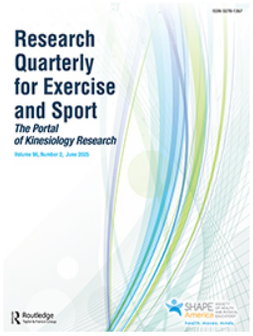

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Effect of Concurrent Exercise Training on Stress, Depression and Anxiety in Inactive Academics: Secondary Analysis of a Randomized Controlled Trial

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ABSTRACT

This randomized controlled trial investigated the effect of concurrent training (CT) on the mental health of inactive academics and examined associations between changes in stress (effort-reward imbalance and general stress), depressive symptoms and systemic inflammation. Fifty-nine inactive academics 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. 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 ($p > .05$). Following CT, symptoms of depression decreased in the CT group ($p = .009$) with no change in control ($p = .463$). There were positive correlations between changes in stress and symptoms of depression ($p < .05$), but no relationship between changes in systemic inflammation and changes in stress or depression ($p > .05$). 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.

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KEYWORDS
Job stress; physical activity; systemic inflammation; university staff; workplace intervention

Academia is an occupation combining high-stress with low physical activity (Cooper & Barton, 2016; Fontinha et al., 2019), which may increase the risk of common mental disorders such as depression and anxiety (Schuch et al., 2018, 2019). Academics experience higher job stress and psychological strain compared to other professions (Fontinha et al., 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 et al., 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., 2018, 2019). Low physical activity is associated with increased stress and is often evident in desk-based occupations, such as academia (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 (Kirk & Rhodes, 2011). Increasing exercise engagement has reduced symptoms of stress and depression within previously inactive workplaces (Atlantis et al., 2004).

Though physical activity is promoted at universities (McDonald et al., 2021), to the best of our knowledge, the impact of exercise interventions on the mental health of academics has not been investigated.

Resistance and endurance training have been shown to respectively decrease symptoms of depression and anxiety in healthy populations (Gordon et al., 2017, 2018). However, preliminary observational research reports that adults participating in concurrent resistance and endurance training (CT) 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 behavior modification on inactive casino employees (Atlantis et al., 2004). Greco (2020) also showed a decrease in general stress in 42 workers from mixed professions after CT was performed 3 times per week for 8-weeks (Greco, 2020). A supervised CT program conducted onsite within a 14-week academic teaching semester may be an ecologically valid intervention to improve the mental health of academics. However, the impact of such a program has not been determined.

There is preliminary evidence of a relationship between chronic stress, systemic inflammation and depression (Lee, 2020). Chronic stress is associated with increased circulating cytokines such as interleukin-6 (IL-6) and tumor necrosis

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factor-alpha (TNF-α), and individuals with depression present with higher levels of both markers (Rohleder, 2019). Chronic systemic inflammation is also associated with increased risk of developing cardiovascular disease and type 2 diabetes, which may partly explain why individuals with depression are at greater risk of these metabolic disorders (Furman et al., 2019). Physical activity is associated with lower levels of IL-6 and TNF-α, and higher volume exercise interventions result in larger decreases in IL-6 in individuals with type 2 diabetes (Hayashino et al., 2014). However, the impact of CT on IL-6 and TNF-α in apparently health populations is mixed (Ihalainen et al., 2018), which contrasts with the more established benefits of CT for symptoms of stress and depression. In turn, further investigation is required into the relationship between stress, inflammation, and depression following CT.

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.

Methods

Participants and study design

This is a secondary analysis of a 14-week randomized (1:1), parallel-group, stratified (VO_{2peak}, age, sex) and matched superiority trial comparing CT to a control group (Higham et al., 2022). The study was approved by the institutional Human Research Ethics Committee (ETH18–3093) and pre-registered with the Australian New Zealand Clinical Trials Registry (ACTRN12619000608167). The CONSORT and TIDieR checklist are provided in a supplementary file. Recruitment and testing commenced in June 2019 and was completed in December 2019. Participants from a single Australian university based in a metropolitan city were recruited via local advertising and e-mail to all academic staff. Potential participants attended a familiarization 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 (verbal and questionnaire-based assessment of <150 min/wk of weighted physical activity); 2) aged between 35 and 65 years; and 3) working a >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 neighbor. 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; $n = 29$), or wait-list control group ($n = 30$), according to the random number sequence (Figure 1) (Urbaniak & Plous, 2019).

Overview

Participants undertook a 60 min testing session 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) (Harris et al., 2009). Participants arrived for testing between 6:00 and 9:00 am after an overnight fast (10–12 h) and 24 h avoidance of alcohol consumption and 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). Ten items (e.g. "during the last 30 days, about how often did you feel hopeless") are scored on a 5-point scale ranging from 1 = "none of the time" through to 5 = "all of the time" and these are summed to provide an overall score of distress experienced over the past 30 days (Kessler et al., 2002). The K10 has previous evidence of convergent and discriminant validity, and test-retest reliability (intraclass correlation coefficients; ICC > 0.84) in Australian adults (Furukawa et al., 2003; Kessler et al., 2002; Merson et al., 2021).

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 (e.g. "I felt that I had nothing to look forward to"), anxiety (e.g. "I felt scared without any good reason") and general stress ("I found it difficult to relax") over the past week. The psychometric properties of the DASS-21 have been evaluated, and it has been found to be valid, consistent (ICC >0.80), and responsive to treatment within Australian populations (Henry & Crawford, 2005).

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." Scores for overcommitment (6 items: e.g. "People close to me say I sacrifice too much for my job") were summed, and ERI was calculated from effort (3 items: e.g. "I have constant time pressure due to a heavy workload") and reward (7 items: e.g. "Considering all my efforts and

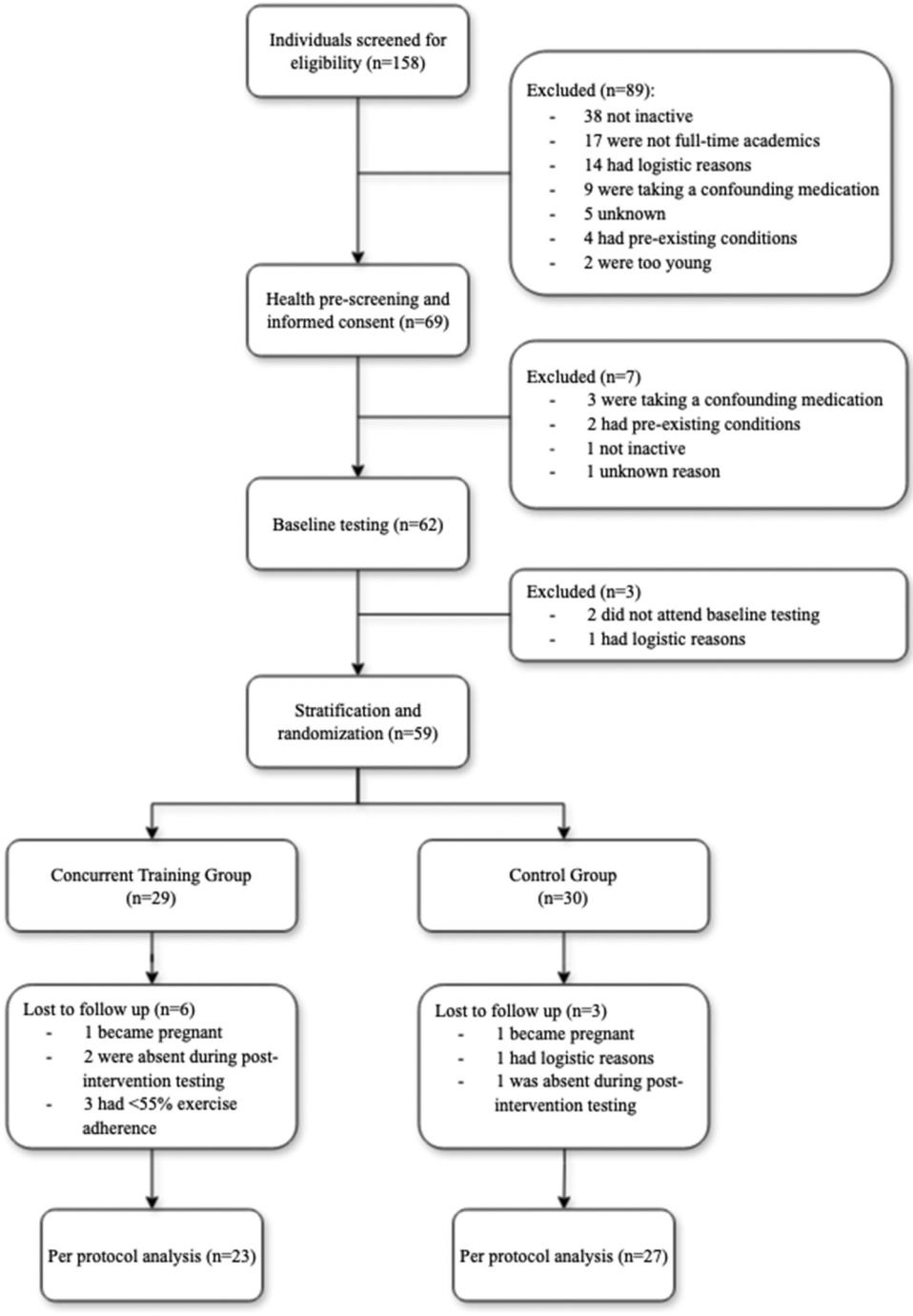

Figure 1. Consolidated standards of reporting trials (CONSORT) flow diagram.

achievements, my salary/income is adequate") items according to instructions (Siegrist et al., 2014). Previously, the ERI questionnaire has shown good internal consistency (Cronbach's α = 0.80–0.85), discriminant validity and criterion validity for all scales and the ERI ratio (Siegrist et al., 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 (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 nighttime sleep. To assist with compliance, alert notifications reminded participants to respond to items in the morning at 07:00 and evening at 21:00, with another reminder 15-min later if items had still not been completed. Questions were presented in random order to avoid ordering effects.

The fatigue and mood items were adapted from the profile of mood states (POMS) questionnaire (McNair et al., 1971). 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 between 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"). Fatigue, stress, mood, sleep quality and workload 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 across the completed days, with higher values representing higher perception of the variable.

Aerobic capacity

Aerobic capacity was assessed via 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 a metabolic gas analyzer (Medgraphics Ultima System, Saint Paul, USA), which was calibrated according to the manufacturer's instructions.

Leisure-time physical activity and body mass index

The Godin Leisure-Time Exercise Questionnaire (GLTEQ) was used to assess leisure-time physical activity (including CT sessions) (Godin & Shephard, 1997). 3-items measured the frequency of mild, moderate, and strenuous exercise during a standard 7-day period. Each exercise intensity was weighted and multiplied by its frequency. The individual scores were then summed to provide a total weekly leisure activity score. Previously, the GLTEQ has shown acceptable test-retest reliability, convergent and criterion validity within adults (Godin & Shephard, 1997; Jacobs et al., 1993; Miller et al., 1994).

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. Systemic levels 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 CT program is detailed elsewhere (Higham et al., 2022). Briefly, the CT group trained for 60 min, three times per week for 14-weeks (supplementary file). Training was conducted in small groups (2–6 participants) within an onsite exercise facility that included machines, dumbbells, ergometers and benches. Training was supervised by an accredited exercise scientist and trained third year undergraduate sport and exercise science students, with a typical instructor:participant ratio of 1:2. The wait-list control group were instructed to maintain their normal lifestyle as assessed by the GLTEQ (Godin & Shephard, 1997).

Resistance training load was increased once a participant completed the required repetitions with proper technique over two consecutive training sessions. Rest periods and repetition velocity were self-determined with consultation from instructors. Training data were recorded in a customized training diary to monitor progress and adherence.

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.

Statistical analysis and power calculation

A per-protocol analysis was performed to assess the intervention efficacy which can only be achieved with exercise adherence. Participants were excluded if they had relatively limited exposure to the exercise intervention and this equated to those that were below 55% adherence (1SD below the mean). Additionally, to increase the validity of EMA responses to reflect day-to-day fluctuations in daily wellness measures, participants were only included in the EMA analysis if they responded to items on at least 4 weekdays. Three (10%) CT participants were excluded due to adherence, and 7 (24%) CT and 11 (37%) control participants were excluded from EMA analysis due to inadequate responses. 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 Levene's 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 normally distributed 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 analyzed within-group differences.

For the second aim, Spearman's rank correlation coefficient (Spearman's rho; r_s) was used to assess the direction and strength of the relationship between changes in general stress, daily stress, ERI, depression, unhappy score, K10, IL6 and TNF-α.

Analysis was performed using SPSS Software (v26, IBM Corporation, Armonk, NY) and missing data were treated as missing (pairwise deletion) in analyses. Significance was accepted as $p < .05$. Effect sizes (ES) were determined using partial eta square (η_p^2) for parametric analysis (0.01 = small; 0.06 = moderate; 0.14 = large), and the Hodges-Lehmann estimator (HL) for non-parametric analysis. This study is a secondary analysis of a randomized controlled trial (Higham et al., 2022), and a retrospective sample size calculation was performed using G*Power software (v3.1.9.3) (Faul et al., 2007). Based on previously published data on the effect of concurrent 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.

Transparency and openness

There were slight deviations from the preregistered protocol. Recruitment was stopped early due to difficulties in participant recruitment, and nonparametric statistics replaced parametric methods for data that were significantly skewed and could not be log transformed.

Data were analyzed using SPSS Software (v26, IBM Corporation, Armonk, NY). We report how we determined our sample size, all data exclusions, all manipulations, and all mental health measures in the study, and we follow CONSORT guidelines. Research materials and de-identified data are available on request.

The study's design and its analysis were preregistered with the Australian New Zealand Clinical Trials Registry (ACTRN12619000608167).

Results

Participant and training characteristics

Baseline characteristics were similar between groups (Table 1), and most participants were in the normal range 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.

Table 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)

Abbreviations: 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.

In the CT group ($n = 29$), there was 79 ± 24% adherence to the CT program with a mean of 32 ± 10 of the 40 training sessions attended. CT participants included in the per protocol (Figure 1) analysis ($n = 23$) completed a mean of 35 ± 5 sessions (89 ± 13%).

Depression, anxiety, stress and daily wellness measures

Table 2 shows the results for symptoms of depression, anxiety and stress. Non-parametric analysis was performed on these variables because the data were significantly skewed and could not be log transformed. Outliers were not removed as there was no clear rationale for exclusion. There was a significant interaction effect for depression ($p = .021$, HL = −1, 95CI = −2, 0), which decreased in CT ($p = .009$) and did not change in control ($p = .463$). There were no

Table 2. Depression, anxiety, stress, VO_{2peak}, BMI and Inflammation before and after the intervention.

	CT			CON					
Variables	Pre	Post	Change	Pre	Post	Change	Mann-Whitney U	Time by Group P value (ES)	Hodges-Lehmann estimator (95% CI)
Depression	2 (3)	1 (2)	−1 (3)	2 (3)	1 (4)	0 (1)	**425.5**	**0.021 (−1)***	**−1 (−2, 0)**
Anxiety	2 (1)	1 (3)	−1 (3)	1 (3)	1 (3)	0 (2)	388.5	0.123 (−1)	**−1 (−2, 0)**
Stress	6 (6)	4 (5)	−2 (4)	6 (4)	5 (6)	0 (6)	360.5	0.328 (−2)	−2 (−3, 1)
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)	347.0	0.473 (0)	0 (−2, 1)
Total weekly leisure activity	17 (27)	41 (20)	21(19)	21 (22)	24 (40)	4 (28)	**177.0**	**0.024 (16)**†	**16 (3, 26)**
VO_{2peak} ($mL.kg^{-1}min^{-1}$)	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)	118.0	0.143 (0.87)	0.87 (−0.24, 4.20)
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)	231.5	0.796 (0.01)	0.01 (−0.20, 0.22)

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.

significant interaction effects for anxiety ($p = .123$,HL = −1, 95CI = −2, 0), distress ($p = .144$,HL = −2, 95CI = −3, 0), general stress ($p = .328$,HL = −2, 95CI = −3, 1) or job stress ($p = .416$, $\eta_p^2 = 0.01$). Daily wellness measures are shown in Table 3. There were no significant interaction effects for total sleep time ($p = .641$, $\eta_p^2 = 0.01$), sleep quality ($p = .097$, HL = 0.3, 95CI = −0.1, 0.7), fatigue ($p = .601$,HL = −0.1, 95CI = −0.4, 0.3), daily stress ($p = .679$, HL = 0.0, 95CI = −0.4, 0.3), mood ($p = .099$,HL = −0.3, 95CI = −0.7, 0.1), work hours ($p = .062$, HL = 0.9, 95CI = −0.1, 1.8) or perceived workload ($p = .295$, $\eta_p^2 = 0.03$).

Physical health measures

There were no significant interaction effects for BMI ($p = .874$, HL = −0.02, 95%CI=−0.38, 0.28), IL-6 ($p = .143$, HL = 0.87, 95CI = −0.24, 4.20) or TNF-α ($p = .796$, HL = 0.01, 95CI = −0.20, 0.22; Table 2). There was an interaction effect for VO_{2peak} ($p < .001$, $\eta_p^2 = 0.296$) which increased in CT ($p < .001$) and did not change in control ($p = .769$).

Correlations

Correlations between changes in stress, depression and inflammation markers are shown in Table 4. Results indicated significant positive relationships between stress and symptoms of depression ($r_s = 0.486$, $p < .001$) and the K10 ($r_s = 0572$, $p < .001$). There was a significant positive correlation between daily stress and daily mood ($r_s = 0.696$, $p < .001$) and the K10 ($r_s = 0.452$, $p = .003$). ERI was positively correlated with depression ($r_s = 0.355$, $p = .011$) and the K10 ($r_s = 0.334$, $p = .018$). There was no relationship between systemic inflammation (IL-6 and TNF-α) and any measures of stress or depression ($p > .05$).

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 training. 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 behavioral intervention, confounding the explicit effect of CT on mental health (Atlantis et al., 2004), we highlight the independent, moderate effect, of CT on symptoms of depression. The lack of change in symptoms of anxiety is unsurprising given the low baseline levels, which has been previously reported (Lucibello et al., 2019). Regardless, increased physical activity can protect against incident depression and anxiety (Schuch et al., 2018, 2019), indicating that CT may help to maintain the mental health of currently

Table 3. Daily wellness measures before and during the intervention.

	CT			CON					
Variables	Pre	During	Change	Pre	During	Change	Mann-Whitney U	Time by Group P value (ES)	Hodges-Lehmann (95% CI)
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)	145.5	0.097 (0.3)	0.3 (−0.1, 0.7)
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)	229.0	0.601 (−0.1)	−0.1 (−0.4, 0.3)
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	219.5	0.679 (0.0)	0.0 (−0.4, 0.3)
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)	272.0	0.099 (−0.3)	−0.3 (−0.7, 0.1)
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)	129.0	0.062 (0.9)	0.9 (−0.1, 1.8)
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	191.0	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 4. Correlations between changes in stress with changes in depression and systemic inflammation.

Variable	n	1	2	3	4	5	6	7	8
1. Δ Stress	50	–							
2. Δ Daily Stress	41	**0.341 (0.029)**	–						
3. Δ ERI	50	0.244 (0.088)	0.039 (0.809)	–					
4. Δ Depression	50	**0.486 (<0.001)**	0.254 (0.110)	**0.355 (0.011)**	–				
5. Δ Daily Mood	41	0.189 (0.236)	**0.696 (<0.001)**	0.194 (0.223)	**0.533 (<0.001)**	–			
6. Δ K10	50	**0.572 (<0.001)**	**0.452 (0.003)**	**0.334 (0.018)**	**0.630 (<0.001)**	**0.443 (0.004)**	–		
7. Δ IL-6 (pg/ml)	38	0.141 (0.400)	0.364 (0.052)	0.049 (0.770)	−0.010 (0.951)	0.214 (0.266)	0.075 (0.656)	–	
8. Δ TNF-α (pg/ml)	44	−0.219 (0.152)	0.104 (0.553)	−0.098 (0.525)	0.020 (0.900)	0.235 (0.174)	−0.193 (0.208)	0.165 (0.321)	–

Results are reported as Spearman's rho correlation (2-tailed p value). Abbreviations: ERI, effort-reward imbalance; IL-6, Interleukin-6; TNF-α, tumor necrosis factor-alpha; K10, Kessler K10 Score.

healthy but 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 et al., 2017). This may have implications for the university sector, given previous research showing a decrease in productivity in workers with higher depressive symptoms (McTernan et al., 2013).

The CT intervention did not affect general stress, daily stress or job stress within academics, in contrast with previous research reporting a decrease in general stress after CT within inactive workers (Atlantis et al., 2004). However, as with symptoms of depression and anxiety, higher baseline symptoms of stress are associated with greater improvements following exercise interventions so there may have been a ceiling effect from the "normal" baseline stress (via DASS-21) in the current sample (Atlantis et al., 2004; King et al., 1993). There was no 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 found that increased self-reported physical activity was 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 physical activity on stress (Schultchen et al., 2019), our pre-post exercise intervention comparison offers a novel understanding of the impact of exercise on daily stress.

There was no change in the job stress measures of ERI and overcommitment following CT. Other studies on the effect of CT on ERI and overcommitment are limited, and different assessments and definitions of job stress can significantly influence results and should be considered when interpreting findings (Houdmont et al., 2010). Within academia, increases in promotion prospects and decreases in workload are suggested to improve ERI and overcommitment (Kinman, 2019). 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.

CT did not affect daily perception of unhappy mood and fatigue. Similar to daily stress, previous research reports improvements in mood following acute exercise, but the effects are transient, peaking shortly after exercise and declining thereafter (Reed & Ones, 2006). 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. EMA studies investigating the effect of exercise on perceived fatigue have reported mixed results (Thogersen-Ntoumani et al., 2015; Vetrovsky et al., 2021). These may be due to the high heterogeneity between studies, wherein differences in population (clinical vs non clinical), exercise intensities (walking vs running) and assessment tools can significantly influence mental health outcomes (Reed & Ones, 2006), and make study comparisons difficult.

There were positive correlations between changes in stress (general and ERI) and changes in symptoms of depression, but no associations between changes in systemic inflammation and changes in stress or depression, despite previous cross-sectional studies reporting positive associations (Lee, 2020). There is a theoretical pathway from stress to inflammation to depression (Slavich & Irwin, 2014), though 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 concurrent decreases in perceived stress, depressive symptoms and TNF-α following 6-weeks of moderate intensity endurance training (Paolucci et al., 2018).

However, associations between these improvements were not formally analyzed. Although the timing and longevity of CT on mental health and systemic inflammation was outside the scope of this research, exercise interventions of longer durations and higher volume may result in larger improvements in systemic inflammation and could provide deeper insight into the apparent relationship between stress, systemic inflammation, and depression. Clarification of these associations in future research would enable the development of targeted interventions to improve these variables.

Limitations

This study included apparently healthy inactive academics from a single Australian university. In turn, the findings may be difficult to generalize to the broader academic population and other inactive workplaces. The use of a passive control group may have introduced a Hawthorne effect, which could obscure the components of the intervention (e.g. supervision, group training environment, or exercise) that affected the outcomes (Benedetti et al., 2016). In addition, the per protocol analysis was bias toward participants that had higher exercise adherence, and this was done to assess the cardiometabolic and mental health adaptations that occur from compliance to an exercise intervention. We performed an intention to treat analysis (CT = 29, control = 30) on the primary outcome measures (depression, stress and anxiety) and results remained the same, with significant improvements in symptoms of depression in the CT group. Most EMA items were sourced from previously validated questionnaires, but their 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 et al., 2009). The complexity of stress provides another limitation, particularly when comparing research. Indeed, there are many ways to characterize stress, for example, acute or chronic, physical or perceived, and job specific or general (Koolhaas et al., 2011; Rohleder, 2019), and each type of stress may respond differently to exercise. 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 emphasizes the benefits of regular CT for non-clinical populations at higher risk of mental disorders. However, due to low baseline values, a ceiling effect may have been present for symptoms of anxiety and stress. Positive associations were evident between changes in stress and depression, but no relationship was found between changes in systemic inflammation and changes in stress or depressive symptoms. This highlights the need for further research into the potential bilateral relationship between systemic inflammation and mental health. Notwithstanding, CT decreased symptoms of depression in inactive academics despite the continued presence of an effort-reward imbalance. These findings may have implications for universities wanting to decrease the risk of depression in inactive academics.

Author contribution statement

SMH, AEM, SR, NGA and RD conceived and designed the research. GS contributed analytical resources and expertise. RD, NGA and SMH collected data. SMH and AEM analyzed data. SMH wrote the original draft manuscript. AEM, SR, RD reviewed and edited the manuscript. All authors read and approved the manuscript.

Disclosure statement

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Data availability statement

The de-identified data that support the findings of this study are available from the corresponding author, SMH, upon reasonable request.

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