., Earnest, C.P. & Gurd, B.J. 2021, 'Exploring Differences in Cardiorespiratory Fitness Response Rates Across Varying Doses of Exercise Training: A Retrospective Analysis of Eight Randomized Controlled Trials', *Sports Med*, vol. 51, no. 8, pp. 1785-97.

Bowman, M.A., Kline, C.E., Buysse, D.J., Kravitz, H.M., Joffe, H., Matthews, K.A., Bromberger, J.T., Roecklein, K.A., Krafty, R.T. & Hall, M.H. 2021, 'Longitudinal Association Between Depressive Symptoms and Multidimensional Sleep Health: The SWAN Sleep Study', *Annals of Behavioral Medicine*.

Boyd, C.M., Bakker, A.B., Pignata, S., Winefield, A.H., Gillespie, N. & Stough, C. 2011, 'A longitudinal test of the job demands-resources model among Australian university academics', *Applied Psychology*, vol. 60, no. 1, pp. 112-40.

Bradbury, K.E., Guo, W., Cairns, B.J., Armstrong, M.E. & Key, T.J. 2017, 'Association between physical activity and body fat percentage, with adjustment for BMI: a large cross-sectional analysis of UK Biobank', *BMJ Open*, vol. 7, no. 3, p. e011843.

Browne, R.A.V., Farias-Junior, L.F., Freire, Y.A., Schwade, D., Macêdo, G.d.A.D.d., Montenegro, V.B., Lopes, T.J.A., Dantas, F.F.O. & Costa, E.C. 2017, 'Sedentary Occupation Workers Who Meet the Physical Activity Recommendations Have a Reduced Risk for Metabolic Syndrome', *Journal of Occupational and Environmental Medicine*, vol. 59, no. 11, pp. 1029-33.

Brunelli, D.T., Chacon-Mikahil, M.P., Gaspari, A.F., Lopes, W.A., Bonganha, V., Bonfante, I.L., Bellotto, M.L., Libardi, C.A. & Cavaglieri, C.R. 2015, 'Combined Training Reduces Subclinical Inflammation in Obese Middle-Age Men', *Med Sci Sports Exerc*, vol. 47, no. 10, pp. 2207-15.

Bull, F.C., Al-Ansari, S.S., Biddle, S., Borodulin, K., Buman, M.P., Cardon, G., Carty, C., Chaput, J.P., Chastin, S., Chou, R., Dempsey, P.C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C.M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P.T., Lambert, E., Leitzmann, M., Milton, K., Ortega, F.B., Ranasinghe, C., Stamatakis, E., Tiedemann, A., Troiano, R.P., van der Ploeg, H.P., Wari, V. & Willumsen, J.F. 2020, 'World Health Organization 2020 guidelines on physical activity and sedentary behaviour', *Br J Sports Med*, vol. 54, no. 24, pp. 1451-62.

Burg, M.M., Schwartz, J.E., Kronish, I.M., Diaz, K.M., Alcantara, C., Duer-Hefele, J. & Davidson, K.W. 2017, 'Does stress result in you exercising less? Or does exercising result in you being less stressed? Or is it both? Testing the bi-directional stress-exercise association at the group and person (N of 1) level', *Annals of Behavioral Medicine*, vol. 51, no. 6, pp. 799-809.

Cairney, J., Veldhuizen, S., Wade, T.J., Kurdyak, P. & Streiner, D.L. 2007, 'Evaluation of 2 measures of psychological distress as screeners for depression in the general population', *The Canadian Journal of Psychiatry*, vol. 52, no. 2, pp. 111-20.

Cameron, A.J., Magliano, D.J., Zimmet, P.Z., Welborn, T. & Shaw, J.E. 2007, 'The metabolic syndrome in Australia: prevalence using four definitions', *Diabetes Res Clin Pract*, vol. 77, no. 3, pp. 471-8.

Cardenas Fuentes, G., Bawaked, R.A., Martinez Gonzalez, M.A., Corella, D., Subirana Cachinero, I., Salas-Salvado, J., Estruch, R., Serra-Majem, L., Ros, E., Lapetra Peralta, J., Fiol, M., Rekondo, J., Gomez-Gracia, E., Tur Mari, J.A., Pinto Sala, X., Babio, N., Ortega, C., Martinez, J.A. & Schroder, H. 2018, 'Association of physical activity with

body mass index, waist circumference and incidence of obesity in older adults', *Eur J Public Health*, vol. 28, no. 5, pp. 944-50.
Carney, C.E., Buysse, D.J., Ancoli-Israel, S., Edinger, J.D., Krystal, A.D., Lichstein, K.L. & Morin, C.M. 2012, 'The consensus sleep diary: standardizing prospective sleep self-monitoring', *Sleep*, vol. 35, no. 2, pp. 287-302.
Caspersen, C.J., Powell, K.E. & Christenson, G.M. 1985, 'Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research', *Public Health Rep*, vol. 100, no. 2, pp. 126-31.
Catano, V., Francis, L., Haines, T., Kirpalani, H., Shannon, H., Stringer, B. & Lozanzki, L. 2010, 'Occupational stress in Canadian universities: A national survey', *International Journal of Stress Management*, vol. 17, no. 3, pp. 232-58.
Ceaser, T.G., Fitzhugh, E.C., Thompson, D.L. & Bassett, D.R., Jr. 2013, 'Association of physical activity, fitness, and race: NHANES 1999-2004', *Med Sci Sports Exerc*, vol. 45, no. 2, pp. 286-93.
Chandola, T., Brunner, E. & Marmot, M. 2006, 'Chronic stress at work and the metabolic syndrome: prospective study', *BMJ*, vol. 332, no. 7540, pp. 521-5.
Cheng, Y., Pardo, M., de Souza Armini, R., Martinez, A., Mouhsine, H., Zagury, J.-F., Jope, R.S. & Beurel, E. 2016, 'Stress-induced neuroinflammation is mediated by GSK3-dependent TLR4 signaling that promotes susceptibility to depression-like behavior', *Brain, Behavior, and Immunity*, vol. 53, pp. 207-22.
Cheserek, M.J., Wu, G.R., Shen, L.Y., Shi, Y.H. & Le, G.W. 2014, 'Disparities in the Prevalence of Metabolic Syndrome (MS) and its Components Among University Employees by Age, Gender and Occupation', *J Clin Diagn Res*, vol. 8, no. 2, pp. 65-9.
Choi, B.C. & Pak, A.W. 2005, 'Peer reviewed: a catalog of biases in questionnaires', *Preventing chronic disease*, vol. 2, no. 1.
Chovanec, L. & Gropel, P. 2020, 'Effects of 8-week endurance and resistance training programmes on cardiovascular stress responses, life stress and coping', *J Sports Sci*, vol. 38, no. 15, pp. 1699-707.
Chow, L.S., Odegaard, A.O., Bosch, T.A., Bantle, A.E., Wang, Q., Hughes, J., Carnethon, M., Ingram, K.H., Durant, N., Lewis, C.E., Ryder, J., Shay, C.M., Kelly, A.S. & Schreiner, P.J. 2016, 'Twenty year fitness trends in young adults and incidence of prediabetes and diabetes: the CARDIA study', *Diabetologia*, vol. 59, no. 8, pp. 1659-65.
Cleven, L., Krell-Roesch, J., Nigg, C.R. & Woll, A. 2020, 'The association between physical activity with incident obesity, coronary heart disease, diabetes and hypertension in adults: a systematic review of longitudinal studies published after 2012', *BMC Public Health*, vol. 20, pp. 1-15.
Coffey, V.G. & Hawley, J.A. 2016, 'Concurrent exercise training: Do opposites distract?', *The Journal of physiology*.
Conn, V.S. 2010, 'Anxiety outcomes after physical activity interventions: meta-analysis findings', *Nurs Res*, vol. 59, no. 3, pp. 224-31.
Conn, V.S., Hafdahl, A.R., Cooper, P.S., Brown, L.M. & Lusk, S.L. 2009, 'Meta-analysis of workplace physical activity interventions', *Am J Prev Med*, vol. 37, no. 4, pp. 330-9.
Conn, V.S., Koopman, R.J., Ruppar, T.M., Phillips, L.J., Mehr, D.R. & Hafdahl, A.R. 2014, 'Insulin sensitivity following exercise interventions: systematic review and meta-analysis of outcomes among healthy adults', *Journal of primary care & community health*, vol. 5, no. 3, pp. 211-22.

Cooper, K. & Barton, G.C. 2016, 'An exploration of physical activity and wellbeing in university employees', *Perspect Public Health*, vol. 136, no. 3, pp. 152-60.
Crewe, C., An, Y.A. & Scherer, P.E. 2017, 'The ominous triad of adipose tissue dysfunction: inflammation, fibrosis, and impaired angiogenesis', *J Clin Invest*, vol. 127, no. 1, pp. 74-82.
Cronin, O., Keohane, D.M., Molloy, M.G. & Shanahan, F. 2017, 'The effect of exercise interventions on inflammatory biomarkers in healthy, physically inactive subjects: a systematic review', *QJM*, vol. 110, no. 10, pp. 629-37.
Crossland, H., Skirrow, S., Puthucheary, Z.A., Constantin-Teodosiu, D. & Greenhaff, P.L. 2019, 'The impact of immobilisation and inflammation on the regulation of muscle mass and insulin resistance: different routes to similar end-points', *J Physiol*, vol. 597, no. 5, pp. 1259-70.
Cuddy, T.F., Ramos, J.S. & Dalleck, L.C. 2019, 'Reduced exertion high-intensity interval training is more effective at improving cardiorespiratory fitness and cardiometabolic health than traditional moderate-intensity continuous training', *International journal of environmental research and public health*, vol. 16, no. 3, p. 483.
Da Silva, M.A., Singh-Manoux, A., Brunner, E.J., Kaffashian, S., Shipley, M.J., Kivimäki, M. & Nabi, H. 2012, 'Bidirectional association between physical activity and symptoms of anxiety and depression: the Whitehall II study', *European journal of epidemiology*, vol. 27, no. 7, pp. 537-46.
Darabi, M., Macaskill, A. & Reidy, L. 2017, 'Stress among UK academics: Identifying who copes best', *Journal of Further and Higher Education*, vol. 41, no. 3, pp. 393-412.
de Sevilla, G.G.P., Vicente-Arche, F.C., Thuissard, I.J., Barcelo, O. & Perez-Ruiz, M. 2021, 'Effectiveness of Workplace Exercise Interventions on Body Composition: A Systematic Review and Meta-Analysis', *Am J Health Promot*, p. 8901171211014726.
Dedele, A., Miskinyte, A., Andrusaityte, S. & Bartkute, Z. 2019, 'Perceived Stress among Different Occupational Groups and the Interaction with Sedentary Behaviour', *Int J Environ Res Public Health*, vol. 16, no. 23, p. 4595.
Dishman, R.K., McDowell, C.P. & Herring, M.P. 2021, 'Customary physical activity and odds of depression: a systematic review and meta-analysis of 111 prospective cohort studies', *Br J Sports Med*, vol. 55, no. 16, pp. 926-34.
Donges, C.E., Duffield, R., Guelfi, K.J., Smith, G.C., Adams, D.R. & Edge, J.A. 2013, 'Comparative effects of single-mode vs. duration-matched concurrent exercise training on body composition, low-grade inflammation, and glucose regulation in sedentary, overweight, middle-aged men', *Appl Physiol Nutr Metab*, vol. 38, no. 7, pp. 779-88.
Dowlati, Y., Herrmann, N., Swardfager, W., Liu, H., Sham, L., Reim, E.K. & Lanctot, K.L. 2010, 'A meta-analysis of cytokines in major depression', *Biol Psychiatry*, vol. 67, no. 5, pp. 446-57.
Eddens, L., van Someren, K. & Howatson, G. 2017, 'The role of intra-session exercise sequence in the interference effect: a systematic review with meta-analysis', *Sports Medicine*, pp. 1-12.
Eddy, P., Heckenberg, R., Wertheim, E.H., Kent, S. & Wright, B.J. 2016, 'A systematic review and meta-analysis of the effort-reward imbalance model of workplace stress with indicators of immune function', *J Psychosom Res*, vol. 91, pp. 1-8.

Eisenberger, N.I., Berkman, E.T., Inagaki, T.K., Rameson, L.T., Mashal, N.M. & Irwin, M.R. 2010, 'Inflammation-induced anhedonia: endotoxin reduces ventral striatum responses to reward', *Biol Psychiatry*, vol. 68, no. 8, pp. 748-54.

Ekelund, U., Brage, S., Griffin, S.J. & Wareham, N.J. 2009, 'Objectively measured moderate- and vigorous-intensity physical activity but not sedentary time predicts insulin resistance in high-risk individuals', *Diabetes care*, vol. 32, no. 6, pp. 1081-6.

Elosua, R., Bartali, B., Ordovas, J.M., Corsi, A.M., Lauretani, F. & Ferrucci, L. 2005, 'Association between physical activity, physical performance, and inflammatory biomarkers in an elderly population: the InCHIANTI study', *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, vol. 60, no. 6, pp. 760-7.

Emeny, R.T., Zierer, A., Lacruz, M.E., Baumert, J., Herder, C., Gornitzka, G., Koenig, W., Thorand, B., Ladwig, K.H. & Investigators, K. 2013, 'Job strain-associated inflammatory burden and long-term risk of coronary events: findings from the MONICA/KORA Augsburg case-cohort study', *Psychosom Med*, vol. 75, no. 3, pp. 317-25.

Emslie, C., Fuhrer, R., Hunt, K., Macintyre, S., Shipley, M. & Stansfeld, S. 2002, 'Gender differences in mental health: evidence from three organisations', *Soc Sci Med*, vol. 54, no. 4, pp. 621-4.

Engelen, L., Gale, J., Chau, J.Y., Hardy, L.L., Mackey, M., Johnson, N., Shirley, D. & Bauman, A. 2017, 'Who is at risk of chronic disease? Associations between risk profiles of physical activity, sitting and cardio-metabolic disease in Australian adults', *Australian and New Zealand journal of public health*, vol. 41, no. 2, pp. 178-83.

Engler, H., Brendt, P., Wischermann, J., Wegner, A., Rohling, R., Schoemberg, T., Meyer, U., Gold, R., Peters, J., Benson, S. & Schedlowski, M. 2017, 'Selective increase of cerebrospinal fluid IL-6 during experimental systemic inflammation in humans: association with depressive symptoms', *Mol Psychiatry*, vol. 22, no. 10, pp. 1448-54.

Esser, N., Legrand-Poels, S., Piette, J., Scheen, A.J. & Paquot, N. 2014, 'Inflammation as a link between obesity, metabolic syndrome and type 2 diabetes', *Diabetes research and clinical practice*, vol. 105, no. 2, pp. 141-50.

Fain, J.N., Madan, A.K., Hiler, M.L., Cheema, P. & Bahouth, S.W. 2004, 'Comparison of the release of adipokines by adipose tissue, adipose tissue matrix, and adipocytes from visceral and subcutaneous abdominal adipose tissues of obese humans', *Endocrinology*, vol. 145, no. 5, pp. 2273-82.

Fan, L.B., Blumenthal, J.A., Watkins, L.L. & Sherwood, A. 2015, 'Work and home stress: associations with anxiety and depression symptoms', *Occup Med (Lond)*, vol. 65, no. 2, pp. 110-6.

Faul, F., Erdfelder, E., Lang, A.G. & Buchner, A. 2007, 'G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences', *Behav Res Methods*, vol. 39, no. 2, pp. 175-91.

Fetherston, C., Fetherston, A., Batt, S., Sully, M. & Wei, R. 2020, 'Wellbeing and work-life merge in Australian and UK academics', *Studies in Higher Education*, pp. 1-15.

Figueiredo, V.C., de Salles, B.F. & Trajano, G.S. 2018, 'Volume for muscle hypertrophy and health outcomes: the most effective variable in resistance training', *Sports Medicine*, vol. 48, no. 3, pp. 499-505.

Fiuza-Luces, C., Garatachea, N., Berger, N.A. & Lucia, A. 2013, 'Exercise is the real polypill', *Physiology*.

Fleshner, M., Frank, M. & Maier, S.F. 2017, 'Danger Signals and Inflammasomes: Stress-Evoked Sterile Inflammation in Mood Disorders', *Neuropsychopharmacology*, vol. 42, no. 1, pp. 36-45.

Fontana, L., Eagon, J.C., Trujillo, M.E., Scherer, P.E. & Klein, S. 2007, 'Visceral fat adipokine secretion is associated with systemic inflammation in obese humans', *Diabetes*, vol. 56, no. 4, pp. 1010-3.

Fontinha, R., Easton, S. & Van Laar, D. 2019, 'Overtime and quality of working life in academics and nonacademics: The role of perceived work-life balance', *International Journal of Stress Management*, vol. 26, no. 2, p. 173.

Ford, E.S., Li, C. & Sattar, N. 2008, 'Metabolic syndrome and incident diabetes: current state of the evidence', *Diabetes Care*, vol. 31, no. 9, pp. 1898-904.

Fransson, E.I., Heikkilä, K., Nyberg, S.T., Zins, M., Westerlund, H., Westerholm, P., Väänänen, A., Virtanen, M., Vahtera, J. & Theorell, T. 2012, 'Job strain as a risk factor for leisure-time physical inactivity: an individual-participant meta-analysis of up to 170,000 men and women: the IPD-Work Consortium', *American journal of epidemiology*, vol. 176, no. 12, pp. 1078-89.

Freda, P.U., Shen, W., Reyes-Vidal, C.M., Geer, E.B., Arias-Mendoza, F., Gallagher, D. & Heymsfield, S.B. 2009, 'Skeletal muscle mass in acromegaly assessed by magnetic resonance imaging and dual-photon x-ray absorptiometry', *J Clin Endocrinol Metab*, vol. 94, no. 8, pp. 2880-6.

Fritz, C.O., Morris, P.E. & Richler, J.J. 2012, 'Effect size estimates: current use, calculations, and interpretation', *Journal of experimental psychology: General*, vol. 141, no. 1, p. 2.

Fuezeki, E., Engeroff, T. & Banzer, W. 2017, 'Health benefits of light-intensity physical activity: a systematic review of accelerometer data of the National Health and Nutrition Examination Survey (NHANES)', *Sports Medicine*, vol. 47, no. 9, pp. 1769-93.

Fukumoto, Y., Yamada, Y., Ikezoe, T., Watanabe, Y., Taniguchi, M., Sawano, S., Minami, S., Asai, T., Kimura, M. & Ichihashi, N. 2018, 'Association of physical activity with age-related changes in muscle echo intensity in older adults: a 4-year longitudinal study', *J Appl Physiol (1985)*, vol. 125, no. 5, pp. 1468-74.

Furman, D., Campisi, J., Verdin, E., Carrera-Bastos, P., Targ, S., Franceschi, C., Ferrucci, L., Gilroy, D.W., Fasano, A., Miller, G.W., Miller, A.H., Mantovani, A., Weyand, C.M., Barzilai, N., Goronzy, J.J., Rando, T.A., Effros, R.B., Lucia, A., Kleinstreuer, N. & Slavich, G.M. 2019, 'Chronic inflammation in the etiology of disease across the life span', *Nat Med*, vol. 25, no. 12, pp. 1822-32.

Furukawa, T.A., Kessler, R.C., Slade, T. & Andrews, G. 2003, 'The performance of the K6 and K10 screening scales for psychological distress in the Australian National Survey of Mental Health and Well-Being', *Psychol Med*, vol. 33, no. 2, pp. 357-62.

Fyfe, J.J., Bishop, D.J. & Stepto, N.K. 2014, 'Interference between concurrent resistance and endurance exercise: molecular bases and the role of individual training variables', *Sports medicine*, vol. 44, no. 6, pp. 743-62.

Gan, Y., Gong, Y., Tong, X., Sun, H., Cong, Y., Dong, X., Wang, Y., Xu, X., Yin, X., Deng, J., Li, L., Cao, S. & Lu, Z. 2014, 'Depression and the risk of coronary heart disease: a meta-analysis of prospective cohort studies', *BMC Psychiatry*, vol. 14, no. 1, p. 371.

Gauvin, L., Rejeski, W.J. & Reboussin, B.A. 2000, 'Contributions of acute bouts of vigorous physical activity to explaining diurnal variations in feeling states in active, middle-aged women', *Health Psychol*, vol. 19, no. 4, pp. 365-75.

Gayoso-Diz, P., Otero-Gonzalez, A., Rodriguez-Alvarez, M.X., Gude, F., Garcia, F., De Francisco, A. & Quintela, A.G. 2013, 'Insulin resistance (HOMA-IR) cut-off values and the metabolic syndrome in a general adult population: effect of gender and age: EPIRCE cross-sectional study', *BMC Endocr Disord*, vol. 13, no. 1, p. 47.

Geiker, N., Astrup, A., Hjorth, M., Sjödin, A., Pijls, L. & Markus, C.R. 2018, 'Does stress influence sleep patterns, food intake, weight gain, abdominal obesity and weight loss interventions and vice versa?', *Obesity Reviews*, vol. 19, no. 1, pp. 81-97.

Genin, P.M., Dessenne, P., Finaud, J., Pereira, B., Thivel, D. & Duclos, M. 2018, 'Health and fitness benefits but low adherence rate: effect of a 10-month onsite physical activity program among tertiary employees', *Journal of occupational and environmental medicine*, vol. 60, no. 9, pp. e455-e62.

Gerber, M., Brand, S., Herrmann, C., Colledge, F., Holsboer-Trachsler, E. & Pühse, U. 2014, 'Increased objectively assessed vigorous-intensity exercise is associated with reduced stress, increased mental health and good objective and subjective sleep in young adults', *Physiology & behavior*, vol. 135, pp. 17-24.

Gianfredi, V., Koster, A., Eussen, S., Odone, A., Amerio, A., Signorelli, C., Stehouwer, C., Savelberg, H., Wesselius, A. & Köhler, S. 2020, 'The association between cardio-respiratory fitness and incident depression: The Maastricht Study', *Journal of Affective Disorders*, p. 12493.

Gillespie, N.A., Walsh, M., Winefield, A.H., Dua, J. & Stough, C. 2001, 'Occupational stress in universities: Staff perceptions of the causes, consequences and moderators of stress', *Work & Stress*, vol. 15, no. 1, pp. 53-72.

Glickman, S.G., Marn, C.S., Supiano, M.A. & Dengel, D.R. 2004, 'Validity and reliability of dual-energy X-ray absorptiometry for the assessment of abdominal adiposity', *J Appl Physiol (1985)*, vol. 97, no. 2, pp. 509-14.

Gmelch, W.H., Wilke, P.K. & Lovrich, N.P. 1986, 'Dimensions of stress among university faculty: Factor-analytic results from a national study', *Research in higher education*, vol. 24, no. 3, pp. 266-86.

Godin, G. & Shephard, R.J. 1997, 'Godin leisure-time exercise questionnaire', *Med Sci Sports Exerc*, vol. 29, no. 6s, p. S36.

Goldberg, D.P. 1988, 'User's guide to the General Health Questionnaire', *Windsor*.

Golden, S.H., Lazo, M., Carnethon, M., Bertoni, A.G., Schreiner, P.J., Roux, A.V.D., Lee, H.B. & Lyketsos, C. 2008, 'Examining a bidirectional association between depressive symptoms and diabetes', *Jama*, vol. 299, no. 23, pp. 2751-9.

Gordon, B.R., McDowell, C.P., Hallgren, M., Meyer, J.D., Lyons, M. & Herring, M.P. 2018, 'Association of Efficacy of Resistance Exercise Training With Depressive Symptoms: Meta-analysis and Meta-regression Analysis of Randomized Clinical Trials', *JAMA Psychiatry*, vol. 75, no. 6, pp. 566-76.

Gordon, B.R., McDowell, C.P., Lyons, M. & Herring, M.P. 2017, 'The Effects of Resistance Exercise Training on Anxiety: A Meta-Analysis and Meta-Regression Analysis of Randomized Controlled Trials', *Sports Med*, vol. 47, no. 12, pp. 2521-32.

Gouin, J.P., Glaser, R., Malarkey, W.B., Beversdorf, D. & Kiecolt-Glaser, J. 2012, 'Chronic stress, daily stressors, and circulating inflammatory markers', *Health Psychol*, vol. 31, no. 2, pp. 264-8.

Grace, A., Chan, E., Giallauria, F., Graham, P.L. & Smart, N.A. 2017, 'Clinical outcomes and glycaemic responses to different aerobic exercise training intensities in type II diabetes: a systematic review and meta-analysis', *Cardiovasc Diabetol*, vol. 16, no. 1, p. 37.

Graham, E.A., Deschenes, S.S., Khalil, M.N., Danna, S., Filion, K.B. & Schmitz, N. 2020, 'Measures of depression and risk of type 2 diabetes: A systematic review and meta-analysis', *J Affect Disord*, vol. 265, pp. 224-32.

Greco, G. 2020, 'Effects of combined exercise training on work-related burnout symptoms and psychological stress in the helping professionals'.

Grgic, J., Mcllvenna, L.C., Fyfe, J.J., Sabol, F., Bishop, D.J., Schoenfeld, B.J. & Pedisic, Z. 2019, 'Does aerobic training promote the same skeletal muscle hypertrophy as resistance training? A systematic review and meta-analysis', *Sports Medicine*, vol. 49, no. 2, pp. 233-54.

Grontved, A., Rimm, E.B., Willett, W.C., Andersen, L.B. & Hu, F.B. 2012, 'A prospective study of weight training and risk of type 2 diabetes mellitus in men', *Arch Intern Med*, vol. 172, no. 17, pp. 1306-12.

Groves, R.M., Fowler Jr, F.J., Couper, M.P., Lepkowski, J.M., Singer, E. & Tourangeau, R. 2011, *Survey methodology*, vol. 561, John Wiley & Sons.

Gupta, P., Lanca, C., Gan, A.T., Soh, P., Thakur, S., Tao, Y., Kumari, N., Man, R.E., Fenwick, E.K. & Lamoureux, E.L. 2019, 'The association between body composition using dual energy X-ray absorptiometry and type-2 diabetes: a systematic review and meta-analysis of observational studies', *Scientific reports*, vol. 9, no. 1, pp. 1-10.

Guzik, T.J., Skiba, D.S., Touyz, R.M. & Harrison, D.G. 2017, 'The role of infiltrating immune cells in dysfunctional adipose tissue', *Cardiovasc Res*, vol. 113, no. 9, pp. 1009-23.

Haczeyni, F., Bell-Anderson, K.S. & Farrell, G.C. 2018, 'Causes and mechanisms of adipocyte enlargement and adipose expansion', *Obes Rev*, vol. 19, no. 3, pp. 406-20.

Hallgren, M., Nguyen, T.T., Herring, M.P., McDowell, C.P., Gordon, B.R., Stubbs, B., Bellocco, R. & Lagerros, Y.T. 2019, 'Associations of physical activity with anxiety symptoms and disorders: Findings from the Swedish National March Cohort', *Gen Hosp Psychiatry*, vol. 58, pp. 45-50.

Hallgren, M., Nguyen, T.T., Owen, N., Vancampfort, D., Dunstan, D.W., Wallin, P., Andersson, G. & Ekblom-Bak, E. 2020, 'Associations of sedentary behavior in leisure and occupational contexts with symptoms of depression and anxiety', *Prev Med*, vol. 133, p. 106021.

Hamer, M., Sabia, S., Batty, G.D., Shipley, M.J., Tabak, A.G., Singh-Manoux, A. & Kivimaki, M. 2012, 'Physical activity and inflammatory markers over 10 years: follow-up in men and women from the Whitehall II cohort study', *Circulation*, vol. 126, no. 8, pp. 928-33.

Hammen, C., Kim, E.Y., Eberhart, N.K. & Brennan, P.A. 2009, 'Chronic and acute stress and the prediction of major depression in women', *Depress Anxiety*, vol. 26, no. 8, pp. 718-23.

Han, M.S., White, A., Perry, R.J., Camporez, J.P., Hidalgo, J., Shulman, G.I. & Davis, R.J. 2020, 'Regulation of adipose tissue inflammation by interleukin 6', *Proc Natl Acad Sci U S A*, vol. 117, no. 6, pp. 2751-60.

Harris, P.A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N. & Conde, J.G. 2009, 'Research electronic data capture (REDCap)--a metadata-driven methodology and workflow

process for providing translational research informatics support', *J Biomed Inform*, vol. 42, no. 2, pp. 377-81.
Hartmann, T.E., Robertson, C.V., Miller, T.D., Hunter, J.R. & Skein, M. 2021, 'Associations between exercise, inflammation and symptom severity in those with mental health disorders', *Cytokine*, vol. 146, p. 155648.
Harvey, S.B., Overland, S., Hatch, S.L., Wessely, S., Mykletun, A. & Hotopf, M. 2018, 'Exercise and the Prevention of Depression: Results of the HUNT Cohort Study', *Am J Psychiatry*, vol. 175, no. 1, pp. 28-36.
Hassard, J., Teoh, K.R.H., Visockaite, G., Dewe, P. & Cox, T. 2018, 'The cost of work-related stress to society: A systematic review', *J Occup Health Psychol*, vol. 23, no. 1, pp. 1-17.
Hayashino, Y., Jackson, J.L., Hirata, T., Fukumori, N., Nakamura, F., Fukuhara, S., Tsujii, S. & Ishii, H. 2014, 'Effects of exercise on C-reactive protein, inflammatory cytokine and adipokine in patients with type 2 diabetes: a meta-analysis of randomized controlled trials', *Metabolism*, vol. 63, no. 3, pp. 431-40.
He, D., Xi, B., Xue, J., Huai, P., Zhang, M. & Li, J. 2014, 'Association between leisure time physical activity and metabolic syndrome: a meta-analysis of prospective cohort studies', Series Association between leisure time physical activity and metabolic syndrome: a meta-analysis of prospective cohort studies Springer.
Healy, G.N., Winkler, E.A.H., Eakin, E.G., Owen, N., Lamontagne, A.D., Moodie, M. & Dunstan, D.W. 2017, 'A Cluster RCT to Reduce Workers' Sitting Time: Impact on Cardiometabolic Biomarkers', *Med Sci Sports Exerc*, vol. 49, no. 10, pp. 2032-9.
Henry, J.D. & Crawford, J.R. 2005, 'The short-form version of the Depression Anxiety Stress Scales (DASS-21): construct validity and normative data in a large non-clinical sample', *Br J Clin Psychol*, vol. 44, no. Pt 2, pp. 227-39.
Heo, J.E., Shim, J.-S., Song, B.M., Bae, H.Y., Lee, H.J., Lee, E. & Kim, H.C. 2018, 'Association between appendicular skeletal muscle mass and depressive symptoms: review of the cardiovascular and metabolic diseases etiology research center cohort', *Journal of affective disorders*, vol. 238, pp. 8-15.
Heraclides, A., Chandola, T., Witte, D.R. & Brunner, E.J. 2009, 'Psychosocial stress at work doubles the risk of type 2 diabetes in middle-aged women: evidence from the Whitehall II study', *Diabetes care*.
Hewitt, J.A., Whyte, G.P., Moreton, M., van Someren, K.A. & Levine, T.S. 2008, 'The effects of a graduated aerobic exercise programme on cardiovascular disease risk factors in the NHS workplace: a randomised controlled trial', *J Occup Med Toxicol*, vol. 3, no. 1, p. 7.
Hidalgo-Santamaria, M., Fernandez-Montero, A., Martinez-Gonzalez, M.A., Moreno-Galarraga, L., Sanchez-Villegas, A., Barrio-Lopez, M.T. & Bes-Rastrollo, M. 2017, 'Exercise Intensity and Incidence of Metabolic Syndrome: The SUN Project', *Am J Prev Med*, vol. 52, no. 4, pp. e95-e101.
Hilyer, J.C., Wilson, D.G., Dillon, C., Caro, L., Jenkins, C., Spencer, W.A., Meadows, M.E. & Booker, W. 1982, 'Physical fitness training and counseling as treatment for youthful offenders', *Journal of Counseling Psychology*, vol. 29, no. 3, p. 292.
Hirshkowitz, M., Whiton, K., Albert, S.M., Alessi, C., Bruni, O., DonCarlos, L., Hazen, N., Herman, J., Katz, E.S., Kheirandish-Gozal, L., Neubauer, D.N., O'Donnell, A.E., Ohayon, M., Peever, J., Rawding, R., Sachdeva, R.C., Setters, B., Vitiello, M.V., Ware, J.C. & Adams Hillard, P.J. 2015, 'National Sleep Foundation's sleep time duration

recommendations: methodology and results summary', *Sleep Health*, vol. 1, no. 1, pp. 40-3.
Hivert, M.F., Sullivan, L.M., Fox, C.S., Nathan, D.M., D'Agostino, R.B., Sr., Wilson, P.W. & Meigs, J.B. 2008, 'Associations of adiponectin, resistin, and tumor necrosis factor-alpha with insulin resistance', *J Clin Endocrinol Metab*, vol. 93, no. 8, pp. 3165-72.
Hivert, M.F., Sullivan, L.M., Shrader, P., Fox, C.S., Nathan, D.M., D'Agostino, R.B., Sr., Wilson, P.W., Benjamin, E.J. & Meigs, J.B. 2010, 'The association of tumor necrosis factor alpha receptor 2 and tumor necrosis factor alpha with insulin resistance and the influence of adipose tissue biomarkers in humans', *Metabolism*, vol. 59, no. 4, pp. 540-6.
Hjerkind, K.V., Stenehjem, J.S. & Nilsen, T.I. 2017, 'Adiposity, physical activity and risk of diabetes mellitus: prospective data from the population-based HUNT study, Norway', *BMJ Open*, vol. 7, no. 1, p. e013142.
Ho, S.S., Dhaliwal, S.S., Hills, A.P. & Pal, S. 2012, 'The effect of 12 weeks of aerobic, resistance or combination exercise training on cardiovascular risk factors in the overweight and obese in a randomized trial', *BMC Public Health*, vol. 12, no. 1, p. 704.
Hogan, J.M., Carlson, J.G. & Dua, J. 2002, 'Stressors and stress reactions among university personnel', *International Journal of stress management*, vol. 9, no. 4, pp. 289-310.
Hogan, V., Hogan, M., Hodgins, M., Kinman, G. & Bunting, B. 2015, 'An examination of gender differences in the impact of individual and organisational factors on work hours, work-life conflict and psychological strain in academics', *The Irish Journal of Psychology*, vol. 35, no. 2-3, pp. 133-50.
Hong, S., Chang, Y., Jung, H.S., Yun, K.E., Shin, H. & Ryu, S. 2017, 'Relative muscle mass and the risk of incident type 2 diabetes: A cohort study', *PLoS One*, vol. 12, no. 11, p. e0188650.
Hotamisligil, G.S. 2017a, 'Foundations of Immunometabolism and Implications for Metabolic Health and Disease', *Immunity*, vol. 47, no. 3, pp. 406-20.
Hotamisligil, G.S. 2017b, 'Inflammation, metaflammation and immunometabolic disorders', *Nature*, vol. 542, no. 7640, pp. 177-85.
Houdmont, J., Cox, T. & Griffiths, A. 2010, 'Work-related stress case definitions and prevalence rates in national surveys', *Occup Med (Lond)*, vol. 60, no. 8, pp. 658-61.
Hovland, A., Nordhus, I.H., Sjobo, T., Gjestad, B.A., Birknes, B., Martinsen, E.W., Torsheim, T. & Pallesen, S. 2013, 'Comparing physical exercise in groups to group cognitive behaviour therapy for the treatment of panic disorder in a randomized controlled trial', *Behav Cogn Psychother*, vol. 41, no. 4, pp. 408-32.
Howren, M.B., Lamkin, D.M. & Suls, J. 2009, 'Associations of depression with C-reactive protein, IL-1, and IL-6: a meta-analysis', *Psychosom Med*, vol. 71, no. 2, pp. 171-86.
Hu, F.B., Meigs, J.B., Li, T.Y., Rifai, N. & Manson, J.E. 2004, 'Inflammatory markers and risk of developing type 2 diabetes in women', *Diabetes*, vol. 53, no. 3, pp. 693-700.
Hunter, C.A. & Jones, S.A. 2015, 'IL-6 as a keystone cytokine in health and disease', *Nature immunology*, vol. 16, no. 5, p. 448.
Hunter, J.R., Gordon, B.A., Bird, S.R. & Benson, A.C. 2020, 'Exercise supervision is important for cardiometabolic health improvements: a 16-week randomized controlled trial', *The Journal of Strength & Conditioning Research*, vol. 34, no. 3, pp. 866-77.

Hystad, S.W. & Johnsen, B.H. 2020, 'The Dimensionality of the 12-Item General Health Questionnaire (GHQ-12): Comparisons of Factor Structures and Invariance Across Samples and Time', *Front Psychol*, vol. 11, p. 1300.

Ihalainen, J.K., Schumann, M., Eklund, D., Hamalainen, M., Moilanen, E., Paulsen, G., Hakkinen, K. & Mero, A.A. 2018, 'Combined aerobic and resistance training decreases inflammation markers in healthy men', *Scand J Med Sci Sports*, vol. 28, no. 1, pp. 40-7.

Imboden, M.T., Swartz, A.M., Finch, H.W., Harber, M.P. & Kaminsky, L.A. 2017, 'Reference standards for lean mass measures using GE dual energy x-ray absorptiometry in Caucasian adults', *PLoS One*, vol. 12, no. 4, p. e0176161.

Imboden, M.T., Welch, W.A., Swartz, A.M., Montoye, A.H., Finch, H.W., Harber, M.P. & Kaminsky, L.A. 2017, 'Reference standards for body fat measures using GE dual energy x-ray absorptiometry in Caucasian adults', *PLoS One*, vol. 12, no. 4, p. e0175110.

Iso, H., Date, C., Yamamoto, A., Toyoshima, H., Tanabe, N., Kikuchi, S., Kondo, T., Watanabe, Y., Wada, Y. & Ishibashi, T. 2002, 'Perceived mental stress and mortality from cardiovascular disease among Japanese men and women: the Japan Collaborative Cohort Study for Evaluation of Cancer Risk Sponsored by Monbusho (JACC Study)', *Circulation*, vol. 106, no. 10, pp. 1229-36.

Jakobsen, M.D., Sundstrup, E., Brandt, M., Jay, K., Aagaard, P. & Andersen, L.L. 2015, 'Effect of workplace-versus home-based physical exercise on musculoskeletal pain among healthcare workers: a cluster randomized controlled trial', *Scandinavian journal of work, environment & health*, pp. 153-63.

Jamka, M., Madry, E., Krzyzanowska-Jankowska, P., Skrypnik, D., Szulinska, M., Madry, R., Lisowska, A., Batyrova, G., Dus-Zuchowska, M., Gotz-Wieckowska, A., Bogdanski, P. & Walkowiak, J. 2021, 'The effect of endurance and endurance-strength training on body composition and cardiometabolic markers in abdominally obese women: a randomised trial', *Sci Rep*, vol. 11, no. 1, p. 12339.

Janssen, I. & Ross, R. 2012, 'Vigorous intensity physical activity is related to the metabolic syndrome independent of the physical activity dose', *International journal of epidemiology*, vol. 41, no. 4, pp. 1132-40.

Jayakody, K., Gunadasa, S. & Hosker, C. 2014, 'Exercise for anxiety disorders: systematic review', *Br J Sports Med*, vol. 48, no. 3, pp. 187-96.

Jorge, M.L., de Oliveira, V.N., Resende, N.M., Paraiso, L.F., Calixto, A., Diniz, A.L., Resende, E.S., Ropelle, E.R., Carvalheira, J.B., Espindola, F.S., Jorge, P.T. & Geloneze, B. 2011, 'The effects of aerobic, resistance, and combined exercise on metabolic control, inflammatory markers, adipocytokines, and muscle insulin signaling in patients with type 2 diabetes mellitus', *Metabolism*, vol. 60, no. 9, pp. 1244-52.

Junior, L.C.H., Pillay, J.D., van Mechelen, W. & Verhagen, E. 2015, 'Meta-analyses of the effects of habitual running on indices of health in physically inactive adults', *Sports medicine*, vol. 45, no. 10, pp. 1455-68.

Jurado-Fasoli, L., De-la, O.A., Molina-Hidalgo, C., Migueles, J.H., Castillo, M.J. & Amaro-Gahete, F.J. 2020, 'Exercise training improves sleep quality: A randomized controlled trial', *Eur J Clin Invest*, vol. 50, no. 3, p. e13202.

Kaminsky, L.A., Imboden, M.T., Arena, R. & Myers, J. 2017, 'Reference standards for cardiorespiratory fitness measured with cardiopulmonary exercise testing using cycle

ergometry: data from the Fitness Registry and the Importance of Exercise National Database (FRIEND) registry', vol. 92, Elsevier, pp. 228-33.
Kan, C., Silva, N., Golden, S.H., Rajala, U., Timonen, M., Stahl, D. & Ismail, K. 2013, 'A systematic review and meta-analysis of the association between depression and insulin resistance', *Diabetes care*, vol. 36, no. 2, pp. 480-9.
Kang, W., Park, W.-J., Jang, K.-H., Lim, H.-M., Ann, J.-S., Cho, S.-h. & Moon, J.-D. 2016, 'Comparison of anxiety and depression status between office and manufacturing job employees in a large manufacturing company: a cross sectional study', *Annals of occupational and environmental medicine*, vol. 28, no. 1, pp. 1-7.
Kaptoge, S., Seshasai, S.R., Gao, P., Freitag, D.F., Butterworth, A.S., Borglykke, A., Di Angelantonio, E., Gudnason, V., Rumley, A., Lowe, G.D., Jorgensen, T. & Danesh, J. 2014, 'Inflammatory cytokines and risk of coronary heart disease: new prospective study and updated meta-analysis', *Eur Heart J*, vol. 35, no. 9, pp. 578-89.
Karatrantou, K., Gerodimos, V., Manouras, N., Vasilopoulou, T., Melissopoulou, A., Mesiakaris, A.F. & Theodorakis, Y. 2020, 'Health-Promoting Effects of a Concurrent Workplace Training Program in Inactive Office Workers (HealPWorkers): A Randomized Controlled Study', *Am J Health Promot*, vol. 34, no. 4, pp. 376-86.
Kassi, E., Pervanidou, P., Kaltsas, G. & Chrousos, G. 2011, 'Metabolic syndrome: definitions and controversies', *BMC Med*, vol. 9, no. 1, p. 48.
Kawai, T., Autieri, M.V. & Scalia, R. 2021, 'Adipose tissue inflammation and metabolic dysfunction in obesity', *Am J Physiol Cell Physiol*, vol. 320, no. 3, pp. C375-C91.
Kern, P.A., Ranganathan, S., Li, C., Wood, L. & Ranganathan, G. 2001, 'Adipose tissue tumor necrosis factor and interleukin-6 expression in human obesity and insulin resistance', *Am J Physiol Endocrinol Metab*, vol. 280, no. 5, pp. E745-51.
Kessler, R.C., Andrews, G., Colpe, L.J., Hiripi, E., Mroczek, D.K., Normand, S.L., Walters, E.E. & Zaslavsky, A.M. 2002, 'Short screening scales to monitor population prevalences and trends in non-specific psychological distress', *Psychol Med*, vol. 32, no. 6, pp. 959-76.
Keyes, C.L. 2002, 'The mental health continuum: from languishing to flourishing in life', *J Health Soc Behav*, vol. 43, no. 2, pp. 207-22.
Kiecolt-Glaser, J.K., Preacher, K.J., MacCallum, R.C., Atkinson, C., Malarkey, W.B. & Glaser, R. 2003, 'Chronic stress and age-related increases in the proinflammatory cytokine IL-6', *Proc Natl Acad Sci U S A*, vol. 100, no. 15, pp. 9090-5.
Kim, G., Lee, S.E., Jun, J.E., Lee, Y.B., Ahn, J., Bae, J.C., Jin, S.M., Hur, K.Y., Jee, J.H., Lee, M.K. & Kim, J.H. 2018, 'Increase in relative skeletal muscle mass over time and its inverse association with metabolic syndrome development: a 7-year retrospective cohort study', *Cardiovasc Diabetol*, vol. 17, no. 1, p. 23.
Kim, H.J., Higashimori, T., Park, S.Y., Choi, H., Dong, J., Kim, Y.J., Noh, H.L., Cho, Y.R., Cline, G., Kim, Y.B. & Kim, J.K. 2004, 'Differential effects of interleukin-6 and -10 on skeletal muscle and liver insulin action in vivo', *Diabetes*, vol. 53, no. 4, pp. 1060-7.
Kim, J.Y., Oh, S., Park, H.Y., Jun, J.H. & Kim, H.J. 2019, 'Comparisons of different indices of low muscle mass in relationship with cardiometabolic disorder', *Sci Rep*, vol. 9, no. 1, p. 609.
Kim, K. & Park, S.M. 2018, 'Association of muscle mass and fat mass with insulin resistance and the prevalence of metabolic syndrome in Korean adults: a cross-sectional study', *Sci Rep*, vol. 8, no. 1, p. 2703.

Kim, K.B., Kim, K., Kim, C., Kang, S.J., Kim, H.J., Yoon, S. & Shin, Y.A. 2019, 'Effects of Exercise on the Body Composition and Lipid Profile of Individuals with Obesity: A Systematic Review and Meta-Analysis', *J Obes Metab Syndr*, vol. 28, no. 4, pp. 278-94.

King, A.C., Taylor, C.B. & Haskell, W.L. 1993, 'Effects of differing intensities and formats of 12 months of exercise training on psychological outcomes in older adults', *Health Psychol*, vol. 12, no. 4, pp. 292-300.

Kinman, G. 2001, 'Pressure Points: A review of research on stressors and strains in UK academics', *Educational Psychology*, vol. 21, no. 4, pp. 473-92.

Kinman, G. 2016, 'Effort–reward imbalance and overcommitment in UK academics: implications for mental health, satisfaction and retention', *Journal of Higher Education Policy and Management*, vol. 38, no. 5, pp. 504-18.

Kinman, G. 2019, 'Effort-reward imbalance in academic employees: Examining different reward systems', *International Journal of Stress Management*, vol. 26, no. 2, pp. 184-92.

Kinman, G. & Jones, F. 2003, ''Running Up the Down Escalator': Stressors and strains in UK academics', *Quality in Higher education*, vol. 9, no. 1, pp. 21-38.

Kinman, G. & Jones, F. 2008, 'A Life Beyond Work? Job Demands, Work-Life Balance, and Wellbeing in UK Academics', *Journal of Human Behavior in the Social Environment*, vol. 17, no. 1-2, pp. 41-60.

Kirk, M.A. & Rhodes, R.E. 2011, 'Occupation correlates of adults' participation in leisure-time physical activity: a systematic review', *Am J Prev Med*, vol. 40, no. 4, pp. 476-85.

Klaperski, S. & Fuchs, R. 2021, 'Investigation of the stress-buffering effect of physical exercise and fitness on mental and physical health outcomes in insufficiently active men: A randomized controlled trial', *Mental Health and Physical Activity*, p. 100408.

Klover, P.J., Zimmers, T.A., Koniaris, L.G. & Mooney, R.A. 2003, 'Chronic exposure to interleukin-6 causes hepatic insulin resistance in mice', *Diabetes*, vol. 52, no. 11, pp. 2784-9.

Knaeps, S., Bourgois, J.G., Charlier, R., Mertens, E., Lefevre, J. & Wijndaele, K. 2018, 'Ten-year change in sedentary behaviour, moderate-to-vigorous physical activity, cardiorespiratory fitness and cardiometabolic risk: independent associations and mediation analysis', *Br J Sports Med*, vol. 52, no. 16, pp. 1063-8.

Kodama, S., Saito, K., Tanaka, S., Maki, M., Yachi, Y., Asumi, M., Sugawara, A., Totsuka, K., Shimano, H. & Ohashi, Y. 2009, 'Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis', *Jama*, vol. 301, no. 19, pp. 2024-35.

Koolhaas, J.M., Bartolomucci, A., Buwalda, B., de Boer, S.F., Flugge, G., Korte, S.M., Meerlo, P., Murison, R., Olivier, B., Palanza, P., Richter-Levin, G., Sgoifo, A., Steimer, T., Stiedl, O., van Dijk, G., Wohr, M. & Fuchs, E. 2011, 'Stress revisited: a critical evaluation of the stress concept', *Neurosci Biobehav Rev*, vol. 35, no. 5, pp. 1291-301.

Kouvonen, A., Vahtera, J., Oksanen, T., Pentti, J., Vaananen, A.K., Heponiemi, T., Salo, P., Virtanen, M. & Kivimaki, M. 2013, 'Chronic workplace stress and insufficient physical activity: a cohort study', *Occup Environ Med*, vol. 70, no. 1, pp. 3-8.

Kovacevic, A., Mavros, Y., Heisz, J.J. & Fiatarone Singh, M.A. 2018, 'The effect of resistance exercise on sleep: A systematic review of randomized controlled trials', *Sleep Med Rev*, vol. 39, pp. 52-68.

Krasilshchikov, O., Shaw, B. & Shaw, I. 2009, 'Comparison of Aerobic and Combined Aerobic and Resistance Training on Low-Density Lipoprotein Cholesterol Concentrations in Men: Cardiovascular Topic', *Cardiovascular Journal of Africa*.

Kraus, W.E., Powell, K.E., Haskell, W.L., Janz, K.F., Campbell, W.W., Jakicic, J.M., Troiano, R.P., Sprow, K., Torres, A., Piercy, K.L. & Physical Activity Guidelines Advisory, C. 2019, 'Physical Activity, All-Cause and Cardiovascular Mortality, and Cardiovascular Disease', *Med Sci Sports Exerc*, vol. 51, no. 6, pp. 1270-81.

Krogh-Madsen, R., Plomgaard, P., Moller, K., Mittendorfer, B. & Pedersen, B.K. 2006, 'Influence of TNF-alpha and IL-6 infusions on insulin sensitivity and expression of IL-18 in humans', *Am J Physiol Endocrinol Metab*, vol. 291, no. 1, pp. E108-14.

Kunz, H.E., Hart, C.R., Gries, K.J., Parvizi, M., Laurenti, M., Dalla Man, C., Moore, N., Zhang, X., Ryan, Z., Polley, E.C., Jensen, M.D., Vella, A. & Lanza, I.R. 2021, 'Adipose tissue macrophage populations and inflammation are associated with systemic inflammation and insulin resistance in obesity', *Am J Physiol Endocrinol Metab*, vol. 321, no. 1, pp. E105-E21.

Kuo, W.c., Bratzke, L.C., Oakley, L.D., Kuo, F., Wang, H. & Brown, R.L. 2019, 'The association between psychological stress and metabolic syndrome: A systematic review and meta-analysis', *Obesity Reviews*, vol. 20, no. 11, pp. 1651-64.

Kuusmaa-Schildt, M., Liukkonen, J., Vuong, M.K., Nyman, K., Hakkinen, K. & Hakkinen, A. 2019, 'Effects of morning vs. evening combined strength and endurance training on physical performance, sleep and well-being', *Chronobiol Int*, vol. 36, no. 6, pp. 811-25.

Kwon, H., Kim, D. & Kim, J.S. 2017, 'Body Fat Distribution and the Risk of Incident Metabolic Syndrome: A Longitudinal Cohort Study', *Sci Rep*, vol. 7, no. 1, p. 10955.

Laaksonen, D.E., Lakka, H.M., Salonen, J.T., Niskanen, L.K., Rauramaa, R. & Lakka, T.A. 2002, 'Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome', *Diabetes Care*, vol. 25, no. 9, pp. 1612-8.

Lakka, T.A., Lakka, H.M., Rankinen, T., Leon, A.S., Rao, D.C., Skinner, J.S., Wilmore, J.H. & Bouchard, C. 2005, 'Effect of exercise training on plasma levels of C-reactive protein in healthy adults: the HERITAGE Family Study', *Eur Heart J*, vol. 26, no. 19, pp. 2018-25.

LaMonte, M.J., Barlow, C.E., Jurca, R., Kampert, J.B., Church, T.S. & Blair, S.N. 2005, 'Cardiorespiratory fitness is inversely associated with the incidence of metabolic syndrome: a prospective study of men and women', *Circulation*, vol. 112, no. 4, pp. 505-12.

Langleite, T.M., Jensen, J., Norheim, F., Gulseth, H.L., Tangen, D.S., Kolnes, K.J., Heck, A., Storas, T., Grothe, G., Dahl, M.A., Kielland, A., Holen, T., Noreng, H.J., Stadheim, H.K., Bjornerud, A., Johansen, E.I., Nellemann, B., Birkeland, K.I. & Drevon, C.A. 2016, 'Insulin sensitivity, body composition and adipose depots following 12 w combined endurance and strength training in dysglycemic and normoglycemic sedentary men', *Arch Physiol Biochem*, vol. 122, no. 4, pp. 167-79.

Laursen, A.H., Kristiansen, O.P., Marott, J.L., Schnohr, P. & Prescott, E. 2012, 'Intensity versus duration of physical activity: implications for the metabolic syndrome. A prospective cohort study', *BMJ Open*, vol. 2, no. 5, p. e001711.

LeBouthillier, D.M. & Asmundson, G.J.G. 2017, 'The efficacy of aerobic exercise and resistance training as transdiagnostic interventions for anxiety-related disorders and constructs: A randomized controlled trial', *J Anxiety Disord*, vol. 52, pp. 43-52.

Lee, D.C., Sui, X., Church, T.S., Lee, I.M. & Blair, S.N. 2009, 'Associations of cardiorespiratory fitness and obesity with risks of impaired fasting glucose and type 2 diabetes in men', *Diabetes Care*, vol. 32, no. 2, pp. 257-62.

Lee, D.H., Keum, N., Hu, F.B., Orav, E.J., Rimm, E.B., Willett, W.C. & Giovannucci, E.L. 2018, 'Comparison of the association of predicted fat mass, body mass index, and other obesity indicators with type 2 diabetes risk: two large prospective studies in US men and women', *Eur J Epidemiol*, vol. 33, no. 11, pp. 1113-23.

Lee, J. 2020, 'Influences of Cardiovascular Fitness and Body Fatness on the Risk of Metabolic Syndrome: A Systematic Review and Meta-Analysis', *Am J Health Promot*, vol. 34, no. 7, pp. 796-805.

Lee, M., Coutts, R., Fielden, J., Hutchinson, M., Lakeman, R., Mathisen, B., Nasrawi, D. & Phillips, N. 2021, 'Occupational stress in University academics in Australia and New Zealand', *Journal of Higher Education Policy and Management*, pp. 1-15.

Lee., S.T. 2020, 'Inflammation, depression, and anxiety disorder: a population-based study examining the association between Interleukin-6 and the experiencing of depressive and anxiety symptoms', *Psychiatry research*, vol. 285, p. 112809.

Leineweber, C., Wege, N., Westerlund, H., Theorell, T., Wahrendorf, M. & Siegrist, J. 2010, 'How valid is a short measure of effort-reward imbalance at work? A replication study from Sweden', *Occup Environ Med*, vol. 67, no. 8, pp. 526-31.

Leonel, L.D.S., Tozetto, W.R., Delevatti, R.S. & Del Duca, G.F. 2020, 'Effects of Combined Training With Linear Periodization and Non-Periodization on Sleep Quality of Adults With Obesity', *Res Q Exerc Sport*, pp. 1-9.

Leskinen, T., Sipila, S., Alen, M., Cheng, S., Pietilainen, K.H., Usenius, J.P., Suominen, H., Kovanen, V., Kainulainen, H., Kaprio, J. & Kujala, U.M. 2009, 'Leisure-time physical activity and high-risk fat: a longitudinal population-based twin study', *Int J Obes (Lond)*, vol. 33, no. 11, pp. 1211-8.

Levine, M.E. & Crimmins, E.M. 2012, 'The impact of insulin resistance and inflammation on the association between sarcopenic obesity and physical functioning', *Obesity*, vol. 20, no. 10, pp. 2101-6.

Li, Y., Meng, L., Li, Y. & Sato, Y. 2014, 'Depression-related differences in lean body mass distribution from National Health and Nutrition Examination Survey 2005-2006', *J Affect Disord*, vol. 157, pp. 1-7.

Liao, Y., Shonkoff, E.T. & Dunton, G.F. 2015, 'The acute relationships between affect, physical feeling states, and physical activity in daily life: a review of current evidence', *Frontiers in Psychology*, vol. 6, p. 1975.

Libardi, C.A., De Souza, G.V., Cavaglieri, C.R., Madruga, V.A. & Chacon-Mikahil, M.P. 2012, 'Effect of resistance, endurance, and concurrent training on TNF-alpha, IL-6, and CRP', *Med Sci Sports Exerc*, vol. 44, no. 1, pp. 50-6.

Lim, W., Hong, S., Nelesen, R. & Dimsdale, J.E. 2005, 'The association of obesity, cytokine levels, and depressive symptoms with diverse measures of fatigue in healthy subjects', *Arch Intern Med*, vol. 165, no. 8, pp. 910-5.

Lin, X., Zhang, X., Guo, J., Roberts, C.K., McKenzie, S., Wu, W.C., Liu, S. & Song, Y. 2015, 'Effects of Exercise Training on Cardiorespiratory Fitness and Biomarkers of Cardiometabolic Health: A Systematic Review and Meta-Analysis of Randomized Controlled Trials', *J Am Heart Assoc*, vol. 4, no. 7, p. e002014.

Liu, C., Feng, X., Li, Q., Wang, Y., Li, Q. & Hua, M. 2016, 'Adiponectin, TNF-alpha and inflammatory cytokines and risk of type 2 diabetes: A systematic review and meta-analysis', *Cytokine*, vol. 86, pp. 100-9.

Longo, M., Zatterale, F., Naderi, J., Parrillo, L., Formisano, P., Raciti, G.A., Beguinot, F. & Miele, C. 2019, 'Adipose tissue dysfunction as determinant of obesity-associated metabolic complications', *International journal of molecular sciences*, vol. 20, no. 9, p. 2358.

López-Bueno, R., Andersen, L.L., Smith, L., López Sánchez, G.F., Mompel, J., Casedas, L. & Casajús, J.A. 2020, 'Physical activity and perceived stress at work in university workers: a cross-sectional study', *Journal of Sports Medicine and Physical Fitness*, vol. 60, no. 2, pp. 314-9.

Lovibond, P. & Lovibond 1995, 'Manual for the depression anxiety stress scales', *The Psychology Foundation of Australia Inc*.

Lucibello, K.M., Parker, J. & Heisz, J.J. 2019, 'Examining a training effect on the state anxiety response to an acute bout of exercise in low and high anxious individuals', *J Affect Disord*, vol. 247, pp. 29-35.

Luppino, F.S., de Wit, L.M., Bouvy, P.F., Stijnen, T., Cuijpers, P., Penninx, B.W. & Zitman, F.G. 2010, 'Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies', *Arch Gen Psychiatry*, vol. 67, no. 3, pp. 220-9.

Mac Giollabhui, N., Ng, T.H., Ellman, L.M. & Alloy, L.B. 2021, 'The longitudinal associations of inflammatory biomarkers and depression revisited: systematic review, meta-analysis, and meta-regression', *Mol Psychiatry*, vol. 26, no. 7, pp. 3302-14.

Madssen, E., Skaug, E.-A., Wisløff, U., Ellingsen, Ø. & Videm, V. 2019, 'Inflammation is strongly associated with cardiorespiratory fitness, sex, BMI, and the metabolic syndrome in a self-reported healthy population: HUNT3 fitness study', vol. 94, Elsevier, pp. 803-10.

Magliano, D.J., Martin, V.J., Owen, A.J., Zomer, E. & Liew, D. 2018, 'The productivity burden of diabetes at a population level', *Diabetes care*, vol. 41, no. 5, pp. 979-84.

Maliszewska, K., Adamska-Patruno, E., Goscik, J., Lipinska, D., Citko, A., Krahel, A., Miniewska, K., Fiedorczuk, J., Moroz, M., Gorska, M. & Kretowski, A. 2019, 'The Role of Muscle Decline in Type 2 Diabetes Development: A 5-Year Prospective Observational Cohort Study', *Nutrients*, vol. 11, no. 4, p. 834.

Mann, S., Beedie, C. & Jimenez, A. 2014, 'Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: review, synthesis and recommendations', *Sports Med*, vol. 44, no. 2, pp. 211-21.

Marginson, S. 2007, 'Global university rankings: Implications in general and for Australia', *Journal of Higher Education Policy and Management*, vol. 29, no. 2, pp. 131-42.

Mark, G. & Smith, A.P. 2012, 'Effects of occupational stress, job characteristics, coping, and attributional style on the mental health and job satisfaction of university employees', *Anxiety Stress Coping*, vol. 25, no. 1, pp. 63-78.

Marmot, M. & Brunner, E. 2005, 'Cohort Profile: the Whitehall II study', *Int J Epidemiol*, vol. 34, no. 2, pp. 251-6.

Marott, S.C., Nordestgaard, B.G., Tybjaerg-Hansen, A. & Benn, M. 2016, 'Components of the Metabolic Syndrome and Risk of Type 2 Diabetes', *J Clin Endocrinol Metab*, vol. 101, no. 8, pp. 3212-21.

Marsland, A.L., Walsh, C., Lockwood, K. & John-Henderson, N.A. 2017, 'The effects of acute psychological stress on circulating and stimulated inflammatory markers: A systematic review and meta-analysis', *Brain Behav Immun*, vol. 64, pp. 208-19.

Martinez-Gomez, D., Esteban-Cornejo, I., Lopez-Garcia, E., García-Esquinas, E., Sadarangani, K.P., Veiga, O.L. & Rodriguez-Artalejo, F. 2020, 'Physical activity less than the recommended amount may prevent the onset of major biological risk factors for cardiovascular disease: a cohort study of 198 919 adults', *British journal of sports medicine*, vol. 54, no. 4, pp. 238-44.

Matsha, T.E., Ismail, S., Speelman, A., Hon, G.M., Davids, S., Erasmus, R.T. & Kengne, A.P. 2019, 'Visceral and subcutaneous adipose tissue association with metabolic syndrome and its components in a South African population', *Clin Nutr ESPEN*, vol. 32, pp. 76-81.

Matthews, D.R., Hosker, J.P., Rudenski, A.S., Naylor, B.A., Treacher, D.F. & Turner, R.C. 1985, 'Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man', *Diabetologia*, vol. 28, no. 7, pp. 412-9.

Mauer, J., Chaurasia, B., Goldau, J., Vogt, M.C., Ruud, J., Nguyen, K.D., Theurich, S., Hausen, A.C., Schmitz, J. & Brönneke, H.S. 2014, 'Interleukin-6 signaling promotes alternative macrophage activation to limit obesity-associated insulin resistance and endotoxemia', *Nature immunology*, vol. 15, no. 5, p. 423.

McDowell, C.P., Dishman, R.K., Gordon, B.R. & Herring, M.P. 2019, 'Physical Activity and Anxiety: A Systematic Review and Meta-analysis of Prospective Cohort Studies', *Am J Prev Med*, vol. 57, no. 4, pp. 545-56.

McNair, D.M., Loor, M. & Droppleman, L.F. 1981, *Profile of mood states*, San Diego.

McTernan, W.P., Dollard, M.F. & LaMontagne, A.D. 2013, 'Depression in the workplace: An economic cost analysis of depression-related productivity loss attributable to job strain and bullying', *Work & Stress*, vol. 27, no. 4, pp. 321-38.

MetricWire Inc. 2019, *MetricWire (Version 4.2.5) [Mobile application software]*.

Meurs, M., Roest, A.M., Wolffenbuttel, B.H., Stolk, R.P., de Jonge, P. & Rosmalen, J.G. 2016, 'Association of Depressive and Anxiety Disorders With Diagnosed Versus Undiagnosed Diabetes: An Epidemiological Study of 90,686 Participants', *Psychosom Med*, vol. 78, no. 2, pp. 233-41.

Michishita, R., Jiang, Y., Ariyoshi, D., Yoshida, M., Moriyama, H., Obata, Y., Nagata, M., Nagata, T., Mori, K. & Yamato, H. 2017, 'The introduction of an active rest program by workplace units improved the workplace vigor and presenteeism among workers', *Journal of occupational and environmental medicine*, vol. 59, no. 12, pp. 1140-7.

Miller, A.H., Haroon, E., Raison, C.L. & Felger, J.C. 2013, 'Cytokine targets in the brain: impact on neurotransmitters and neurocircuits', *Depress Anxiety*, vol. 30, no. 4, pp. 297-306.

Mitchell, C.J., Churchward-Venne, T.A., West, D.W., Burd, N.A., Breen, L., Baker, S.K. & Phillips, S.M. 2012, 'Resistance exercise load does not determine training-mediated hypertrophic gains in young men', *Journal of applied physiology*, vol. 113, no. 1, pp. 71-7.

Moazzami, K., Lima, B.B., Sullivan, S., Shah, A., Bremner, J.D. & Vaccarino, V. 2019, 'Independent and joint association of obesity and metabolic syndrome with depression and inflammation', *Health Psychol*, vol. 38, no. 7, pp. 586-95.

Mohammad Rahimi, G.R., Bijeh, N. & Rashidlamir, A. 2020, 'Effects of exercise training on serum preptin, undercarboxylated osteocalcin and high molecular weight adiponectin in adults with metabolic syndrome', *Exp Physiol*, vol. 105, no. 3, pp. 449-59.

Molli, A.E.I., Steinhardt, A.P., López, A.P., González, C.D., Vilariño, J., Frechtel, G.D. & Cerrone, G.E. 2017, 'Metabolically healthy obese individuals present similar chronic inflammation level but less insulin-resistance than obese individuals with metabolic syndrome', *PloS one*, vol. 12, no. 12, p. e0190528.

Moradi, Y., Albatineh, A.N., Mahmoodi, H. & Gheshlagh, R.G. 2021, 'The relationship between depression and risk of metabolic syndrome: a meta-analysis of observational studies', *Clinical Diabetes and Endocrinology*, vol. 7, no. 1, pp. 1-12.

Mottillo, S., Filion, K.B., Genest, J., Joseph, L., Pilote, L., Poirier, P., Rinfret, S., Schiffrin, E.L. & Eisenberg, M.J. 2010, 'The metabolic syndrome and cardiovascular risk a systematic review and meta-analysis', *J Am Coll Cardiol*, vol. 56, no. 14, pp. 1113-32.

Mudrak, J., Zabrodska, K., Kveton, P., Jelinek, M., Blatny, M., Solcova, I. & Machovcova, K. 2017, 'Occupational Well-being Among University Faculty: A Job Demands-Resources Model', *Research in Higher Education*, vol. 59, no. 3, pp. 325-48.

Muldoon, M.F., Herbert, T.B., Patterson, S.M., Kameneva, M., Raible, R. & Manuck, S.B. 1995, 'Effects of acute psychological stress on serum lipid levels, hemoconcentration, and blood viscosity', *Arch Intern Med*, vol. 155, no. 6, pp. 615-20.

Muller, M.J., Lagerpusch, M., Enderle, J., Schautz, B., Heller, M. & Bosy-Westphal, A. 2012, 'Beyond the body mass index: tracking body composition in the pathogenesis of obesity and the metabolic syndrome', *Obes Rev*, vol. 13 Suppl 2, pp. 6-13.

Mundwiler, J., Schupbach, U., Dieterle, T., Leuppi, J.D., Schmidt-Trucksass, A., Wolfer, D.P., Miedinger, D. & Brighenti-Zogg, S. 2017, 'Association of Occupational and Leisure-Time Physical Activity with Aerobic Capacity in a Working Population', *PLoS One*, vol. 12, no. 1, p. e0168683.

Murabito, J.M., Massaro, J.M., Clifford, B., Hoffmann, U. & Fox, C.S. 2013, 'Depressive symptoms are associated with visceral adiposity in a community-based sample of middle-aged women and men', *Obesity (Silver Spring)*, vol. 21, no. 8, pp. 1713-9.

Myers, A., Dalton, M., Gibbons, C., Finlayson, G. & Blundell, J. 2019, 'Structured, aerobic exercise reduces fat mass and is partially compensated through energy intake but not energy expenditure in women', *Physiology & behavior*, vol. 199, pp. 56-65.

Myers, J., McAuley, P., Lavie, C.J., Despres, J.-P., Arena, R. & Kokkinos, P. 2015, 'Physical activity and cardiorespiratory fitness as major markers of cardiovascular risk: their independent and interwoven importance to health status', *Progress in cardiovascular diseases*, vol. 57, no. 4, pp. 306-14.

Ng, D.M. & Jeffery, R.W. 2003, 'Relationships between perceived stress and health behaviors in a sample of working adults', *Health psychology*, vol. 22, no. 6, p. 638.

NHLBI Obesity Education Initiative 2000, *The practical guide: Identification, evaluation and treatment of overweight and obesity in adults.*, National Institutes of Health (NIH Publication Number 004084).

Nicklas, B.J., Beavers, D.P., Mihalko, S.L., Miller, G.D., Loeser, R.F. & Messier, S.P. 2016, 'Relationship of Objectively-Measured Habitual Physical Activity to Chronic Inflammation and Fatigue in Middle-Aged and Older Adults', *J Gerontol A Biol Sci Med Sci*, vol. 71, no. 11, pp. 1437-43.

Norcross, J. & Van Loan, M.D. 2004, 'Validation of fan beam dual energy x ray absorptiometry for body composition assessment in adults aged 18-45 years', *Br J Sports Med*, vol. 38, no. 4, pp. 472-6.

Norris, R., Carroll, D. & Cochrane, R. 1990, 'The effects of aerobic and anaerobic training on fitness, blood pressure, and psychological stress and well-being', *J Psychosom Res*, vol. 34, no. 4, pp. 367-75.

Norvell, N. & Belles, D. 1993, 'Psychological and physical benefits of circuit weight training in law enforcement personnel', *J Consult Clin Psychol*, vol. 61, no. 3, pp. 520-7.

Nurminen, E., Malmivaara, A., Ilmarinen, J., Ylöstalo, P., Mutanen, P., Ahonen, G. & Aro, T. 2002, 'Effectiveness of a worksite exercise program with respect to perceived work ability and sick leaves among women with physical work', *Scandinavian journal of work, environment & health*, pp. 85-93.

O'Donoghue, G., Blake, C., Cunningham, C., Lennon, O. & Perrotta, C. 2021, 'What exercise prescription is optimal to improve body composition and cardiorespiratory fitness in adults living with obesity? A network meta-analysis', *Obesity Reviews*, vol. 22, no. 2, p. e13137.

Oftedal, S., Smith, J., Vandelanotte, C., Burton, N.W. & Duncan, M.J. 2019, 'Resistance training in addition to aerobic activity is associated with lower likelihood of depression and comorbid depression and anxiety symptoms: A cross sectional analysis of Australian women', *Preventive medicine*, vol. 126, p. 105773.

Olarescu, N.C., Jørgensen, A.P., Godang, K., Jurik, A.G., Frøslie, K.F. & Bollerslev, J. 2014, 'Dual-energy X-ray absorptiometry is a valid method to estimatimate visceral adipose tissue in adult patients with prader-willi syndrome during treatment with growth hormone', *The Journal of Clinical Endocrinology & Metabolism*, vol. 99, no. 9, pp. E1727-E31.

Ortega, F.B., Lavie, C.J. & Blair, S.N. 2016, 'Obesity and Cardiovascular Disease', *Circ Res*, vol. 118, no. 11, pp. 1752-70.

Oshio, T., Tsutsumi, A. & Inoue, A. 2016, 'The association between job stress and leisure-time physical inactivity adjusted for individual attributes: evidence from a Japanese occupational cohort survey', *Scandinavian journal of work, environment & health*, pp. 228-36.

Osimo, E.F., Pillinger, T., Rodriguez, I.M., Khandaker, G.M., Pariante, C.M. & Howes, O.D. 2020, 'Inflammatory markers in depression: A meta-analysis of mean differences and variability in 5,166 patients and 5,083 controls', *Brain Behav Immun*, vol. 87, pp. 901-9.

Ostman, C., Smart, N.A., Morcos, D., Duller, A., Ridley, W. & Jewiss, D. 2017, 'The effect of exercise training on clinical outcomes in patients with the metabolic syndrome: a systematic review and meta-analysis', *Cardiovasc Diabetol*, vol. 16, no. 1, p. 110.

Pai, J.K., Pischon, T., Ma, J., Manson, J.E., Hankinson, S.E., Joshipura, K., Curhan, G.C., Rifai, N., Cannuscio, C.C., Stampfer, M.J. & Rimm, E.B. 2004, 'Inflammatory markers and the risk of coronary heart disease in men and women', *N Engl J Med*, vol. 351, no. 25, pp. 2599-610.

Pan, A., Keum, N., Okereke, O.I., Sun, Q., Kivimaki, M., Rubin, R.R. & Hu, F.B. 2012, 'Bidirectional association between depression and metabolic syndrome: a systematic review and meta-analysis of epidemiological studies', *Diabetes Care*, vol. 35, no. 5, pp. 1171-80.

Paolucci, E.M., Loukov, D., Bowdish, D.M.E. & Heisz, J.J. 2018, 'Exercise reduces depression and inflammation but intensity matters', *Biol Psychol*, vol. 133, pp. 79-84.
Park, H.S., Park, J.Y. & Yu, R. 2005, 'Relationship of obesity and visceral adiposity with serum concentrations of CRP, TNF-alpha and IL-6', *Diabetes Res Clin Pract*, vol. 69, no. 1, pp. 29-35.
Pattyn, N., Cornelissen, V.A., Eshghi, S.R. & Vanhees, L. 2013, 'The effect of exercise on the cardiovascular risk factors constituting the metabolic syndrome: a meta-analysis of controlled trials', *Sports Med*, vol. 43, no. 2, pp. 121-33.
Pedersen, B.K. 2011, 'Exercise-induced myokines and their role in chronic diseases', *Brain, behavior, and immunity*, vol. 25, no. 5, pp. 811-6.
Pedersen, B.K. 2017, 'Anti-inflammatory effects of exercise: role in diabetes and cardiovascular disease', *Eur J Clin Invest*, vol. 47, no. 8, pp. 600-11.
Pedersen, M.T., Blangsted, A.K., Andersen, L.L., Jorgensen, M.B., Hansen, E.A. & Sjogaard, G. 2009, 'The effect of worksite physical activity intervention on physical capacity, health, and productivity: a 1-year randomized controlled trial', *J Occup Environ Med*, vol. 51, no. 7, pp. 759-70.
Petre, H., Hemmingsson, E., Rosdahl, H. & Psilander, N. 2021, 'Development of Maximal Dynamic Strength During Concurrent Resistance and Endurance Training in Untrained, Moderately Trained, and Trained Individuals: A Systematic Review and Meta-analysis', *Sports Med*, vol. 51, no. 5, pp. 991-1010.
Phillips, C.M., Dillon, C.B. & Perry, I.J. 2017, 'Does replacing sedentary behaviour with light or moderate to vigorous physical activity modulate inflammatory status in adults?', *International Journal of Behavioral Nutrition and Physical Activity*, vol. 14, no. 1, pp. 1-12.
Piantella, S., Dragano, N., McDonald, S.J. & Wright, B.J. 2021, 'Depression symptoms mediate the association between workplace stress and interleukin 6 in women, but not men: The Whitehall II study', *Brain, Behavior, & Immunity-Health*, vol. 12, p. 100215.
Plomgaard, P., Bouzakri, K., Krogh-Madsen, R., Mittendorfer, B., Zierath, J.R. & Pedersen, B.K. 2005, 'Tumor necrosis factor-alpha induces skeletal muscle insulin resistance in healthy human subjects via inhibition of Akt substrate 160 phosphorylation', *Diabetes*, vol. 54, no. 10, pp. 2939-45.
Polacchini, A., Girardi, D., Falco, A., Zanotta, N., Comar, M., De Carlo, N.A. & Tongiorgi, E. 2018, 'Distinct CCL2, CCL5, CCL11, CCL27, IL-17, IL-6, BDNF serum profiles correlate to different job-stress outcomes', *Neurobiol Stress*, vol. 8, pp. 82-91.
Popko, K., Gorska, E., Stelmaszczyk-Emmel, A., Plywaczewski, R., Stoklosa, A., Gorecka, D., Pyrzak, B. & Demkow, U. 2010, 'Proinflammatory cytokines Il-6 and TNF-alpha and the development of inflammation in obese subjects', *Eur J Med Res*, vol. 15 Suppl 2, no. 2, pp. 120-2.
Pou, K.M., Massaro, J.M., Hoffmann, U., Vasan, R.S., Maurovich-Horvat, P., Larson, M.G., Keaney, J.F., Jr., Meigs, J.B., Lipinska, I., Kathiresan, S., Murabito, J.M., O'Donnell, C.J., Benjamin, E.J. & Fox, C.S. 2007, 'Visceral and subcutaneous adipose tissue volumes are cross-sectionally related to markers of inflammation and oxidative stress: the Framingham Heart Study', *Circulation*, vol. 116, no. 11, pp. 1234-41.
Pradhan, A.D., Manson, J.E., Rifai, N., Buring, J.E. & Ridker, P.M. 2001, 'C-reactive protein, interleukin 6, and risk of developing type 2 diabetes mellitus', *JAMA*, vol. 286, no. 3, pp. 327-34.

Preis, S.R., Massaro, J.M., Robins, S.J., Hoffmann, U., Vasan, R.S., Irlbeck, T., Meigs, J.B., Sutherland, P., D'Agostino, R.B., Sr., O'Donnell, C.J. & Fox, C.S. 2010, 'Abdominal subcutaneous and visceral adipose tissue and insulin resistance in the Framingham heart study', *Obesity (Silver Spring)*, vol. 18, no. 11, pp. 2191-8.

Prieske, O., Dalager, T., Herz, M., Hortobagyi, T., Sjogaard, G., Sogaard, K. & Granacher, U. 2019, 'Effects of Physical Exercise Training in the Workplace on Physical Fitness: A Systematic Review and Meta-analysis', *Sports Med*, vol. 49, no. 12, pp. 1903-21.

Prince, S.A., Elliott, C.G., Scott, K., Visintini, S. & Reed, J.L. 2019, 'Device-measured physical activity, sedentary behaviour and cardiometabolic health and fitness across occupational groups: a systematic review and meta-analysis', *Int J Behav Nutr Phys Act*, vol. 16, no. 1, p. 30.

Räikkönen, K., Matthews, K.A. & Kuller, L.H. 2007, 'Depressive symptoms and stressful life events predict metabolic syndrome among middle-aged women: a comparison of World Health Organization, Adult Treatment Panel III, and International Diabetes Foundation definitions', *Diabetes care*, vol. 30, no. 4, pp. 872-7.

Ramirez-Velez, R., Castro-Astudillo, K., Correa-Bautista, J.E., Gonzalez-Ruiz, K., Izquierdo, M., Garcia-Hermoso, A., Alvarez, C., Ramirez-Campillo, R. & Correa-Rodriguez, M. 2020, 'The Effect of 12 Weeks of Different Exercise Training Modalities or Nutritional Guidance on Cardiometabolic Risk Factors, Vascular Parameters, and Physical Fitness in Overweight Adults: Cardiometabolic High-Intensity Interval Training-Resistance Training Randomized Controlled Study', *J Strength Cond Res*, vol. 34, no. 8, pp. 2178-88.

Ramírez-Vélez, R., Correa-Bautista, J.E., Sanders-Tordecilla, A., Ojeda-Pardo, M.L., Cobo-Mejía, E.A., Castellanos-Vega, R.D.P., García-Hermoso, A., González-Jiménez, E., Schmidt-RioValle, J. & González-Ruíz, K. 2017, 'Percentage of body fat and fat mass index as a screening tool for metabolic syndrome prediction in Colombian university students', *Nutrients*, vol. 9, no. 9, p. 1009.

Ranjit, N., Diez-Roux, A.V., Shea, S., Cushman, M., Seeman, T., Jackson, S.A. & Ni, H. 2007, 'Psychosocial factors and inflammation in the multi-ethnic study of atherosclerosis', *Arch Intern Med*, vol. 167, no. 2, pp. 174-81.

Rebar, A.L., Stanton, R., Geard, D., Short, C., Duncan, M.J. & Vandelanotte, C. 2015, 'A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations', *Health Psychol Rev*, vol. 9, no. 3, pp. 366-78.

Reed, J. & Ones, D.S. 2006, 'The effect of acute aerobic exercise on positive activated affect: A meta-analysis', *Psychology of Sport and Exercise*, vol. 7, no. 5, pp. 477-514.

Rethorst, C.D., Wipfli, B.M. & Landers, D.M. 2009, 'The antidepressive effects of exercise: a meta-analysis of randomized trials', *Sports Med*, vol. 39, no. 6, pp. 491-511.

Ricci, J.A., Chee, E., Lorandeau, A.L. & Berger, J. 2007, 'Fatigue in the US workforce: prevalence and implications for lost productive work time', *Journal of occupational and environmental medicine*, vol. 49, no. 1, pp. 1-10.

Richards, J., Jiang, X., Kelly, P., Chau, J., Bauman, A. & Ding, D. 2015, 'Don't worry, be happy: cross-sectional associations between physical activity and happiness in 15 European countries', *BMC public health*, vol. 15, no. 1, pp. 1-8.

Robineau, J., Lacome, M., Piscione, J., Bigard, X. & Babault, N. 2017, 'Concurrent Training in Rugby Sevens: Effects of High-Intensity Interval Exercises', *Int J Sports Physiol Perform*, vol. 12, no. 3, pp. 336-44.

Roest, A.M., Martens, E.J., de Jonge, P. & Denollet, J. 2010, 'Anxiety and risk of incident coronary heart disease: a meta-analysis', *J Am Coll Cardiol*, vol. 56, no. 1, pp. 38-46.
Rohleder, N. 2019, 'Stress and inflammation–The need to address the gap in the transition between acute and chronic stress effects', *Psychoneuroendocrinology*, vol. 105, pp. 164-71.
Rotter, V., Nagaev, I. & Smith, U. 2003, 'Interleukin-6 (IL-6) induces insulin resistance in 3T3-L1 adipocytes and is, like IL-8 and tumor necrosis factor-α, overexpressed in human fat cells from insulin-resistant subjects', *Journal of Biological Chemistry*, vol. 278, no. 46, pp. 45777-84.
Rugulies, R., Aust, B. & Madsen, I.E. 2017, 'Effort-reward imbalance at work and risk of depressive disorders. A systematic review and meta-analysis of prospective cohort studies', *Scand J Work Environ Health*, vol. 43, no. 4, pp. 294-306.
Ruijgrok, C., Dekker, J.M., Beulens, J.W., Brouwer, I.A., Coupé, V.M., Heymans, M.W., Sijtsma, F.P., Mela, D.J., Zock, P.L. & Olthof, M.R. 2018, 'Size and shape of the associations of glucose, HbA 1c, insulin and HOMA-IR with incident type 2 diabetes: the Hoorn Study', *Diabetologia*, vol. 61, no. 1, pp. 93-100.
Runge, K., van Zon, S.K.R., Bultmann, U. & Henkens, K. 2021, 'Metabolic syndrome incidence in an aging workforce: Occupational differences and the role of health behaviors', *SSM Popul Health*, vol. 15, p. 100881.
Saavedra, J.M., Kristjánsdóttir, H., Gunnarsson, S.B. & García-Hermoso, A. 2021, 'Effects of 2 Physical Exercise Programs (Circuit Training and Brisk Walk) Carried Out During Working Hours on Multidimensional Components of Workers' Health: a Pilot Study', *International Journal of Occupational Medicine and Environmental Health*, vol. 34, no. 1, pp. 39-51.
Saeedi, P., Petersohn, I., Salpea, P., Malanda, B., Karuranga, S., Unwin, N., Colagiuri, S., Guariguata, L., Motala, A.A., Ogurtsova, K., Shaw, J.E., Bright, D., Williams, R. & Committee, I.D.F.D.A. 2019, 'Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9(th) edition', *Diabetes Res Clin Pract*, vol. 157, p. 107843.
Safi, A., Cole, M., Kelly, A.L. & Walker, N.C. 2021, 'An Evaluation of Physical Activity Levels amongst University Employees', *Advances in Physical Education*, vol. 11, no. 02, p. 158.
Sanchez-Chaparro, M.A., Calvo-Bonacho, E., Gonzalez-Quintela, A., Fernandez-Labandera, C., Cabrera, M., Sainz, J.C., Fernandez-Meseguer, A., Banegas, J.R., Ruilope, L.M., Valdivielso, P., Roman-Garcia, J. & Ibermutuamur Cardiovascular Risk Assessment Study, G. 2008, 'Occupation-related differences in the prevalence of metabolic syndrome', *Diabetes Care*, vol. 31, no. 9, pp. 1884-5.
Sara, J.D., Prasad, M., Eleid, M.F., Zhang, M., Widmer, R.J. & Lerman, A. 2018, 'Association Between Work-Related Stress and Coronary Heart Disease: A Review of Prospective Studies Through the Job Strain, Effort-Reward Balance, and Organizational Justice Models', *J Am Heart Assoc*, vol. 7, no. 9, p. e008073.
Schroeder, E.C., Franke, W.D., Sharp, R.L. & Lee, D.C. 2019, 'Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: A randomized controlled trial', *PLoS One*, vol. 14, no. 1, p. e0210292.
Schuch, F.B., Stubbs, B., Meyer, J., Heissel, A., Zech, P., Vancampfort, D., Rosenbaum, S., Deenik, J., Firth, J., Ward, P.B., Carvalho, A.F. & Hiles, S.A. 2019, 'Physical activity

protects from incident anxiety: A meta-analysis of prospective cohort studies', *Depress Anxiety*, vol. 36, no. 9, pp. 846-58.
Schuch, F.B., Vancampfort, D., Firth, J., Rosenbaum, S., Ward, P.B., Silva, E.S., Hallgren, M., Ponce De Leon, A., Dunn, A.L., Deslandes, A.C., Fleck, M.P., Carvalho, A.F. & Stubbs, B. 2018, 'Physical Activity and Incident Depression: A Meta-Analysis of Prospective Cohort Studies', *Am J Psychiatry*, vol. 175, no. 7, pp. 631-48.
Schuch, F.B., Vancampfort, D., Richards, J., Rosenbaum, S., Ward, P.B. & Stubbs, B. 2016, 'Exercise as a treatment for depression: a meta-analysis adjusting for publication bias', *Journal of psychiatric research*, vol. 77, pp. 42-51.
Schuch, F.B., Vancampfort, D., Sui, X., Rosenbaum, S., Firth, J., Richards, J., Ward, P.B. & Stubbs, B. 2016, 'Are lower levels of cardiorespiratory fitness associated with incident depression? A systematic review of prospective cohort studies', *Prev Med*, vol. 93, pp. 159-65.
Schultchen, D., Reichenberger, J., Mittl, T., Weh, T.R.M., Smyth, J.M., Blechert, J. & Pollatos, O. 2019, 'Bidirectional relationship of stress and affect with physical activity and healthy eating', *Br J Health Psychol*, vol. 24, no. 2, pp. 315-33.
Schultz, A.B. & Edington, D.W. 2009, 'Metabolic syndrome in a workplace: prevalence, co-morbidities, and economic impact', *Metab Syndr Relat Disord*, vol. 7, no. 5, pp. 459-68.
Schumann, M., Kuusmaa, M., Newton, R.U., Sirparanta, A.I., Syvaoja, H., Hakkinen, A. & Hakkinen, K. 2014, 'Fitness and lean mass increases during combined training independent of loading order', *Med Sci Sports Exerc*, vol. 46, no. 9, pp. 1758-68.
Schwingshackl, L., Dias, S., Strasser, B. & Hoffmann, G. 2013, 'Impact of different training modalities on anthropometric and metabolic characteristics in overweight/obese subjects: a systematic review and network meta-analysis', *PLoS One*, vol. 8, no. 12, p. e82853.
Scollon, C.N., Prieto, C.-K. & Diener, E. 2009, 'Experience sampling: promises and pitfalls, strength and weaknesses', *Assessing well-being*, Springer, pp. 157-80.
Semnani-Azad, Z., Connelly, P.W., Bazinet, R.P., Retnakaran, R., Jenkins, D.J., Harris, S.B., Zinman, B. & Hanley, A.J. 2021, 'Adipose Tissue Insulin Resistance Is Longitudinally Associated With Adipose Tissue Dysfunction, Circulating Lipids, and Dysglycemia: The PROMISE Cohort', *Diabetes Care*.
Senn, J.J., Klover, P.J., Nowak, I.A. & Mooney, R.A. 2002, 'Interleukin-6 induces cellular insulin resistance in hepatocytes', *Diabetes*, vol. 51, no. 12, pp. 3391-9.
Shephard, R.J., Park, H., Park, S. & Aoyagi, Y. 2013, 'Objectively measured physical activity and progressive loss of lean tissue in older Japanese adults: longitudinal data from the Nakanojo study', *J Am Geriatr Soc*, vol. 61, no. 11, pp. 1887-93.
Shibata, A.I., Oka, K., Sugiyama, T., Salmon, J.O., Dunstan, D.W. & Owen, N. 2016, 'Physical Activity, Television Viewing Time, and 12-Year Changes in Waist Circumference', *Med Sci Sports Exerc*, vol. 48, no. 4, pp. 633-40.
Shiel, F., Persson, C., Simas, V., Furness, J., Climstein, M. & Schram, B. 2017, 'Investigating the level of agreement of two positioning protocols when using dual energy X-ray absorptiometry in the assessment of body composition', *PeerJ*, vol. 5, p. e3880.
Shigdel, R., Stubbs, B., Sui, X. & Ernstsen, L. 2019, 'Cross-sectional and longitudinal association of non-exercise estimated cardiorespiratory fitness with depression and anxiety in the general population: The HUNT study', *J Affect Disord*, vol. 252, pp. 122-9.

Shimomitsu, T. 2000, 'The final development of the Brief Job Stress Questionnaire mainly used for assessment of the individuals', *Ministry for Labour sponsored grant for the prevention of work-related illness: The 1999 report*, pp. 126-64.

Shook, R.P., Hand, G.A., Drenowatz, C., Hebert, J.R., Paluch, A.E., Blundell, J.E., Hill, J.O., Katzmarzyk, P.T., Church, T.S. & Blair, S.N. 2015, 'Low levels of physical activity are associated with dysregulation of energy intake and fat mass gain over 1 year', *Am J Clin Nutr*, vol. 102, no. 6, pp. 1332-8.

Siegrist, J. 1996, 'Adverse health effects of high-effort/low-reward conditions', *J Occup Health Psychol*, vol. 1, no. 1, pp. 27-41.

Siegrist, J. 2012, 'Effort-reward imbalance at work: Theory, measurement and evidence', *Department of Medical Sociology, University Düsseldorf, Düsseldorf*.

Siegrist, J., Li, J. & Montano, D. 2014, 'Psychometric properties of the effort-reward imbalance questionnaire', *Department of Medical Sociology, Faculty of Medicine, Duesseldorf University, Germany*.

Sinclair, S.J., Siefert, C.J., Slavin-Mulford, J.M., Stein, M.B., Renna, M. & Blais, M.A. 2012, 'Psychometric evaluation and normative data for the depression, anxiety, and stress scales-21 (DASS-21) in a nonclinical sample of U.S. adults', *Eval Health Prof*, vol. 35, no. 3, pp. 259-79.

Slade, T., Grove, R. & Burgess, P. 2011, 'Kessler Psychological Distress Scale: normative data from the 2007 Australian National Survey of Mental Health and Wellbeing', *Aust N Z J Psychiatry*, vol. 45, no. 4, pp. 308-16.

Slavich, G.M. & Irwin, M.R. 2014, 'From stress to inflammation and major depressive disorder: a social signal transduction theory of depression', *Psychol Bull*, vol. 140, no. 3, pp. 774-815.

Slentz, C.A., Bateman, L.A., Willis, L.H., Shields, A.T., Tanner, C.J., Piner, L.W., Hawk, V.H., Muehlbauer, M.J., Samsa, G.P., Nelson, R.C., Huffman, K.M., Bales, C.W., Houmard, J.A. & Kraus, W.E. 2011, 'Effects of aerobic vs. resistance training on visceral and liver fat stores, liver enzymes, and insulin resistance by HOMA in overweight adults from STRRIDE AT/RT', *Am J Physiol Endocrinol Metab*, vol. 301, no. 5, pp. E1033-9.

Slišković, A. & Seršić, D. 2011, 'Work stress among university teachers: Gender and position differences', *Archives of Industrial Hygiene and Toxicology*, vol. 62, no. 4, pp. 299-307.

Smith, A.D., Crippa, A., Woodcock, J. & Brage, S. 2016a, 'Physical activity and incident type 2 diabetes mellitus: a systematic review and dose-response meta-analysis of prospective cohort studies', *Diabetologia*, vol. 59, no. 12, pp. 2527-45.

Smith, A.D., Crippa, A., Woodcock, J. & Brage, S. 2016b, 'Physical activity and incident type 2 diabetes mellitus: a systematic review and dose–response meta-analysis of prospective cohort studies', Series Physical activity and incident type 2 diabetes mellitus: a systematic review and dose–response meta-analysis of prospective cohort studies Springer.

Smith, K.J., Beland, M., Clyde, M., Gariepy, G., Page, V., Badawi, G., Rabasa-Lhoret, R. & Schmitz, N. 2013, 'Association of diabetes with anxiety: a systematic review and meta-analysis', *J Psychosom Res*, vol. 74, no. 2, pp. 89-99.

Solhan, M.B., Trull, T.J., Jahng, S. & Wood, P.K. 2009, 'Clinical assessment of affective instability: comparing EMA indices, questionnaire reports, and retrospective recall', *Psychol Assess*, vol. 21, no. 3, pp. 425-36.

Soulimane, S., Simon, D., Shaw, J., Zimmet, P., Vol, S., Vistisen, D., Magliano, D., Borch-Johnsen, K. & Balkau, B. 2011, 'Comparing incident diabetes as defined by fasting plasma glucose or by HbA1c. The AusDiab, Inter99 and DESIR studies', *Diabetic Medicine*, vol. 28, no. 11, pp. 1311-8.

Speed, M.S., Jefsen, O.H., Børglum, A.D., Speed, D. & Østergaard, S.D. 2019, 'Investigating the association between body fat and depression via Mendelian randomization', *Translational psychiatry*, vol. 9, no. 1, pp. 1-9.

Spranger, J., Kroke, A., Möhlig, M., Hoffmann, K., Bergmann, M.M., Ristow, M., Boeing, H. & Pfeiffer, A.F. 2003, 'Inflammatory cytokines and the risk to develop type 2 diabetes: results of the prospective population-based European Prospective Investigation into Cancer and Nutrition (EPIC)-Potsdam Study', *Diabetes*, vol. 52, no. 3, pp. 812-7.

SPRINT Research Group, Wright, J.T., Jr., Williamson, J.D., Whelton, P.K., Snyder, J.K., Sink, K.M., Rocco, M.V., Reboussin, D.M., Rahman, M., Oparil, S., Lewis, C.E., Kimmel, P.L., Johnson, K.C., Goff, D.C., Jr., Fine, L.J., Cutler, J.A., Cushman, W.C., Cheung, A.K. & Ambrosius, W.T. 2015, 'A Randomized Trial of Intensive versus Standard Blood-Pressure Control', *N Engl J Med*, vol. 373, no. 22, pp. 2103-16.

Stewart, K.J., Bacher, A.C., Turner, K., Lim, J.G., Hees, P.S., Shapiro, E.P., Tayback, M. & Ouyang, P. 2005, 'Exercise and risk factors associated with metabolic syndrome in older adults', *Am J Prev Med*, vol. 28, no. 1, pp. 9-18.

Stewart, L.K., Flynn, M.G., Campbell, W.W., Craig, B.A., Robinson, J.P., Timmerman, K.L., McFarlin, B.K., Coen, P.M. & Talbert, E. 2007, 'The influence of exercise training on inflammatory cytokines and C-reactive protein', *Med Sci Sports Exerc*, vol. 39, no. 10, pp. 1714-9.

Stonerock, G.L., Hoffman, B.M., Smith, P.J. & Blumenthal, J.A. 2015, 'Exercise as treatment for anxiety: systematic review and analysis', *Annals of behavioral medicine*, vol. 49, no. 4, pp. 542-56.

Strasser, B., Siebert, U. & Schobersberger, W. 2010, 'Resistance training in the treatment of the metabolic syndrome: a systematic review and meta-analysis of the effect of resistance training on metabolic clustering in patients with abnormal glucose metabolism', *Sports Med*, vol. 40, no. 5, pp. 397-415.

Strauss, M., Foshag, P., Brzęk, A., Vollenberg, R., Jehn, U., Littwitz, H. & Leischik, R. 2021, 'Cardiorespiratory Fitness Is Associated with a Reduced Cardiovascular Risk in Occupational Groups with Different Working Conditions: A Cross-Sectional Study among Police Officers and Office Workers', *Journal of Clinical Medicine*, vol. 10, no. 9, p. 2025.

Stubbs, B., Koyanagi, A., Hallgren, M., Firth, J., Richards, J., Schuch, F., Rosenbaum, S., Mugisha, J., Veronese, N., Lahti, J. & Vancampfort, D. 2017, 'Physical activity and anxiety: A perspective from the World Health Survey', *J Affect Disord*, vol. 208, pp. 545-52.

Stubbs, B., Vancampfort, D., Rosenbaum, S., Firth, J., Cosco, T., Veronese, N., Salum, G.A. & Schuch, F.B. 2017, 'An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: A meta-analysis', *Psychiatry Res*, vol. 249, pp. 102-8.

Stults-Kolehmainen, M.A. & Sinha, R. 2014, 'The effects of stress on physical activity and exercise', *Sports Med*, vol. 44, no. 1, pp. 81-121.

Sugiyama, T., Hadgraft, N., Clark, B.K., Dunstan, D.W. & Owen, N. 2020, 'Sitting at work & waist circumference—A cross-sectional study of Australian workers', *Preventive Medicine*, vol. 141, p. 106243.
Sun, K., Tordjman, J., Clement, K. & Scherer, P.E. 2013, 'Fibrosis and adipose tissue dysfunction', *Cell Metab*, vol. 18, no. 4, pp. 470-7.
Swain, D.P. & Franklin, B.A. 2002, 'VO2 reserve and the minimal intensity for improving cardiorespiratory fitness', *Medicine and science in sports and exercise*, vol. 34, no. 1.
Swain, D.P. & Franklin, B.A. 2006, 'Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise', *Am J Cardiol*, vol. 97, no. 1, pp. 141-7.
Swardfager, W., Herrmann, N., Cornish, S., Mazereeuw, G., Marzolini, S., Sham, L. & Lanctot, K.L. 2012, 'Exercise intervention and inflammatory markers in coronary artery disease: a meta-analysis', *Am Heart J*, vol. 163, no. 4, pp. 666-76 e1-3.
Tang, F., Wang, G. & Lian, Y. 2017, 'Association between anxiety and metabolic syndrome: a systematic review and meta-analysis of epidemiological studies', *Psychoneuroendocrinology*, vol. 77, pp. 112-21.
Tavoian, D., Ampomah, K., Amano, S., Law, T.D. & Clark, B.C. 2019, 'Changes in DXA-derived lean mass and MRI-derived cross-sectional area of the thigh are modestly associated', *Sci Rep*, vol. 9, no. 1, p. 10028.
Taylor, J. 2001, 'The impact of performance indicators on the work of university academics: evidence from Australian universities', *Higher education quarterly*, vol. 55, no. 1, pp. 42-61.
Thogersen-Ntoumani, C., Loughren, E.A., Kinnafick, F.E., Taylor, I.M., Duda, J.L. & Fox, K.R. 2015, 'Changes in work affect in response to lunchtime walking in previously physically inactive employees: A randomized trial', *Scand J Med Sci Sports*, vol. 25, no. 6, pp. 778-87.
Timmons, J.F., Minnock, D., Hone, M., Cogan, K.E., Murphy, J.C. & Egan, B. 2018, 'Comparison of time-matched aerobic, resistance, or concurrent exercise training in older adults', *Scand J Med Sci Sports*, vol. 28, no. 11, pp. 2272-83.
Tseng, M.L., Ho, C.C., Chen, S.C., Huang, Y.C., Lai, C.H. & Liaw, Y.P. 2013, 'A simple method for increasing levels of high-density lipoprotein cholesterol: a pilot study of combination aerobic- and resistance-exercise training', *Int J Sport Nutr Exerc Metab*, vol. 23, no. 3, pp. 271-81.
Tsenkova, V.K. 2017, 'Leisure-time, occupational, household physical activity and insulin resistance (HOMAIR) in the Midlife in the United States (MIDUS) national study of adults', *Prev Med Rep*, vol. 5, pp. 224-7.
Tuttle, C.S., Thang, L.A. & Maier, A.B. 2020, 'Markers of inflammation and their association with muscle strength and mass: A systematic review and meta-analysis', *Ageing research reviews*, p. 101185.
Tytherleigh, M.Y., Jacobs, P.A., Webb, C., Ricketts, C. & Cooper, C. 2007, 'Gender, Health and Stress in English University Staff?Exposure or Vulnerability?', *Applied Psychology*, vol. 56, no. 2, pp. 267-87.
Tytherleigh, M.Y., Webb, C., Cooper, C.L. & Ricketts, C. 2005, 'Occupational stress in UK higher education institutions: a comparative study of all staff categories', *Higher Education Research & Development*, vol. 24, no. 1, pp. 41-61.
Urbaniak, G.C. & Plous, S. 2019, *Research Randomizer*, version 4.0 [Computer software], viewed August 7, 2019, from https://www.randomizer.org/.

Vaisanen, D., Kallings, L.V., Andersson, G., Wallin, P., Hemmingsson, E. & Ekblom-Bak, E. 2020, 'Lifestyle-associated health risk indicators across a wide range of occupational groups: a cross-sectional analysis in 72,855 workers', *BMC Public Health*, vol. 20, no. 1, p. 1656.

van Baak, M.A., Pramono, A., Battista, F., Beaulieu, K., Blundell, J.E., Busetto, L., Carraca, E.V., Dicker, D., Encantado, J., Ermolao, A., Farpour-Lambert, N., Woodward, E., Bellicha, A. & Oppert, J.M. 2021, 'Effect of different types of regular exercise on physical fitness in adults with overweight or obesity: Systematic review and meta-analyses', *Obes Rev*, vol. 22 Suppl 4, p. e13239.

van der Velde, J.H., Schaper, N.C., Stehouwer, C.D., van der Kallen, C.J., Sep, S.J., Schram, M.T., Henry, R.M., Dagnelie, P.C., Eussen, S.J. & van Dongen, M.C. 2018, 'Which is more important for cardiometabolic health: sedentary time, higher intensity physical activity or cardiorespiratory fitness? The Maastricht Study', *Diabetologia*, vol. 61, no. 12, pp. 2561-9.

Vazquez, G., Duval, S., Jacobs, D.R., Jr. & Silventoinen, K. 2007, 'Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: a meta-analysis', *Epidemiol Rev*, vol. 29, no. 1, pp. 115-28.

Vetrovsky, T., Omcirk, D., Malecek, J., Stastny, P., Steffl, M. & Tufano, J.J. 2021, 'Morning fatigue and structured exercise interact to affect non-exercise physical activity of fit and healthy older adults', *BMC Geriatr*, vol. 21, no. 1, p. 179.

Villarroya, F., Cereijo, R., Gavalda-Navarro, A., Villarroya, J. & Giralt, M. 2018, 'Inflammation of brown/beige adipose tissues in obesity and metabolic disease', *J Intern Med*, vol. 284, no. 5, pp. 492-504.

Virani, S.S., Alonso, A., Aparicio, H.J., Benjamin, E.J., Bittencourt, M.S., Callaway, C.W., Carson, A.P., Chamberlain, A.M., Cheng, S., Delling, F.N., Elkind, M.S.V., Evenson, K.R., Ferguson, J.F., Gupta, D.K., Khan, S.S., Kissela, B.M., Knutson, K.L., Lee, C.D., Lewis, T.T., Liu, J., Loop, M.S., Lutsey, P.L., Ma, J., Mackey, J., Martin, S.S., Matchar, D.B., Mussolino, M.E., Navaneethan, S.D., Perak, A.M., Roth, G.A., Samad, Z., Satou, G.M., Schroeder, E.B., Shah, S.H., Shay, C.M., Stokes, A., VanWagner, L.B., Wang, N.Y., Tsao, C.W., American Heart Association Council on, E., Prevention Statistics, C. & Stroke Statistics, S. 2021, 'Heart Disease and Stroke Statistics-2021 Update: A Report From the American Heart Association', *Circulation*, vol. 143, no. 8, pp. e254-e743.

Virtanen, M., Ferrie, J.E., Singh-Manoux, A., Shipley, M.J., Stansfeld, S.A., Marmot, M.G., Ahola, K., Vahtera, J. & Kivimaki, M. 2011, 'Long working hours and symptoms of anxiety and depression: a 5-year follow-up of the Whitehall II study', *Psychol Med*, vol. 41, no. 12, pp. 2485-94.

Virtanen, M., Jokela, M., Madsen, I.E., Magnusson Hanson, L.L., Lallukka, T., Nyberg, S.T., Alfredsson, L., Batty, G.D., Bjorner, J.B., Borritz, M., Burr, H., Dragano, N., Erbel, R., Ferrie, J.E., Heikkila, K., Knutsson, A., Koskenvuo, M., Lahelma, E., Nielsen, M.L., Oksanen, T., Pejtersen, J.H., Pentti, J., Rahkonen, O., Rugulies, R., Salo, P., Schupp, J., Shipley, M.J., Siegrist, J., Singh-Manoux, A., Suominen, S.B., Theorell, T., Vahtera, J., Wagner, G.G., Wang, J.L., Yiengprugsawan, V., Westerlund, H. & Kivimaki, M. 2018, 'Long working hours and depressive symptoms: systematic review and meta-analysis of published studies and unpublished individual participant data', *Scand J Work Environ Health*, vol. 44, no. 3, pp. 239-50.

von Kanel, R., Mills, P.J., Mausbach, B.T., Dimsdale, J.E., Patterson, T.L., Ziegler, M.G., Ancoli-Israel, S., Allison, M., Chattillion, E.A. & Grant, I. 2012, 'Effect of Alzheimer caregiving on circulating levels of C-reactive protein and other biomarkers relevant to cardiovascular disease risk: a longitudinal study', *Gerontology*, vol. 58, no. 4, pp. 354-65.

Wang, X., Bao, W., Liu, J., Ouyang, Y.Y., Wang, D., Rong, S., Xiao, X., Shan, Z.L., Zhang, Y., Yao, P. & Liu, L.G. 2013, 'Inflammatory markers and risk of type 2 diabetes: a systematic review and meta-analysis', *Diabetes Care*, vol. 36, no. 1, pp. 166-75.

Webb, M.B., Davies, M., Ashra, N., Bodicoat, D., Brady, E., Webb, D., Moulton, C., Ismail, K. & Khunti, K. 2017, 'The association between depressive symptoms and insulin resistance, inflammation and adiposity in men and women', *PloS one*, vol. 12, no. 11, p. e0187448.

Weber, M.D., Frank, M.G., Tracey, K.J., Watkins, L.R. & Maier, S.F. 2015, 'Stress induces the danger-associated molecular pattern HMGB-1 in the hippocampus of male Sprague Dawley rats: a priming stimulus of microglia and the NLRP3 inflammasome', *J Neurosci*, vol. 35, no. 1, pp. 316-24.

Wedell-Neergaard, A.-S., Eriksen, L., Grønbæk, M., Pedersen, B.K., Krogh-Madsen, R. & Tolstrup, J. 2018, 'Low fitness is associated with abdominal adiposity and low-grade inflammation independent of BMI', *PloS one*, vol. 13, no. 1, p. e0190645.

Weisberg, S.P., McCann, D., Desai, M., Rosenbaum, M., Leibel, R.L. & Ferrante, A.W. 2003, 'Obesity is associated with macrophage accumulation in adipose tissue', *The Journal of clinical investigation*, vol. 112, no. 12, pp. 1796-808.

Wewege, M.A., Thom, J.M., Rye, K.A. & Parmenter, B.J. 2018, 'Aerobic, resistance or combined training: A systematic review and meta-analysis of exercise to reduce cardiovascular risk in adults with metabolic syndrome', *Atherosclerosis*, vol. 274, pp. 162-71.

Whitaker, K.M., Pettee Gabriel, K., Buman, M.P., Pereira, M.A., Jacobs, D.R., Jr., Reis, J.P., Gibbs, B.B., Carnethon, M.R., Staudenmayer, J., Sidney, S. & Sternfeld, B. 2019, 'Associations of Accelerometer-Measured Sedentary Time and Physical Activity With Prospectively Assessed Cardiometabolic Risk Factors: The CARDIA Study', *J Am Heart Assoc*, vol. 8, no. 1, p. e010212.

Wichers, M., Peeters, F., Rutten, B.P., Jacobs, N., Derom, C., Thiery, E., Delespaul, P. & van Os, J. 2012, 'A time-lagged momentary assessment study on daily life physical activity and affect', *Health Psychol*, vol. 31, no. 2, pp. 135-44.

Wiebe, N., Ye, F., Crumley, E.T., Bello, A., Stenvinkel, P. & Tonelli, M. 2021, 'Temporal associations among body mass index, fasting insulin, and systemic inflammation: a systematic review and meta-analysis', *JAMA network open*, vol. 4, no. 3, pp. e211263-e.

Willis, L.H., Slentz, C.A., Bateman, L.A., Shields, A.T., Piner, L.W., Bales, C.W., Houmard, J.A. & Kraus, W.E. 2012, 'Effects of aerobic and/or resistance training on body mass and fat mass in overweight or obese adults', *Journal of applied physiology*, vol. 113, no. 12, pp. 1831-7.

Wilson, J.M., Marin, P.J., Rhea, M.R., Wilson, S.M., Loenneke, J.P. & Anderson, J.C. 2012, 'Concurrent training: a meta-analysis examining interference of aerobic and resistance exercises', *J Strength Cond Res*, vol. 26, no. 8, pp. 2293-307.

Winefield, A.H., Gillespie, N., Stough, C., Dua, J., Hapuarachchi, J. & Boyd, C. 2003, 'Occupational stress in Australian university staff: Results from a national survey', *International Journal of Stress Management*, vol. 10, no. 1, p. 51.

Winefield, A.H., Gillespie, N., Stough, C., Dua, J. & Hapuararchchi, J. 2002, 'Occupational stress in Australian universities: A national survey', National Tertiary Education Union Melbourne.

Winefield, A.H. & Jarrett, R. 2001, 'Occupational stress in university staff', *International journal of stress management*, vol. 8, no. 4, pp. 285-98.

Winkler, G., Kiss, S., Keszthelyi, L., Sápi, Z., Ory, I., Salamon, F., Kovács, M., Vargha, P., Szekeres, O. & Speer, G. 2003, 'Expression of tumor necrosis factor (TNF)-a protein in the subcutaneous and visceral adipose tissue in correlation with adipocyte cell volume, serum TNF-a, soluble serum TNF-receptor-2 concentrations and C-peptide level', *Eur J Endocrinol*, vol. 149, no. 2, pp. 129-35.

Wipfli, B.M., Rethorst, C.D. & Landers, D.M. 2008, 'The anxiolytic effects of exercise: a meta-analysis of randomized trials and dose-response analysis', *J Sport Exerc Psychol*, vol. 30, no. 4, pp. 392-410.

Wood, G., Taylor, E., Ng, V., Murrell, A., Patil, A., van der Touw, T., Sigal, R., Wolden, M. & Smart, N. 2021, 'Determining the effect size of aerobic exercise training on the standard lipid profile in sedentary adults with three or more metabolic syndrome factors: a systematic review and meta-analysis of randomised controlled trials', *Br J Sports Med*.

World Health Organization 2011, *Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, 8-11 December 2008*.

Wunderlich, F.T., Strohle, P., Konner, A.C., Gruber, S., Tovar, S., Bronneke, H.S., Juntti-Berggren, L., Li, L.S., van Rooijen, N., Libert, C., Berggren, P.O. & Bruning, J.C. 2010, 'Interleukin-6 signaling in liver-parenchymal cells suppresses hepatic inflammation and improves systemic insulin action', *Cell Metab*, vol. 12, no. 3, pp. 237-49.

Xu, F., Earp, J.E., Vadiveloo, M., Adami, A., Delmonico, M.J., Lofgren, I.E. & Greaney, M.L. 2020, 'The Relationships between Total Protein Intake, Protein Sources, Physical Activity, and Lean Mass in a Representative Sample of the US Adults', *Nutrients*, vol. 12, no. 10, p. 3151.

Yerramalla, M.S., Fayosse, A., Dugravot, A., Tabak, A.G., Kivimaki, M., Singh-Manoux, A. & Sabia, S. 2020, 'Association of moderate and vigorous physical activity with incidence of type 2 diabetes and subsequent mortality: 27 year follow-up of the Whitehall II study', *Diabetologia*, vol. 63, no. 3, pp. 537-48.

Zafar, U., Khaliq, S., Ahmad, H.U. & Lone, K.P. 2019, 'Serum profile of cytokines and their genetic variants in metabolic syndrome and healthy subjects: a comparative study', *Bioscience reports*, vol. 39, no. 2, p. BSR20181202.

Zeiher, J., Duch, M., Kroll, L.E., Mensink, G.B., Finger, J.D. & Keil, T. 2020, 'Domain-specific physical activity patterns and cardiorespiratory fitness among the working population: Findings from the cross-sectional German Health Interview and Examination Survey', *BMJ open*, vol. 10, no. 4, p. e034610.

Zeiher, J., Ombrellaro, K.J., Perumal, N., Keil, T., Mensink, G.B.M. & Finger, J.D. 2019, 'Correlates and Determinants of Cardiorespiratory Fitness in Adults: a Systematic Review', *Sports Med Open*, vol. 5, no. 1, p. 39.

Zhai, L., Zhang, Y. & Zhang, D. 2015, 'Sedentary behaviour and the risk of depression: a meta-analysis', *Br J Sports Med*, vol. 49, no. 11, pp. 705-9.

Zhang, D., Liu, X., Liu, Y., Sun, X., Wang, B., Ren, Y., Zhao, Y., Zhou, J., Han, C., Yin, L., Zhao, J., Shi, Y., Zhang, M. & Hu, D. 2017, 'Leisure-time physical activity and incident metabolic syndrome: a systematic review and dose-response meta-analysis of cohort studies', *Metabolism*, vol. 75, pp. 36-44.

Zheng, G., Qiu, P., Xia, R., Lin, H., Ye, B., Tao, J. & Chen, L. 2019, 'Effect of Aerobic Exercise on Inflammatory Markers in Healthy Middle-Aged and Older Adults: A Systematic Review and Meta-Analysis of Randomized Controlled Trials', *Front Aging Neurosci*, vol. 11, p. 98.

Appendices

Appendix A – Ethics Approval

Dear Applicant

Thank you for your response to the Committee's comments for your project titled, "Concurrent exercise training for physical and mental health in the academic workplace; bilateral benefits for employer and employee". The Committee agreed that this application now meets the requirements of the National Statement on Ethical Conduct in Human Research (2007) and has been approved on that basis. You are therefore authorised to commence activities as outlined in your application, subject to any conditions detailed in this document.

You are reminded that this letter constitutes ethics approval only. This research project must also be undertaken in accordance with all UTS policies and guidelines including the Research Management Policy (http://www.gsu.uts.edu.au/policies/research-management-policy.html).

Your approval number is UTS HREC REF NO. ETH18-3093.

Approval will be for a period of five (5) years from the date of this correspondence subject to the submission of annual progress reports.

The following special conditions apply to your approval:
• GCP training should be undertaken by all members of the research team, and evidence of attainment should be provided to the Ethics Secretariat when obtained.

The following standard conditions apply to your approval:

• Your approval number must be included in all participant material and advertisements. Any advertisements on Staff Connect without an approval number will be removed.

• The Principal Investigator will immediately report anything that might warrant review of ethical approval of the project to the Ethics Secretariat (Research.Ethics@uts.edu.au).
• The Principal Investigator will notify the UTS HREC of any event that requires a modification to the protocol or other project documents, and submit any required amendments prior to implementation. Instructions can be found at https://staff.uts.edu.au/topichub/Pages/Researching/Research%20Ethics%20and%20Integrity/Animal%20care%20and%20ethics/Post-Approval/post-approval.aspx.
• The Principal Investigator will promptly report adverse events to the Ethics Secretariat (Research.Ethics@uts.edu.au). An adverse event is any event (anticipated or otherwise) that has a negative impact on participants, researchers or the reputation of the University. Adverse events can also include privacy breaches, loss of data and damage to property. Any cases of serious adverse event (SAE), adverse drug reaction (ADR), or serious unexpected suspected adverse reaction (SUSAR) must be reported to the Sponsor within 24 hours of becoming aware of the event, and to the CTSC within 72 hours of becoming aware of the event, using the appropriate reporting form. Refer to https://staff.uts.edu.au/topichub/Pages/Researching/Research%20Ethics%20and%20Integrity/Human%20research%20ethics/Clinical%20trials/clinical-trials.aspx#tab4 for more information.
• The Principal Investigator will report to the UTS HREC annually and notify the HREC

when the project is completed at all sites. The Principal Investigator will notify the UTS HREC of any plan to extend the duration of the project past the approval period listed above through the progress report.
• The Principal Investigator will obtain any additional approvals or authorisations as required (e.g. from other ethics committees, collaborating institutions, supporting organisations).
• The Principal Investigator will notify the UTS HREC of his or her inability to continue as Principal Investigator including the name of and contact information for a replacement.
I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Professor Meera Agar
Chairperson
UTS Human Research Ethics Clinical Trials Subcommittee
C/- Research Office
University of Technology Sydney
T: (02) 9514 9772
F: (02) 9514 1244
E: Research.Ethics@uts.edu.au
I: https://staff.uts.edu.au/topichub/Pages/Researching/Research%20Ethics%20and%20Integrity/research-ethics-and-integrity.aspx
P: PO Box 123, BROADWAY NSW 2007
[Level 14, Building 1, Broadway Campus]

Appendix B – Participant Information Sheet and Consent Form

Participant Information Sheet

Interventional Study - *Adult providing own consent*

University of Technology Sydney

Title	Concurrent exercise training for physical and mental health in the academic workplace; bilateral significance for employer and employee
Coordinating Principal Investigator/ Principle Investigator	Professor Rob Duffield/ Samuel Higham
Location	University of Technology Sydney

HREC approval number ETH18-3093

Part 1 What does my participation involve?

1 Introduction

You have been approached because you meet the criteria for participation in this research. You have indicated that you are; 1) aged 35-65y; 2) working as a full-time academic; 3) free from known disease; 4) eligible for Medicare; and 5) currently inactive. Furthermore, you; 1) are not pregnant; 2) have not been diagnosed with a metabolic disease (e.g. diabetes) or severe musculoskeletal disorder (e.g rheumatoid arthritis); and 3) are not receiving specific types of anti-inflammatory or pharmacological treatment, Your contact details were obtained from respective faculty contact lists.

This Participant Information Sheet tells you about the research project. It explains the tests and intervention involved. Knowing what is involved will help you decide if you want to take part in the research.

Please read this information carefully. Ask questions about anything that you don't understand or want to know more about. Before deciding whether or not to take part, you might want to talk about it with a relative, friend or your local doctor.

Participation in this research is voluntary. If you don't wish to take part, you don't have to.

If you decide you want to take part in the research project, you will be asked to sign a consent form. By signing it you are telling us that you:
• Understand what you have read
• Consent to take part in the research project
• Consent to have the tests and intervention that are described
• Consent to the use of your personal and health information as described.

You will be given a copy of this Participant Information and Consent Form to keep.

2 What is the purpose of this research?

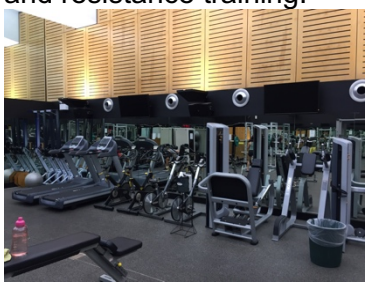
The aim of this research is to examine the effects of concurrent exercise (which includes both endurance and resistance training) on mental and physical health in full-time academics. Body composition and fitness measures as well as a range of risk factors for common mental disorders and metabolic disease (e.g. diabetes) will be measured in response to exercise training. An additional analysis will be performed to determine the applicability of the exercise program in the real-world (cost-effectiveness). The research will contribute to the growing interest in the mental and physical health of desk-based employees, particularly within the Higher Education sector, and how exercise can influence outcomes for both employees and employers.

The results of this research will be used by the PhD candidate, Samuel Higham, to obtain his PhD Thesis in Sport and Exercise Science.

3 What does participation in this research involve?

If you choose to take part in this study, you will be invited to:

- Attend a brief 30-minute health screening and information session
- Participate in a 14-week training program (1 hour, 3 times per week) at the UTS Private Gym in the city campus or Resistance Training Room at Moore Park, involving aerobic and resistance training.




- Attend a 60-minute testing session before and after the training period at the UTS Exercise Physiology Laboratory in Moore Park, involving:
    - Questionnaires in relation to symptoms of depression, anxiety and stress, and sickness at work, absenteeism and quality of life. Your gross hourly wage will be used in productivity calculations.
    - Dual-energy x-ray absorptiometry (DEXA) scan to determine body composition, involving a full-body non-contact scan.

    - Measures of height, mass, and blood pressure

- A small blood sample (6mL) will be obtained from the forearm to measure disease indicators related to chronic diseases like diabetes and depression.
- Measurement of aerobic fitness via the VO_{2max} cycling test (cycling at increasing intensities until exhaustion).

- Provide additional information for 1-2 weeks before and in the final weeks of the training period, involving:
  - Responding daily (1-minute) for 2 weeks to short questions on feelings of fatigue, sleep quality, stress, mood, and work load on a freely downloadable application for smart phones and other electronic devices
  - An online dietary intake assessment (30-minutes) on 3 non-consecutive days
- Provide ratings of perceived exertion after each training session.

You will be participating in a randomised controlled research project. Sometimes we do not know which treatment is best for treating a condition. To find out we need to compare different treatments. We put people into groups and give each group a different treatment. The results are compared to see if one is better. To try to make sure the groups are the same, each participant is put into a group by chance (random). Following the baseline testing period, you will be randomly allocated to either a; concurrent training group, or control group. **Please note:** if you are allocated to the control group you will be offered the same supervised training as the concurrent training group at the completion of the study.

This research project has been designed to make sure the researchers interpret the results in a fair and appropriate way and avoids study doctors or participants jumping to conclusions.

There are no additional costs associated with participating in this research project, nor will you be paid. All services and equipment required as part of the research project will be provided to you free of charge, except for parking if you choose to drive.

4 Do I have to take part in this research project?

Participation in any research project is voluntary. If you do not wish to take part, you do not have to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage.

If you decide not to participate, it will not affect your relationship with the researchers or the University of Technology Sydney. If you wish to withdraw from the study once it has started, you can do so at any time. We may ask why you are withdrawing; however, you do not have to provide a reason. You can withdraw from the study by contacting:
Prof Rob Duffield (Rob.Duffield@uts.edu.au - 02 9514 5294),

Sam Higham (Samuel.M.Higham@student.uts.edu.au – [redacted]) or
Shiree Miert (shiree.vanmiert@uts.edu.au - 02 9514 5206)

If you do decide to take part, you will be given this Participant Information and Consent Form to sign and you will be given a copy to keep.

5 What are the possible benefits of taking part?

By participating in this research, you will receive 14 weeks of exercise training under the guidance and supervision of trained instructors and exercise scientists. Further, you will receive a comprehensive health screening, including information about fitness, body composition, mental health and disease risk profiles. Finally, following the completion of the study, the research team will offer optional further health/exercise consultation.

6 Are there any risks/inconveniences?

Yes, there are some risks/inconveniences. Exercise training of this nature carries an inherent risk of muscle soreness and fatigue; however, the investigators will design and implement training in a manner that minimises these risks to participants. You may also be asked sensitive questions. However, you are under no obligation to respond to any questions.

Cardiorespiratory Fitness testing
The fitness testing protocols used in this study are strenuous and fatiguing; however, you are free to terminate the test at any time and we ask only that you continue until you feel you can no longer meet the demands of the test protocol.

Venous blood collection
Venous blood collection may cause some temporary discomfort or even minor bruising. Accordingly, only trained researchers will perform this procedure, and will do so in a way that minimises your discomfort. Further, steps will be taken to ensure safety and cleanliness at all times, including sterilisation of venepuncture sites, use of protective gloves, and appropriate disposal of sharp and/or contaminated items.

Procedures involving ionising radiation
This research project involves exposure to a very small amount of radiation during the DEXA scan. As part of everyday living, everyone is exposed to naturally occurring background radiation and receives a dose of about 2 millisieverts (mSv) each year. The effective dose from this project is about 0.004mSv. At this dose level, no harmful effects of radiation have been demonstrated and the risk is very low.

7 What will happen to my test samples?

With your consent, the investigators will extract approximately 12mL of blood using venepuncture at both the beginning and end of the study. These samples will be stored and later analysed to detect changes in disease biomarkers. The identities of the individuals associated with data will be known only to the researchers and will not be made public. No photographs or video of you will be taken without your consent, and these will be used for research dissemination purposes only.

8 What if I withdraw from this research project?

If you decide to leave the research project, we will not collect additional personal information from you, although personal information already collected will be retained to ensure that the results of the research project can be measured properly and to comply with law. You should be aware that data collected up to the time you withdraw will form part of the research project results.

9 What happens when the research project ends?

Following the completion of the study, the research team will collate and analyse all data. You will have access to your individual results if you so choose. You will also be invited to attend a brief informal meeting to discuss the results (both individual and anonymized group data) and you will be welcome to ask questions. Additionally, upon request the research team can provide guidelines for you to continue exercising after the study has finished.

Part 2 How is the research project being conducted?

10 What will happen to information about me?

By signing the consent form you agree to the collection and use of personal information about you for the study project and any future follow-up projects. Future projects may include follow-up studies linking the physical and mental health results to exercise adherence.

Layered security will be used to protect personal information relating to physical and mental health, absenteeism and presenteeism. Indeed, confidential information will be anonymized via coding of participant names and stored on UTS eResearch storage within a complex of password-protected documents. Only Sam Higham and Rob Duffield will have access to this information, ensuring that your data will be used only for research purposes and will not affect your employment or relationship with UTS.

It is anticipated that the results of this study will be published in a variety of forums. In any publication or presentation, information will be presented such that you cannot be identified, except with your express permission.

You have the right to request access to the information collected by the study team about you. Please contact the study team if you would like to access your information.

Any information obtained for the purpose of this research project and for future follow-up projects that can identify you will be treated as confidential and securely stored. It will be disclosed only with your permission, or as required by law.

11 What if something goes wrong?

If you suffer any injuries or complications as a result of this study, you should contact the study team as soon as possible, who will assist you in arranging appropriate medical treatment. If you suffer any distress or psychological injury as a result of this study, contact the study team for support and/or referral to a health professional. A safety protocol is in

place for any adverse events that occur during testing or training. In the unlikely event of an injury or complication, first aid will be provided, and further medical assistance will be available. Counselling services will be available for any psychological distress. Incidents will be documented and reviewed, and adjustments to the study procedure and safety protocols will be made if appropriate.

During the health screening and information session, any "yes" responses in stage 1 of the ESSA pre-exercise screening tool indicate that you may be at risk of adverse events during exercise. In this case, you will be emailed and advised to seek guidance from a GP or appropriate allied health professional before taking part in the study. In order to participate, you will require a signed medical clearance letter from a GP or allied health professional, clearing you for participation in the exercise training study.

Following study completion, physical and mental health data will be analysed. The results may indicate that you are at risk of chronic disease. If so, you will be contacted, informed of the risk factor/s and advised to consult with an appropriate GP, psychologist or allied health professional for further information.

12 Who has reviewed the research project?

All research in Australia involving humans is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this research project have been approved by the HREC of the University of Technology Sydney

This project will be carried out according to the *National Statement on Ethical Conduct in Human Research (2007)*. This statement has been developed to protect the interests of people who agree to participate in human research studies.

13 Further information and who to contact

If you have concerns about the research that you think I, Sam Higham (Samuel.M.Higham@student.uts.edu.au – [redacted]) or my supervisor A/Prof Rob Duffield (Rob.Duffield@uts.edu.au - 02 9514 5294) can help you with, please feel free to contact us. Alternatively, if you would like speak to a third party, please contact Shiree Miert (shiree.vanmiert@uts.edu.au - 02 9514 5206)

Complaints and concerns contact

If you have any complaints about any aspect of the project, the way it is being conducted or any questions about being a research participant in general, then you may contact:

Local HREC Office contact

Name	Ethics Secretariat
Telephone	+61 2 9514 2478
Email	Research.Ethics@uts.edu.au