PHYSICAL ACTIVTY, RESILIENCY, MENTAL HEALTH, AND HEART RATE VARIABILITY IN GRAUDATE STUDENTS DURING A PANDEMIC

EXAMINING THE ASSOCIATIONS OF PHYSICAL ACTIVTY, RESILIENCY, MENTAL HEALTH, AND HEART RATE VARIABILITY IN GRAUDATE STUDENTS DURING A PANDEMIC

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TITLE: Examining the associations of physical activity, resiliency, mental health, and heart rate variability in graduate students during a pandemic

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ABSTRACT

Introduction: The COVID-19 pandemic has resulted in higher-than-normal levels of anxiety and depression, especially among graduate students whose academic trajectory was disrupted. Physical activity and trait resiliency have both been shown to protect against stress-induced anxiety and depression during the pandemic. However, it remains unknown whether the same was true for graduate students and what biological mechanism, such as heart rate variability (HRV) might underpin these relationships.

Method: We examined change in stress, current physical activity, and trait resiliency to identify key factors associated with better mental health outcomes in a national sample of graduate students (N = 61) who were recruited during the COVID-19 pandemic. We evaluated the unique contributions of change in graduate-school-related stress, physical activity (moderate, vigorous, and fitness), and trait resiliency to both anxiety and depression. We conducted moderation analyses to explore the processes through which these variables interact and mediation analyses to examine whether HRV was part of the underlying mechanism. Questionnaire were used to assess graduate-school-related stress, physical activity (moderate, vigorous), and trait resiliency. We estimated physical fitness using the six-minute walk test and captured resting HRV using a validated mobile application.

Results: Graduate students reporting greater change in school-related stress were more anxious and depressed; however, those who engaged in more moderate physical activity were less anxious and those with higher trait resiliency were less anxious and depressed. Moderation analyses revealed a “stress threshold” for moderate physical activity whereby students who were more physically active were more protected from anxiety symptoms than their lower active peers; but this was only true for people whose stress levels increased a little or moderately but not for people whose stress levels increased a lot. In contrast, trait resiliency was shown to buffer against depression regardless of change in stress level. HRV did not mediate these relationships.

Conclusion: Graduate students experienced significant mental strain during the COVID-19 pandemic, but physical activity and trait resiliency may be promising protective factors.

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LIST OF ABBREVIATIONS

MVPA	Moderate-to-vigorous physical activity
BDNF	Brain derived neurotrophic factor
IGF-1	Insulin-like growth factor 1
VEG-F	Vascular endothelial growth factor
METs	Metabolic equivalents
VO_2 max	Maximal oxygen uptake
HRV	Heart rate variability
SNS	Sympathetic nervous system
PNS	Parasympathetic nervous system
SNC	Sympathetic nerve chain
Ca^{2+}	Calcium ions
ACh	Acetylcholine
ECG	Electrocardiogram
PPG	Photoplethysmography
IBI	Interbeat intervals
SDNN	Standard deviation of all interbeat intervals
rMSSD	Root mean sum of successive differences between heart beats
pNN50	% of successive normal sinus R-R intervals > 50 milliseconds
Hz	Hertz
ULF	Ultra-low frequency
VLF	Very-low frequency
LF	Low-frequency
HF	High-frequency
CAN	Central autonomic network
PFC	Prefrontal cortex
VNS	Vagus nerve stimulation
tVNS	Transcutaneous vagus nerve stimulation
MDD	Major depressive disorder
BMI	Body mass index
GSI-R	Graduate Stress Inventory-Revised
GAD-7	Generalized Anxiety Disorder 7-item Scale
GAD	Generalized anxiety disorder
PHQ-9	Patient Health Questionnaire 9-item Scale
RS-14	14-item Resilience Scale
IPAQ	International Physical Activity Questionnaire
CRF	Cardiorespiratory fitness
6MWT	Six-minute walking test
6WT	Six-minute walking test mobile application
HRV4T	Heart rate variability 4 training mobile application
LED	Light-emitting diode
MCAR	Missing completely at random
STEM	Science, technology, engineering, and mathematics

DECLARACTIONS OF ACADEMIC ACHIEVEMENT

Maryam Marashi's role:

- Wrote and submitted ethics application at McMaster University
- Designed study protocol and selected measures
- Recruited participants
- Scheduled and conducted screening phone calls
- Led data collection, analysis, and interpretation
- Prepared manuscript

Role of co-authors:

- JH obtained study funding
- JH assisted MM with ethics application
- JH assisted MM with study design
- JH assisted MM with data analysis and interpretation

INTRODUCTION

Mental health has been negatively affected by the public lockdown and the consequent social isolation measures that were initiated to protect people from the novel corona virus. Since the onset of the COVID-19 pandemic, global rates of anxiety and depression have increased by over thirty percent (Xiong et al., 2020). Students and other young adults have been disproportionally affected (Varma et al., 2021). Graduate students, in particular, have reported high levels of stress concerning the uncertainty of their academic trajectory, and as a result, are experiencing higher-than-normal levels of anxiety and depression (Chirikov et al., 2020). Several behavioural, physiological, and psychological factors may be protecting some students from the perils of stress-induced mental illness. When considering the general population, people who were more physically active (Jacob et al., 2020; Marashi et al., 2021; Rogowska et al., 2020) and more resilient (Kavčič et al., 2021; Vos et al., 2021) felt less anxious and depressed during the pandemic. However, it remains unknown whether the same was true for graduate students. Furthermore, the biological mechanism underpinning the relationship between physical activity, trait resiliency, and mental health warrants further investigation.

Physical Activity and Mental Health

Although chronic exposure to psychological stress increases the risk of mental illness (Koutsimani et al., 2019), regular moderate-to-vigorous physical activity (MVPA) reduces that risk via a combination of neurobiological, psychosocial, and behavioural mechanisms. At the neural levels, physical activity stimulates increases in trophic factors such as brain derived neurotrophic factor (BDNF) (Marais et al., 2009), insulin-like growth factor 1 (IGF-1) (Trejo et al., 2001), and vascular endothelial growth factor (VEG-F) to promote the growth of new neurons and new capillaries that are critical for brain function (Kiuchi et al., 2012; Voss et al., 2013; Wittfield et al., 2013). Physical activity also promotes the reduction of peripheral pro-inflammatory cytokines to reduce symptoms of depression and anxiety (Hartmann et al., 2021; Paolucci et al., 2018). Psychosocially, physical activity improves wellbeing because it increases social connectedness (Harvey et al., 2010) and enhances one's sense of self-efficacy and self-mastery (Petruzzello et al., 1991) leading to more positive affect (Reed & Ones, 2006). Physical activity also fosters good mental health by eliciting positive changes in relevant health behaviours such as sleep (Loprinzi & Cardinal, 2011) and by promoting better self-regulation of health behaviours (Oaten & Cheng, 2010).

When considering physical activity as a potential protective factor of mental health it is important to distinguish between behavioural measures (e.g., total physical activity completed over a seven-day period) versus physiological measures (e.g., biological adaptations that occur in face of regular engagement in physical activity). A key adaptation induced by physical activity is increased cardiorespiratory fitness, defined as the ability of the circulatory and respiratory systems to supply oxygen to working muscles during sustained physical activity (Lee et al., 2010). Typically, cardiorespiratory fitness is expressed in metabolic equivalents (METs), or maximal oxygen uptake (VO_2 max), and is measured by graded exercise tests on treadmills or cycle ergometers (Lee et al., 2010); however, submaximal tests like the six-minute walk test can be used to estimate cardiorespiratory fitness (Burr et al., 2011). Importantly, people with higher cardiorespiratory fitness are less likely to become depressed or anxious (Gianfredi et al., 2021; Kandola et al., 2019). And these protective effects of cardiorespiratory fitness against depression seem to be strongest among groups experiencing higher levels of perceived stress (Gerber et al., 2013). Increasing cardiorespiratory fitness also increases one's heart rate variability (HRV), an index of autonomic nervous system functioning, and it may be through HRV that regular engagement in MVPA and subsequent gains in fitness, protects one against stress-induced mental illness (Hallman et al., 2017; Levy et al., 1998; Sandercock et al., 2005).

Heart Rate Variability

HRV is defined as the beat-to-beat variability of the heart measured over time (McCraty & Shaffer, 2015), which is influenced by the coordinated actions of the two branches of the autonomic nervous system: the sympathetic nervous systems (SNS) and the parasympathetic nervous system (PNS)(McCorry, 2007). An optimal level of HRV at rest has been established as an index of favorable neurovisceral integration in response to environmental stress (McCraty & Shaffer, 2015). Too much instability can be detrimental to fostering efficient physiological functioning, while too little variation in the absence of pathology or age-related depletion, can be indicative of a lack of adaptability to stress (McCraty & Shaffer, 2015).

Autonomic regulation of heart rate

The SNS initiates the 'fight or flight' response by promoting physiological functions for the alertness and energy mobilization needed to overcome a stressor. Heart rate increases through the actions of the sympathetic nerve chain (SNC), or sympathetic ganglia, which consists of a paired bundle of nerve fibers that originate in the brainstem and synapses with the sinoatrial and atrioventricular nodes of the heart (Tortora & Nielsen, 2013). Specifically, the SNC releases norepinephrine onto these nodes, increasing both the Ca^{2+} influx into the cardiac contractile cells and the slope of the pacemaker potential for a *faster* heart rate (Tortora & Nielsen, 2013).

In contrast, the PNS maintains a state of 'rest and digest' by promoting physiological functions that conserve energy. Heart rate decreases through the actions of the vagus nerve (i.e., cranial nerve X), which exits the brainstem in the form of a pre-ganglionic efferent fiber. Like the SNC, the vagus nerve synapses with the sinoatrial and atrioventricular nodes of the heart

(Fitzgerald et al., 2005). Unlike the SNC, the vagus nerve releases acetylcholine (ACh) onto these nodes, decreasing both the Ca^{2+} influx into the cardiac contractile cells and the slope of the pacemaker potential for a *slower* heart rate (Tortora & Nielsen, 2013).

In response to a stressor, the PNS withdraws and the SNS dominates causing HRV to decrease (McCraty & Shaffer, 2015). During rest and recovery, the SNS is inhibited allowing the PNS to re-engage causing HRV to increase (McCraty & Shaffer, 2015). Therefore, HRV provides a window onto the stress response and recovery. HRV is typically measured using an electrocardiogram (ECG), though readily accessible measurements using mobile photoplethysmography (PPG) show acceptable agreement with gold standard measures (Plews et al., 2017).

Indices of heart rate variability

More than 70 variables can be calculated from HRV analysis (Bravi et al., 2011), which can be performed in the time-domain, frequency-domain or using non-linear indices (Bravi et al., 2011). Time-domain measures of HRV include the standard deviation of all interbeat intervals (IBI) (SDNN), the root mean square of successive differences between R-r intervals (RMSSD), and the percentage of successive normal sinus R-R intervals more than 50 milliseconds (ms) (pNN50) (Malik et al., 1996). The RMSSD is measured by selecting each successive time difference between heart beats (R-waves) in milliseconds, squaring them, averaging the results, and obtaining the square-root of the total (Shaffer & Ginsberg, 2017). Frequency-domain measures of HRV require filtering the signal into different bands based on frequency measured in hertz (Hz) (Malik et al., 1996). They include an ultra-low frequency (ULF) band located below 0.0033 Hz, a very-low frequency (VLF) band between 0.0033 and 0.04 Hz, a low-frequency (LF) band ranging between 0.03 and 0.15 Hz, and a high-frequency (HF) band ranging between 0.15 and 0.40 Hz (Malik et al., 1996). Finally, given the biological origin of HRV and the fact that it is derived from the sum of processes that operate on a variety of time scales, HRV displays characteristics of a non-linear signal (Quintana & Heathers, 2014). For this reason, Poincaré plots are used as visual, non-linear indices of HRV (Quintana & Heathers, 2014). Poincaré plots are comprised of points that represent two consecutive heart periods with a 45° slope (identity line) that passes through the origin, which represents equal consecutive heart periods. Points located above the identity line represent a longer heart period, whereas points located below the identity line represent a shortening of the heart period (Quintana & Heathers, 2014). Although non-linear measures of HRV are favoured as a prognostic tool for examining heart failure patients (Mäkikallio et al., 1999), their utility has been questioned due to a lack of reproducibility along with the fact that their physiological origin remains unclear (Laborde et al., 2017).

RMSSD and HF HRV are both shown to reflect vagal tone (Kleiger et al., 2005; Thayer & Lane, 2000) and are therefore recommended as vagal indices in psychophysiological research (Kleiger et al., 2005; Thayer & Lane 2000). However, RMSSD is relatively free of respiratory influences (Hill et al., 2009) and is shown to be the most accurate index in the context of short-term R-R interval readings (i.e., 5 minutes or less) (Munoz et al., 2015). For these reasons, RMSSD was selected as the measure of HRV for this study.

The Neurovisceral Integration Model

Thayer and Lane (2000) propose the neurovisceral integration model which suggests that adaptations to stress are determined by the integration of physiological, cognitive, and emotional systems (Thayer & Lane, 2000). A key component of the neurovisceral integration model is the central autonomic network (CAN) which represents the integration of the central and autonomic nervous systems (Benarroch, 1993). Structurally, the CAN is composed of a constellation of brain regions. Higher-order cognitive processors within the frontal lobe (the anterior cingulate, orbitofrontal, and ventromedial prefrontal cortices; PFC) govern mental representations of inputs from the body and serve to amplify or suppress these representations based on a person's behavioural goals. Emotional processors within the central nucleus of the amygdala and the insula initiate changes in attention to one's own somatic state. Lastly, more visceral processors within the paraventricular and related nuclei of the hypothalamus and other midbrain and brainstem regions orchestrate coordinated motor and endocrine reactions to stress (Benarroch, 1993; Smith et al., 2017). Information is communicated between these brain regions and output onto the sympathetic and parasympathetic neurons, which innervate the sinoatrial and atrioventricular nodes of the heart (Thayer & Friedman, 2004). It is therefore the ANS, and specifically its parasympathetic branch, that serves as a "bridge" linking psychological experiences of stress in the brain with physiological manifestations of stress in the body, and this "bridge" can be indexed viscerally by HRV (Thayer & Friedman, 2004).

The neurovisceral integration model and mental health

The neurovisceral integration model has been useful in understanding the somatic symptoms of people with anxiety disorders whose excessive fear or worry are often accompanied by a range of physical symptoms including racing heart, especially when considering communication between the amygdala and PFC. Normally, the amygdala's activity is tonically inhibited by the PFC; however, in people with anxiety disorders, heightened amygdala activity disrupts the PFC's inhibitory control, thus allowing amygdala activity to rise unregulated (Hilbert et al., 2014). Critically, this abnormal activation of the amygdala (which is indexed by HRV) has downstream effects that can alter its communication with brainstem regions to directly impact physiological arousal (Meeten et al., 2016). Like anxiety disorders, symptoms of depression are related to dampening of prefrontal inhibitory function and insufficient affective information processing and physiological regulation (Beauchaine & Thayer, 2015).

Critically, these neurological changes in anxiety and depression are associated with lower (unfavorable) HRV. Therefore, within the framework of neurovisceral model, HRV provides a window onto physiological outcomes that arise from effective (or ineffective) emotional regulation, i.e., one's ability to exert cognitive control over one's emotional state and respond appropriately to emotional stimuli (Thayer et al., 2009). Higher resting HRV is associated with more appropriate emotional responses (Thayer et al., 2009; Ruiz-Padial et al., 2003) whereas people suffering from mental illness, who have lower HRV, also show poorer emotional regulation (Berking & Wupperman, 2012). For example, people with anxiety have lower HRV at rest (Chalmers et al., 2014; Henje Blom et al., 2010; Pittig et al., 2013) and in response to an acute stressor (Meeten et al., 2016). Similar results are seen in people with depressive disorders (Beauchaine & Thayer, 2015), who have lower HRV compared to their non-depressed peers (Chalmers et al., 2014; Henje Blom et al., 2010; Pittig et al., 2013). Critically, when lower HRV is detected in non-clinical populations, it puts them at greater risk of experiencing burnout from chronic work stress (Wekenborg et al., 2019), and thus may be particularly relevant in the context of the chronic stress related to the COVID-19 pandemic.

Importantly, the relationship between HRV and mental health is thought to be bidirectional whereby affective states influence HRV, and vice versa. The body-to-brain relationship is exemplified by the success of interventions that were originally designed to increase cardiac vagal innervation but end up reducing symptomology of stress-induced mental illness. For example, the use of both direct (VNS) and transcutaneous vagus nerve stimulation (tVNS) to improve cardiac vagal innervation has been shown to modulate cardiovascular and peripheral autonomic responses to stress (Gurel et al., 2020), reduce symptoms of major depressive disorder (MDD) (Kong et al., 2018) and reduce symptoms of anxiety (Kong et al., 2018). However, these methods are often expensive, risky, or inaccessible for those struggling with symptoms of stress-induced mental illness which is why it is important to explore behavioural modifications that can increase HRV. One such behavioural intervention known to modulate HRV is increased physical activity (Thayer & Lane, 2009). When higher fit individuals experience an acute stressor, they exhibit higher HRV than their untrained peers, indicating less stress reactivity (Klaperski et al., 2014; von Haaren et al., 2016). Therefore, physical activity may help increase HRV that is lowered by anxiety and depression.

The brain-to-body relationship is further exemplified by the impact of resiliency on HRV. Resiliency is defined as one's ability to withstand and recover from negative emotional experiences and to adapt flexibly in face of changing environmental demands (Luthar et al., 2000; Masten et al., 1990). Within the neurovisceral integration model, resiliency may provide a proxy for emotional regulation (Kay, 2016) that stems from higher-order processes related to one's sense of self-efficacy and self-mastery over stressful situations (Thayer et al., 2009; Ruiz-Padial et al., 2003). Although there are multiple ways to conceptualize resiliency, one of the most common frameworks used in psychological research is to treat resiliency as a *trait* (Luthar et al., 2000). A trait refers to a consistent pattern of thinking, feeling, or behaving across common situations. Traits differ between individuals but tend to remain relatively stable within an individual across time (Schmitt and Blum, 2020). Trait resiliency is viewed as a factor that can influence positive or negative outcomes associated with a specified risk factor (Luthar et al., 2000; Masten et al., 1990) related to things like socioeconomic disadvantage or catastrophic life events such as the COVID-19 pandemic. Individuals with high trait resiliency display more favourable HRV responses to stressor (Lü et al., 2016; Souza et al., 2007). Trait resiliency also explains significant variance in anxiety and depressive symptoms across broad populations (Hu et al., 2015) and has been shown to have a buffering role against stress-induced mental illness brought on by the COVID-19 pandemic (Kavčič et al., 2021; Vos et al., 2021).

Purpose and Hypotheses

The purpose of the current study was to examine the mental health of graduate students whose research efforts were affected by the COVID-19 pandemic. We assessed whether graduate students' anxiety and depression during the pandemic were uniquely associated with change in perceived graduate-school-related stress since the onset of the pandemic, current physical activity levels and trait resiliency. We also explored the influence of change in stress on the relationships between physical activity and trait resiliency with mental health. Additionally, we aimed to examine HRV as a mechanism underlying the relationships between physical activity and trait resiliency with mental health.

It was hypothesized that:

1. Change in graduate-school-related stress, current physical activity levels (moderate activity, vigorous activity, and fitness) and trait resiliency would account for unique variance in both anxiety and depression.
2. Change in graduate-school-related stress would moderate the relations of current physical activity levels (moderate activity, vigorous activity, and fitness) and trait resiliency with both anxiety and depression such that the protective effects of physical activity and trait resiliency would be strongest for students experiencing greater changes in stress.

3. HRV would mediate the relationships of current physical activity levels and trait resiliency with both anxiety and depression.

METHODS

Participants

A sample size estimate was calculated using an a priori power analysis for linear multiple regression using the G*Power 3.1 software (Faul et al., 2007). No existing studies have examined the mediating effect of HRV in the relationship between cardiorespiratory fitness and mental health. However, a meta-analysis by Papasavvas et al. (2015) found a small effect size for the correlation between depression symptom severity and cardiorespiratory fitness (r = -.16, 95 % CI = -.21 to -.10) while Chalmers et al. (2014) found a moderate effect size for the association between anxiety disorders and heart rate variability (Hedges' g = −.45, 95% CI = −.57 to −.33). Based on these findings, a small-to-moderate effect size (Cohen's f = .20) was chosen using parameters of power being .90 and alpha equaling 0.05. G*Power indicated a total of 67 participants would be required. Participants were recruited through social media advertisements (Twitter, Facebook, Instagram, and Reddit) as well as through email recruitment from graduate student associations across Canada.

Participants were eligible to participate if they were 18 years of age or older, currently enrolled in full-time studies in a thesis-based graduate degree program and could confirm that their research efforts had been affected by COVID-19 mandates. Additionally, to control for the effect of confounding variables, participants were required to confirm that they were free from diagnosis of diabetes type 1 or 2, cardiovascular or cerebrovascular disease, infectious disease, or acute illness, were non-smokers, had a BMI of 35 or less, were not taking prescription drugs to treat anxiety, depression, or blood pressure, and not currently using illicit drugs. Fulfillment of these criteria was confirmed verbally over the phone. This study received ethics clearance from McMaster Research Ethics Board (MREB #5100). Participants were compensated for their participation.

Materials

Questionnaires

A virtual survey was used to report demographic information on the graduate student including biological sex, gender, age, year of study, research phase, faculty of study, and income. The survey also included the following questionnaires.

Change in graduate-school-related stress. Change in perceived stress related to graduate school since COVID-19 was measured using an in-house scale adapted from the Graduate Stress Inventory-Revised (GSI-R) (Rocha-Singh, 1994). The GSI-R assesses the psychometric characteristics of a theory-driven measure of perceived stress for graduate students. Its items are categorized into three domains of graduate student experience :1) university environment, 2) academic and professional responsibilities, and 3) financial and familial responsibilities. Normally, the GSI-R is rated on a “not at all stressful” to “extremely stressful” 7-point Likert scale. However, questions were adapted to instead capture a difference in perceived stress from 6-months prior to COVID-19 to the onset of COVID-19 (See Appendix). Specifically, participants were asked to rate how much stress they have perceived in “…relation to the following events encountered in graduate school since the onset of COVID-19 relative to 6-months prior to COVID-19”. Responses included “much less” (-2), “less” (-1), “the same” (0), “more” (+1) and “much more” (+2). Item scores were summed for a maximum of 50.

Anxiety. Anxiety was measured using the Generalized Anxiety Disorder 7-item (GAD-7) Scale (Spitzer et al., 2006). The GAD-7 is a validated tool used to measure anxiety symptoms associated with generalized anxiety disorder (GAD) and asks participants to score each of the seven DSM-IV criteria of GAD, on a scale from 0 to 3 where 0 = "not at all" and 3 = "nearly every day". Item scores were summed for a maximum score of 21 (none/minimal, 0-4; mild, 5-9; moderate, 10-14; severe, 15-21) (Spitzer et al., 2006).

Depression. Depression was measured using a modified version of the Patient Health Questionnaire-9 (PHQ-9) (Gilbody et al., 2007). The PHQ-9 is a validated tool used to monitor depressive symptoms and asks participants to score each of the nine DSM-IV criteria of MDD, on a scale from 0 to 3 where 0 = "not at all" and 3 = "nearly every day" (Gilbody et al., 2007). Due to concerns surrounding disclosure of sensitive information, the ninth item regarding suicidal thoughts and self-harm was omitted. Item scores were summed for a maximum score of 24 (none/minimal, 0-4; mild, 5-9; moderate, 10-14; moderately severe, 15-19; severe, 20-24).

Trait Resiliency. Trait resiliency was operationalized using the 14-item Resilience Scale (RS-14) (Wagnild, 2009). The RS-14 measures five characteristics of resiliency, termed the Resilience Core: 1) meaning and life purpose, 2) perseverance, 3) equanimity, 4) self-reliance, and 5) existential aloneness (Wagnild, 2009). The RS–14 employs a 7-point Likert scale where 1 = "strongly disagree" and 7 = "strongly agree". Item scores were summed for a maximal score of 98 (low, < 64; moderate, 65-81; moderately high, 82-90; high, > 90).

Physical Activity. Self-reported physical activity and sedentary behavior was measured using the International Physical Activity Questionnaire (IPAQ) (Wanner et al., 2016). Specifically, participants were asked to denote the number of minutes per week that they typically engage in moderate physical activity (e.g., carrying light loads, or bicycling at a regular pace) and vigorous physical activity (e.g., heavy lifting, digging, aerobics, or fast bicycling). Minutes per week of total MVPA as well as moderate physical activity and vigorous physical activity were calculated.

Physiological Measurements

Estimated cardiorespiratory fitness (CRF). Cardiorespiratory fitness was estimated using a validated six-minute walking test (6MWT) mobile application (Stienen et al., 2019). The 6WT application measures a person's walking distance in meters using GPS coordinates accumulated over the course of a six-minute period. Participants were asked to walk as far as possible for six minutes without jogging or running while abiding by the following: 1) ensuring that the measurement was conducted in a place where there were no blockades of GPS signal, 2) conducting the measurement on a straight and flat path, 3) conducting the measuring in an environment where testing was not interrupted, and 4) avoiding indoor spaces or zig zag courses. To estimate cardiorespiratory fitness (VO_2 max), the total meters accumulated during the test by each individual participant were entered into the following equation:

$$\textit{Estimated } VO_2 \textit{ max } (mL \cdot kg^{-1} \cdot min^{-1}) = 70.161 + (0.023 \times 6MWT\ [m]) - (0.276 \times weight\ [kg]) - (6.79 \times sex, \textit{ where } m = 0, f = 1) - (0.193 \times \textit{resting HR [beats per minute]}) - (0.191 \times age\ [y]),$$

Outputs from the estimated VO_2 max equation above have been shown to account for 72.4% of the variance in measures of VO_2 max in healthy young-middle aged adults (Burr et al., 2011). Furthermore, Spearman's rank order correlation revealed a moderate strength correlation ($r = .49$; $p = .001$) between the distance walked during the 6MWT and VO_2 max rank orders

(Burr et al., 2011). The 6MWT can therefore be considered a valid tool to estimate cardiorespiratory fitness.

Heart rate variability (HRV). HRV was measured using the mobile application, HRV4Training (HRV4T) (https://www.hrv4training.com/). HRV4T is a validated tool that utilizes photoplethysmography (Dobbs et al., 2019) to detect volumetric changes in blood peripheral circulation by illuminating the skin and measuring changes in light absorption (Allen, 2007). The mobile application calculates the time difference between successive heart beats in milliseconds and automatically computes the rMSSD by squaring each data point, computing the average of those squared data points, and taking the square root of that average(Shaffer & Ginsberg, 2017). We used the HRV4T application to calculate rMSSD by having participants place their index finger over a smartphone's camera and LED flash for a five-minute reading. They did this upon waking, while lying in a supine position and breathing normally, for seven consecutive days and the average rMSSD across those seven days was used in the analysis.

Procedure

The study followed a cross-sectional design. All participants were provided with an information sheet outlining the study protocol and were instructed to complete each step as follows. Participants completed the six-minute walk test and then filled out the questionnaires using the online platform Limesurvey. Resting heart rate and HRV were measured each morning for one week. All steps were done asynchronously and unsupervised.

Statistical analysis

Data were analyzed using IBM SPSS Statistic Software version 26. Descriptive statistics were computed for all study variables. Normality was assessed using visual inspection of histograms, and skewness and kurtosis based on recommendations by Kim (2013).

Multicollinearity was assessed using tolerance and variance inflation factor (VIF). Missing values were analyzed for pattern of missing data using Little's MCAR test. For all statistical analyses, a *p* value (2-tailed) of <.05 was considered significant.

First, we conducted separate hierarchical regression analyses for anxiety and depression to determine the independent contribution of change in graduate-school-related stress, current physical activity levels (moderate, vigorous, and fitness), and trait resiliency. Biological sex (coded: 0 = males; 1 = females) was entered in step 1 of the model as a covariate because of the established differences between males and females for anxiety (Gater et al., 1998) and perceived stress (Brougham et al., 2009). Change in graduate-school-related stress since the onset of the pandemic (referred to hereafter as Δ stress) was entered in step 2. All three physical activity measures (moderate activity, vigorous activity, and fitness) were entered stepwise in step 3 and trait resiliency was added in step 4.

Next, we conducted separate moderation analyses to examine whether the association between moderate physical activity and anxiety and trait resiliency and anxiety was moderated by Δ stress. The same moderation analysis was conducted for depression. However, in both cases, only significant variables identified in the regression analyses (above) were examined as input variables. We used Model 1 in *PROCESS* software macro v3.3 for SPSS (Hayes, 2018). Moderate physical activity or trait resiliency was entered as the input variable, anxiety or depression was entered as the output variable, Δ stress was entered as the moderator, and biological sex was entered as a covariate. Bootstrap procedures utilizing 10,000 simulations were computed and a 95% confidence interval that does not cross zero is indicative of a significant interaction (moderation) effect.

Finally, to determine whether HRV mediated the association between the input variables (identified above) and anxiety/depression, we conducted mediation analyses using Model 4 in the *PROCESS* software macro v3.3 for SPSS (Hayes, 2018). Moderate physical activity or trait resiliency was entered as the input variable. Anxiety or depression was entered as the output variable, HRV was entered as the mediator, and biological sex was entered as a covariate. Bootstrap procedures utilizing 10,000 simulations were computed and a 95% confidence interval that does not cross zero is indicative of a significant indirect (mediation) effect.

RESULTS

Data screening and assumptions

Sixty-eight participants were recruited for the study. However, five participants did not submit their data or follow up with emails and therefore, a total of 63 completed the whole protocol. Two participants were removed from analyses. One participant withdrew their data, and one participant reported a family emergency during the protocol. The final sample consisted of 61 participants.

The data were screened for missing data; 0.5% was missing (BMI, n= 2; Year of Study n=1; Income Since COVID, n= 2; Income Pre COVID, n = 2). The pattern of missingness was missing completely at random (MCAR), according to Little's MCAR test. Therefore, no replacement strategy was employed, and pairwise deletion was used for missing values. All outliers fell within a possible physiological range and were therefore preserved. Both dependent variables (anxiety and depression) had skewness and kurtosis within an acceptable range and in all analyses, the VIF was less than 3 and tolerance was more than .1 indicating low collinearity and no issues with performing hierarchical regression analyses (Field, 2013).

Descriptive characteristics

Descriptive characteristics for the study sample are presented in Table 1. Participants were graduate students between the ages of 22 and 46 years, predominantly female (70%) with all females identifying as women and all males identifying as men, and at various stages in a masters or PhD program based on year of study and research phase. Most participants were domestic students enrolled in a STEM program of study. Most participants rated their current financial status as "*earning just enough*" or "*earning more than enough*".

On average, participants were experiencing more graduate school-related stress since the onset of the pandemic (i.e., Δ stress), their anxiety symptoms were indicative of mild anxiety (Spitzer et al., 2006), their depressive symptoms were indicative of mild depression (Kroenke & Spitzer, 2002), and their trait resiliency was moderate (Hyphantis, 2017).

The sample was highly active with a mean moderate-to-vigorous physical activity (MVPA) of 223.6 minutes (> 3 hours) per week, which exceeds that of the recommended 150 minutes (2.5 hours) per week (Ross et al., 2020). Just over half of respondents reported meeting those guidelines; however, nearly sixty percent reported that their physical activity level had dropped since the start of the pandemic. With respect to fitness, on average (and according to population norms), our female participants were in the 80th percentile and our male participants were in the 70th percentile (Hoffmann et al., 2019). Resting heart rate was considered normal (Nanchen, 2018), and resting rMSSD was in the ideal range (Heiss et al., 2021).

Anxiety

Hierarchical regression coefficients for anxiety are displayed in Table 2. The hierarchical regression analysis revealed that at step 1, biological sex explained 1% of variance for anxiety but this change in R^2 was not significant, $F(1, 58) = .49$, $p = .48$, indicating no difference in anxiety scores between males and females. Introducing Δ stress in step 2 explained 33% of variance (34% overall) for anxiety and this change in R^2 was significant, $\Delta F(2, 58) = 28.6$, $p < .001$, indicating that graduate students who reported greater increases in stress since the onset of the pandemic were more anxious. Of the three measures of physical activity entered stepwise in step 3, moderate physical activity explained an additional 6% of variance (40% overall) for anxiety and this change in R^2 was significant, $\Delta F(3, 58) = 5.23$, $p = .03$, indicating that graduate students who reported less moderate physical activity were more anxious. Adding trait resiliency into the regression model in step 4 explained an additional 8% of variance (48% overall) for anxiety and this change in R^2 was also significant, $\Delta F(4, 58) = 8.26$, $p = .006$, indicating that graduate students who reported lower trait resiliency were more anxious.

To examine the buffering role of physical activity and trait resiliency on anxiety at different levels of Δ stress we conducted separate moderation analyses (see Table 3). Notably, there was a significant interaction effect for the relationship between moderate physical activity and anxiety ($b = .002$, $SE\ b = .007$, 95% CI = .0006 to 003) but not between trait resiliency and anxiety ($b = .004$, $SE\ b = .003$, 95% CI = -.003 to 01). Conditional effects revealed that participants engaging in more moderate activity were less anxious when Δ stress was low or moderate but not when it was high (Figure 2).

Finally, we conducted a mediation analysis to examine whether HRV indexed by rMSSD mediated the relationship between moderate physical activity and anxiety; however, the results were not significant indicating no mediation (Figure 3; 95% CI = -.004 to .002).

Depression

Hierarchical regression coefficients for depression are displayed in Table 4. The hierarchical regression analysis revealed that at step 1, biological sex explained 2% of variance for depression but this change in R^2 was not significant, $F(1, 58) = 1.17$, $p = .28$, indicating no difference in depression scores between males and females. Introducing Δ stress in step 2 explained 19% of variance (21% overall) for depression and this change in R^2 was significant, $\Delta F(2, 58) = 13.39$ $p = .001$, indicating that graduate students who reported greater increases in stress since the onset of the pandemic were more depressed. Then, physical activity was entered stepwise but none of the measures significantly contributed to the regression model. Next, trait resiliency was entered into the regression model and it explained an additional 21% of variance (42% overall) for depression and this change in R^2 was significant, $\Delta F(3, 58) = 19.51$, $p < .001$, indicating that graduate students who reported lower trait resiliency were more depressed.

To further examine the buffering role of trait resiliency on depression at different levels of Δ stress, we conducted a moderation analysis (see Table 5). There was a significant interaction effect between Δ stress and trait resiliency ($b = .006$, $SE\ b = .003$, 95% CI = .0001 to .01). Conditional effects revealed that participants with higher trait resiliency were less depressed regardless of how much their stress levels changed (Figure 4).

Finally, we conducted a mediation analysis to examine whether HRV indexed by rMSSD mediated the relationship between trait resiliency and depression; however, the results were not significant, indicating no mediation (Figure 5; 95% CI = -.03 to .01).

DISCUSSION

Graduate students, nation-wide, who experienced greater increases in school-related stress since the onset of the COVID-19 pandemic felt more anxious and depressed. However, students who were more physically active and more resilient were less anxious, and those who were more resilient were less depressed.

Of all our measures of physical activity, only moderate (and not vigorous) physical activity was associated with reduced anxiety. The lack of association between vigorous physical activity and anxiety aligns with past research (Paolucci et al., 2018), which suggest that vigorous physical activity may not alleviate, and may even exacerbate, anxiety because it elicits similar physiological symptoms as anxiety including laboured breathing and elevated heart rate (Tabor et al., 2019). This is especially relevant for those suffering from anxiety sensitivity who become more anxious when experiencing somatic symptoms of anxiety (Zinbarg et al., 1999).

That said, moderate physical activity did not buffer anxiety for students reporting the highest change in stress, and this is in contrast to what we had predicted based on the prior results (Gerber et al., 2013). When stress increased substantially from baseline, students reported feeling anxious regardless of how physically activity they were. Why might moderate physical activity not have protected our students from stress-induced anxiety when stress increased a lot? One potential reason may be allostatic load, i.e., stress overload. During *tolerable* exposures to stress, the system responds through allostasis with a dynamic coordination of autonomic, immune, and metabolic functions that help the body overcome the threat (McEwen, 1998). Once the threat is delt with, all functions return to their homeostatic set-points (McEwen, 1998). Allostatic load occurs when a person is repeatedly exposed to more stress than their system can physiologically manage (McEwen, 1998). This results in a raised homeostatic set point whereby various stress response factors such as sympathetic tone, cortisol and pro-inflammatory cytokines become dysregulated (McEwen, 1998). It is possible that students experiencing significant changes in stress were in a state of allostatic load. Although physical activity usually helps promote an adaptive stress response, it is important to recognize that physical activity itself is a physical stressor that can add further stress to an already stressed-out. As a result, students experiencing a dramatic rise in stress levels due to the unprecedented nature of the pandemic may not have reaped the same anxiolytic benefits from their physical activity as did their peers experiencing less change in stress. Our results point to a "stress threshold" for physical activity whereby physically active students are more protected from stress-induced anxiety than their more sedentary peers but only up until a certain point. Unfortunately, allostatic load not only impacts the physiology of the body, but it also impacts behaviour too. As prior research reported that the anxiety brought on by the pandemic created a new barrier to being physically active whereby people felt too anxious or lacked the motivation to be physically active (Marashi et al., 2021).

Despite the relationship between moderate physical activity and anxiety, our objective measure of *fitness* did not explain significant variance in anxiety and thus cannot be attributed as a mechanism linking activity with better mental health. Although increasing cardiorespiratory fitness is a key adaptation from regular MVPA, other things adapt too. Increased self-efficacy is one. One's self-efficacy or belief in their ability to manage potential threats is thought to increase through physical activity which in turn reduces anxiety (Bandura et al., 1997; Petruzzello et al., 1991). Furthermore, researchers have found that it is moderate physical activity (and not light or vigorous) that reduces anxiety through self-efficacy (Katula et al., 1999), which is consistent with the lack of association with vigorous activity observed here.

Surprisingly, although anxiety and depression tend to be comorbid, moderate physical activity *did not* explain variance in depression. This contrasts with prior studies and may be due to the unprecedented circumstances surrounding the COVID-19 pandemic, including a lack of social engagement that is typically part of a physical activity program (Marashi et al., 2021) and has been pegged as in important determinant of physical activity's efficacy for mitigating symptoms of depression (Hallgren et al., 2017; Harvey et al., 2010).

However, depression and anxiety were both associated with trait resiliency aligning with prior studies that identify resiliency as a key factor protecting people from the unprecedented stress of the pandemic (Kavčič et al., 2021; Vos et al., 2021). Furthermore, trait resiliency interacted with change in stress for depression, suggesting it was protective against stress-induced depression. This was true regardless of how much stress levels had changed, even when change in stress is high; a notable association that was not seen between anxiety and physical activity.

Surprisingly, trait resiliency protected against stress-induced depression but not anxiety. This discrepancy may be due to the psychometric evaluation of trait resiliency as a construct and the specific questionnaire used here to examine it. Namely, we used the RS-14, and perhaps the most relevant item was used to measure "life meaning", which is an important predictor of depression (Mascaro and Rosen, 2005), including depression brought on by COVID-19-related-stress (Arslan and Yıldırım, 2021). Another reason why depression and not anxiety was protected by trait resiliency may reside in the stepwise worsening of stress-induced mental illness, which is thought to typically begin with anxiety before progressing toward depression via perceived helplessness in response to a stressor (Maier and Seligman, 2016). According to the neurovisceral integration model, self-regulation (an important component of trait resiliency) may be especially important in differentiating between one's susceptibility to developing depressive symptoms when faced with a chronic, high, or uncontrollable stressor (Thayer et al., 2009), like the COVID-19 pandemic. It follows that students scoring high on trait resiliency items that capture self-regulatory behaviour (i.e., students who endorsed the following items: "I have self-discipline"; "In an emergency, I'm someone people can generally rely on"; "When I'm in a difficult situation, I can usually find my way out of it") may be better able to ward off feelings of helplessness brought on by the chronic unrelenting stress of the pandemic (Durand-Bush et al., 2015). Future work should investigate this hypothesis.

HRV and Mental Health

HRV was expected to underlie the association between physical activity, trait resiliency and mental health; however, in contrast to our prediction, which was based on the neurovisceral integration model (Thayer & Lane, 2000), it did not. The null effect may be due to our cross-sectional study design that may have undermined the complex dynamical nature of resiliency. According to Hill and colleagues (2018), the dynamical model of resiliency highlights the back-and-forth interaction between all variables influenced by resiliency (Hill et al., 2018). From this perspective, resiliency is a factor that exerts influence on, *and* is influenced by, stress-induced anxiety and depression (Hill et al., 2018). Resiliency, therefore, may be a difficult construct to measure at a single time-point without considering its dynamic interactions with stress and mental health. Like resiliency, HRV may not be best represented using a cross-sectional study design given that it can be influenced by a plethora of factors, including the interactions between different brain networks proposed by the neurovisceral integration model (Thayer et al., 2009), cannabis use (Williams et al., 2021), sleep measures (da Estrela, 2021), and nutrition (Young and Benton, 2018); none of which were not controlled for here. Future intervention research is needed to examine whether physical activity and trait resiliency impact how HRV responds to different stressors over time.

Strengths and Limitations

The present study is the first to examine mental health in graduate students during COVID-19 pandemic as it relates to physical activity behaviour and trait resiliency. The addition of HRV measurement should be viewed as a strength since this is the first study to apply the neurovisceral integration model to explore HRV as a mediator in the relationship between physical activity, trait resiliency, and mental health. Past research exploring this relationship has focused on neuronal and peripheral biomarkers, such as circulating growth factors and inflammatory markers. One key advantage of our use of a biomarker like HRV is its relative accessibility and non-invasive nature. Developing sound transdiagnostic measures of mental health that are accessible and non-invasive provide a seamless way for health practitioners and researchers to diagnose, treat, and monitor mental health. Furthermore, there is a dearth of literature examining efficacious tools to address mental health in graduate students even under normal circumstances. Results from our study provide groundwork for future research interested in addressing mental health concerns in this population.

The cross-sectional design of our study is a limitation since we cannot establish causality in the observed relationships. Additionally, we employed an unsupervised and sub-maximal measure cardiorespiratory fitness, the six-minute walking test. The use of a supervised and traditional graded exercise test to maximal exertion would have provided us with a more valid and accurate measure of fitness levels in our sample; however, due to COVID-19 pandemic restrictions we were unable to conduct in-person research. We also did not standardize the delay between the six-minute walking test and self-report measures of mental health and therefore, it is possible that some participants may have completed the questionnaires immediately following the walking test, which may have influenced how they reported their mental health status. Lastly, our sample of graduate students were predominately from STEM backgrounds, reported high levels of activity, and were relatively high fit, and thus, may not have been representative of a general graduate student population.

Conclusion

In summary, graduate students experiencing greater increases in graduate-school-related stress since the onset of the COVID-19 pandemic were more anxious and depressed. However, those who engaged in more moderate physical activity were less anxious, and those with higher trait resiliency were less anxious and depressed. Furthermore, our results point to a buffering role that moderate physical activity and trait resiliency may play in protecting against stress-induced anxiety and depression.

TABLES AND FIGURES

Figure 1. The moderating effect of change in stress on moderate physical activity and anxiety. Moderate physical activity significantly predicted anxiety severity when change in stress was low and moderate but not when it was high.

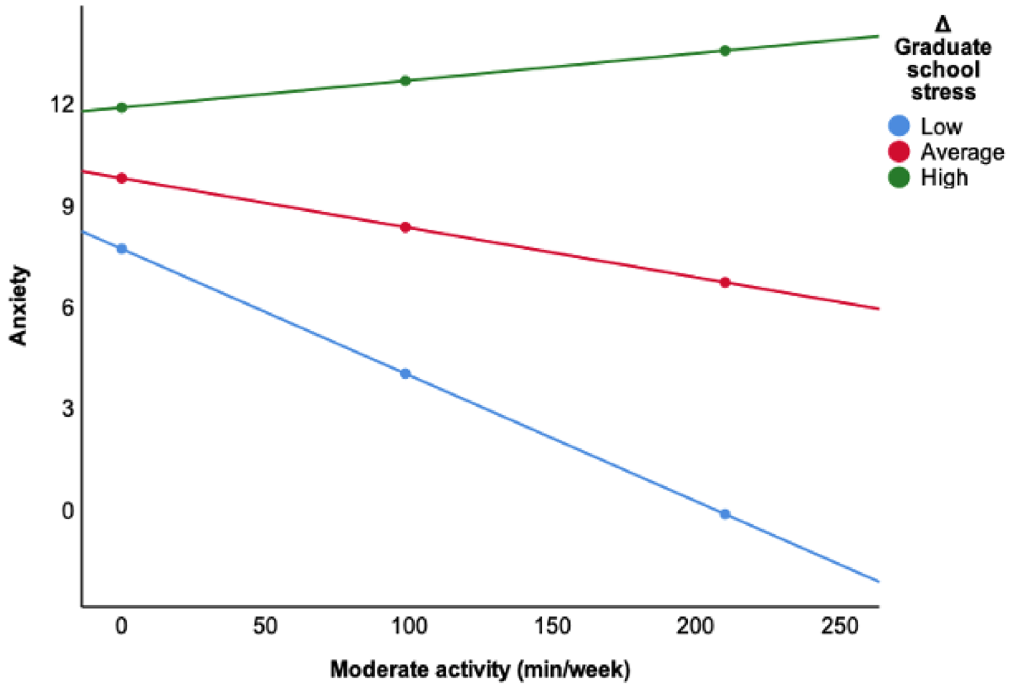

Figure 2. The mediation model examining whether HRV (indexed by rMSSD) mediated the relationship between moderate physical activity and anxiety. Biological sex was included as a covariate. There was no indirect effect through rMSSD.

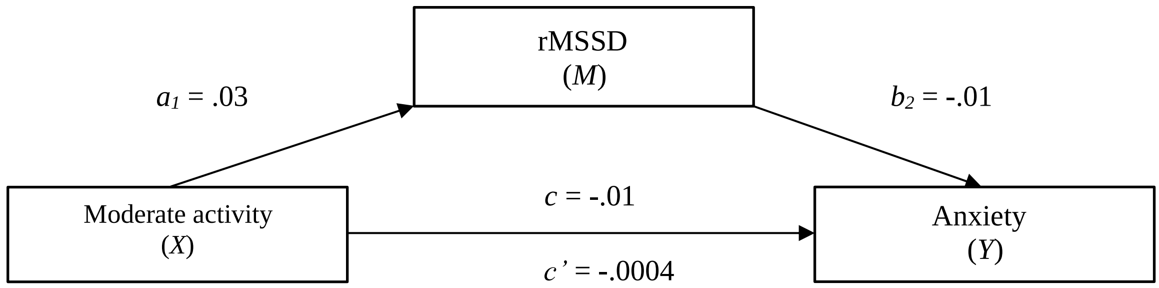

Figure 3. The moderating effect of change in stress on trait resiliency and depression. Trait resiliency significantly predicted depression severity in graduate students reporting low, moderate, and high changes in stress.

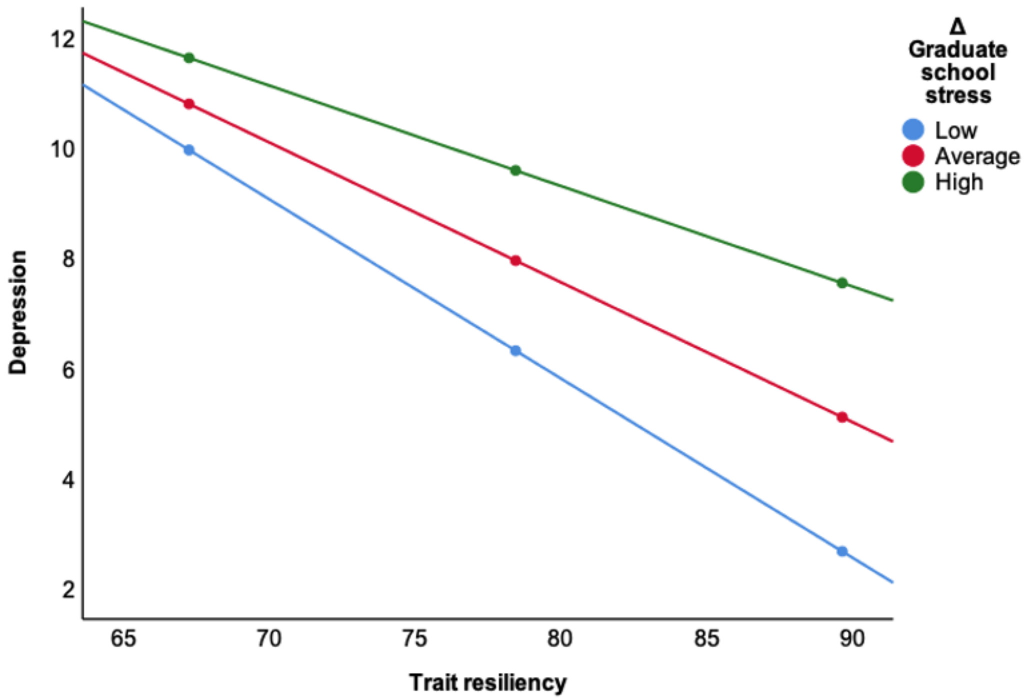

Figure 4. The mediation model examining whether HRV (indexed by rMSSD) mediated the association of trait resiliency with depression. Biological sex was included as a covariate. There was no indirect effect through rMSSD. $^{**}p < .01$.

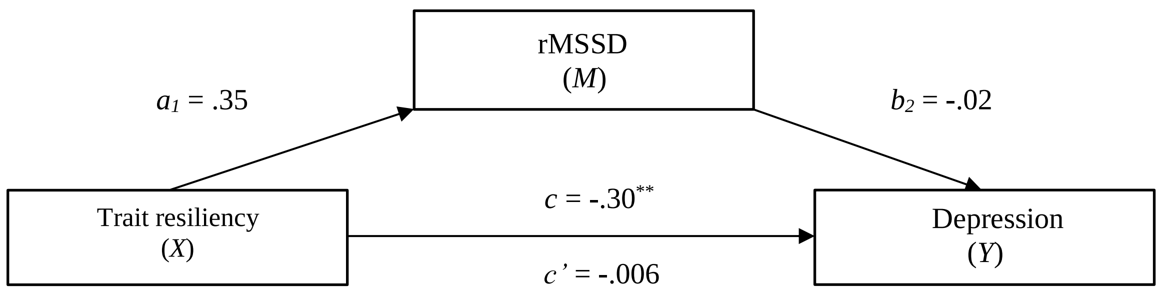

Table 1. Descriptive characteristic for study sample

Variable	Mean (SD)/Frequency (%)
Age	28.2 (4.6)
Biological sex	
Male	18 (30%)
Female	43 (70%)
Gender	
Man	18 (30%)
Woman	43 (70%)
Year of Study	
Masters 1	12 (20%)
Masters 2	12 (20%)
Masters 3	2 (3%)
PhD 1	9 (15%)
PhD 2	8 (13%)
PhD 3	10 (16%)
PhD 4	4 (7%)
PhD 5-7	3 (5%)
Research Phase	
Design	9 (5%)
Proposal	15 (25%)
Data collection	17 (28%)
Writing/Analysis	13 (21%)
Writing/Defense	4 (7%)

Other	3 (5%)
International from U.S.	2 (3%)
International outside U.S.	3 (5%)
Domestic	55 (92%)
Faculty	
STEM	52 (85%)
Humanities	8 (13%)
Business	1 (2%)
Income pre-COVID	
<Enough	4 (7%)
Just enough	23 (39%)
>Enough	32 (54%)
Income since COVID	
<Enough	5 (8.2%)
Just enough	27 (45.8%)
>Enough	27 (45.8%)
Δ stress (-50 – 50)	12.2 (11.3)
Anxiety (0-21)	8.5 (5.9)
Depression (0-24)	7.7 (5.2)
Trait Resiliency (14-98)	78.5 (11.1)
Total MVPA (min/week)	223.6 (202.4)
Vigorous PA (min/week)	124.9 (124.6)
Moderate PA (min/week)	98.7 (110.4)

Meeting PA guidelines	
Yes	35 (57%)
No	26 (43%)
Perceived PA level since COVID	
Higher	10 (17%)
No Change	15 (25%)
Lower	35 (58%)
Estimated VO_2 max (ml/kg/min)	43.9 (5.0)
Resting heart rate (bpm)	63.6 (8.6)
rMSSD (ms)	68.9 (38.2)

Table 2. Hierarchical regression coefficients: Anxiety.

		Unstandardized coefficients		Standardized coefficients					
Step	Predictor	B	SE	β	p	R^2	ΔR^2	F	p
1						.01	.01	.49	.48
	Biological sex	1.1	1.7	.093	.48				
2						.34	.33	28.6	**.00**
	Biological sex	-.10	1.4	-.01	.94				
	Δ stress	.30	.05	.59	**.00**				
3						.40	.06	5.23	**.03**
	Biological sex	-.67	1.3	-.05	.62				
	Δ stress	.31	.05	.61	**.00**				
	Moderate activity	-.01	.01	-.24	**.03**				
4						.48	.08	8.26	**.006**
	Biological sex	-.29	1.3	-.02	.82				
	Δ stress	.25	.05	.49	**.00**				
	Moderate activity	-.01	.01	-.19	**.06**				
	Trait resiliency	-.16	.05	-.30	**.006**				

Note: Biological sex was coded as 0 = male, 1 = female.

Table 3. Regression coefficients of the moderating effect of change in stress on the relationship between moderate activity and anxiety and trait resiliency and anxiety.

	R_2	ΔR_2	b	SE b
	$.49^{**}$			
Moderate activity			$-.04^{**}$	.01
Δ stress			$.18^{**}$	.06
Stress x Activity Interaction		$.08^{**}$	$.002^{**}$	
Trait resiliency	$.67^{**}$			
Δ stress			-.02	.27
Stress x Resiliency Interaction		.01	.004	.003

Note: In both models, Δ stress acted as the moderator and anxiety acted as the dependent variable. Moderate activity served as the input variable in model A and trait resiliency served as the input variable in model B. $^{*}p$ <.05, $^{**}p$ <.01.

Table 4. Hierarchical regression coefficients: Depression

		Unstandardized coefficients		Standardized coefficients					
Step	Predictor	B	SE	β	p	R^2	ΔR^2	F	p
1						.02	.02	1.17	.28
	Biological sex	1.6	1.5	.14	.28				
2						.21	.19	13.39	**.001**
	Biological sex	.69	1.4	.06	.50				
	Δ stress	.21	.06	.44	**.001**				
3						.42	.21	19.51	**.001**
	Biological sex	1.1	1.2	.10	.91				
	Δ stress	.13	.05	.30	**.02**				
	Trait resiliency	-.23	.05	-.49	**.001**				

Note: Biological sex was coded as 0 = male, 1 = female.

Table 5. Regression coefficients of the moderating effect of change in stress on trait resiliency and depression.

	R_2	ΔR_2	b	SE b
	$.46^{**}$			
Trait resiliency			$-.33^{**}$	.07
Δ stress			-.35	.23
Stress x Resiliency Interaction		$.04^{*}$	$.01^{*}$	

Note: Δ stress served as the moderator, trait resiliency acted as the independent variable, and depression acted as the dependent variable. $^{*}p$ <.05, $^{**}p$ <.01.

APPENDIX

Appendix A. COVID-related stress questionnaire adapted from the Graduate Student Inventory Revised (GSI-R) (Rocha-Singh, 1994).

COVID-19 Related Stress

Please rate how much stress you have perceived in relation to the following events encountered in graduate school since the onset of COVID-19 relative to 6-months prior to COVID-19.

Environmental Stress

-2= Much less stress
-1= Less stress
0= The same amount of stress
1= More stress
2= Much more stress

	-2 (Much less stress)	-1 (Less stress)	0 (The same amount of stress)	1 (More stress)	2 (Much more stress)	No answer
Trying to meet peers of my race/ethnicity in my field	○	○	○	○	○	●
Lack of social support groups sensitive to my needs	○	○	○	○	○	●
Pressure to perform better than my peers to be viewed as equally competent	○	○	○	○	○	●
Feelings that I must perform well because I represent my ethnic/racial group	○	○	○	○	○	●
Meeting with faculty	○	○	○	○	○	●
Living in the local community	○	○	○	○	○	●
Peers treating me unlike the way they treat each other	○	○	○	○	○	●
Faculty treating me differently from my peers	○	○	○	○	○	●
Adjusting to my work environment	○	○	○	○	○	●

Academic Stress

-2= Much less stress

-1= Less stress

0= The same amount of stress

1= More stress

2= Much more stress

	-2 (Much less stress)	-1 (Less stress)	0 (The same amount of stress)	1 (More stress)	2 (Much more stress)	No answer
Fulfilling responsibilities at home and at school/in the lab	○	○	○	○	○	●
Taking exams	○	○	○	○	○	●
Fear of failing to meet program expectations	○	○	○	○	○	●
Handling relationships	○	○	○	○	○	●
Handling the academic workload	○	○	○	○	○	●
Writing papers	○	○	○	○	○	●
Meeting deadlines	○	○	○	○	○	●
The anticipation of finding full-time professional work	○	○	○	○	○	●
Finding a work-life balance	○	○	○	○	○	●

Family/Monetary Stress

-2= Much less stress

-1= Less stress

0= The same amount of stress

1= More stress

2= Much more stress

	-2 (Much less stress)	-1 (Less stress)	0 (The same amount of stress)	1 (More stress)	2 (Much more stress)	No answer
Being obligated to function both as a caretaker and a student	○	○	○	○	○	●
Arranging childcare	○	○	○	○	○	●
Lack of sufficient income to pay monthly expenses	○	○	○	○	○	●
Family having money problems	○	○	○	○	○	●
Family having health problems	○	○	○	○	○	●
Being obligated to repay loans	○	○	○	○	○	●
Being concerned about future funding	○	○	○	○	○	●

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