School of Physiotherapy and Exercise Science

Stress, Physical Activity, Sedentary Behaviour and Resilience Resources: Tests of Cross-Sectional and Longitudinal Effects.

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This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Numbers HRE2016-0017 & HRE2016-0512).

Signature:

Date: 12/04/2019

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Dedication

This thesis is dedicated to my nana Eileen Bromley for all her love and support and in memory of my grandad John Phillip Bromley.

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List of Abbreviations

ABIC	sample size Adjusted Bayesian Information Criteria
ADA	Adaptability
AHS	Adult Hope Scale
AIC	Akaike's Information Criteria
aLMR	adjusted Lo-Mendell-Rubin Likelihood RatioTest
BIC	Bayesian Information Criteria
BLRT	Bootstrap Likelihood Ratio Test
BMI	Body Mass Index
BRS	Brief Resilience Scale
CAIC	Consistent Akaike's Information Criteria
CI	Confidence Interval
cm	centimetre
ELISA	Enzyme-Linked Immunosorbent Assay
Enviro	Environmental
GAS	General Adaptation Syndrome
GSE	General Self Efficacy
H	Hypothesis
Harass	Harassment
HCC	Hair Cortisol Concentration
HOP	Hope Scale
HPA	Hypothalamic Pituitary Adrenal Axis
hrs	hours
Hz	Hertz

ILL	Illness
INJ	Injury
IPAQ	International Physical Activity Questionnaire
kg/m^2	kilogram per meter squared
LCA	Latent Class Analysis
LL	Loglikelihood
LMR	Lo-Mendell-Rubin Likelihood RatioTest
LOT-R	Life Orientation Test – Revised
LPA	Latent Profile Analysis
LTA	Lifetime Adversity
M	Mean
MET	Metabolic Equivalents of Task
min·day	minutes per day
MPA	Moderate Physical Activity
MVPA	Moderate to Vigorous Physical Activity
N	Number
ORU	Online Research Unit
PA	Physical Activity
PBS	Phosphate Buffered Saline
pg·mg	picogram per milligram
PSS	Perceived Stress Scale
PsyCap	Psychological Capital Questionnaire
PTE	Potentially Traumatic Event
SB	Sedentary Behaviour

SD	Standard Deviation
SE	Standard Error
VPA	Vigorous Physical Activity
WHO	World Health Organisation

Abstract

The beneficial effects of physical activity (PA) for both physical and mental health are well established in the literature (e.g., Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017), as are the adverse health outcomes associated with sedentary behaviour (SB) (Ekelund et al., 2018). Therefore, the identification and amelioration of factors that act as barriers to achieving recommended levels of PA and reducing sedentary time is required. Stress is one important consideration for understanding why individuals take part in limited or no PA, and engage in high amounts of sedentary time. In a large-scale systematic review of 168 studies, for example, higher levels of stress were associated with lower levels of PA and higher levels of SB (Stults-Kolehmainen & Sinha, 2014). Yet the effects of stress on PA and SB does not hold for everyone, so examinations of possible moderators that protect individuals from the harmful effects of stress are required. Aligned with a resilience framework, individual resources (e.g., hope, self-efficacy) may buffer the maladaptive effects of stress, such that people who have access to these resources in greater quantity may be more "resilient" to the deleterious effects of stress on PA. Accordingly, the aim of this thesis was to examine the associations and interactions among stress, PA, SB, and resilience resources. This overarching aim was examined via three empirical studies in which we examined the degree to which adversity exposure provides individuals with salient experiences by which to develop and/or refine resilience resources (Study 1); tested direct and moderating effects of resilience resources on the effects of stress on PA and SB via cross-sectional (Study 2) and longitudinal designs (Study 3).

Study 1: Unique profiles of adversity experiences and differences in resilience resources

This study was a cross-sectional examination of how people's experiences of multiple adversities cluster together and in turn how these classes are related to resilience resources. The study extended past research by considering the breadth or type of adversities experienced simultaneously (referred to as polyadversity), with a focus on individual profiles of lifetime adversities. Latent class analysis was employed to explore different configurations of lifetime adversity experiences in two independent samples, and examine how these latent classes differed with regard to resilience resources (i.e., optimism, hope, self-efficacy, and bounce-back ability). University students (N=348) and members from the broader community (N=1506) completed measures of lifetime adversity exposure and resilience resources. Three

polyadversity classes were revealed in each sample, with both producing a high and a low polyadverstiy class. The third class differed between samples; in the student sample, this class represented experiences of vicarious adversity, whereas in the community sample it represented moderate levels of exposure to adversity. Support for the adaptive nature of a moderate amount of adversity exposure was found in the community sample but not in the student sample. This study produced initial evidence of how lifetime adversity experiences group together and how class membership is related to resilience resources.

Study 2: A statistic snapshot of stress, PA, SB, and resilience resources

This study was a cross-sectional examination of the effects of physiological and self-report measures of stress on PA and SB, and the buffering effect of individual-level resilience resources. In total, 140 Australian undergraduate students (70.7% female, $M_{age} = 21.68 \pm 4.88$) completed a multi-section survey, and provided a sample for hair cortisol concentration (HCC) analysis using immunoassays. Main effects demonstrated primarily small and non-significant associations between perceived stress and HCC with different intensities of PA. Similar findings were observed between individual-level resilience resources and PA intensities, with the exception of hope (i.e., positive association with vigorous PA and negative association with sitting), self-efficacy (i.e., positive association with vigorous PA), and resilience (i.e., positive association with walking). Although certain individual-level resilience resources were perceived as beneficial for PA and SB, the moderating role of resilience resources was not supported by the findings. The direct and moderating effects between stress, PA, SB, and resilience resources require further testing using longitudinal designs in which stressful periods occur naturally (e.g., exams for students) or are experimentally manipulated.

Study 3: A longitudinal examination of stress, PA, SB, and resilience resources

This study was a longitudinal investigation of the temporal associations between stress, PA, SB and resilience resources, utilising a combination of objective and self-report measures of key variables. The study used a longitudinal measurement-burst design following a sample of 53 students over a six-month period. Three bursts of six days of measurement separated by an eight week gap were chosen to represent naturalistically different periods of stress (i.e., examination period). At the beginning of each burst, students completed a multi-section survey, and provided a hair sample for hair cortisol concentration (HCC) analysis. During each burst, participants wore an accelerometer to assess PA and SB, and completed a daily diary assessment of perceived stress. Analyses examined associations between stress, PA, and SB and the possible buffering effect of resilience. A three-level multilevel model was used to analyse the within-person daily associations (Level 1), the within person burst associations (Level 2), and between-person associations (Level 3). Expectations regarding the possible moderating effects of resilience resources were unsupported. Daily reports of academic and general stress were positively associated with SB, and negatively associated with light and moderate intensity activity. HCC significantly moderated the association between academic stress and SB, such that in bursts where HCC was lower the daily positive effect of stress on SB was lower. The finding that academic and general stress are dynamically associated with lower levels of a device based measure of light and moderate intensity PA and higher levels of SB is an important extension to previous research, which has relied mainly on cross-sectional and self-report methods. Although resilience resources did not moderate these effects, it may be that other resources both internal (e.g., self-efficacy) and external (e.g., social support) may be more salient, thus warranting further investigation.

Conclusion

This thesis provides a number of salient findings and offers an important foundation for future research. Study 1 provided initial evidence of how exposure to lifetime adversities group together in two samples, and how class membership is associated with individual-level resilience resources. Additional, support for the supposition that stress and adversity can have adaptive effects in the right amount. Study 2 found that resilience resources were related to more PA time and less time in SB, and demonstrated that higher levels of resilience resources were associated with lower levels of perceived stress. Finally, study 3 found that higher levels of daily academic and general stress are dynamically associated with lower levels of light and moderate PA and higher levels of SB.

Publications Included as Part of the Hybrid Thesis

The following list of publications are included as part of this thesis and are included in the Appendices.

Study 1 (Chapter 2) of this thesis has been published (see Appendix A);

Lines, R. L. J., Crane, M., Ducker, K. J., Ntoumanis, K., Thøgersen-Ntoumani, C., Fletcher, D., & Gucciardi, D. F. (in press). Profiles of adversity and resilience resources: A latent class analysis of two samples. *British Journal of Psychology*. doi: 10.1111/bjop.12397

Study 2 (Chapter 3) of this thesis has been published (see Appendix B);

Lines, R. L. J., Ducker, K. J., Ntoumanis, N., Thøgersen-Ntoumani, C., Fletcher, D., McGarry, S., & Gucciardi, D. F. (in press). Stress, physical activity, and resilience resources: Tests of direct and moderation effects in young adults. *Sport, Exercise, and Performance Psychology*. doi: 10.1037/spy0000152

Copyright Statement

Chapter 1: Literature Review

1.1. Physical Activity and Sedentary Behaviour

From the time of the industrial revolution, the development of increasingly advanced technology has made the completion of tasks faster and reduced the amount of physical labour required to complete many tasks in everyday and occupational life. With the increasing availability of these new technologies, there has been a knock-on effect on people's energy expenditure in many aspects of their lives. The effects of many of these advances in technology on physical activity (PA) are clear (e.g., cars, trains, construction equipment), though the effect of many others are less obvious (e.g., the internet, computers, and mobile phones) (Hallal et al., 2012). There are innumerable benefits associated with the technological revolution, however, one major cost has come in the shape of a dramatic increase in physical inactivity in people's lives. Many of the systems in our body (e.g., cardiovascular, and metabolic) require the stimulation from regular PA in order to function optimally (Booth, Laye, Lees, Rector, & Thyfault, 2008). This downward trend in activity has led to the World Health Organisation (WHO) identifying physical inactivity as the fourth highest risk factor for global mortality, accounting for a preventable 6% of deaths globally (WHO, 2010). Suffice to say, physical in/activity represents a major public health issue for many developed nations.

Physical activity is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure (Caspersen, Powell, & Christenson, 1985) above resting (basal) levels (USDHHS, 1999)…[and therefore comprises a broad variety of activities including] exercise, sports, and physical activities done as part of daily living, occupation, leisure, and active transportation" (Garber et al., 2011, p. 1337). The Physical Activity Guidelines Committee (2018) recommends that adults take part in a minimum of 150 to 300 minutes of moderate intensity, or 75 to 150 minutes of vigorous intensity activity to reap important health benefits. These recommended levels can also be achieved with an equivalent combination of moderate-to-vigorous physical activity (MVPA). MVPA requires an expenditure of between 3 – 8 metabolic equivalents of task (METs; Ainsworth et al., 2000) and incorporates activities such as running, swimming, and cycling. A single MET is equivalent to a person's resting metabolic rate when quietly sitting, with activities ranging between 0.9 MET's (sleeping) to 18 METS (running at 10.9 mph) (Ainsworth et al., 2000). The WHO (2010) further suggests that additional health benefits can be gained from higher levels of activity, proposing 300 minutes of moderate or 150 minutes of vigorous intensity or an equivalent combination of MVPA, along with resistance training (muscle strengthening) involving major muscle groups at least twice a week.

Taking part in regular PA is associated with numerous health benefits for adults of both gender. A plethora of evidence supports an inverse association between increasing PA and a reduction in all-cause mortality (e.g., Garber et al., 2011; Hallal et al., 2012; Kokkinos, 2012; Piercy & Troiano, 2018). For individuals who meet PA guidelines their risk of all-cause mortality is reduced by about 75%, with the benefits in risk reduction increasing for those who exceed the guidelines (Piercy & Troiano, 2018). The numerous other physiological benefits include reduced risks of cardiovascular disease, type 2 diabetes, obesity, strokes, hypertension, osteoporosis, and some cancers (e.g., breast cancer) (Rhodes et al., 2017; Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010). Furthermore, intervention studies aimed at increasing PA levels have demonstrated significant improvements in some of these health conditions (Rhodes et al., 2017). Similar results are evident for the benefits of PA on mental health (Stults-Kolehmainen & Sinha, 2014). For example, research has consistently shown that individuals who take part in regular PA have lower levels of depression (e.g., Rethorst, Wipfli, & Landers, 2009), anxiety (e.g., Wipfli, Rethorst, & Landers, 2008), subjective stress (e.g., Burg et al., 2017), and are less likely to suffer from post-traumatic stress disorder (e.g., Warburton, Nicol, & Bredin, 2006).

Despite the wealth of information on the related benefits of PA and exercise, many individuals do not partake in regular PA/exercise (Lutz, Stults-Kolehmainen, & Bartholomew, 2010). A recent report suggests that currently only 22% of adults are meeting the PA targets, with roughly 36% of adults taking part in no leisure-time PA at all (Piercy & Troiano, 2018). Global estimates suggest that approximately 31% of people aged 15 years and over are physically inactive (Hallal et al., 2012). In Australia, for example, only 20% of youths (5 – 17 years) meet PA guidelines (Schranz et al., 2014). Furthermore, in the Australian health survey 56% of adults were considered either insufficiently active (36%) or inactive (20%) (Australian Bureau of Statistics, 2013). In today's modern society, we strive to make things easier for ourselves; one cost of this efficiency is that sedentary behaviours have replaced time that previously may have been spent engaged in light PA (e.g., taking an elevator rather than stairs).

In fact, research has shown that adults spend between 51% and 68% of their waking hour's seated (Martinez-Ramos et al., 2015).

Sedentary behaviours are distinct from physical inactivity and are defined as any waking behaviour which has an energy expenditure of less than 1.5 METs that takes place in a seated, reclined, or supine position (Tremblay et al., 2017). These behaviours include activities such as passive transport (e.g., car, train) and screen based activities (e.g., computer use, television viewing, and use of gaming consoles) (Teychenne, Costigan, & Parker, 2015). Research has found that sedentary behaviour (SB) is associated positively with adverse health outcomes, such as all-cause mortality and cardiovascular disease, and that these associations are independent of an individual's PA (Ekelund et al., 2018). Sedentary behaviour has also been found to be associated positively with a number of other adverse health outcomes, such as obesity (Hu, Li, Colditz, Willett, & Manson, 2003), osteoporosis (Warburton, Nicol, & Bredin, 2006), type two diabetes (Hu et al., 2003), and certain cancers (World Cancer Research Fund, 2007). A recent meta-analysis of 34 studies found an increase in the risk of disease with sedentary activities; specifically, the risk of negative health outcomes increases rapidly over thresholds of 6 - 8 hours a day of total sitting time and 3 - 4 hours a day of television watching (Patterson et al., 2018). As well as the deleterious physical health outcomes, SB has been linked with a number of poor mental health outcomes (Teychenne, Olstad, Turner, Costigan, & Ball, 2018), such as anxiety (Teychenne et al., 2015; Teychenne & Hinkley, 2016) and depression (Zhai, Zang, & Zhang, 2015). For these reasons, SB is of utmost importance for the health of individuals, societies, and nations worldwide.

Recent research has begun to demonstrate that the associations between sedentary activities and negative health consequences can be attenuated by PA (Eklund et al., 2018). It was found that for individuals engaging in low levels of PA, the adverse effects of SB's are consistent, whereas for individuals who took part in over one hour of moderate PA, the effects disappeared. Furthermore, there is an adaptive effect for those who do less MVPA, but this effect disappears in those individuals who are seated for over eight hours a day. These findings are important; if we can encourage people to sit for less than eight hours a day, the deleterious effects may be attenuated, and for those who cannot avoid sitting for long periods an increase in MVPA will also have this effect.

In Australia alone, it is suggested that the consequences of physical inactivity and SB cost the economy an estimated $805 million in 2013 (Ding et al., 2016). Thus, there are both health and economic reasons for clarifying our understanding of the antecedents of inactivity as well as factors that promote the uptake and maintenance of PA. The determinants of physical (in)activity are complex, and span multiple levels (e.g., individual, social, environmental) and various life domains (e.g., work, study) (Chastin et al., 2015; Deliens, Deforche, Bourdeaudhuij, & Clarys, 2015). Therefore, identification of factors that act as a barrier to a healthy lifestyle is of paramount importance. The demands of daily life can impede our efforts to be active, consequently the concept of stress has been examined to determine its function as a barrier to PA levels and in the perpetuation of SB's (Burg et al., 2017).

1.2. Stress

Stress is for many a common part of daily life, with most people at some point in their lives experiencing an event which may affect their mental or physical health (Cooper & Quick, 2017). Stressors include daily hassles at home and work, such as getting the kids to school, financial worries, and work deadlines. At the other end of the spectrum are less frequently experienced possibly life changing events, for example the death of a loved one, or a serious injury. Although daily hassles operate chronically at a low level, these major stressors are more acute in nature and usually lead to chronic stress following the event (McEwan, 2006). The stressors people face can be psychological or physiological in nature, and represent an actual or perceived event (Russell, Koren, Rieder, & Van Uum, 2012). Therefore, it is important to consider both physiological and psychological responses to stress.

1.2.1. Psychological stress.

There are numerous theories of stress and with these come numerous definitions, though at the heart of them is the transactional model, one of the most fundamental perspectives on psychological stress (Dewe, O'Driscoll, & Cooper, 2012). Guided by the transactional model of stress (Lazarus & Folkman, 1984), stress is considered an ongoing transaction between an individual's resources and demands in their environment, with a perceived imbalance between the two resulting in strain. The environmental demands people encounter are termed stressors, and the strain component represents any negative psychological, behavioural, or physical responses people display in response to these stressors (Lazarus, 1998, 1999). Rather than considering stress as an interaction between a person and their environment, a transactional perspective focuses less on specific person or environmental components but on the psychological processes that occur (e.g., appraisals and coping; Fletcher, Hanton, & Mellalieu, 2006). Therefore, stress resides in the transaction between individuals and their environment (Lazarus, 1999). A central tenant, and strength, of the perspective is the relational meaning individuals give to the transaction between themselves and their environment (Dewe et al., 2012). Relational meaning ascribes meaning to a situation through a consideration of both the individual's resources and the demands of the environment generating cognitive-evaluative responses (Fletcher et al., 2006). This appraisal process links people to their environment and reflects how people think and what people do when faced with a stressful experience, representing a process orientated perspective (Lazarus, 2001). Therefore, stress can be considered a process encapsulating stressors, appraisals, strain, and people's coping responses (Fletcher et al., 2006).

From a transactional perspective people perform two types of appraisal – primary and secondary. The primary appraisal represents an acknowledgement that there is something at stake (Lazarus, 2001). Four types of appraisals have been proposed, in which the situation poses (i) immediate threat of harm or loss, (ii) the threat of harm or loss at a future point, (iii) a challenge that may create the opportunity for mastery, gain, or challenge, and (iv) a benefit from the stressful experience. The secondary appraisal relates to what can be done and involves an evaluation of the availability of coping resources. This appraisal focuses specifically on people's perceptions of their available resources or coping strategies, the likelihood that the resources will be able to accomplish what they are intended to, and their ability to apply them to the situation (Miller & McCool, 2003). Therefore, the secondary appraisal is an interaction between the individual and their environment dealing with the perceived utility of their coping resources in response to a specific stressor. These appraisals do not work in isolation but are part of a common process, shaping the stressful experience through the attachment of meaning by the primary filter which is in turn refined by the secondary appraisal (Dewe et al., 2012). Consistent with this perspective, individuals will experience stress when they encounter an event or challenge that is perceived as threatening in nature and they do not possess the necessary resources to cope with the situation. This subjective process of appraisal, when faced with an objective demand has been found to be able to impact various health behaviours (e.g., PA and SB; Stults-Kolehmainen & Sinha, 2014). In recent times research has begun to move away from cognitive models of stress with interest growing in the exploration of the role of the brain in the stress process (McEwan, 2007).

1.2.2. Physiological stress.

The roots of our understanding of the physiological stress response come from Claude Bernard who, in the 19th century, introduced scientists to the concept of homeostasis as a mechanism with which an organism maintains an internal equilibrium in order to survive. He discovered that the pancreas is able to secrete insulin, which regulates the amount of sugar stored in the liver and how much is released into the blood stream for cellular energy. Although his work was indirectly associated with stress, it helped explain adaptive processes through survival behaviours. Organisms must maintain the right levels of oxygen, water, sugar, etc. to survive and function optimally (Lazarus, 2006). These evolutionary survival behaviours such as seeking shelter and dealing with predators threatened and disrupted organisms state of homeostasis. Walter Cannon (1932) was the first to use the term homeostasis (Koolhaas et al., 2011) in his work focusing on the 'fight or flight' response when faced with a predator. This response causes the body to mobilise resources to be able to either physically fight the threat or run away from danger, placing strain on the organism's ability to maintain a steady internal state. In addition, if the fear and anger experienced are sufficiently intense and long lasting they can be physiologically stressful and cause damage to the body. Building upon this earlier work, Selye (1956) developed one of the most important theories of physiological stress in which he outlined how the body responds when threatened by a stressor. Selye observed that in response to an imposed stimuli such as pain, extremes of temperature, or perceived challenges, organisms would exhibit a common reaction. This observation led him to propose the theory of General Adaptation Syndrome (GAS) which explains how the body utilises a set of neuro-chemical defences to protect itself against noxious stimuli. Selye identified a three stage physiological reaction to these noxious stimuli: alarm, resistance, and exhaustion. The final stage of exhaustion, referring to the depletion of the stress defence systems of the body, was linked to subsequent risk of disease (e.g., heart disease, high blood pressure) (Thoits, 2010). Selye further proposed that psychological as well as physical stimuli may initiate GAS.

Stress can be thought of as a state in which an organism's homeostasis is threatened or is perceived to be threatened, where the body must then go through a complex process of adaptive physiological and behavioural responses to return to homeostasis (Chrousos, 2009). This activation of the stress response when faced with threatening situations beyond one's control can be associated with psychological or physiological disease (Tsigos & Chrousos, 2002). During these situations, the brain focuses attention on the threat, attention is heightened, respiration and cardiac output are increased, and blood flow is redirected to supply the aroused brain, heart, and muscles (Chrousos & Gold, 1992). One of the main endocrine response to a stressor is activation of the hypothalamic pituitary adrenal (HPA) axis, resulting in an increase in secretion of glucocorticoids that are essential for the body's metabolic adaptation to a stressor (Aguilera, 2012). In humans, the primary downstream effect from activation of the HPA is cortisol, which regulates a number of physiological processes, such as metabolism of fats, proteins and carbohydrates, inflammatory responses, and gluconeogenesis (Cohen, Janicki-Deverts, & Miller, 2007). An increase in its secretion in response to a stressor has adaptive benefits such as increased muscle strength, increased memory function, and decreased pain sensitivity (Staufenbiel, Penninx, Spijker, Elzinga, & van Rossum, 2013). Although acute increases in HPA activity are a natural part of the adaptive response to a stressor and are an effective coping mechanism, the cumulative effect of repeated activation or prolonged activation, for example in chronic stress exposure, are maladaptive to both physical and psychological health (Stalder et al., 2017). For this reason, stress researchers have focused their efforts on the measurement of cortisol as an objective physiological marker of stress.

Historically, the most commonly used objective markers of stress include cortisol concentration extracted from saliva, urine, or blood serum (Herane Vives et al., 2015; Staufenbiel et al., 2013). When exposed to an acute stressor, cortisol levels will rise rapidly to a peak, dependent on the stressor, followed by a return to baseline once the stressor is gone (Burnard, Ralph, Hynd, Edwards, & Tilbrook, 2017). These methods are an effective means by which to measure acute levels of HPA activity, though it should be understood that they only provide a snapshot of acute cortisol levels circulating at the time of sampling (saliva and plasma), or in the case of urine cortisol secretion over a period of up to 24 hours (Gerber et al., 2012; Stadler & Kirschbaum, 2012; Stalder et al., 2017). These methods have been used to assess cortisol secretion over longer periods; for example, cortisol extracted from blood samples has been used in research examining the association between regular PA and cortisol levels over a 12 week program (Karacabey, 2009). Nevertheless, research has suggested that they are less than ideal for use in natural circumstances for a number of reasons (Gerber et al., 2012). Activity of the HPA is highly variable and levels of transient cortisol can fluctuate a great deal depending on a number of factors (Stadler & Kirschbaum, 2012). For example, levels of cortisol display large variability due to circadian rhythmicity, acute stress, nicotine, alcohol consumption, exercise, and food intake (e.g., Gerber et al., 2012; Gerber et al., 2013; Stadler et al., 2017; Stalder & Kirschbaum, 2012). Therefore, repeated measurements must be made to effectively measure cortisol secretion over longer periods, making these methods logistically difficult to use and leaving a gap in our ability to examine long-term cortisol output (Burnard et al., 2017).

The analysis of hair cortisol concentration (HCC) has been advocated as a biochemical marker to alleviate the methodological limitations of analysis of cortisol levels over longer periods (Gow, Thomson, Rieder, Van Uum, & Koren, 2010; Gerber et al., 2013; Stadler & Kirschbaum, 2012). Although the exact mechanisms through which cortisol is incorporated into growing hair are not yet fully understood (Burnard et al., 2017), it is thought that cortisol may enter the hair via passive diffusion from the blood stream (Stadler & Kirschbaum, 2012). There is a general acceptance that HCC is able to provide an easily attainable retrospective measure of HPA activity over extended periods (i.e. several months; Burnard et al., 2017; Stadler et al., 2017; Stadler & Kirschbaum, 2012; Wosu, Valdimarsdóttir, Shields, Williams, & Williams, 2013). Consequently, assessment of cortisol via hair provides a picture of average cortisol secretion over longer periods, rather than fluctuations that may be attributed to transient challenges. Add to this the ease of collection and it being relatively non-invasive compared to other methods of cortisol collection, the use of HCC has a number of advantages over other matrices. Hair has been found to grow at an average growth rate of 1 centimetre per month (Wennig, 2000), with the posterior vertex region showing the least variability in growth rates (Pragst & Balikova, 2006). Given these findings, researchers are able to align HPA activity temporally in periods where higher stress was present without the need for collection at that time point. Though caution must be shown when interpreting HPA activity over these epochs as research has demonstrated variability in growth rates between people (.65 to 2.2 cm per month; LeBeau et al., 2011). Notwithstanding this individualised variability in hair growth, the overall validity of the use of HCC as a metric of long term HPA activity has been supported in a number of studies (e.g., Abell et al., 2016; Grass et al., 2015; Manenschijn, Koper, Lamberts, & van Rossum, 2011; Short et al., 2016) including meta-analyses (e.g., Stadler et al., 2017). Researchers have also demonstrated high levels of test-retest reliability (Short et al., 2016; Stalder et al., 2011), and situational stability (Grass et al., 2015). In light of these findings, analysis of cortisol via hair has become an established metric in psychoneuroendocrinological research.

When considering the covariates of HCC, research suggests that levels of HCC increase with age (Feller et al., 2014; Stalder et al., 2013; Staufenbiel et al., 2015), is higher in males (Abell et al., 2016; Manenschijn et al., 2013; Staufenbiel et al., 2015), and higher in black populations (Abell et al., 2016; Wosu et al., 2015). Links to other factors have demonstrated conflicting results; for example, BMI has been reported to share a positive association in some studies (e.g., Abell et al., 2016; Stalder et al., 2013), yet null in others (Feller et al., 2014; Fischer et al., 2017). HCC has been found to be associated positively with both alcohol (Manenschijn et al., 2013; Wells et al., 2014) and smoking (Feller et al., 2014; Wosu, et al., 2015), though other studies have also reported null findings with alcohol and smoking (Dettenborn, Tietze, Kirschbaum, & Stalder, 2012; Fischer et al., 2017; Stalder et al., 2013; Staufenbiel et al., 2015). Stadler et al. (2017) reviewed and statistically synthesised the literature using HCC and examined covariates, associations with stress related measures, and mental health outcomes. They reported that HCC levels were higher in males, increased with age, were associated with higher BMI levels, and decreases after the first proximal 3 centimetres of hair growth. The association between HCC and self-reported measures of perceived stress has also been examined, though findings in this area are equivocal. In one review of the literature exploring subjective stress measures and HCC, less than half of the studies reported significant associations (6 out of 14; Staufenbiel et al., 2013). Looking specifically at the Perceived Stress Scale (PSS) (Cohen, Kamarck, & Mermelstein, 1983), a widely employed measure of subjective perceptions of stress, two studies reported a positive association, two a negative association, and the remaining seven no association was found. A recent meta-analysis by Stadler et al. (2017) also reported no significant relationships between HCC and perceived stress.

These often reported inconsistencies in the association between HCC and perceived stress add to a growing body of literature advocating a lack of psychoendocrine covariance between self-report and physiological measures (Stalder et al., 2017; Staufenbiel et al., 2013). A possible reason for the equivocal findings is the timeframes that the HCC represent (e.g., 1, 2, and 3 months), and the timeframe of the PSS (1 month) for the most case are incongruent (Staufenbiel et al., 2013). Furthermore, self-reported measures may be negatively affected by factors such as social desirability or retrospection bias (Podsakoff, MacKenzie, & Podsakoff, 2012). In their recent meta-analysis, Stalder et al. (2017) examined the association between HCC and chronic stress in chronically stressed populations, such as caregivers, unemployed individuals, and shift-workers. In contrast to the lack of significant findings with perceived stress, chronic stress was reported to be significantly associated with elevated levels of HCC. Most recently, HCC has also been found, meta-analytically, to be significantly related to adversity (Khoury, Enlow, Plamondon, & Lyons-Ruth, 2019). In light of the evidence, it may be beneficial to use HCC over traditional methods when assessing physiological stress over longer periods, though factors such as correlates and temporal alignment must be considered when interpreting findings. Due to its recognised potential and the increasing support for the utility of HCC within psychoneuroendocrinological research, the current body of work used HCC as an objective indicator of physiological stress levels.

1.3. Adversity

To understand adversity it may be necessary to recap what is meant by a stressor, that is, "the environmental demands (i.e., stimuli) encountered by an individual" (Fletcher, Hanton, & Mellalieu, 2006, p. 359). As a stressor (or multiple stressors) increases in severity, it (or they) reaches a point where one could describe it as an adversity. This threshold is suggested to occur when an individual is more likely to experience a maladaptive response than an adaptive response in the face of the stressor(s) (Fletcher, 2018). Therefore, adversity has been defined as "negative life circumstances that are known to be statistically associated with adjustment difficulties." (Luthar & Cicchetti, 2000, p. 858). Adversities, then, refer to experiences that can elicit undesirable outcomes through disruption to an individual's normal functioning (Noltemeyer & Bush, 2013).

Epidemiological studies show the worldwide prevalence rates of exposure to lifetime adversities to be relatively high. For example, in a study covering 24 countries over six continents, 70.4% of all respondents (N = 68,894) reported experiencing at least one traumatic adversity (Benjet et al., 2016). National rates varied between 28.6% (Bulgaria) and 84.6% (Ukraine) (IQR = 60.7% – 76.2%), with the rate in Australia being 76.2%. The most commonly experienced adversity was the sudden death of a loved one, with 31.4% of people having experienced it, accounting for 16.5% of all reported adversities. Other adversities reported in the literature include parental divorce, physical or verbal abuse, bullying, serious injury or illness, relationship issues, developmental disorders (e.g., speech impediment), and symptoms of mental health disorders (e.g., depression) (Fletcher, 2018). Research has found adversity to be associated positively with a number of negative psychological and physiological health outcomes, including but not limited to depression (Burns, Lagdon, Boyda, & Armour, 2016), posttraumatic stress disorder (Burns et al., 2016; Cavanaugh, Martins, Petras, & Campbell, 2013), and substance abuse (Armour & Sleath, 2014; Young-Wolff et al., 2013).

Though research has examined how different types of adversities can affect functioning, less attention has been paid to how adversities may group together and consequently how these collective experiences may associate with functioning (Holt et al., 2017). Considering multiple types of adversities in tandem allows us to see how differing combinations of adversities can affect functioning. This is advantageous for negating the possibility of overstating the salience of any one adversity in the absence of a detailed clinical interview or life history analysis. Indeed, it has been found that including multiple adversities can better predict outcomes (e.g., college adjustment) than single adversities in isolation (Elliott, Alexander, Pierce, Aspelmeier, Richmond, 2009; Finkelhor, Ormrod, & Turner, 2007). The term 'polytraumatization' (Gustafsson, Nilsson, & Svedin, 2009) was developed to represent this exposure to multiple types of trauma or adversity, rather than repeated instances of single or chronic adversity. Research has shown that compared to a single or repeated instance of the same adversity, polytraumatization has a negative effect on both mental and physical health (e.g., Briere, Agee, & Dietrich, 2016; Finkelhor et al., 2009; Gustafsson et al., 2009).

The study of multiple adversities requires a person centred approach, for which latent class analysis (LCA) is considered the optimal statistical method (Contractor, Caldas, Fletcher, Shea, & Armour, 2018). Unlike variable-centred approaches (e.g., regression), LCA organises a sample into a finite number of meaningful latent subgroups comprised of individuals who have similar response patterns on a set of variables (Lanza & Cooper, 2016). In short, the analysis examines similarities and differences between individuals as opposed to associations between variables. There has been relatively little work using this technique in regards to adversity. In a systematic review including nine papers (Contractor et al., 2018), three main commonalities between trauma classes were identified: those who reported low trauma, classes of high trauma exposure, and specific trauma classes (e.g., physical assault). Classes also differed on a number of mental health indices (e.g., post-traumatic stress disorder, and depression), with those in high trauma classes demonstrating the worst mental health. Though some research has utilised LCA to examine associations of adversity class membership with indicators of resilience outcomes such as depression, anxiety, and posttraumatic stress disorder (e.g., Burns et al., 2016; Holt et al., 2017; Young-Wolff et al., 2013), there has been little consideration of the associations between class membership and resilience resources or determinants. As resilience involves adjustment to adversity, it is important to understand how classes of adversities are associated with resilience resources, which in turn may affect an individual's response to future adversities. In light of the paucity of research examining the consequences of the collective experience of adversity and what effect this has on personal resources, the current work sought to address this gap using a person centred approach to shed light on this under studied association.

1.4. Stress and Physical Activity and Sedentary Behaviour

Stress and PA are inextricably linked in everyday life. For example, trying to maintain a healthy lifestyle and personal health conditions are major sources of stress for Australians (Australian Psychological Society, 2015). Research has found that in response to stress people will often take part in unhealthy behaviours as a means of coping, including poor eating habits, substance abuse, drinking, smoking, and an increase in SB's (e.g., TV viewing, and less PA; Stults-Kolehmainen & Sinha, 2014). In a large national stress and wellbeing survey, a majority of the ways by which people manage their stress were sedentary activities (e.g., playing video games, watching movies/television, reading, listening to music; Australian Psychological Society, 2015). Thus, the stressors people face may act as a barrier to healthy behaviours (e.g., PA) and perpetuate unhealthy choices (e.g., sedentary activities; Burg et al., 2017).

Stress can be considered an important factor in understanding why people take part in little or no PA (Burg et al., 2017). Research has typically examined the effects of PA on stress, demonstrating its salubrious effects (Wipfli, Rethorst, & Landers 2008). However, in a large systematic review of 168 studies (Stults-Kolehmainen & Sinha, 2014) stress was found to have a negative effect on PA, with 76.4% of the studies reporting that higher levels of self-reported stress lead to lower levels in PA or an increase in SB. These findings were present across both subjective and objective measures of stress. Of the 168 studies reviewed, only seven assessed stress objectively, with six of the seven demonstrating the relationship. The association was observed in chronically stressed populations (e.g., caregivers) and in varying periods of elevated stress (e.g., examination periods vs a baseline control time point).

A small body of literature has explored the stress-PA association in student populations, utilising examination periods as a naturalistic period of elevated stress (Oaten & Cheng, 2005; Sherman, Bunyan, Creswell, & Jaremka, 2009; Steptoe, Wardle, Pollard, Canaan, & Davies, 1996). Steptoe et al. (1996), for example, used a sample of 180 students, comparing changes in health behaviours between baseline assessments in two conditions, examinations vs control. They found perceived stress to increase from baseline in the exam condition, resulting in a significant decrease in PA, yet both stress and PA remained stable in the control condition. Support for these findings was offered in a later study by Oaten and Cheng (2005), who explored the effects of real world stress on regulatory behaviours (e.g., PA, consumption behaviours, study habits, and self-care habits) in a sample of 57 university students. Similarly, they found that the exam stress group demonstrated a significant increase in perceived stress from baseline compared to a control group, resulting in a significant decrease in PA levels. Specifically, they reported significant decreases in exercise frequency, duration, and perceived ease of maintaining exercise regimes among those students who were exposed to examination stress. One limitation with these studies is that they excluded an examination of the changes in activity following the perceived highly stressful period. Exploring this post-event change would help to shed new light on the dynamic nature of the stress/PA relationship (Stults-Kolehmainen, 2013), possibly demonstrating a return to normative levels post-event. Furthermore, the limited use of device-based measures of PA and predominance of cross-sectional designs highlights the need for further research utilising physiological measures in tandem with longitudinal studies. There is a need to use more rigorous study designs to address limitations present in past empirical work (Stults-Kolehmainen & Sinha, 2014), which we address this within the current body of work in an attempt to shed light on the dynamic relationship between stress and PA.

Based upon Stults-Kolehmainen and Sinha's (2014) review, the effect of stress on PA does not appear to be universal and therefore further examination of possible moderators that may protect an individual from the deleterious effects of stress is required. This explanation is in line with a resilience framework in which resources are said to buffer the maladaptive effects of stress and adversity on human functioning (Luthar, Cicchetti, & Becker, 2000; Masten, 2011). Therefore, there is a need to examine resilience resources that may buffer the effects of stress on PA.

1.5. Resilience

Over the last two decades, there has been a surge of research on psychological resilience (Windle, 2011). For example, when looking at the frequency of the word resilience, and variants, in titles of social science journals, a substantial threefold increase can be seen from the 2000's to the 2010's (Bonanno, Romero, & Klein, 2015). This research is wide-reaching crossing a number of disciplines, including education, business, sport, and the military (Fletcher & Sarker, 2013). The substantial increase in interest has brought with it numerous definitions of resilience, with debate remaining around a universally accepted definition (Aburn, Gott, & Hoare, 2016; Fletcher & Sarker, 2013). Resilience is literally defined as 'the ability of a substance or object to spring back into shape' or 'the capacity to recover quickly from difficulties' (Soanes & Stevenson, 2008). When resilience is applied to people there are a number of definitions within the literature. Early definitions within the field of psychological research define it as "protective factors which modify, ameliorate or alter a person's response to some environmental hazard that predisposes to a maladaptive outcome'' (Rutter, 1987, p. 316). Via a concept analysis, systematic review, and stakeholder consultation, synthesising over 270 papers, Windle (2011) developed the following definition of resilience, "the process of effectively negotiating, adapting to, or managing significant sources of stress or trauma. Assets and resources within the individual, their life and environment facilitate this capacity for adaptation and "bouncing back" in the face of adversity. Across the life course, the experience of resilience will vary" (p. 163). This definition is comprised of a number of key concepts; initially, there must be a significant stressor which holds the threat of a negative outcome; second, both individual and environmental resources are utilised to bring about positive adaptation; and finally resilience is a dynamic process which alters across a lifetime. Though resilience has been defined in many ways the definitions are, in general, based around two key concepts; adversity and positive adaptation, with the research community in agreement that both must be evident for resilience to be shown (Fletcher & Sarker, 2013; Luthar, 2006).

In a recent review of empirical literature, five key themes were found to underpin the numerous definitions of resilience (Aburn et al., 2016). First is the theme of rising above to overcome adversity, with terms such as flourishing and thriving used to indicate the ability to overcome troubles leading to higher levels of functioning. Second are the themes of adaptation and adjustment, whereby individuals are able to respond to difficult situations positively by adjustment or adaptation. Third is the idea of ordinary magic, meaning that resilience is not an extraordinary phenomenon but is commonplace, though not easy to quantify. Fourth is the reliance on mental health as a proxy for resilience, where an absence or lower likelihood of mental illness following a difficult period represents resilience working as a protective factor. The final theme is the notion of bouncing back, or the ability to recover and return to one’s normal levels of functioning. Aburn et al. (2016) go on to state that the lack of agreement on a universal definition of resilience may hamper efforts to forward research in this area. Furthermore, a universal definition would allow researchers, professionals, and the general population to have a better understanding about the resilience concept as a whole and in its use as a descriptive term to define, for example individuals, teams, communities etc.

As well as the problems faced with a universally accepted definition of resilience, there is also debate about the conceptualisation and operationalisation of resilience (Fletcher & Sarker, 2013). One of the main issues is whether resilience is best conceptualised as a trait, an outcome, or a process (Helmreich et al., 2017). When it is conceptualised as a trait, resilience is said to represent the characteristics of individuals that they bring with them to adversity exposure that allows them to adapt to the different circumstances they confront (Conner & Davidson, 2003). The trait conceptualisation of resilience first came to prominence with the use of the term ego resilience (Block & Block, 1980), which described a set of traits that reflected an individual’s strength of character, resourcefulness, and flexibility of functioning when faced with environmental demands. Such traits or characteristics later became known as protective factors (Rutter, 1985), where a number of these factors have now been identified within literature such as extraversion, positive affect, positive emotions, hardiness, self-esteem, and spirituality (Fletcher & Sarker, 2013). The trait orientated perspective suggests that one’s personality type determines their level of resilience, enabling them to adapt in the face of stress or adversity, thus is a relatively stable attribute (Conner, Davidson, & Lee, 2003; Hu, Zang, & Wang, 2015).

There has been a shift in the conceptualisation of resilience from a trait-orientation towards an outcome-orientated perspective (Chmitorz et al., 2018). This approach is based on the notion that resilience is demonstrated when an individual’s health/functioning (physical or psychological) is either maintained or regained despite encountering significant stress or adversity (e.g., acute, chronic, or physical) (Kalisch et al., 2017). Central to this perspective is exposure to adversity, whereby an individual’s psychological resilience can only be demonstrated if they are, or were exposed to a significant stress or adversity (Chmitorz et al., 2018). In line with this perspective, there are a number of resilience factors that might determine a resilient outcome (Kalisch, Müller, & Tüscher, 2015). These resilience factors represent resources an individual can draw upon to protect them against the negative effects of an encountered stressor, modifying their response to the stressor (Fletcher & Sarker, 2013). Researchers have examined numerous factors including genetics, personality traits (e.g., optimism), and beliefs (e.g., self-efficacy) (Chmitorz et al., 2018; Helmriech et al., 2017). In addition to these individual factors, research has identified possible external or environmental (e.g., community, society, material resources) factors that help mitigate the deleterious effects of stressors (Hobfall, Stevens, & Zalta, 2015). Resilience then may be seen as an interaction between an individual and their environment, which can be influenced by both individual (e.g., self-efficacy) and environmental (e.g., social-support) resources (Kalisch et al., 2015). Therefore, when resilience is viewed as an outcome, it is modifiable and therefore able to be improved via interventions (Helmriech et al., 2017).

Finally, the dynamic nature of resilience has been recognised in which it is considered to the process of adjustment when faced with an adverse event. This view is advocated by the American Psychological Association who define resilience as “the process of adapting well in the face of adversity, trauma, tragedy, threats or significant sources of stress” (www.apa.org/helpcenter/road-resilience.aspx). Evidence for this conceptualisation has come from a number of sources which have demonstrated that people change and adapt when they are able to successfully cope with stressors (Kalisch et al., 2017). Examples of such evidence have been observed in individuals who develop new skills or strengths (Luthar, Cicchetti, & Becker, 2000), people who demonstrate improved resistance to future stressors (Seery, Leo, Lupien, Kondrak, & Almonte, 2013), and even in modifications and alterations to genetics (Boks et al., 2015). Therefore, resilience as a process cannot be a trait, a specific personality profile, or a genetic predisposition. Although these specific factors may increase the likelihood of a resilient response, they do so in a facilitative manor via activation of coping mechanisms (Kalisch et al., 2017). Resilience is the process of what people do in response to an adversity, such that in a stressful situation one can access and use their strong self-efficacy beliefs to facilitate an actual belief in their ability to cope with the situation.

The lack of agreement in how resilience should be defined and operationalised is not limited to resilience, as it is a commonly encountered problem when trying to operationalise latent psychological constructs (Pangallo, Zibarras, Lewis, & Flaxman, 2015). For example, this issue was encountered when developing the operationalisation of mindfulness and body awareness (Pangallo et al., 2015). Against this backdrop, for the scope of this PhD research, resilience is conceptualised to reflect a system's (e.g., individual, team) trajectory of functioning over time within the context of adversity exposure, whereby the system might withstand the potentially negative effects or bounce back quickly to normal or healthy levels of functioning post adversity (e.g., Gucciardi et al., 2018; Kalisch et al., 2017). This definition helps clarify the distinction between resilience resources, processes, and outcomes. Resources are considered factors that might maximise the likelihood of a system withstanding or bouncing back from the negative effects of adversity exposure, whereas processes reflect the translation of one's potential for action via cognitive, emotional, or behavioural mechanisms into a demonstrable outcome. Resources can include personal (e.g., self-efficacy), community (e.g., social support), and societal (e.g., health care) factors (Masten, 2011; Windle, 2011).

1.6. Stress, Adversity and Resilience

Research within the remit of stress and adversity usually focuses on deleterious outcomes. Despite this focus, there are theories which suggest that, in the right amount, exposure to stressors or adversities may actually foster psychological resilience

(Dooley, Slavich, Moreno, & Bower, 2017). One such theory, Dienstbier's theory of psychophysiological toughness (1989, 1992), postulates that exposure to stress can have a toughening effect when exposure is balanced alongside opportunity for recovery. Other similar theories include stress inoculation (e.g., Meichenbaum, 1976, 1977), steeling (e.g., Rutter, 1987), and immunisation (e.g., Basoglu et al., 1997). A common theme among these perspectives is that exposure to a challenging yet manageable amount of stress or adversity creates an opportunity for an individual to develop individual-level resources (e.g., hope, self-efficacy), which in turn will help foster resilience outcomes to future adversities. Indeed, it has been suggested that to develop the resilience necessary for high performance, individuals may first need to be vulnerable to adversity to subsequently benefit from the psychological and behavioural changes that only this level of trauma can bring (Fletcher, 2018; Fletcher & Sakar, 2016). Therefore, toughness can be seen to be analogous to physical fitness in that toughness can only develop through exposure to stressors, much like fitness can only develop through physical exertion, though too much exposure to stressors can have debilitating effects on toughness, just like over training can for fitness (Seery, Leo, Lupien, Kondrak, & Almonte, 2013). This toughening effect is suggested to generalise across different domains, having a positive effect on both familiar and novel experiences (Seery & Quinton, 2016). This notion of toughening has generally been supported (e.g., Dooley et al., 2017; Neff & Broady, 2011; Seery, Holman, & Silver, 2010; Seery et al., 2013). For example, in an adolescent sample, exposure to higher amounts of moderately severe stressors in childhood resulted in attenuated depressive responses to proximal stressors, when compared against individuals who had little exposure to moderate stressors (Shapero et al., 2015). Within the context of the theory of toughness, it is likely that individuals who have experienced challenging yet manageable levels of adversity/stress have had the chance to develop adaptive personal resources (e.g. hope, self-efficacy) and thus be able to be more resilient to future adversities.

Scholars have examined the effects of exposure to lifetime adversities on resilience outcomes across various life contexts and indices of functioning (Höltge, McGee, Maerker, & Thoma, 2018). In one of the first studies to explore the effects of exposure to lifetime adversities on resilience, Seery et al., (2010) found an inverted U-shaped relationship between the number of adversities experienced and mental health and well-being. Specifically, those who had exposure to some adversity had better mental health and well-being (e.g., lower global distress, and higher life satisfaction) than those who had experienced either no or high levels of lifetime adversity. In another study of sufferers of chronic back pain, individuals who had experienced some lifetime adversities reported lower levels of functional impairment (i.e., extent to which mental/physical health affected social/work activities) and use of health care than those who had experienced either none or high levels of adversity (Seery, Leo, Holman, & Silver, 2010). These findings have also been supported in response to laboratory stressors (Seery et al., 2013). Recent work has differentiated between cumulative acute and chronic adversities, and found that breast cancer survivors who experienced moderate levels of acute lifetime adversities (i.e., time limited events, like the death of a loved one) reported higher levels of positive affect and fewer cancer-related intrusions (i.e., intrusive thoughts, nightmares, intrusive feelings, and imagery) than survivors who had experienced either low or high levels of acute adversities (Dooley, Slavich, Moreno, & Bower, 2017). Taken together, these findings provide evidence that some exposure to adversities may help protect individuals from the deleterious effects of future stressors/adversities via the development or refinement of resilience resources. These deleterious effects are wide ranging encompassing both psychological and physiological factors, including reduced levels of PA or an increase in sedentary time (e.g., Stults-Kolehmainen & Sinha, 2014). In the context of the current work, it may be that this exposure provides people with the opportunity to develop resources enabling them to maintain an active lifestyle when faced with stressful periods.

1.7. Stress, Physical Activity, and Resilience

When considering associations between resilience, stress, and PA, research has predominantly focused on how engagement in PA may increase an individual's resilience to the negative effects of stress (e.g., Gerber & Puhse, 2009; Hegberg & Tone, 2015). With past work suggesting that PA can buffer against the negative effects of both perceived and physiological stress (von Haaren et al., 2016). In a review of 31 studies almost half supported a stress buffering effect of PA on the deleterious effects of stress (Gerber & Puhse, 2009). A smaller body of work has examined the associations between resilience and PA, and provided support for the beneficial effects of resilience. For example, in a large latent profile analysis study of employed adults (n = 2660), participants in higher resilience profiles were found to take part in higher levels of PA than those with lower levels of resilience (Gerber et al., 2014). Similar findings have been reported when looking at regular PA with those who took part in regular PA reporting significantly higher levels of resilience (Yoshikawa, Nishi, & Matsuoka, 2016). It should be noted that both studies assessed resilience with a unidimensional measure of resilience and PA was measured using only a single item. Of the small body of work in this area the assessment of PA is a common problem with research mainly focused on moderate-to-vigorous PA (Thogerson-Ntoumani et al., 2017). Knowledge of the associations between resilience and different intensities of PA (e.g., light) are lacking, as it is likely that the associations between stress, resilience and PA may vary dependent on PA intensities (Thogerson-Ntoumani et al., 2017). Due to the lack of research examining moderators of the stress/PA relationship (Stults-Kolehmainen & Sinha, 2014), and the propensity for a myopic focus on unidimensional measures of resilience and PA, further research is required. Therefore extension of past work is required utilising a multidimensional perspective of resilience, multiple intensities of PA including sedentary time, and utilising a longitudinal approach to understand the dynamics of these associations.

1.8. Aims and Innovations

Against this backdrop, the aims of this PhD were to investigate the effects of stress on PA and SB, and test the possible buffering effect of resilience resources. The study utilised both cross-sectional and longitudinal designs to examine these associations using a combination of physiological (i.e., HCC), device-based (i.e., accelerometers), and self-report measures. This research aims to offer several substantive and methodological innovations to further our understanding of the relationship between stress and PA and SB. Substantively, whereas past work has captured stress through short periods of everyday life, examinations of the associations between stress and PA and SB during periods in which there are naturalistically varying degrees of stress (e.g., low, high) can offer a more nuanced understanding of the interplay between these factors. Within an educational context, examination periods offer a naturalistic period of elevated stress (Oaten & Cheng, 2005; Sherman et al., 2005; Steptoe et al., 1996). For example, Steptoe et al. (1996) found perceived stress, measured using the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983), to increase from baseline to examination period in an exam group (M = 18.4 to 20.2) yet remain stable in a student control group (M = 15.4 to 15.3). Key here is the distinction between acute and chronic stressors, as they may have differential influences on PA and SB; failure to distinguish between these types of stressors may impede efforts to identify important targets for interventions that can buffer the effects of stress.

There has also been no research to date examining changes in PA and SB following stressful periods. Shedding light on the dynamic relations between stress and PA and SB after stressful periods has the potential to clarify the temporal dynamics of these behaviours; for example, does PA 'rebound' or return to usual levels after high periods of stress? Such an approach is consistent with substantive perspectives of resilience, which encompass a "bounce back" component, and therefore is well placed to enable a theoretically rich examination of the usefulness of specific resilience resources. A third substantive innovation of this work relates to the focus on resilience resources, as limited work has focused on moderators of the relations between stress and PA. The study of moderator effects acknowledges the complexity of behaviour (MacKinnon, 2011), and can provide insight into the potential targets for interventions. For example, if optimism is found to moderate the effect of stress on PA (e.g., those high in optimism can buffer the effects of stress to maintain PA, but not those low in optimism), then this individual difference variable would be an obvious target for intervention (i.e., building individual's optimism). Finally, there is limited research examining the effects of multiple adversities and their association with resilience. We will take a person centred approach to identify adversity classes using the optimum statistical method (LCA) and examine how these classes are associated with resilience resources.

From a methodological standpoint, much of the available work has relied on self-report measures of stress, PA and SB. For example, in a review of 168 studies, only seven used objective measures for stress (cortisol) (Stults-Kolehmainen & Sinha, 2014). The use of objective measures is important as they can address limitations such as recall bias and social desirability associated with self-report measures (Pavey, Gomersall, Clark, & Brown, 2015). Therefore, we will utilise a physiological marker of stress (HCC), which will provide a retrospective measure of accumulated HPA activity over a specific time frame (i.e., 1 cm of hair equates to 1 month of cortisol secretion; Wenning, 2000). Furthermore, accelerometers will be used to quantify PA and SB levels, providing a more accurate method than relying on self-report measures.

The temporal nature of research designs employed in past work is another important methodological consideration. Longitudinal research permits an understanding of the temporal dynamics of psychological and behavioural processes. Broadly speaking, there are two types of longitudinal research that differ in the interval between assessments and durations of follow-ups (Bryman, 2015). First, one of the most common longitudinal designs encompasses widely spaced measurements of single time points, usually spanning several months (e.g., 6 - 12 months). With this design, researchers are interested in average or typical change and predictors of this (in)stability. Second, longitudinal designs can involve several repeated assessments taken over short intervals (e.g., every day, several times per day). Referred to as diary studies, this intensive focus on short intervals permits a fine-grained analysis of rapidly fluctuating processes over a designated time period (e.g., 7-days, 28-days). Both single-measurement, multiwave and diary studies are important longitudinal designs, yet their limitations mean that they may not adequately capture the temporal dynamics of psychological and behavioural processes. For example, there is an inherent assumption in single-measurement, multiwave designs that each assessment on the variable(s) of interest is representative of an individual and therefore there is little intraindividual variability in the variables (Sliwinski, 2008). When the construct of interest is highly variable across days or even weeks (e.g., stress), there is little confidence in this single-measurement to accurately capture the 'true' level for individuals. Diary designs, in contrast, provide little insight into the cross-contextual (in)stability of intraindividual changes over different temporal periods (Sliwinski, 2008). For example, it may be that variation in daily stressors accounts for within-personal variability in PA across days within a given week, yet changes in chronic stressors are most important across longer temporal periods (e.g., several months). A hybrid of short- and long-term longitudinal designs, referred to as measurements bursts, enables researchers to minimise such methodological limitations by capitalising on the strengths of both approaches within a single study.

1.9. Potential Impact

The health benefits of PA and the harmful effects of stress are well established within the literature. These deleterious effects are associated with large economic costs; for example, physical inactivity and SB has been estimated to cost the global economy an estimated $53.8 billion annually (Ding et al., 2016), whereas workplace stress has been found to cost national economies between $580 million to $187 billion per year (in Australia and America respectively; Hassard, Teoh, Visockaite, Dewe, & Cox, 2018). Therefore, the identification of factors that might inform strategies to increase (or maintain recommended) levels of PA, and help reduce stress levels are needed to reduce these health and economic burdens. Against this backdrop, the primary focus of this PhD is to further our understanding of the dynamic nature of the association between contextual stressors, PA and SB, and explore the possible salubrious effects of resilience resources on these associations.

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Chapter 2: Profiles of Adversity and Resilience Resources: A Latent Class Analysis of Two Samples

Bad things can and do happen to people; whether it is being struck down by serious illness, being exposed to a natural disaster, or experiencing the death of a loved one, most if not all people will experience one or more of these highly aversive events during their lives. Adversities refer broadly to "negative life circumstances that are known to be statistically associated with adjustment difficulties" (Luthar & Cicchetti, 2000, p. 858). Epidemiological studies show the worldwide prevalence rates of exposure to lifetime adversities to be relatively high. For example, in a study covering 24 countries over six continents, 70.4% of respondents (N=68,894) reported experiencing at least one traumatic event, with 30.5% reporting four or more different events (Benjet et al., 2016). National rates varied between 28.6% (Bulgaria) and 84.6% (Ukraine). The most commonly experienced traumatic events included unexpected death of a loved one (31.4%), witnessing death, a dead body or someone seriously injured (23.7%), and being mugged (14.5%). In general, adversity and potentially traumatic events (PTE's) [1] are statistically associated with various negative psychological and physiological health outcomes such as depression (Burns, Lagdon, Boyda, & Armour, 2016), posttraumatic stress disorder (Burns et al., 2016; Cavanaugh, Martins, Petras, & Campbell, 2013), and substance abuse (Armour & Sleath, 2014; Young-Wolff et al., 2013). Research within the field of stress and adversity usually focuses on these and other deleterious outcomes. However, not everyone who experiences adversity is afflicted with such negative consequences (e.g., Bonanno, Westphal, & Mancini, 2011).

Different theories suggest that, in the right amount, exposure to stressors or adversities may actually foster resilience. For example, Dienstbier's proposed theory of toughness (1989, 1992) postulates that exposure to stress can have a toughening effect when this exposure is limited and there is opportunity for recovery. Similar concepts to toughness have been referred to as stress inoculation (i.e., Meichenbaum,

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[1] We acknowledge that events are termed traumatic when they involve perceived or real threat to one's or another person's life or limb (American Psychiatric Association, 2013). Here we use the term adversity to capture the breadth of possible events that might disrupt the functioning of a system, yet adopt traumatic where appropriate (e.g., study cited focused solely on traumatic events).

1976, 1977), steeling (e.g., Rutter, 1987), and immunization (e.g., Başoğlu et al., 1997). A common theme among these perspectives is that exposure to moderate amounts of stress/adversity that are sufficiently challenging to be successfully coped with creates an opportunity for an individual to develop resources (e.g., self-efficacy) which will help them cope with future adversities. Indeed, it has been suggested that to develop the resilience necessary for high performance, individuals may first need to be vulnerable to adversity to subsequently benefit from the psychological and behavioral changes that only this level of trauma can bring (Fletcher, 2018; Fletcher & Sakar, 2016). In this view toughness can be seen as analogous to physical fitness, in that improvement in physical fitness requires physical exertion followed by a period of recovery to build one's capacity. Though too much exposure to stressors can have debilitating effects on toughness just as overtraining can for physical fitness (Seery, Leo, Lupien, Kondrak, & Almonte, 2013). This developed toughness is also proposed to be transferable to other domains, both familiar and novel, which has positive implications for resilience to future adversity (Seery & Quinton, 2016). Toughening may occur via self-reflection, whereby exposure to adversity offers the opportunity to reflect on one's initial response to a stressor and develop resilient capacities (e.g., coping resources) that maximise the likelihood of resilience to future events (Crane, Searle, Kangas, & Nwiran, 2019). Furthermore, similar to the previously mentioned concepts, this reflective process is most effective during moderate exposure to adversity (Crane et al., 2019). Therefore, moderate levels of adversity offer more opportunity to systematically self-reflect than experiencing no or high levels of adversity, resulting in the strengthening of resilience to future adversities.

Over the last twenty years there has been a surge of interest examining psychological resilience, and with this numerous definitions have been presented leading to debate around a universally accepted definition (Bonanno, Romero, & Klein, 2015). We ascribe to the view that resilience is a system's (e.g., individual, team) trajectory of functioning over time within the context of adversity exposure, whereby the system (e.g., individual, team) might withstand the potentially negative effects, or bounce back quickly to normal (i.e., pre-adversity) or healthy levels of functioning (e.g., Fletcher, 2018; Gucciardi et al., 2018). This conceptualisation helps clarify the distinction between resilience resources (often referred to as protective factors), processes, and outcomes. Resources help maximise the likelihood of a system withstanding or bouncing back from the negative effects of adversity exposure, whereas processes reflect the translation of one's potential for action via cognitive, emotional, or behavioural mechanisms into a demonstrable outcome. Thus, resilience as an emergent outcome is displayed when salient resources are activated in response to an adverse event to enact adaptive processes that result in optimal functioning either in terms of withstanding the negative effects of the adversity or bouncing back from deteriorations in functioning.

Broadly speaking, resilience resources encompass individual (e.g., personality, biological), community (e.g., social support), and societal (e.g., health and social services) factors (Masten, 2011; Windle, 2011). Our focus on individual resources in the current study was informed by a recent conceptual and methodological review of resilience measures that are designed to operationalise such resources (Pangallo, Zibarras, Lewis, & Flaxman, 2015). The Psychological Capital Questionnaire (PsyCap; Luthans, Youssef, & Avolio, 2007) received the highest rating of 17 resilience measures reviewed against seven quality assessment criteria, namely theory formulation, internal consistency, replicability, convergent validity, discriminant validity, and application. PsyCap, which is designed to assess four resilience resources, was awarded maximum marks in all but one criteria (replicability). First, the resilience component assesses one's ability to bounce back or recover from stress or adversity. The other three resources of hope, self-efficacy, and optimism share a commonality in that they are related to one's thoughts and beliefs about the attainment of future positive states (Feldman & Kubota, 2015). Hope refers to a cognitive process of self-determined motivation towards personally valued objectives and ways by which to achieve them (Snyder et al., 2002). Self-efficacy is defined as a belief in one's ability to accomplish a desired goal; these beliefs instil individuals with the motivation to face new challenges and persist in the face of barriers (Bandura, 1997). Finally, optimism reflects an individual's expectancy that positive things will happen (Scheier, Carver, & Bridges, 1994). Each of these concepts have gained substantial support as key resilience resources across a broad range of samples and contexts (e.g., Chmitorz et al., 2018; Fletcher, 2018). Together, these beliefs can influence behaviours towards a goal, in turn affecting achievement of goals and one's psychological well-being (Rand, Martin, & Shea, 2011). As beliefs are largely founded in experience, encountering many difficulties (adversities) that are perceived as overwhelming may lead to formation of a belief that we have low agency in the world. In contrast, if we overcome something then we may believe that we are able to overcome difficulties. Thus, forming positive beliefs about your efficacy to overcome demands may be challenging unless you have experienced such adversities. Therefore, the experience of adversities may help one to develop adaptive beliefs through these examined resources.

Scholars have examined the effects of exposure to lifetime adversities on resilience outcomes across various life contexts and indices of functioning (Höltge, McGee, Maerker, & Thoma, 2018). For example, Seery, Holman, and Silver (2010) found a U-shaped association between the number of lifetime adversities experienced and mental health and well-being. Specifically, individuals who had been exposed to some adversity reported better mental health and well-being (e.g., lower global distress, and higher life satisfaction) than people who had experienced either no (0 adversities) or high levels (Mean+1SD) of lifetime adversity. In a sub-sample of sufferers of chronic back pain, individuals who had experienced some lifetime adversity (just below the logarithmic mean of 2.22; raw score median = 9 lifetime adverse events) reported lower levels of functional impairment (i.e., extent to which mental/physical health affected social/work activities) and use of health care than people who had experienced either no or high levels of adversity (defined as + 1 SD [.73] above the logarithmic mean of 2.22; Seery, Leo, Holman, & Silver, 2010). These findings have also been supported in response to laboratory stressors requiring passive endurance and active instrumental performance, in student samples (Seery et al., 2013). In Seery and colleagues' research, lifetime adversities were operationalised using a cumulative measure (i.e., a score of 4 could represent 4 different adversities or the same adversity 4 times). Recent work has differentiated between cumulative acute and chronic adversities, and found that breast cancer survivors who experienced moderate levels of acute lifetime adversities (i.e., time limited events, e.g., death of a loved one) reported higher levels of positive affect and fewer cancer-related intrusions (i.e., intrusive thoughts, nightmares, intrusive feelings, and imagery) than survivors who had experienced either low or high levels of acute adversities (Dooley, Slavich, Moreno, & Bower, 2017). Taken together, these findings provide evidence that moderate exposure to adversities may help protect individuals from the negative psychological effects of future stressors/adversities via the selection and development or refinement of resilience resources.

Though research has examined how different degrees of adversity exposure affects functioning, less attention has been paid to how adversities may cluster together (Holt et al., 2017). Considering multiple types of adversities in tandem allows for an examination of differing combinations of adversity experiences, and how such distinct typologies might be differentially associated with various indicators of functioning. For example, multiple adversities can better predict outcomes, such as college adjustment (Elliott, Alexander, Pierce, Aspelmeier, Richmond, 2009) and trauma symptoms (Finkelhor, Ormrod, & Turner, 2007), than single adversities in isolation. The term 'polytraumatisation' (Gustafsson, Nilsson, & Svedin, 2009) was developed to represent this notion of exposure to multiple types of adversities, rather than repeated instances of single or chronic adversity. Compared to a single or repeated instance of the same adversity, polytraumatisation has a negative effect on mental and physical indices of health (e.g., Briere, Agee, & Dietrich, 2016; Finkelhor et al., 2007; Gustafsson et al., 2009, Hughes et al., 2017).

To study polytraumatisation or, in the current study 'polyadversity', a person-centred approach is required to identify homogenous groups of individuals based on their adversity experiences. For the assessment of polyadversity classes Latent Class Analysis (LCA) is considered to be an optimal statistical method (Contractor, Caldas, Fletcher, Shea, & Armour, 2018). Unlike variable-centred approaches (e.g., regression), in LCA the sample is organised into a finite number of meaningful latent subgroups comprised of individuals who have similar response patterns on a set of variables, yet maximises differences between these individuals with people assigned to other clusters (Lanza & Cooper, 2016). Simply put, there is a focus on the similarities and differences amongst people, rather than associations between variables. In LCA individuals are probabilistically assigned to classes based on the probability of their membership in all identified classes (Berlin, Williams, & Parra, 2014), often with no a priori decisions about the number of classes, though decision making is led by theory and evidence (Holt et al., 2017). Past work focused on classes of trauma experiences among adult samples has underscored the importance of person-centred analyses. Contractor et al. (2018) identified nine studies via a systematic search of the literature, and found three common types of trauma profiles across this work: individuals who had experienced low or high counts of trauma, and specific types of traumas (e.g., childhood maltreatment). These trauma groupings differed on a range of mental health indicators (e.g., depression), with the high trauma class characterised by the poorest degree of mental health.

Though some research has utilised LCA to examine associations of polyadversity class membership with indicators of resilience outcomes such as depression, anxiety, and posttraumatic stress disorder (e.g., Burns et al., 2016; Holt et al., 2017; Young-Wolff et al., 2013), there has been little consideration of the associations between polyadversity class membership and resilience resources or determinants. As resilience involves adjustment to adversity, it is important to understand how polyadversity classes are associated with resilience resources, which in turn may affect an individual's response to future adversities. To do so, we used a person-centred approach to explore polyadversity in two samples (student and community), and examined how the identified classes differ with regard to individual-level resilience resources (i.e., optimism, hope, self-efficacy, and bounce-back ability). In accordance with the findings of a recent meta-analysis of studies utilising person-centred analyses for polytraumatisation class analyses (Contractor et al., 2018), we hypothesised that we would find a class characterised by a higher likelihood to have experienced most or all of the assessed adversities (H1), a class characterised by a lower likelihood of experiencing most or all of the assessed adversities (H2), and a class/classes characterised by a high likelihood of experiencing a specific adversity (H3). We also hypothesised that individuals who have experienced moderate levels of polyadversity (relative to the other classes identified) will report higher levels of individual-level resilience resources when compared to those who have experienced no/low or high levels of polyadversity (H4).

2.1. Study One Methods

2.1.1. Participants.

A convenience sample of 348 undergraduate university students (61.5% female) aged 18 – 52 years (mean ± SD; 22.09 ± 4.97) was recruited from universities in Western Australia (77%) and the United Kingdom (33%).

2.1.2. Procedure.

Approval for the study was granted by an accredited Human Research Ethics Committee prior to data collection. Participants were recruited via three methods: (i) an online research participation pool, where students completing health science degrees sign up to participate in studies in return for course credit; (ii) posters placed around the university campus inviting participants to take part in the study; and (iii) announcements about the study, including the information sheet and survey link, distributed by unit co-ordinators to students enrolled within their units. The students who chose to participate in the study completed a multi-section survey online via Qualtrics (Provo, UT, USA). All participants provided informed consent to take part in the study, via a check box at the beginning of the survey.

2.1.3. Measures.

2.1.3.1. Adversity exposure.

Participants' exposure to adversity across their lifetime was assessed using an adapted version of Seery et al.'s (2010) cumulative lifetime adversity measure. The adapted measure consisted of 15 negative events that captured the following six broad categories: own illness or injury, loved ones illness or injury, violence, bereavement, social/environmental stress, and relationship stress. An additional two categories were included within our adapted version to capture common experienced adversities: threat or harassment, and others' death or injury. Respondents indicated whether or not they had ever experienced the adversity (0 = no, 1 = yes) and, if so, how many times. For the purposes of this study a single dichotomous (yes or no) variable was created to represent each of the eight categories of adversity. For example, if participants indicated that they had experienced a 'major illness' but not a 'life threatening accident' (or vice versa), they would be scored as yes (1) to the adversity category own illness or injury. In cases where participants experienced both of these adversities, they were also coded as yes (1) to the adversity category own illness or injury. The combining of conceptually similar items to create a single binary category has been used in previous studies (e.g. Holt et al., 2017; Young-Wolff et al., 2013).[2]

2.1.3.2. Resilience resources.

Informed by findings from a recent conceptual and methodological review of resilience measures (Pangallo, Zibarras, Lewis, & Flaxman, 2015), we assessed four broad resilience resources encapsulated by the concept of psychological capital, namely hope, efficacy, resilience, and optimism (Luthans, Youssef, & Avolio, 2007). For each of the four scales items were measured on a 7-point scale anchored by 1 strongly disagree and 7 strongly agree.

[2] One reviewer asked why we used a binary score (yes/no) to operationalize adversity exposure rather than a continuous or summative score to indicate the number of times participants had experienced each adverse event category. As explained in the Supporting Information (see supplementary material), this decision was largely statistical in nature rather than substantively informed (e.g., model fit statistics were unclear about the optimal number of classes, classes contained <5% of the total sample).

2.1.3.2.1. *Bounce back ability (Smith et al., 2008).* The Brief Resilience Scale (BRS) is a measure of one's perceived ability to bounce back or recover from stress. The scale is comprised of six items, three of which are positively worded (e.g., "I tend to bounce back quickly after hard times") and three are negatively worded (e.g., "It is hard for me to snap back when something bad happens"). Scores on the BRS have demonstrated good levels of internal consistency (α = .81 - .91) and test-retest reliability (1 month r = .69 and 3 months r = .62) evidence in past work (Smith et al., 2008). Internal reliability evidence in the current sample was excellent (α = .91).

2.1.3.2.2. *Adult hope scale (Snyder et al., 1991).* The Adult Hope Scale (AHS) is a measure of an individual's cognitive and motivation towards personally valued objectives. The scale is comprised of 12 items consisting of two factors, each of which is measured by four items; the four filler items were omitted in this study to minimise participant burden. The pathway items measure one's perception of their ability to overcome goal-related barriers to their goals (e.g., "There are lots of ways round any problem"), whereas the agency items reflect people's motivation and goal-directed energy to use pathways to reach their goal (e.g., "My past experiences have prepared me well for my future"). Scores on the AHS have demonstrated good reliability (α = .79; Feldman & Kubota, 2015) and test-retest reliability evidence (3 weeks, r = .85 up to 10 weeks, r = .82; Snyder et al., 1991). Internal reliability evidence in the current sample was sound (α = .86).

2.1.3.2.3. *General self-efficacy scale (Chen, Gully, & Eden, 2001).* The General Self-Efficacy Scale (GSE) is an 8-item measure of one's belief in their capabilities to perform the courses of action required to meet situational demands (e.g., "When facing difficult tasks, I am certain that I will accomplish them"). Scores on the GSE have demonstrated good internal consistency (α = .82; Chen, Li, & Leung, 2016) and test-retest reliability evidence (r = .62 to .86; Chen et al., 2001). Internal reliability evidence in the current sample was excellent (α = .92).

2.1.3.2.4. *Life orientation test – revised (Scheier, Carver, & Bridges, 1994).* The Life Orientation Test-Revised (LOT-R) is a 10-item measure of an individual's perceived optimism (e.g., "I'm always optimistic about my future") and pessimism (e.g., "I rarely count on good things happening to me"). The two dimensions are measured with three items; the four filler items were omitted in the current study to minimise participant burden. Scores on the LOT-R have demonstrated good levels of internal consistency (α = .85; Feldman & Kubota, 2015; α = .85; Huffman et al., 2016) and test-retest reliability evidence (r = .73; Atienza, Stephens, & Townsend, 2004). Internal reliability evidence in the current sample was sound (α = .81).

2.1.4. Data Analysis.

Latent class analyses (LCA) were conducted to identify subgroups or clusters of individuals based on their breadth (categorical indicator) of lifetime adversity exposure; that is, the total number of unique adversity experiences. These analyses are useful in reducing indicator variables into latent subgroups (Oberski, 2016). In the present study, we utilised the automatic 3-step method within M*plus* (Muthén & Muthén, 1998-2017) to model auxiliary variables (e.g., covariates and distal outcomes). First, the 3-step method determines the number of latent classes based on the indicator variables, which in our case included eight broad categories of unique adverse events. Second, the most likely class membership for participants is determined based upon the posterior distribution obtained in step one. Finally, this classification scheme is related to covariates and distal outcomes. The 3-step method was chosen because it takes into account error in classification when estimating associations with other variables (Gabriel, Daniels, Diefendorff, & Greguras, 2015), and class identification is uninfluenced by covariates or outcomes variables (Asparouhov & Muthén, 2013). We initially fitted a 2-class model, then increased the number of classes by one, comparing the model fit statistics to ascertain if the increase in classes produced groups that were substantively meaningful and had a good fit statistically. A high number of initial stage random starts (1000) were utilised to avoid local solutions (i.e., a false maximum likelihood), which is a common problem with LCA models (Holt et al., 2017). All analyses were run using M*plus* 8 (Muthén & Muthén, 2017).

Different sources of information should be considered when assessing the optimum number of latent classes, including the substantive meaningfulness and the level of statistical fit of the possible solutions (Gillet, Morin, Cougot, & Gagné, 2017; Marsh, Lüdtke, Trautwein, & Morin, 2009). Multiple statistical indicators can be used to aid decision making (McLachlan & Peel, 2000) and include: (a) Akaike's Information Criteria (AIC), (b) Consistent AIC (CAIC), (c) Bayesian Information Criteria (BIC), (d) sample size Adjusted Bayesian Information Criteria (ABIC), (e) Lo-Mendell-Rubin Likelihood RatioTest (LMR), (f) adjusted Lo-Mendell-Rubin

Likelihood RatioTest (aLMR), and (g) Bootstrap Likelihood Ratio Test (BLRT). For the four information criteria (AIC, CAIC, BIC, and ABIC), a lower value indicates better model fit. The two likelihood ratio tests (aLMR and BLRT) are accompanied by a *p* value for a comparison of model fit with a model with one less class, where a non-significant *p* value indicates the model with one less profile should be retained (Morin & Wang, 2016). Finally, entropy is an indicator of model precision with regard to classifying individuals into their most likely classes. Scores range from 0 – 1 with a higher value representing greater accuracy (Diallo, Morin, & Lu, 2016).

Simulation work has found four statistical indicators (CAIC, BIC, ABIC, and BLRT) to be most informative in identifying the correct number of classes (Nyland, Asparouhov, & Muthén, 2007; Peugh & Fan, 2013; Tofighi & Enders, 2008). Conversely, the AIC, LMR and aLMR are suboptimal for informing decisions regarding the number of classes because they tend to support the extraction of the incorrect number of classes (Diallo et al., 2016; Nyland et al., 2007; Peugh & Fan, 2013). All model fit indicators are reported here for clarity, though only the CAIC, BIC, ABIC, and BLRT were used to decide upon the optimal number of classes. Simulation work (Diallo et al., 2016) suggests that the ABIC and BLRT are preferred when entropy is lower (closer to .50), and the BIC and CAIC preferred when entropy levels are higher (closer to .90). Sample size is another important consideration for selecting the final model, because with a sufficiently large sample size the observed indicators may carry on suggesting the addition of more classes without reaching a minimum (Morin & Wang, 2016). In such cases, the information criteria can be presented in elbow plots to show the gains offered by additional classes; the point at which the line flattens shows the optimum number of classes (Wang, Morin, Ryan, & Liu, 2016).

Once the optimal solution had been identified, the covariates and outcomes were examined. For the covariates of age and sex, we used the R3STEP command (Asparouhov & Muthén, 2013). To explore the outcomes as auxiliary variables we utilised the automatic BCH approach (Bakk & Vermont, 2016). The BCH approach was chosen because it accounts for classification error and unequal variance across classes (Asparouhov & Muthén, 2014). Means for outcomes were computed for each class and compared. The analyses of the covariates (R3STEP) and outcomes (BCH) were conducted separately, as these two methods cannot be run simultaneously in M*plus* (Asparouhov & Muthén, 2014).

2.2. Study One Results

2.2.1. Descriptive statistics.

The proportions of the sample who had experienced a lifetime adversity category as well as descriptive statistics of the psychosocial factors by sex are detailed in Table 2.1. Sex differences were examined using chi-squared and *t* tests. Adversities related to 'loved one's illness/injury' (49.7%) and 'bereavement' (48.5%) were the most commonly reported. Males reported significantly higher proportions of being threatened/harassed than females (p = .007), with no other significant differences observed between groups for adversities (p = .102 - .857). In terms of psychosocial factors, males reported significantly higher levels of perceived bounce back resilience than females (p = .000).

Table 2.1. *Descriptive Statistics by Sex*

Study 1 (N = 324[#])				
Variables	Total (%)	Male (%)	Female (%)	X^2
LCA Indicators				
Illness/Injury	39.8	36.4	41.6	0.36
Threat/Harassment	31.2	40.9	26.2	7.36**
Violence	31.2	31.8	30.8	0.30
Bereavement	48.5	54.5	45.3	2.47
Loved Ones Illness/Injury	49.7	51.8	48.6	0.30
Others Death/Injury	35.2	40.9	32.2	2.39
Social/Environmental Stress	29.6	31.8	28.5	0.38
Relationship Stress	27.5	21.8	30.4	2.67
Outcomes	Overall *M (SD)*	Male *M (SD)*	Female *M (SD)*	T
BRS	3.44 (1.29)	3.85 (1.16)	3.22 (1.30)	-4.29***
HOPE	4.08 (.97)	4.04 (.96)	4.09 (.97)	0.47
LOT-R	3.64 (1.06)	3.74 (1.03)	3.60 (1.07)	-1.14
GSE	4.15 (.97)	4.22 (.98)	4.11 (.96)	-0.96
Study 2 (N = 1506)				
Variables	Total (%)	Male (%)	Female (%)	X^2
LCA Indicators (No. missing values)				
Illness/Injury (133)	46.1	48.9	42.5	5.48*
Threat/Harassment (141)	12.7	12.8	12.7	0.01
Violence (135)	23.0	24.1	21.6	1.16
Bereavement (130)	85.9	85.5	86.4	0.27
Loved Ones Illness/Injury (136)	55.9	51.2	62.0	15.93***
Others Death/Injury (138)	24.0	29.4	17.2	27.41***
Social/Environmental Stress (135)	42.7	39.6	46.5	6.55**
Relationship Stress (133)	40.9	38.9	43.5	3.04
Outcomes	Overall *M (SD)*	Male *M (SD)*	Female *M (SD)*	T
BRS	4.49 (1.21)	4.68 (1.15)	4.26 (1.24)	-5.76***
HOPE	2.93 (.52)	2.99 (.50)	2.85 (.54)	-4.51***
LOT-R	3.25 (.78)	3.29 (.74)	3.20 (.83)	-1.86
GSE	5.16 (1.18)	5.29 (1.11)	5.00 (1.23)	-4.11***

Note. BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LCA = latent class analysis; LOT-R = Life Orientation Test - Revised; * $p < .05$, ** $p < .01$, *** $p < .001$; [#] missing 24.

Table 2.2. *Model Fit Statistics for all latent class models tested*

Model	LL	AIC	CAIC	BIC	ABIC	ALMRT (*p*)	BLRT (*p*)	Entropy
Study 1								
1-class	-1769.967	3555.935	3568.267	3586.753	3561.374	Na	Na	Na
2-class	-1703.837	3441.674	3467.881	**3507.161**	3453.232	0.000	0.000	0.562
3-class	-1683.664	**3419.328**	**3459.409**	3519.485	**3437.004**	0.002	0.000	0.787
4-class	-1676.728	3423.457	3477.411	3558.284	3447.253	**0.050**	**0.775**	0.828
5-class	-1670.012	3428.024	3495.854	3597.521	3457.939	0.191	0.840	0.854
6-class	-1663.371	3432.741	3514.446	3636.908	3468.775	0.205	0.745	**0.860**
Study 2								
1-class	-6326.156	12668.312	12685.429	12710.145	12684.732	Na	Na	Na
2-class	-5892.634	11819.269	11855.641	11908.164	11854.162	0.000	0.000	0.667
3-class	-5805.008	11662.017	**11717.645**	**11797.974**	**11715.382**	0.000	0.000	**0.704**
4-class	-5788.248	11646.495	11721.381	11829.514	11718.333	**0.727**	0.000	0.633
5-class	-5772.175	11632.349	11726.491	11862.430	11722.660	0.462	0.000	0.593
6-class	-5760.745	**11627.490**	11740.887	11904.633	11736.273	0.021	**0.065**	0.602

Notes. ABIC = adjusted BIC; AIC = Akaike Information Criteria; ALMRT = adjusted Lo-Mendell Rubin Likelihood Ratio Test; BIC = Bayesian Information Criteria; BLRT = Bootstrap Likelihood Ratio Test; CAIC = Consistent AIC; LL = Loglikelihood. Boldface represents optimal fit.

2.2.2. Class identification.

Model fit statistics are detailed in Table 2.2. The CAIC, ABIC, and BLRT supported the superiority of the 3-class solution, whereas the BIC reached its minimum value at the 2-class solution. As the entropy value was high, we preferred the CAIC and BIC values over the ABIC and BLRT. An examination of the elbow plot (see Figure 2.1) shows that with the exception of BIC, the lowest values were at the 3-class solution and the slopes began to increase with the addition of classes. These data suggest a preference for the 2-class and 3-class solutions; we accepted the 3-class solution as the most viable because of the higher entropy value. Substantively, although the 2-class solution produced distinct classes in line with the study hypotheses, the addition of the third class clearly identified members who had experienced a different profile of adversities than the other classes. Notably, the 4-class solution produced a class consisting of only 12 members (3.4%), which evidenced a similar pattern to the third class.

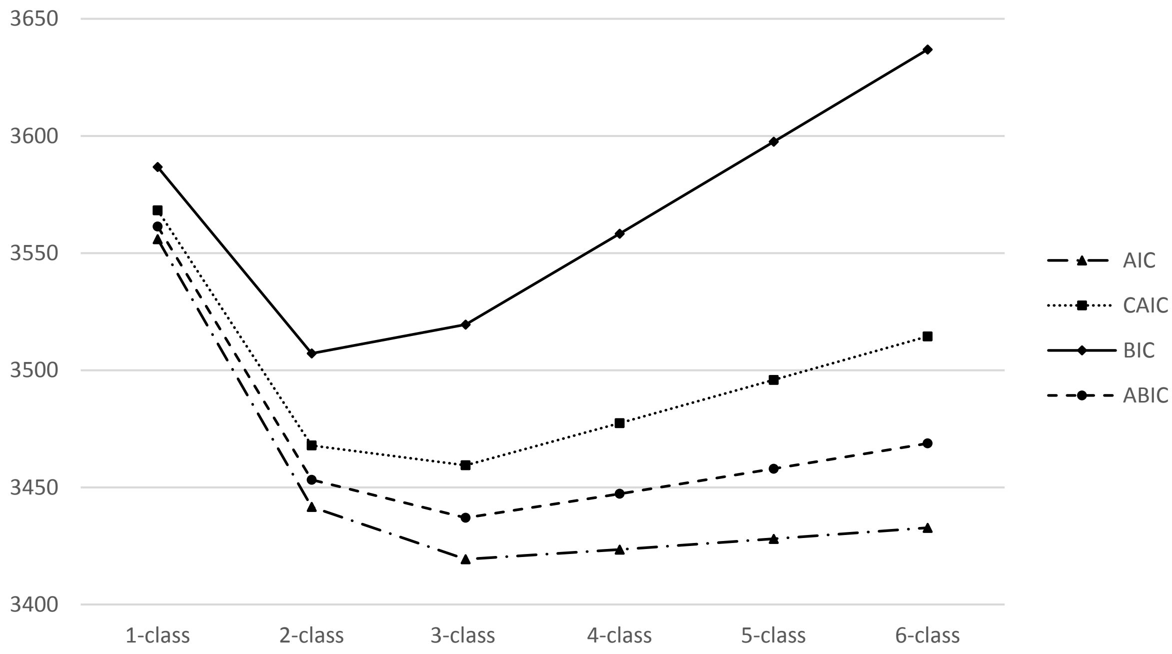

Figure 2.1. Elbow plot of the information criteria for latent class models in Study 1.
Note. ABIC = adjusted BIC; AIC = Akaike's Information Criteria; BIC = Bayesian Information Criteria; CAIC = Consistent AIC.

The estimated probabilities of the 3-class model are depicted in Figure 2.2. These plots display the probability that an individual within a latent class has experienced one of the lifetime adversity categories, and therefore how different latent classes are from each other across the lifetime adversity categories. The first class along the bottom of the plot, denoted by the dashed line, is characterised by relatively low probabilities (< .33) of having experienced each of the lifetime adversity categories. This class was labelled Low Polyadversity and accounted for 41.1% of the

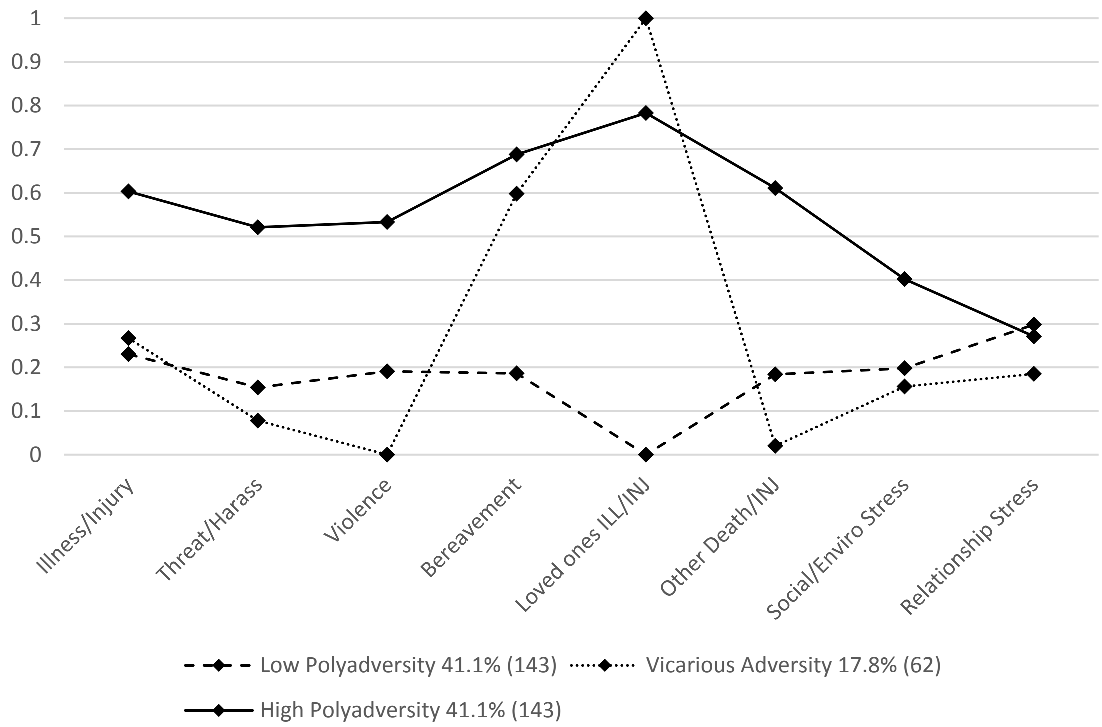

Figure 2.2. Category probability plot of the three LTA classes in Study 1.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

sample. The second class, identified by the dotted line, had a low probability (< .33) of experiencing all but two categories, where individuals reported moderate to high probabilities of experiencing bereavement (.60) and a loved one's illness/injury (1). This class contained 17.8% of the sample and was called Vicarious Adversity. The final class, denoted by the solid line, constituted the remaining 41.1% of the sample. This class was characterised by moderate to high probability of experiencing all categories, with the exception of relationship stress (.27); as such, we labelled this class as High Polyadversity.

2.2.3. Covariates.

Sex and age differences were observed across the three classes. With regards to sex, females were more likely than males to be in the High Polyadversity class than the Vicarious Adversity (-.95, SE = .47, p = .04) and Low Polyadversity classes (-.63, SE = .31, p = .04). With regard to age, participants in the High Polyadversity class were older than individuals in both the Vicarious Adversity (-.21, SE = .08, p = .01) and Low Polyadversity (-.09, SE = .03, p = .01) classes.

2.2.4. Outcomes.

An examination of differences across classes in terms of psychosocial factors (see Table 2.3) shows a single statistically significant difference, with those students in the Vicarious Adversity class reporting lower levels of optimism than individuals in the Low Polyadversity class. The standardised outcome scores across the three classes are depicted in Figure 2.3.

Table 2.3. *Means and Mean-Level Class Difference of Outcome Variables in Study 1*

Reference Class	Mean (*SD*)	High Polyad	Vicarious Ad	Low Polyad
High Polyad				
BRS	3.44 (0.13)		1.21	0.08
HOPE	4.14 (0.10)		0.78	0.43
LOT-R	3.58 (0.10)		0.95	2.15
GSE	4.14 (0.09)		0.32	0.29
Vicarious Ad				
BRS	3.19 (0.16)			2.23
HOPE	3.98 (0.14)			0.19
LOT-R	3.38 (0.16)			4.87*
GSE	4.03 (0.16)			1.08
Low Polyad		Overall Test		
BRS	3.49 (0.12)	2.28		
HOPE	4.05 (0.09)	0.83		
LOT-R	3.80 (0.10)	5.64		
GSE	4.21 (0.09)	1.17		

Notes. Ad = Adversity; BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LOT-R = Life Orientation Test - Revised; Polyad = polyadversity; * $p < .05$.

2.3. Study Two

The results of the first study provided initial support for our expectations regarding classes of individuals who experienced low or high amounts of adversities (H1 and H2), or one specific type of adversity (H3). However, there were minimal differences between these classes in terms of self-reported resilience resources (H4). In this study, we replicated the aforementioned methodological approach with a larger sample and broader representation of the community than university students, particularly with regard to lifetime adversity exposure.

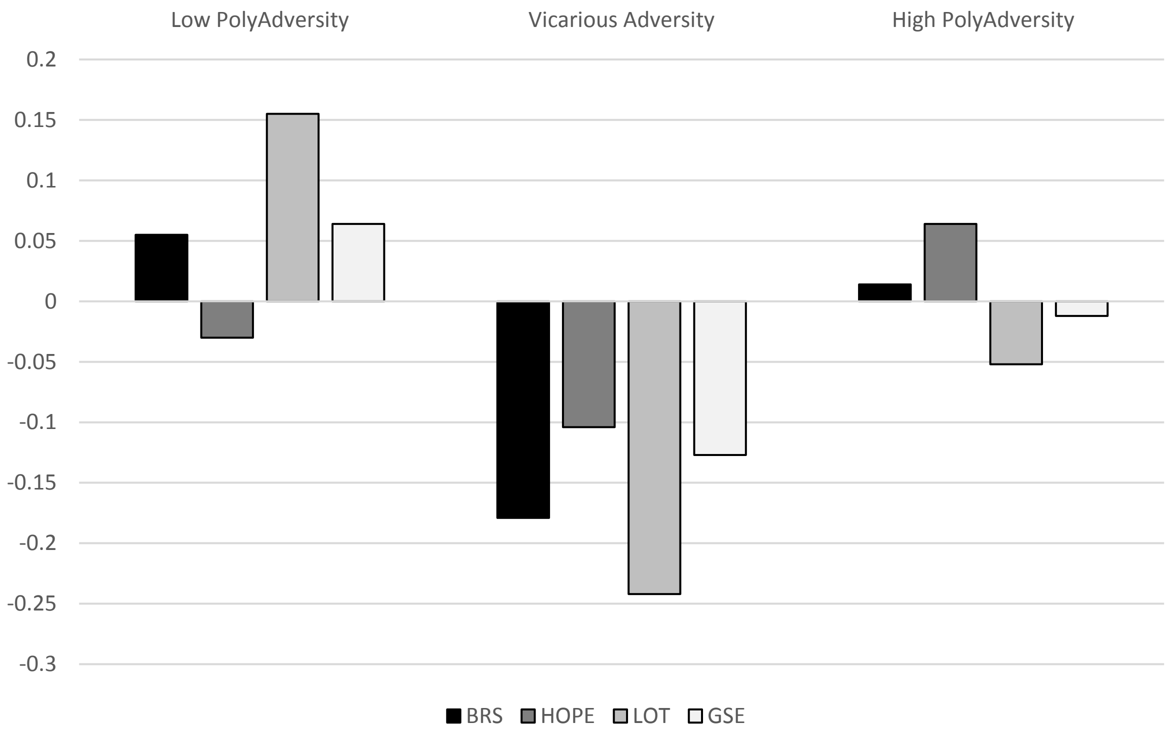

Figure 2.3. Standardised outcome variable scores across classes in Study 1.
Note. BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LOT = Life Orientation Test.

2.4. Study Two Methods

2.4.1. Participants.

A sample of 1506 participants (51.8% male) aged between 18 – 90 years (mean ± SD; 52.77 ± 17.01) were recruited through the Online Research Unit (ORU), Australia's largest on-line research panel. Simulation work suggests that a sample of this size should provide 80% power to detect small effects (~ w = .15) for a three or four class solution (Dziak, Lanza, & Tan, 2014).

2.4.2. Procedure.

Approval for the study was granted by an accredited Human Research Ethics Committee prior to data collection. Participants were recruited using an online data collection agency (http://theoru.com). From a population of approximately 400,000 participants, the data collection agency distributed our survey via e-mail to a random sub-sample representative of the general population in terms of age, gender and geographical location. Those participants who opted to participate in the study completed the survey online via Qualtrics (Qualtrics LLC, Utah, USA). The survey included questions regarding basic demographic information, the occurrence of past adversities and individual level resilience resources. Participants also received a five dollar shopping voucher as compensation for their time completing the survey.

2.4.3. Measures.

2.4.3.1. ***Adversity exposure.*** Similarly to Study 1, participants' exposure to adversity was assessed using an adapted version of Seery et al.'s (2010) measure. The measure differed slightly from the first study, in that 21, as opposed to 15, items were selected from the original measure (see supplementary material). The items again reflected the 8 broad categories of: own illness or injury, loved ones illness or injury, violence, bereavement, social/environmental stress, relationship stress, threat or harassment, and others death or injury. Participants indicated for each item whether they had experienced the adversity (0 = no, 1 = yes). A composite score was created for each category of adversity to indicate whether the category had been experienced or not.

2.4.3.2. ***Resilience resources.*** The measures for the individual level resources again captured the four broad resilience resources encapsulated by the concept of psychological capital, namely hope, efficacy, resilience, and optimism (Luthans et al., 2007). With the exception of self-efficacy, the measures were identical to tools used in Study 1. Test scores in this study demonstrated good reliability evidence; BRS ($\alpha = .86$), LOT-R ($\alpha = .81$), and hope ($\alpha = .90$).

2.4.3.2.1. *Self-efficacy.* An adapted measure based upon Bell and Kozlowski's (2002) tool was utilised to assess participant's self-efficacy in relation to lifetime adversity. The measure consisted of four items (e.g., "I am convinced that I can handle the demands in my life") that were assessed on a 7-point scale anchored by 1 strongly disagree and 7 strongly agree. Scores on the scale have demonstrated good levels of internal consistency evidence ($\alpha = .82$) in past research (Lindberg, Wincent, & Örtqvist, 2013). Internal reliability evidence was excellent in the present study ($\alpha = .95$).

2.4.4. Data analysis.

We used the same analyses as reported in Study 1.

2.5. Study Two Results

2.5.1. Descriptive statistics.

The proportions of the sample who experienced each lifetime adversity category and differences in psychosocial factors means are presented in Table 2.1. Bereavement was the most commonly reported adversity (85.9%) followed by loved one's illness/injury (55.9%). Males were more likely to have experienced illness/injury ($p = .019$) and other death/injury ($p = .000$), and less likely to have experienced loved one's illness/injury ($p = .000$) and social/environmental stress ($p = .010$) than females. Sex differences were also observed in outcome variables, with males reporting higher levels of bounce-back resilience ($p < .001$), hope ($p < .001$) and self-efficacy ($p < .001$).

2.5.2. Class identification.

Model fit statistics of all models tested are detailed in Table 2. The CAIC, BIC, and ABIC all suggested a 3-class solution, whereas the BLRT supported additional classes until the 6-class solution. The entropy level was generally high, which would suggest a preference for the CAIC and BIC over the ABIC and BLRT. An examination of the elbow plot shows a flattening of the slope at the 3-class model (see Figure 2.4). In light of these results, the 3-class solution was retained for further examination.

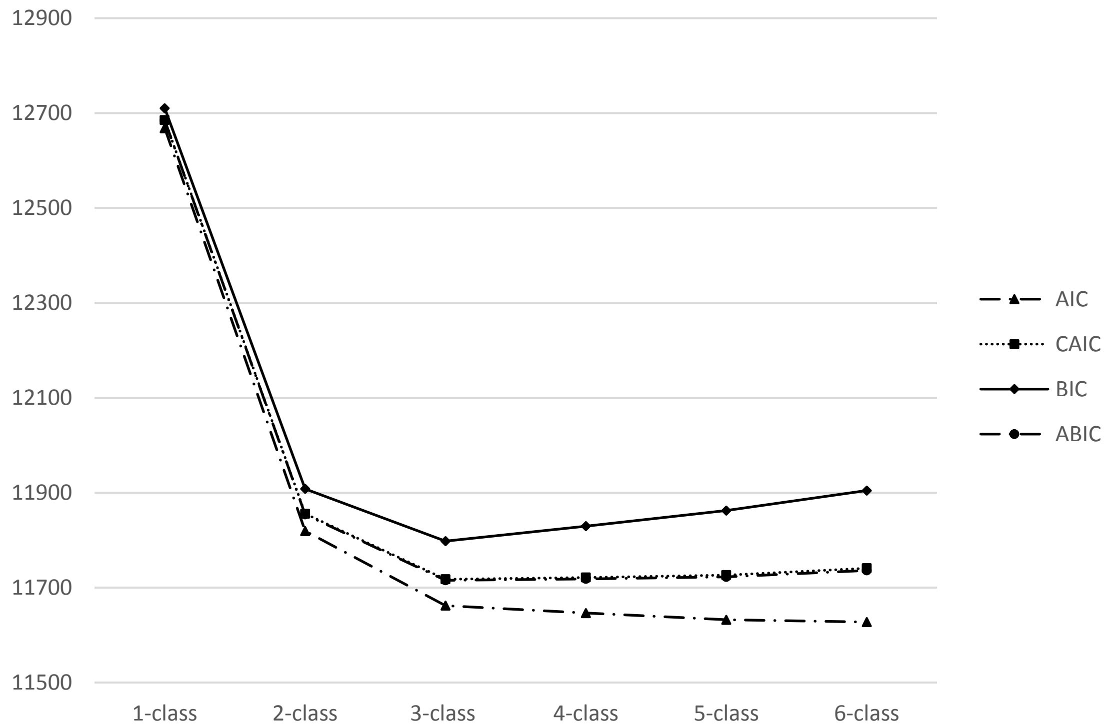

Figure 2.4. Elbow plot of the information criteria for latent class models in Study 2.
Note. ABIC = adjusted BIC; AIC = Akaike's Information Criteria; BIC = Bayesian Information Criteria; CAIC = Consistent AIC.

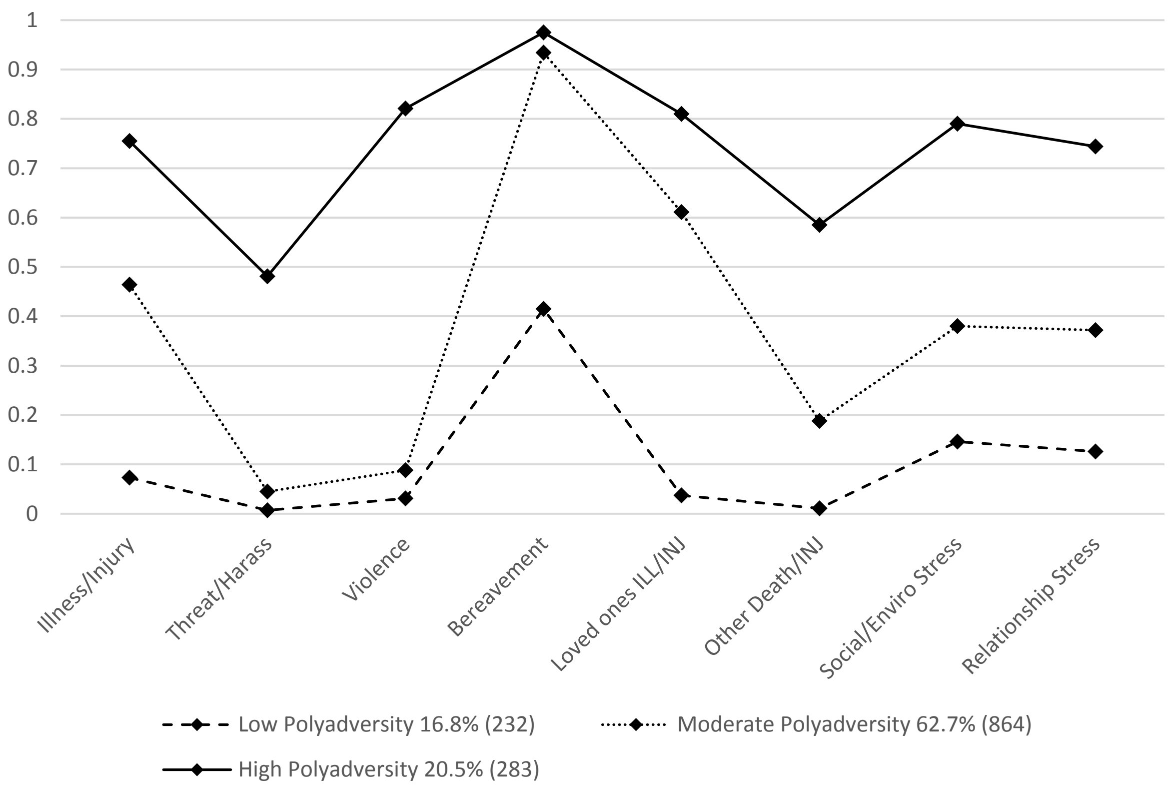

Figure 2.5. Category probability plot for the three LTA classes in Study 2.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

Three distinct classes can be seen in the estimated probability plot for an individual having experienced the examined lifetime adversity categories (see Figure 2.5). The first class can be seen along the bottom of the plot, denoted by the dashed line; participants in this class had the lowest probabilities of experiencing all lifetime adversity categories, with the exception of bereavement (.42). This class accounted for 16.8% of the sample and was labelled Low Polyadversity. The second class, denoted by the solid line, accounted for 20.5% of the sample. This class had the highest probabilities of experiencing all lifetime adversity categories (.66 – 1), with the exception of threat/harassment (.48) and other death/injury (.59). This class was labelled High Polyadversity. The final class, identified by the dotted line, can be seen to have category probabilities that fall between those of the other two classes. They experienced low probabilities in three categories (threat/harassment, violence, and other death/injury), moderate probabilities in four (illness/injury, loved one's illness/injury, social/environmental stress, and relationship stress), and a high probability of bereavement (.93). This class was labelled Moderate Polyadversity, and contained 62.7% of the sample.

2.5.3. Covariates.

A number of demographic differences were found between classes in terms of the observed covariates. Males were more likely to be in the Low Polyadversity class than the Moderate Polyadversity class (.55, SE = .24, p = .02). Individuals within the Low Polyadversity class were younger than those participants in both the Moderate Polyadversity (.08, SE = .01, p < .001) and High Polyadversity (.06, SE = .01, p < .001) classes. Finally, individuals in the High Polyadversity class were significantly younger than those people in the Moderate Polyadversity (-.02, SE = .01, p < .01) class.

2.5.4. Outcomes.

The results for the psychosocial variables show a number of differences between classes (see Table 2.4); standardised scores for each psychosocial variable across the three classes are depicted in Figure 6. Individuals in the Low Polyadversity class reported lower levels of resilience and optimism than people in the Moderate Polyadversity Class. The Low Polyadversity class also reported higher levels of all outcome variables than individuals in the High Polyadversity class. Participants in the High Polyadversity class reported lower levels of all psychosocial variables than individuals in the Moderate Polyadversity class.

Table 2.4. *Means and Mean-Level Class Difference of Outcome Variables in Study 2*

Reference Class	Mean (*SD*)	High Polyad	Mod Polyad	Low Polyad
High Polyad				
BRS	4.41 (0.09)		5.05*	7.20**
HOPE	2.95 (0.05)		0.40	8.80**
LOT-R	3.20 (0.06)		4.31*	6.33*
GSE	5.13 (0.10)		1.98	5.93*
Mod Polyad				
BRS	4.66 (0.06)			22.58***
HOPE	2.98 (0.02)			16.22***
LOT	3.36 (0.04)			20.01***
GSE	5.29 (0.05)			15.28***
Low Polyad		Overall Test		
BRS	4.05 (0.10)	22.67***		
HOPE	2.75 (0.05)	16.81***		
LOT	2.98 (0.07)	20.09***		
GSE	4.77 (0.11)	15.28***		

Note. Ad = Adversity; BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LOT = Life Orientation Test; Polyad = polyadversity; * *p* < .05, ** *p* < .01, *** *p* < .001.

2.6. Discussion

The current study utilised a person-centred approach to examine subpopulations of adversity exposure in two samples. We further examined differences between adversity class memberships and individual-level resilience resources. H1 was supported, such that we observed in both samples a class characterised by a relatively high likelihood of experiencing most or all of the assessed adversities (High Polyadversity). H2 was also supported with a class identified in both samples characterised by a lower likelihood of experiencing most or all of the assessed adversities (Low Polyadversity). H3 was partially supported, such that in Study 1 we identified a class characterised by a high likelihood of experiencing a specific trauma (Vicarious Adversity), yet in Study 2 the third class was characterised by moderate experiences of adversities (Moderate Polyadversity). H4 was also partially supported, such that in Study 2 the moderate polyadversity class was associated with higher levels of all resources than the high adversity class and higher levels in two of the four resources (optimism and resilience) than the low adversity class. However, these differences in reported individual-level resilience resources were largely absent from the student sample in Study 1, with the exception of optimism.

Although past work has examined how certain adversities can affect individual-level resilience resources (e.g., Kivimäki et al., 2005), there has been little research on how the experience of multiple adversities might contribute to an individual's resilience capacity. The question is of interest for both substantive (e.g., qualitative differences in adversity experiences) and practical (e.g., interventions, and health care) reasons. The latent classes we observed within the present study were largely in line with our hypotheses, such that we revealed three distinct classes that best represented polyadversity profiles. The review informing our hypotheses found seven of the nine reviewed studies reported a 'high-trauma class' and all nine reported a 'low-trauma class' (Contractor et al., 2018). Classes with a similar interpretation were observed in the current study across the student and community samples. Although the two samples revealed both high and low polyadversity classes with similar numbers within each, the proportional distribution of classes differed between studies. Specifically, in the student sample the high and low polyadversity classes were comprised of the same proportion of participants (41.3%), whereas in the community sample classes the proportion of members was roughly half (low = 16.8%; high =

20.5%). Contractor et al. (2018) found in their review that the classes characterised by high levels of adversity were the smallest. It should be noted that within the review, the studies mainly focused on interpersonal adversities (8 of 9). It has also been found that when categorising participants by total number of adversities experienced (e.g., zero, low, high), the high category contained more participants than the zero- and low-adversity categories (Seery et al., 2010). A key methodological difference with past work is that we considered a broad array of lifetime adversities, many of which were absent from previous research on adversity exposure. This extension was informed by recommendations for researchers to take into consideration adversities beyond the narrow focus of interpersonal adversities (Contractor et al., 2018). This widening of scope may account for the observed differences in the proportions of those who reported higher levels of polyadversity.

Differences between latent classes of adversity exposure in terms of individual-level resilience resources were mixed. Briefly, the findings of Study 2 were consistent with our expectations, such that members of the moderate polyadversity class reported the highest levels of all resources across the three classes. These differences were statistically significant for all four resilience resources when comparing the moderate class with the high polyadversity class, yet only for bounce back resilience and optimism when comparing against the low polyadversity class. Conceptually, the findings are consistent with the view that a moderate amount of adversity is optimal, over high and no adversity, to allow for toughening or the opportunity for individual's to develop and/or refine resilience resources (Dienstbier, 1992; Höltge et al., 2018). Speculatively, this opportunity may occur via systematic self-reflection strengthening resilience (Crane et al., 2019). Empirically, the findings are consistent with previous work which has identified a U-shaped association between lifetime adversity and indicators of positive functioning or an inverted U-shaped association with markers of negative functioning (e.g., Höltge et al., 2018; Kondrak & Seery, 2015; Seery et al., 2010; Seery et al., 2013; Seery, Leo et al., 2010). These series of studies consistently found that exposure to some adversity was associated with adaptive (higher/lower) levels of a variety of psychological well-being outcomes (e.g., life satisfaction, global distress, post-traumatic stress) than a history of no/low or high levels of adversity. Furthermore, exposure to some adversity was associated with being less negatively affected by recent adversity, consistent with the development of resilience (Seery et al., 2010; Seery, Leo et al., 2010).

Our findings add another layer to previous work by suggesting that exposure to a moderate amount of adversity builds resilience through providing the opportunity to develop these individual-level resources. In turn, research has supported the adaptive nature of these resilience resources, such that people who report higher levels fare better psychologically and physiologically in terms of perceived stress (Lines et al., In Press; Riolli, Savicki, & Richards, 2012), well-being (Avey, Reichard, Luthans, & Mhatre, 2011), BMI, and blood cholesterol concentration (Luthans, Youssef, Sweetman, & Harms, 2013). Interestingly, members of the high polyadversity class also had significantly lower levels of all resources than those in the low polyadversity class. This suggests that exposure to fewer adversities may enable an individual to develop these adaptive resources to a lesser extent than a moderate amount of adversity, though exposure to high amounts is highly detrimental to the perceived availability of resources. In a recent review, members of high polytraumatisation classes demonstrated the worst health outcomes when compared to those in other classes (e.g., greater likelihood of posttraumatic stress disorder, anxiety, depression, alcohol and drug use and self-harm; Contractor et al., 2018). These deleterious effects may be a result of the sensitising role of stressors or adversities, in that exposure to an adversity may sensitise an individual to a lower level adversity in the future (Stroud, Davila, Hammen, & Vrshek-Schallhorn, 2011). This sensitisation may lead to maladaptive responses being triggered, undermining resilience (e.g., rumination, self-doubt) in response to lesser adverse events which in turn develops into one's natural response to an adversity (Crane et al., 2018). In light of the frequently observed beneficial effects of a moderate amount of exposure to adversity, research exploring this sensitisation hypothesis should also look at both positive and negative effects.

Differences in individual-level resilience resources between the three classes among the student sample were mixed. Of all the comparisons, only one difference was statistically significant, whereby individuals in the vicarious adversity class reported lower levels of optimism than people in the low polyadversity class. One key difference between the two classes is in the category of loved one's illness/injury, with all members of the vicarious class and none in the low polyadversity having experienced this type of adversity. Kivimäki et al. (2005) examined changes in optimism and pessimism following death or severe illness of a loved one, and found that pessimism rose by 10% following the onset of an illness of a loved one, though fell by 4% with the absence of such an adversity. This past work provides a useful backdrop upon which to interpret the finding in the current study, as we used a cumulative score for optimism based on the support for the summative unidimensional approach within the literature (Carver & Scheier, 2018). This observation can be seen as important as higher levels of optimism are associated with protective benefits following both severe and mild adverse events (e.g., Chang & Sanna, 2003; Kivimäki et al., 2005). Therefore, it may be beneficial in future research to examine whether interventions aiming to increase optimism (e.g., Blackwell et al., 2013) help individuals via these adaptive benefits following bereavement, or illness/injury of a loved one.

The main difference between the two samples in this study was the nature of the third class. Both classes were characterised by a relatively high ($\geqslant 0.6$) likelihood of experiencing the adversities of bereavement and loved ones illness/injury. However, the community sample in Study 2 had a moderate probability of having experienced an illness/injury, social/environmental stressor, and relationship stressor alongside the two vicarious adversities, whereas the student sample evidenced a low probability of all other adversities. Within both samples the shapes of the probability plots are similar for this third class, though they differed on the proportion of members with only 17.3% in the first sample, compared to 62.7% in the second sample. Interestingly, in Contractor et al.'s (2018) review none of the papers reported a moderate class, though all reported at least one specific trauma class with proportions ranging from 3.6% - 62.6% (mean = 22.1%). The nature of this third class makes comparison between the two classes complex as they are substantively different; that is, one is characterised by endorsement of specific adversities whereas the other is characterised by an overall moderate degree of exposure. The observed differences may have emerged due to the nature of the samples within the two studies, with the first consisting of students (Mage = 22.09) and the second an older community sample (Mage = 52.77). One might think that with a higher age the older participants have had more time to experience adversities than their younger counterparts, though the adversities faced by younger people may have occurred in more recent memory and are thus more easily recalled (Seery & Quinton, 2016). Indeed, when age has been controlled for as a covariate in past research, it has no effect on outcomes across student and community samples (e.g., Seery et al., 2010; Seery et al., 2013; Seery, Leo et al., 2010). A second possible reason for the findings is that within younger samples of individuals, the categories of bereavement and loved one's illness/injury may be more pertinent. In their study of

68,894 individuals, Benjet and colleagues (2016) found that younger (18-34 years) participants were more likely than older (65+ years) people to report having experienced, amongst others, unexpected death of a loved one. Finally, adversities that are important for this age group may have been missing from the checklist used in the current study and past work, or were not entirely obvious to participants (e.g., peer bullying).

2.6.1. Strengths and limitations.

Key strengths of this study include the person-centred approach to examining adversity exposure, differential effects of adversity experiences and resilience resources, and tests of the study hypotheses in two independent samples. Nevertheless, the current study is not without limitation. Our focus on four individual-level resilience resources may be seen as narrow and therefore requires expansion within future research (e.g., social resources). Furthermore, the assessment of adversity exposure was characterised by a dichotomous yes/no response, and therefore excluded an indication as to when the adversity occurred in their developmental pathway. Future research may look to consider the breadth (i.e., number of different adversities) and the depth (i.e., the frequency, intensity, and duration) of adversities experienced. Despite our efforts to examine the robustness of the findings across two samples, the extent to which the nature of the tripartite typology of lifetime adversity exposure generalises remain uncertain, particularly with respect to the third class where we observed important differences between the university study and community samples and the minimal demographic information collected from our two samples. The cross-sectional nature of the study means that we cannot speak confidently to causality and can only infer such relations from theory (e.g., toughness). Finally, the data was collected via self-report and as such may be affected by self-report biases.

2.6.2. Conclusion.

The current study provides initial evidence of how exposure to lifetime adversities group together in two samples, and how class membership is associated with individual-level resilience resources. Across two independent samples – one a group of university students and the other a largely representative community sample – we revealed support for a tripartite representation of individual’s experiences of multiple lifetime adversities. A low polyadversity and high polyadversity profile were evident among both samples, with the third class characterised by either two core vicarious adversities (students) or moderate levels across several adversities (community sample). Mixed support was found for our hypotheses regarding differences in individual-level resilience resources between classes; the adaptive nature of a moderate amount of adversity experiences was supported in the community sample but not the students. Our findings regarding the adaptive nature of adversity in the community sample are consistent with literature in other areas. For example, within the context of competitive sport, adversity has been found to distinguish between the super-elite (won at least one gold plus another gold or silver at a major championship) and elite (received athlete personal awards but not medalled at a major championship) athletes, particularly when coupled with a positive sport-related event (Hardy et al., 2017). Broadly, our findings underscore the importance of person-centred approaches to advancing our understanding on the nature of adversity experiences, their interplay, and their associations with resilience resources.

2.7. Chapter 2 - Supplementary Materials

Provided below are the model fit statistics and category probability plots for a series of Latent Profile Analyses (LPA) carried out on both samples using continuous indicators of adverse events categories. As with the main analyses the CAIC, BIC, ABIC and BLRT were used to decide upon the optimal number of profiles. Within both samples the entropy values were all above .80 suggesting a preference for the BIC and CAIC. A lower value on these criteria indicates a better model fit, and in both samples these values continued to decrease with the addition of profiles, up to 7 (see Table S1). This trend can be seen in the elbow plots for samples 1 and 2 (Figure S1 and S8, respectively), in which the point at which the line flattens out shows the optimum number of classes. In both of the plots, the lines continue to decrease with no obvious plateau. In addition, several profiles were characterised by a number of participants that was less than 5% of the sample population, from the 4 profile solution in Study 1 and the 2 profile solution in Study 2, which are typically considered spurious (e.g., Hipp & Bauer, 2006; Lubke & Neale, 2006). Finally, in LCA's a common error is that a local solution only is reached for the tested models; to avoid this issue it is important to use multiple sets of starting values to find the global maximum (i.e. replicate the highest log-likelihood; Berlin et al., 2014). The default in Mplus is 20; despite increasing the random starts to 20000 with 50 iterations for each start and 200 bootstrap draws, producing an extremely computationally heavy analysis, a number of the models converged only on a local solution and therefore the loglikelihood was considered untrustworthy. Local maxima typically indicates that too many classes were extracted. When considered in conjunction with the model fit statistics, a best fitting model was unable to be identified when using a continuous indictor for each adverse event category.

Table S2.1. *Model Fit Statistics for all Latent Profile Models Tested*

Model	LL	AIC	CAIC	BIC	ABIC	ALMRT (*p*)	BLRT (*p*)	Entropy
Sample 1								
1-class	-5119.844	10271.689	10296.353	10333.324	10282.567	Na	Na	Na
2-class	-4906.375	9862.749	9901.289	9959.054	9879.746	0.14	.000	0.985
3-class	-4773.303	9614.606	9667.020	9745.581	9637.722	0.26	.000	0.982
4-class#	-4504.131	9094.262	9160.550	9259.907	9123.497	0.87	.000	1
5-class#	-4342.133	8788.266	8868.428	8988.581	8823.620	0.41	.000	0.998
6-class#	-4261.617	8645.233	8739.270	8880.218	8686.706	0.21	.000	0.991
7-class#	-4194.570	8529.140	8637.051	8798.795	8576.732	0.69	.000	0.987
Sample 2								
1-class	-21625.618	43283.235	43317.469	43366.901	43316.075	Na	Na	Na
2-class	-20175.709	40401.418	40454.907	40532.146	40452.731	0.00	.000	0.997
3-class	-19476.914	39021.827	39094.573	39199.617	39091.612	0.00	.000	0.998
4-class	-18955.966	37997.932	38089.933	38222.784	38086.190	0.06	.000	0.993
5-class#	-18448.499	37000.999	37112.255	37272.913	37107.729	0.06	.000	0.994
6-class#	-17954.406	36030.813	36161.325	36349.789	36156.016	0.42	.000	0.994
7-class#	-17554.665	35249.331	35399.100	35615.369	35393.007	0.36	1	0.979

Note. LL = Loglikelihood; AIC = Akaike Information Criteria; CAIC = Consistent AIC; BIC = Bayesian Information Criteria; ABIC = adjusted BIC; ALMRT = adjusted Lo-Mendell Rubin Likelihood Ratio Test; BLRT = Bootstrap Likelihood Ratio Test; # Model not correctly identified.

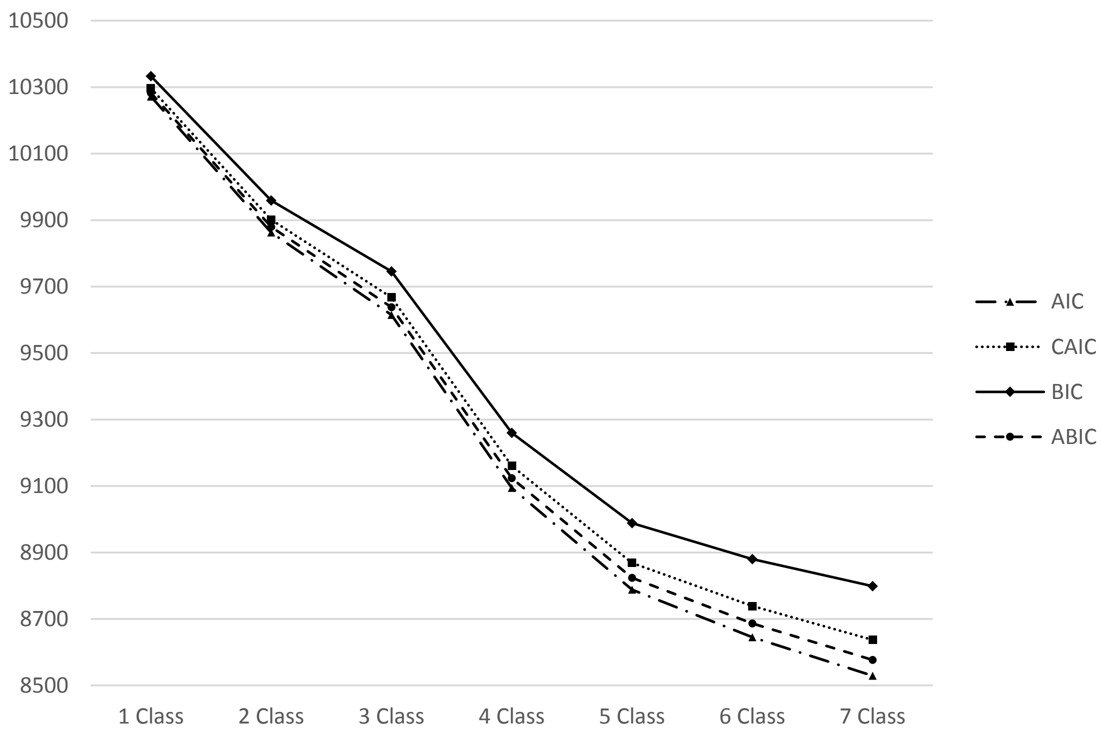

Figure S2.1. Elbow plot of the information criteria for latent profile models in Sample 1.
Note. AIC = Akaike's Information Criteria; CAIC = Consistent AIC; BIC = Bayesian Information Criteria; ABIC = adjusted BIC.

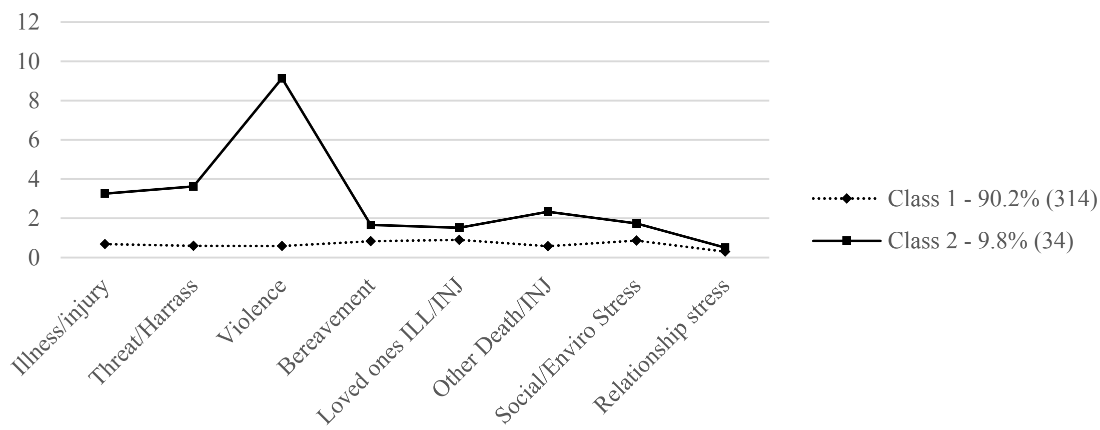

Figure S2.2. Category means plot for 2 classes in Sample 1.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

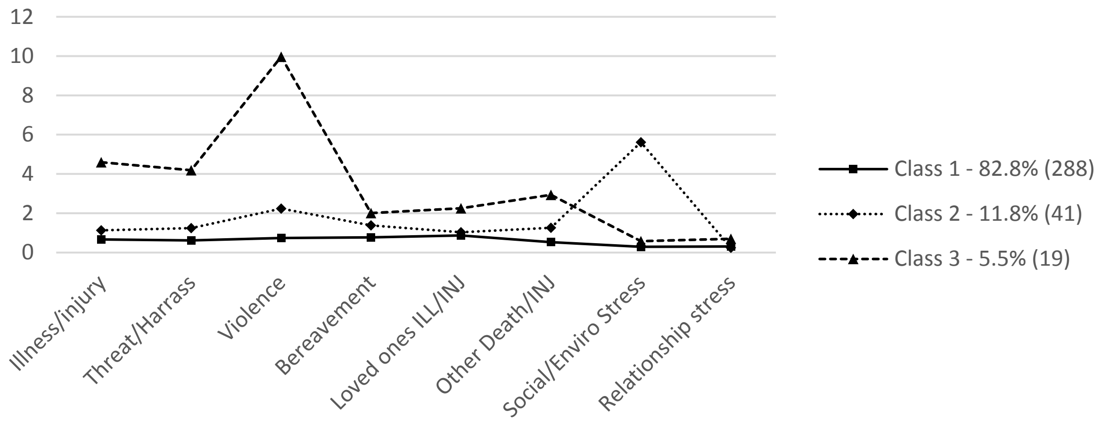

Figure S2.3. Category means plot for 3 classes in Sample 1.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

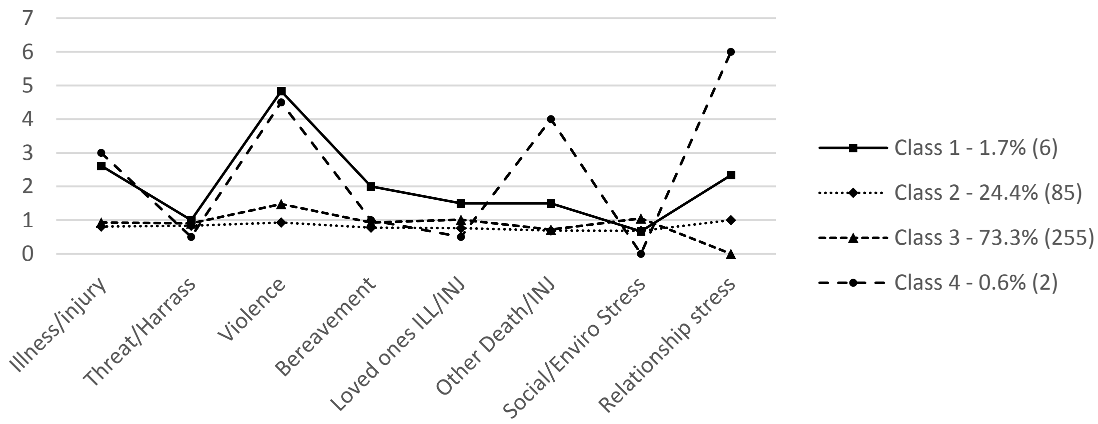

Figure S2.4. Category means plot for 4 classes in Sample 1.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

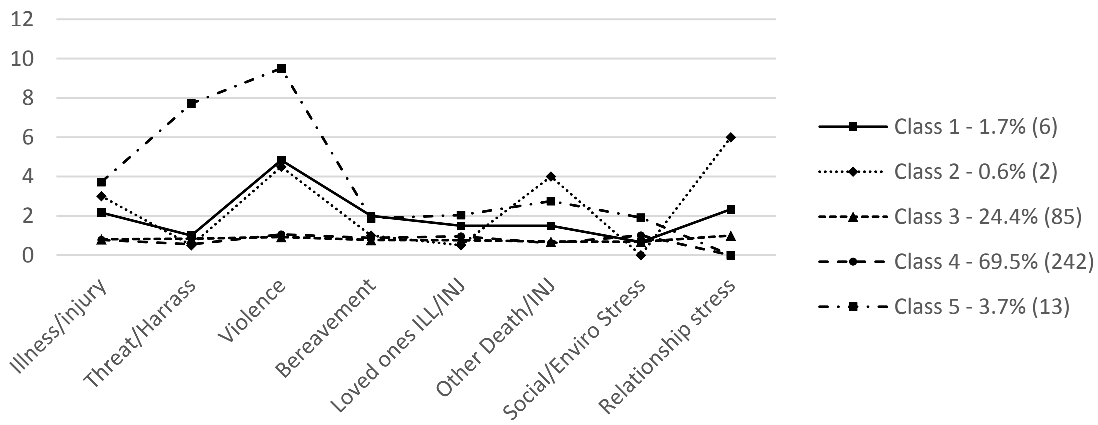

Figure S2.5. Category means plot for 5 classes in Sample 1.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

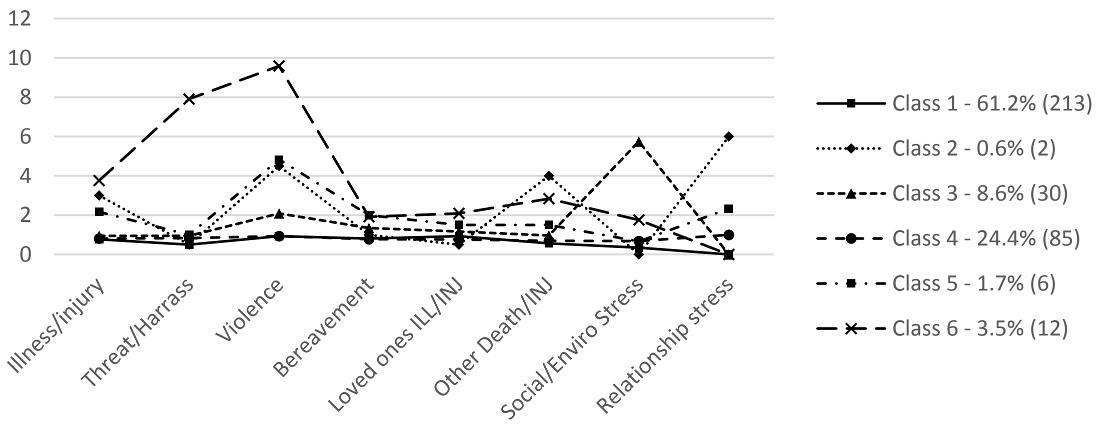

Figure S2.6. Category means plot for 6 classes in Sample 1.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

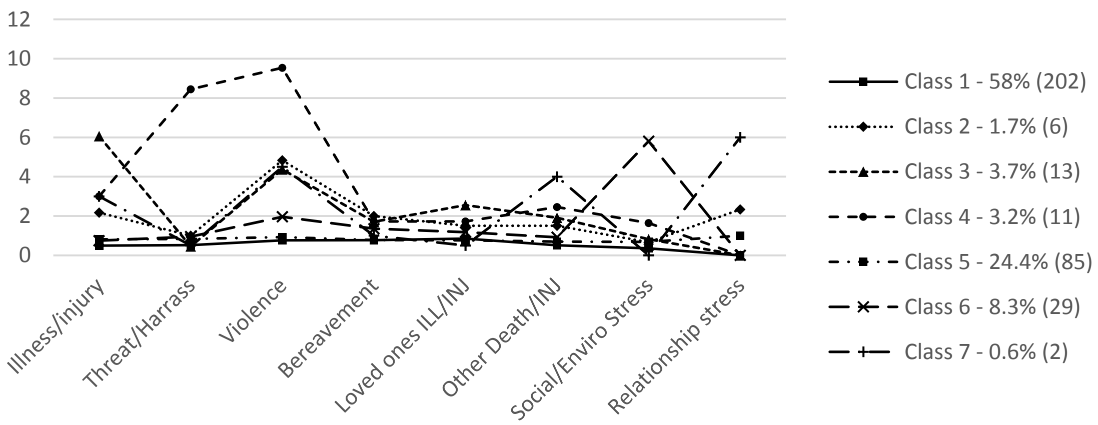

Figure S2.7. Category means plot for 7 classes in Sample 1.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

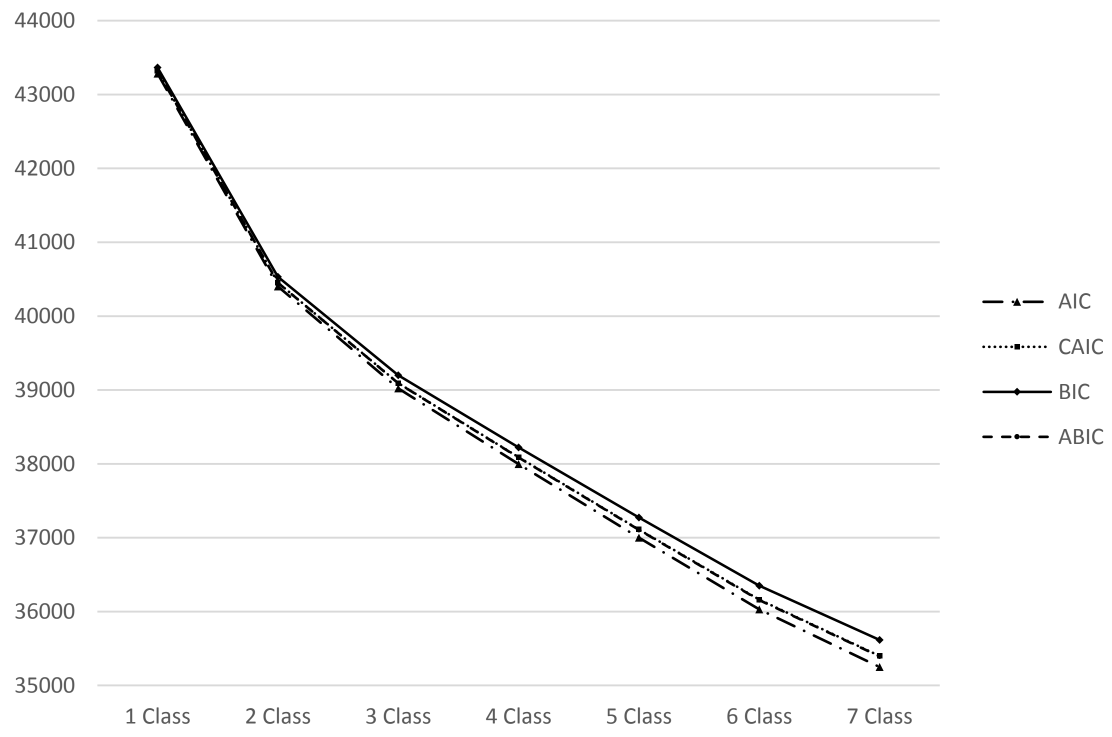

Figure S2.8. Elbow plot of the information criteria for latent profile models in Sample 2.
Note. AIC = Akaike's Information Criteria; CAIC = Consistent AIC; BIC = Bayesian Information Criteria; ABIC = adjusted BIC.

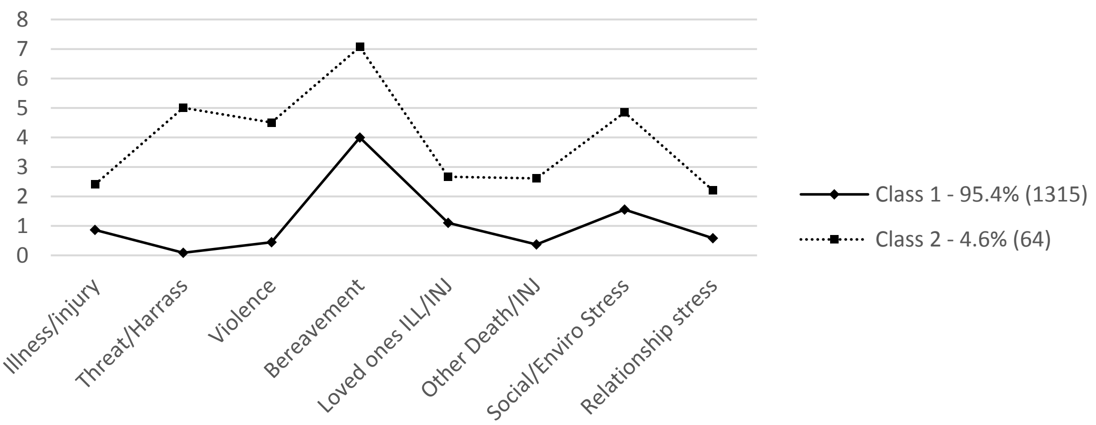

Figure S2.9. Category means plot for 2 classes in Sample 2.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

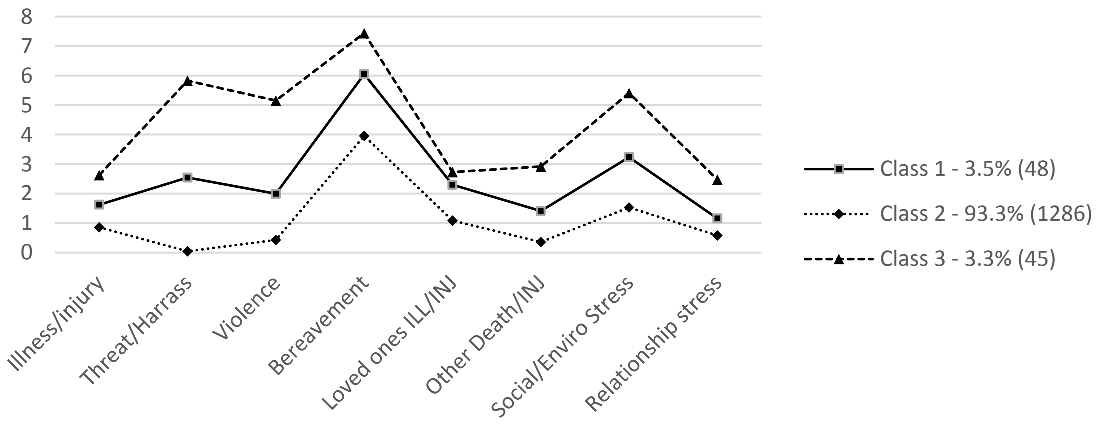

Figure S2.10. Category means plot for 3 classes in Sample 2.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

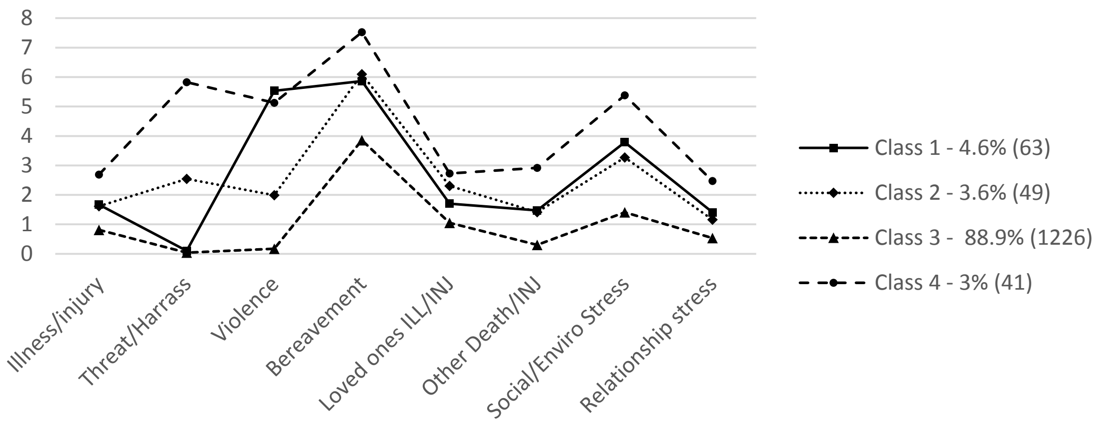

Figure S2.11. Category means plot for 4 classes in Sample 2.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

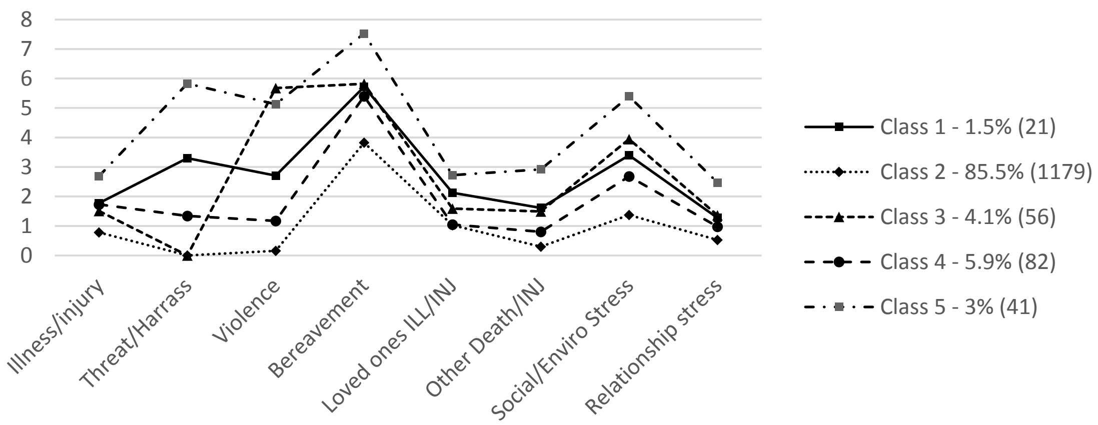

Figure S2.12. Category means plot for 5 classes in Sample 2.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

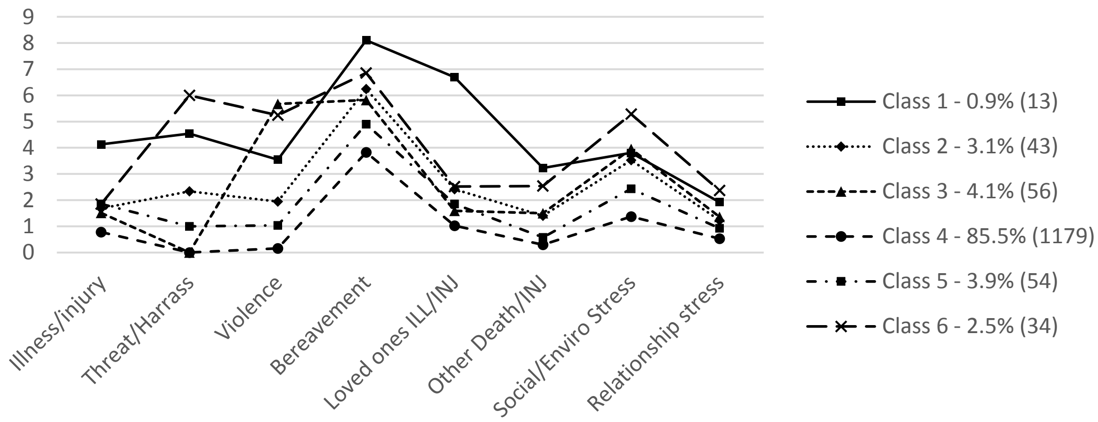

Figure S2.13. Category means plot for 6 classes in Sample 2.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

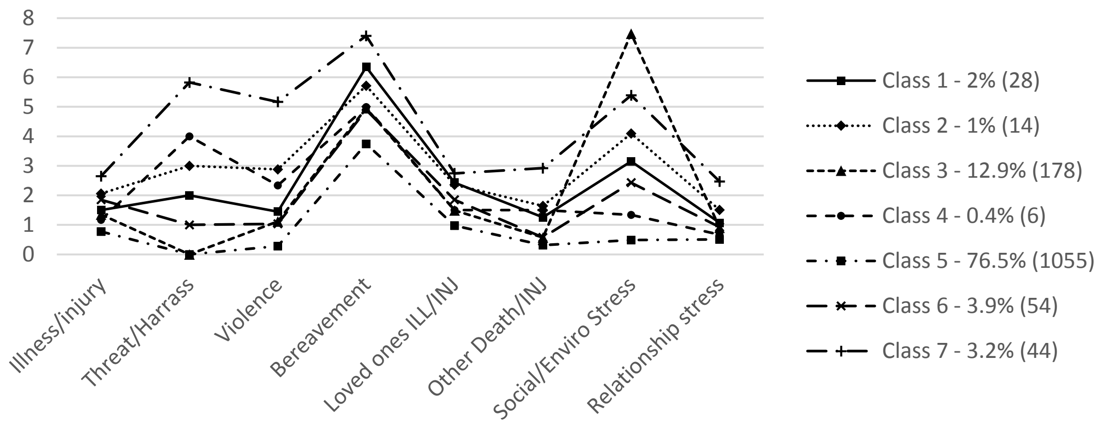

Figure S2.14. Category means plot for 7 classes in Sample 2.
Note. Enviro = Environmental; Harass = Harassment; ILL = Illness; INJ = Injury.

Lifetime Adversity Scale Study 1

Item No.	Adversity	Category
1	Major illness (physical or psychological)	Illness/Injury
2	Life threatening accident	Illness/Injury
3	Fire, flood or other natural disaster	-
4	Witnessed someone badly injured or killed	Others Death/Injury
5	Parents divorced	Relationship Stress
6	Sexual abuse	Violence
7	Serious physical attack or assault	Violence
8	Threatened/harassed without a weapon	Threat/Harassment
9	Threatened/harassed with a weapon/held	Threat/Harassment
10	Tortured or victim of terrorists	-
11	Domestic violence	Violence
12	Witnessed domestic violence	Violence
13	Death of a loved one (e.g., parent, sibling)	Bereavement
14	Serious illness or accident of a loved one (e.g., parent, sibling)	Loved Ones Illness/Injury
15	Discrimination because of your ethnicity, religious background, or sexual orientation	Social/Environmental Stress
16	Serious financial difficulties (e.g., no money for food or housing)	Social/Environmental Stress
17	Witnessed someone suicide or attempt suicide	Others Death/Injury
18	Any other stressful event, please specify;	-
19	Did you ever suffer a great shock because one of these events happened to someone close to you?	-

Lifetime Adversity Scale Study 2

Item No.	Adversity	Category
1	Suffered a serious accident or injury	Illness/Injury
2	Were physically attacked or assaulted (including domestic violence)	Violence
3	Serious accident or injury of a loved one	Loved Ones Illness/Injury
4	Suffered a serious illness	Illness/Injury
5	Serious illness of a loved one	Loved Ones Illness/Injury
6	Witnessed someone being injured or killed	Others Death/Injury
7	Witnessed family member injured or killed	Others Death/Injury
8	Been coerced with threats of harm to yourself or family	Threat/Harassment
9	Experienced forced separation from family/children	Social/Environmental Stress
10	Had combat experience	Violence
11	Death of your spouse/partner	Bereavement
12	Death of your mother	Bereavement
13	Death of your father	Bereavement
14	Death of a sibling	Bereavement
15	Death of your child	Bereavement
16	Death of a Friend	Bereavement
17	Death of a close family member	Bereavement
18	Got divorced yourself	Relationship Stress
19	Experienced your parents' divorce	Relationship Stress
20	Being bullied at work or other places (e.g. school)	Social/Environmental Stress
21	Experienced discrimination on the basis of sex, sexuality, race, other	Social/Environmental Stress

Note: The following chapter has been published in Sport, Exercise, and Performance Psychology.

Reference for manuscript

Lines, R. L. J., Ducker, K. J., Ntoumanis, N., Thøgersen-Ntoumani, C., Fletcher, D., McGarry, S., & Gucciardi, D. (in press). Stress, physical activity, and resilience resources: Tests of direct and moderation effects in young adults. *Sport, Exercise, and Performance Psychology*, https://doi.org/10.1037/spy0000152

Chapter 3: Stress, Physical Activity, and Resilience Resources: Tests of Direct and Moderation Effects in Young Adults

Stress is a common part of everyday life, with most people at some point exposed to events which may affect their mental or physical health (Cooper & Quick, 2017). Stressors range from everyday hassles (e.g., financial worries) to life changing events (e.g., death of a loved one). Within the stress literature (e.g., Blascovich, 2008; Lazarus & Folkman, 1984), stress is said to occur when individuals perceive events or situations in their environment as taxing or exceeding their available resources. Broadly speaking, resources are concepts that "either are centrally valued in their own right (e.g., self-esteem, close attachments, health, and inner peace) or act as a means to obtain centrally valued ends (e.g., money, social support, and credit)" (Hobfoll, 2002, p. 307). When individuals perceive that their resources exceed the perceived demands of a stressor, stress is appraised as a challenge, yet when demands outweigh resources stress is evaluated as a threat (Blascovich, 2008). Following an appraisal of threat, stress typically leads to physiological and/or psychological responses that can be maladaptive for one's functioning (Chrousos, 2009). The deleterious health outcomes of stress are well-established and encompass both psychological (e.g., depression, generalised anxiety disorder, post-traumatic stress disorder) and physiological consequences (e.g., cardiovascular disease, obesity, Type 2 diabetes; Thoits, 2010).

When examining the physiological responses to stress, one of the most widely studied markers is associated with activation of the hypothalamic-pituitary-adrenal (HPA) axis, namely the release of cortisol in response to the perceived threat or challenge. The HPA is highly responsive to stimulation from external stressors with acute levels of reactivity allowing for beneficial adaptive responses, namely "fight or flight" (Gidlow, Randall, Gillman, Smith, & Jones, 2016). However, dysregulation in secretion over longer periods and/or high levels of repeated reactivity are maladaptive and represent a serious issue for both psychological and psychological health (Short et al., 2016; Stalder et al., 2017). Therefore, measures of HPA activity and its secretion of steroid hormones, particularly cortisol, have become important physiological markers of stress (Fischer et al., 2017).

Cortisol levels have traditionally been determined from salivary, blood, and/or urine samples (Stalder & Kirschbaum, 2012). Although well-established within the literature, a single assessment of these methods provides only a snapshot of acute circulating cortisol levels at the time of sampling (saliva and plasma), or in the case of urine cortisol secretion a 24 hour period (Dettenborn, Tietze, Kirschbaum, & Stalder, 2012; Gerber, Jonsdottir, et al., 2013; Stalder & Kirschbaum, 2012). This temporal dimension represents a problem when attempting to assess cortisol levels over longer periods because HPA activity is highly variable (Stalder et al., 2017). Furthermore, the aforementioned methods are affected by a number of factors including circadian rhythmicity, transient levels of stress at the time of sampling, and factors that take place before sampling such as smoking, alcohol, physical activity (PA), and food consumption (e.g., Gerber, Kalak, et al., 2013; Gidlow Stalder & Kirschbaum, 2012; Stalder et al. 2017). Thus, although these methods have utility for capturing acute reactivity of the HPA, their use in measuring long-term or chronic activity is limited (Stalder et al., 2017).

The analysis of hair cortisol concentration (HCC) can attenuate the methodological limitations of traditional methods (Gerber, Jonsdottir, et al., 2013; Short, et al., 2016; Stalder & Kirschbaum, 2012). As human hair grows approximately 1 centimetre per month (Wenning, 2000), HCC provides a reliable retrospective measure of cumulative secretion for up to 6 months (Kirschbaum, Tietze, Skolunda, & Dettenborn, 2009). Research has linked HCC to conditions that are known to alter HPA functioning, such as Cushing's syndrome (Chrousos, 2009; Gidlow, Randall, Gillman, Silk, & Jones, 2016). There is also strong evidence of the overall validity of HCC (e.g., Short et al., 2016; Stalder & Kirschbaum, 2012), including good test re-test reliability and high levels of intraindividual stability (Stalder et al., 2017). For these reasons, HCC has been used increasingly over the past decade to examine the effects of chronic stress on a broad range of health-related outcomes (e.g., Stalder et al., 2017), including PA (e.g., Gerber, Jonsdottir, et al., 2013) and sedentary behaviour (SB)(e.g., Teychenne, Olstad, Turner, Costigan, & Ball, 2018).

The beneficial effects of PA on a wide range of positive health outcomes, both psychological and physical, are well-established within the literature (e.g., Stults-Kolehmainen & Sinha, 2014). Despite the wealth of information on its numerous benefits, many individuals do not partake in regular or sufficient levels of PA to confer health benefits (Hallal et al., 2012). It is also important to consider sedentary time (i.e., seated or reclined posture with low energy expenditure; Tremblay et al., 2017) alongside PA because high levels of "sitting time" can co-exist with an active lifestyle

(Healy et al., 2008) and have deleterious effects on health (Ekelund et al., 2018). Stress is one of the major considerations when it comes to understanding why people engage in little PA or perform none at all (Burg et al., 2017), with research typically examining the salubrious effects of PA on stress (e.g., Wipfli, Rethorst, & Landers, 2008). However, a systematic review of 168 studies examining the association between stress and PA and SB (Stults-Kolehmainen & Sinha, 2014) found a majority of the reviewed studies (72.8%) identified a negative association between stress and PA, suggesting there may be an inverse association with stress negatively affecting one's PA. In the case of prospective studies (n=55), 76.4% found stress to predict lower levels of PA and exercise or higher levels of SB. Thus, the stressors people face may act as a barrier to healthy behaviours (e.g., PA) and perpetuate unhealthy choices (e.g., sedentary activities; Burg et al., 2017). Based upon the recent review, the effects of stress on PA do not appear to be universal and therefore further examination of possible moderators that may protect an individual from the deleterious effects of stress is required (Stults-Kolehmainen & Sinha, 2014). This explanation is in line with a resilience framework in which resources are said to buffer the maladaptive effects of stress and adversity on human functioning (Luthar, Cicchetti, & Becker, 2000; Masten, 2011). Thus, there is a need to examine resilience resources that may buffer the effects of stress on PA.

Over the past two decades, there has been a surge of research on psychological resilience (Bonanno, Romero, & Klein, 2015). Although debate remains regarding a universally accepted definition of resilience (Fletcher & Sarkar, 2013), we ascribe to the perspective which suggests that resilience encapsulates one's capacity to sustain or regain relatively stable, healthy levels of psychological and physical functioning despite exposure to significant stressors or adversities (Luthar et al., 2000; Masten, 2011; Windle, 2011). Central to this process of recovery or adjustment are protective factors that encompass personal (e.g., optimism), community (e.g., social support), and societal (e.g., health services) resources (Masten, 2011; Windle, 2011). A recent conceptual and methodological review of resilience measures (Pangallo, Zibarras, Lewis, & Flaxman, 2015) informed our choice of resilience resources in the current study. The higher-order concept of psychological capital (Luthans, Youssef, & Avolio, 2007) is comprised of measures of hope, self-efficacy, resilience (bounce back), and optimism, and received the highest psychometric rating amongst 17 resilience measures. In addition, these individual-level resilience resources are modifiable and therefore can be targeted via interventions (e.g., self-efficacy, Sheeran et al., 2016;

optimism, Littman-Ovadia & Nir, 2014). Within the context of a stress framework, it is likely that some people may have access to these resources in greater quantity and/or quality and therefore be more "resilient" to the deleterious effects of stress. However, the supposition that these resources may interact with stress and PA has not yet been examined with respect to the effects of stress on PA. Conducting research on this issue could shed light on which resources may help individuals to better cope with the demands of life and retain PA levels during stressful periods.

In summary, the objective of this study was to examine the associations between perceived and objective measures of stress, individual-level resilience resources, and their interaction in predicting different intensities of self-reported PA and SB. Aligned with a resilience perspective (Luthar, et al., 2000; Masten, 2011), we expected resilience resources to buffer the effects of stress on PA, such that the negative association between stress and PA would be attenuated for individuals with higher levels of these resources. We focus on university students for two key reasons. First, tertiary studies can be a highly stressful period (Dixon & Kurpius, 2008), where students face numerous stressors across personal (e.g., relationship difficulties), academic (e.g., coursework demands) and occupational (e.g., career aspirations) contexts (Hurst, Baranik, & Daniel, 2012). The stressful nature of this developmental period is reflected in prevalence statistics reported in national surveys (e.g., 64.2% of university students report their academic experiences to be very or extremely stressful; Headspace National Youth Mental Health Foundation, 2016). Second, during stressful periods it is important that students remain active, as 40-50% of students are physically inactive and spend up to eight hours a day completing sedentary activities such as studying and watching TV (Deliens, Deforche, De Bourdeaudhuij, & Clarys, 2015).

3.1. Methods

3.1.1. Participants.

Given the unavailability of existing work to inform expectations regarding a true effect size, we sought a compromise between financial resources (for hair cortisol analysis) and the smallest effect size of interest to determine how much data to collect. Power analysis using G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that 121 participants would be required to detect a small-to-moderate increase in variance explained by the addition of the two interaction terms to the regression equation (8 total predictors, 2 tested predictors, 80% power, f^2 = .12, α

= .01). A convenience sample of 140 adults (70.7% female) aged 18 – 49 years (mean ± *SD* = 21.68 ± 4.88) was recruited from two universities in Australia. Eligibility criteria included being an undergraduate student, willingness to provide a hair sample, and sufficient hair length (2 cm) on the posterior vertex region of the head. Participants were excluded from the analyses if they had an existing medical condition or musculoskeletal injury preventing them taking part in regular PA (*n* = 5), resulting in a final sample of 135 participants (71.1% female) aged 18 – 49 years (mean ± *SD* = 21.71 ± 4.94).

3.1.2. Procedure.

This study was approved by the Human Research Ethics Committee at the lead author's institution. Participants were recruited to the study by two methods: (i) online via a research participation pool, via which students enrolled in health science degrees can elect to participate in research in return for course credit or gift vouchers ($10 iTunes voucher); and (ii) face-to-face via researcher-delivered invitations provided at the start of lectures within courses where students learn about the importance of PA (e.g., exercise science, physiotherapy). Students who expressed an interest in the study attended a 30 minute laboratory session where they provided informed consent, completed a multi-section survey[1] online via Qualtrics (Provo, Utah, USA) and provided a sample of hair. The hair sample was cut as close as possible to the scalp and taken from the posterior vertex region, as previously described (Sauvé, Koren, Walsh, Tokmakejian, & Van Uum, 2007). Hair samples were cut to approximately 1.5 cm (minimum ~ 30-50 mg), wrapped in aluminium foil with an elastic band closest to the root end, and stored at room temperature before being sent to a specialist laboratory for analysis (Stratech Scientific APAC, Sydney, Australia).

3.1.3. Measures.

3.1.3.1. Demographics.

Participants self-reported the following demographic information: age, sex (female = 0, male = 1), existing musculoskeletal injury, height and weight.

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[1] Participants also completed measures of lifetime adversity, academic stressors, social support, proactive goal regulation, and mental toughness. These variables will be the focus of separate publications; any overlap will be acknowledged appropriately.

3.1.3.2. Perceived stress.

The 10-item version of the Perceived Stress Scale (PSS; Cohen, Kamark, & Mermelstein, 1983) was used to assess to the degree to which situations in an individual's life over the past month were perceived as stressful (e.g., "In the last month, how often have you felt confident in your ability to handle your personal problems?"). Items were assessed on a 5-point scale from 0 (*never*) to 4 (*very often*). Past work with student samples has provided reliability and validity evidence of test scores obtained with the PSS (Shapiro, Brown, Thoresen, & Plante, 2011).

3.1.3.3. Physical activity.

Participants self-reported their PA over the past 7 days using the seven-item short form of the International Physical Activity Questionnaire (IPAQ) (Booth, 2000). Six items assess the frequency (days per week) and duration (hours and minutes) of PA intensities (vigorous, moderate, and walking), with two items per intensity (e.g. "On how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling? How much time did you usually spend doing vigorous physical activities on one of those days?"). One question is also included as an indicator of SB ("During the last 7 days, how much time did you usually spend sitting on a weekday?"). Using guidelines for data processing, the total number of minutes of each PA intensity were calculated following recommendations from the IPAQ website (www.ipaq.ki.se). In the current study, the three PA intensities were analysed as minutes per week, and sitting time as a daily average. In line with data processing guidelines (www.ipaq.ki.se) participants who answered 'don't know' for an intensity were omitted from analyses for that intensity. The IPAQ is one of the most widely used PA questionnaires, and meta-analytic data of 21 studies including 152 effect sizes spanning five PA categories has provided reliability and validity evidence of IPAQ scores (Kim, Park, & Kang, 2013).

3.1.3.4. Resilience resources.

Participants completed established measures of the components which comprise the higher-order construct of psychological capital (Luthans et al., 2007) including hope, generalised self-efficacy, resilience, optimism, as well as a measure of adaptability. All scales were measured on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

3.1.3.4.1. *Adult hope scale (AHS) (Snyder et al., 1991).* The AHS measures an individual's hope toward goals and consists of 12 items, including four fillers. Two factors are measured, each with four items. The *pathway* items reflect people's perceptions of their capability to overcome goal-related barriers to achieve their goals (e.g., "I can think of many ways to get out of a jam"), whereas the *agency* subscale captures motivation and goal-directed energy to utilise pathways to pursue goals (e.g., "I energetically pursue my goals"). In this study, the filler items were omitted to reduce participant burden. In the current study, the two subscale scores were combined to create a total hope score, with a higher score reflecting greater hope. The full scales scores, including filler items, have demonstrated reliability evidence for use within student samples (e.g., Feldman & Kubota, 2015).

3.1.3.4.2. *General self-efficacy scale (GSE) (Chen, Gully, & Eden, 2001).* The GSE is an eight-item, unidimensional measure of an individual's belief in their ability to perform in a variety of differing situations (e.g., "I believe I can succeed at most any endeavour to which I set my mind"). Scores on the GSE are summative with larger scores indicating higher levels self-efficacy. Test scores on the GSE have demonstrated good internal consistency (α between .86 and .90) and test-retest reliability evidence (r = .62 to .66; Chen et al., 2001) in a student sample.

3.1.3.4.3. *Life orientation test – revised (LOT-R) (Scheier, Carver, & Bridges, 1994).* The 10 item LOT-R is a measure of Optimism (e.g., "In uncertain times, I usually expect the best") and Pessimism (e.g., "I hardly ever expect things to go my way"), with each dimension assessed using three items (the remaining four are fillers and were omitted in this study). We created a composite score by combining the Optimism and Pessimism items (first reversed scored), with higher scores reflecting greater optimism. This cumulative scoring method has been commonly utilised in previous research (e.g., Atienza, Stephens, & Townsend, 2004; Feldman & Kubota, 2015; Hinz et al., 2017). Scores on the full LOT-R, including filler items, have demonstrated good internal consistency within a student sample (α between .70 and .80; Scheier et al., 1994) and test-retest reliability evidence (.58 - .79; Atienza et al., 2004) in a female sample (M_{age} = 43.7).

3.1.3.4.4. *Brief resilience scale (BRS) (Smith et al., 2008).* The BRS measures an individual's perception of their ability to bounce back from stress. The scale consists of six items with three positively worded (e.g., "I usually come through difficult times with little trouble) and three negatively worded (e.g., "I have a hard time making it through stressful events") statements. The three negatively worded items were reverse scored to give a total resilience score with a higher score reflecting increased levels of resilience. The BRS scores have demonstrated good internal consistency (α between .8 and .91) and test-retest reliability evidence (r = .69 after 1 month and r = .62 after 3 months; Smith et al., 2008) across samples consisting of students and cardiac rehabilitation patients.

3.1.3.4.5. *Adaptability Scale (Martin, Nejad, Colmar, & Liem, 2012).* This nine-item tool is a measure of psycho-behavioural adjustment in response to novelty and/or uncertainty (e.g., "I am able to revise the way I think about a new situation to help me through it"). A higher score on the scale indicates a greater level of adaptability. Validity and reliability evidence of the scale scores has been demonstrated in cross-sectional and longitudinal studies, within high school and university student samples (e.g., Martin et al., 2012; Martin, Nejad, Colmar, & Liem, 2013).

3.1.3.5. Hair cortisol.

For preparation and cleaning, hair was cut to 1.5cm from root end to represent cortisol secretion over a period of at least the previous month, due to the variability of hair growth rate (Wennig, 2000). Cortisol extraction followed the widely published enzyme-linked immunosorbent assay (ELISA) method (e.g. Davenport, Tiefenbacher, Lutz, Novak, & Meyer, 2006). Samples were first treated with isopropanol and then methanol, and allowed to dry for 5 days. In preparation for analysis, the hair was weighed for extraction and mechanically crushed. Methanol was used for extraction for 24 hours with sonication, with the tubes subsequently dried to remove all methanol before the samples were reconstituted in Phosphate buffered saline (PBS) for analysis. Cortisol was then analysed in duplicate using a commercially available ELISA immunoassay (Salimetrics, USA) according to the manufacturer's instructions (intra-assay variability = 5.4%, inter-assay variability = 6%).

3.1.4. Statistical analysis.

Descriptive statistics were calculated using SPSS version 24 (SPSS Inc., Chicago, Illinois, USA). Linear regression was employed to examine the primary research questions. With regard to moderation effects, variables were grand mean centred prior to interaction terms being computed between each of the resilience resources and both subjective and objective measures of stress. Five potential individual-level resilience resources were tested (resilience, hope, optimism, self-efficacy, and adaptability) for each of four PA intensities (vigorous, moderate, walking, and sitting). Each moderator variable was examined separately against each of the PA intensities. The analysis was completed in a sequential stepwise fashion to examine the effects of the covariates (age, sex, and BMI) alone (Step 1) and with the inclusion of direct effects of the stress variables and resilience resources (Step 2), followed by the addition of the interaction terms (Step 3).[2] We planned to probe significant interactions using a simple slopes analysis (Aiken & West, 1991). HCC's were log-transformed so as to approximate a normal distribution, which is common in research utilising hair cortisol (e.g., Gerber, Jonsdottir et al., 2013; Gidlow et al., 2016; Staufenbiel, Penninx, de Rijke, van den Akker, & van Rossum, 2015).[3]Due to the nature of the analysis and concerns relating to type I errors, we adopted a conservative level of statistical significance at $p < 0.01$ to minimise the chances of a possible Type I error whilst not choosing a level which was so stringent so as to risk the chance of a Type II error. The moderation analyses were performed with M*plus* 8 (Muthén & Muthén, 2017) using a robust maximum likelihood estimator.

3.2. Results

3.2.1. Descriptive statistics and bivariate correlations.

Subscale level statistics including means, standard deviations, internal reliability estimates and bivariate correlations are presented in Table 3.1. Briefly, individual-level resilience resources demonstrated significant moderate to strong correlations with each other ($.43 < r < .80$), significant moderate to strong negative correlations with subjective stress ($-.47 < r < -.61$), weak negative correlations with objective stress ($-.06 < r < -.17$), and weak to moderate correlations with PA ($.21 < r$

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[2] A model was run including all moderators simultaneously; this information is provided as supplementary materials (Tables S3.1–S3.4) due to being underpowered to detect a meaningful effect: 20 total predictors, 10 tested predictors (i.e., interaction terms), 80% power, $f^2 = .12$, $\alpha = .01$, would require 198 participants.

[3] Analyses were also run with non-transformed PA data see supplementary materials for comparisons (Tables S3.6–S3.9).

< .32). The different intensities of PA demonstrated weak to moderate correlations with each other (-.21 < *r* < .32), a single significant weak negative correlation was observed between subjective stress and vigorous PA (*r* = -.23), and weak correlations were demonstrated between objective stress (-.16 < *r* < .03) and the different intensities of PA.

3.2.2. Vigorous physical activity.

Full details of the results for vigorous physical activity (VPA) are presented in Table 3.2; we focus here on statistically significant effects at Step 3 of the analysis. Sex was positively associated with VPA across all models for each resilience resource, such that males reported higher levels of VPA. Conversely, age was negatively associated with VPA within the model for which bounce back resilience (BRS) was the individual-level resilience resource tested. In terms of resilience resources, hope and general self-efficacy evidenced moderate positive associations with VPA. There were no significant interaction effects for VPA.

3.2.3. Moderate physical activity.

Full details of the results for moderate physical activity (MPA) are presented in Table 3.3. Sex was positively associated across all models for each resilience resource, such that males took part in higher levels of MPA. There were no other significant main or interaction effects for MPA.

3.2.4. Walking.

Full details of the results for walking can be seen in Table 3.4. Age was negatively associated with walking in Steps 2 and 3 of the BRS model. Within this model, BRS also demonstrated a moderate positive association with walking in Steps 2 and 3. There were no significant interaction effects for walking.

3.2.5. Sitting.

Full details of the results for sitting are presented in Table 3.5. Age demonstrated a positive association with sitting time within Step 2 of the models including hope, optimism and adaptability. There were no other significant main or interaction effects for sitting.

Table 3.1. *Descriptive Statistics, Internal Reliability Estimates and Bivariate Correlations Among Study Variables*

Variables	Descriptive Statistics					Correlations													
	N	Mean	SD	Skew	Kurtosis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	135	21.71	4.94	3.02	10.89	-													
2. Gender	135	-	-	-	-	-.06	-												
3. BMI [a]	135	22.75	3.03	0.52	-0.12	.20*	.09	-											
4. Perceived Stress [b]	135	1.89	0.64	0.20	0.10	-.16	-.22*	-.02	(.88)										
5. Hair Cortisol [c]	135	0.49	0.28	0.24	1.60	.08	-.34**	.17	.12	-									
6. Vigorous PA [d]	132	155.04	186.71	1.78	3.42	-.12	.35**	.04	-.23**	-.16	-								
7. Moderate PA [e]	130	142.27	208.14	2.72	8.62	.05	.33**	.03	-.14	-.15	.32**	-							
8. Walking [f]	111	264.82	271.81	1.86	3.62	-.15	.25*	.06	.07	-.14	.09	.11	-						
9. Sitting [g]	127	376.54	191.00	0.86	0.52	.16	-.14	-.03	.08	.03	-.21*	-.17	.00	-					
10. Resilience [h]	135	4.41	1.33	-0.44	-0.32	.16	.33**	.05	-.61**	-.17*	.28**	. 22*	.16	.02	(.89)				
11. Hope [h]	135	5.01	0.96	-0.82	1.79	.09	.12	.04	-.55**	-.06	.32**	.16	-.00	-.21*	.59**	(.87)			
12. Optimism [h]	135	4.60	1.04	-0.35	-0.29	.14	.08	.01	-.50**	-.11	.14	.01	.02	-.08	.43**	.60**	(.78)		
13. Self-Efficacy [h]	135	5.10	1.01	-1.22	2.69	.08	.16	.05	-.47**	-.08	.29**	.11	-.06	-.11	.61**	.80**	.58**	(.93)	
14. Adaptability [h]	135	4.80	1.01	-0.84	1.35	.14	.29**	-.02	-.47**	-.15	.26**	.14	.10	-.17	.64**	.74**	.51**	.74**	(.92)

Note. BMI = body mass index; PA = Physical activity; [a] BMI scores in kg/m^2; [b] Range 0 – 4; [c] Hair cortisol concentrations in $pg \cdot mg^{-1}$ log transformed; [d] Vigorous physical activity minutes per week; [e] Moderate physical activity minutes per week; [f] Walking minutes per week; [g] Sitting minutes per day; [h] Range 1 – 7; *Correlation is significant at the 0.05 level (two-tailed); ** Correlation is significant at the 0.01 level (two-tailed).

3.3. Discussion

In the current study we examined the moderating effects of individual-level resilience resources on the association between stress and PA among a sample of adults. Aligned with a stress-buffering hypothesis, we expected individual-level resilience resources (self-efficacy, hope, optimism, bounce back resilience, and adaptability) to moderate the effects of perceived and physiological stress on self-reported PA, such that individuals with higher levels of these resources would be less affected by the deleterious effects of stress and, therefore, report higher levels of PA. Direct effects, bivariate correlations and regression coefficients indicated primarily small and non-significant negative associations between subjective and objective indices of stress and the different intensities of PA. The associations between individual-level resilience resources and PA intensities were mixed, though largely consistent across the bivariate correlations and regression coefficients in terms of magnitude and sign. Specifically, there were mainly significant small to moderate positive associations between individual-level resilience resources with VPA; small, non-significant positive associations with MPA and walking; and small, non-significant negative associations with sitting. Our predictions regarding the moderating effect of individual-level resilience resources were unsupported.

The small and primarily non-significant associations between perceived and physiological stress and PA have also been demonstrated in past research (e.g., Gidlow et al., 2016; Stalder et al., 2017). When examining the bivariate correlations, although they were primarily small and non-significant, the direction of the effects observed were mostly consistent with Stults-Kolehmainen and Sinha's (2014) review in that the majority of studies found a negative association, with higher levels of stress associated with lower levels of PA. Of the cross-sectional studies reviewed, 67% reported a negative association, with correlations within the small-moderate range (-0.28 to -0.42). In the current study we sought to gain a more nuanced understanding of this association by examining different intensities of PA. We found a negative association for VPA and MPA, though not for walking, which may suggest that the association strengthens as PA intensity increases. Further support comes from the finding of a salient negative association between perceived stress and VPA which approached reported levels in the review paper. This finding suggests that the association between stress and PA is more important at the vigorous end of the PA spectrum, something

Table 3.2. *Vigorous Physical Activity Three-Step Regression Analyses*

	Step 1 Observations: 132				Step 2				Step 3			
Variables	β	95% CI		*p*	β	95% CI		*p*	β	95% CI		*p*
Age	-0.105	-0.212	0.003	0.056	**-0.157**	**-0.275**	**-0.040**	**0.009**	**-0.163**	**-0.287**	**-0.040**	**0.009**
Sex	**0.338**	**0.182**	**0.495**	**0.000**	**0.243**	**0.064**	**0.422**	**0.008**	**0.241**	**0.058**	**0.425**	**0.010**
BMI	0.033	-0.114	0.180	0.661	0.063	-0.084	0.211	0.401	0.055	-0.089	0.199	0.457
PSS					-0.085	-0.252	0.082	0.320	-0.082	-0.250	0.086	0.338
HCC					-0.036	-0.247	0.174	0.736	-0.037	-0.237	0.164	0.721
BRS					0.175	-0.023	0.372	0.083	0.193	-0.011	0.396	0.063
PSS x BRS									-0.077	-0.210	0.056	0.258
HCC x BRS									0.007	-0.151	0.165	0.931
R^2		0.132				0.181				0.186		
Age	-0.105	-0.212	0.003	0.056	-0.136	-0.247	-0.024	0.017	-0.113	-0.233	0.008	0.068
Sex	**0.338**	**0.182**	**0.495**	**0.000**	**0.281**	**0.116**	**0.446**	**0.001**	**0.287**	**0.123**	**0.452**	**0.001**
BMI	0.033	-0.114	0.180	0.661	0.040	-0.107	0.187	0.590	0.020	-0.122	0.163	0.780
PSS					-0.028	-0.193	0.137	0.741	-0.016	-0.180	0.148	0.852
HCC					-0.039	-0.250	0.171	0.714	-0.048	-0.251	0.156	0.645
HOP					**0.272**	**0.105**	**0.438**	**0.001**	**0.340**	**0.147**	**0.532**	**0.001**
PSS x HOP									-0.105	-0.252	0.041	0.159
HCC x HOP									-0.128	-0.279	0.023	0.097
R^2		0.132				0.214				0.243		
Age	-0.105	-0.212	0.003	0.056	-0.140	-0.266	-0.015	0.029	-0.139	-0.268	-0.010	0.035
Sex	**0.338**	**0.182**	**0.495**	**0.000**	**0.284**	**0.108**	**0.461**	**0.002**	**0.291**	**0.114**	**0.468**	**0.001**
BMI	0.033	-0.114	0.180	0.661	0.046	-0.096	0.188	0.523	0.037	-0.107	0.181	0.615
PSS					-0.153	-0.309	0.004	0.056	-0.156	-0.309	-0.002	0.047
HCC					-0.036	-0.256	0.183	0.746	-0.038	-0.258	0.182	0.738
LOT					0.053	-0.115	0.220	0.538	0.048	-0.115	0.212	0.562
PSS x LOT-R									-0.020	-0.147	0.106	0.753
HCC x LOT-R									-0.049	-0.240	0.141	0.613
R^2		0.132				0.165				0.168		
Age	-0.105	-0.212	0.003	0.056	-0.138	-0.249	-0.026	0.015	-0.130	-0.248	-0.012	0.030
Sex	**0.338**	**0.182**	**0.495**	**0.000**	**0.270**	**0.099**	**0.442**	**0.002**	**0.252**	**0.080**	**0.424**	**0.004**
BMI	0.033	-0.114	0.180	0.661	0.040	-0.105	0.184	0.590	0.033	-0.112	0.178	0.658
PSS					-0.081	-0.244	0.082	0.332	-0.085	-0.249	0.079	0.311
HCC					-0.037	-0.248	0.174	0.731	-0.049	-0.244	0.147	0.627
GSE					**0.210**	**0.073**	**0.347**	**0.003**	**0.275**	**0.106**	**0.445**	**0.001**
PSS x GSE									-0.125	-0.299	0.050	0.163
HCC x GSE									-0.178	-0.339	-0.018	0.030
R^2		0.132				0.197				0.247		
Age	-0.105	-0.212	0.003	0.056	-0.153	-0.276	-0.031	0.014	-0.151	-0.284	-0.017	0.027
Sex	**0.338**	**0.182**	**0.495**	**0.000**	**0.250**	**0.075**	**0.426**	**0.005**	**0.240**	**0.062**	**0.419**	**0.008**
BMI	0.033	-0.114	0.180	0.661	0.056	-0.086	0.198	0.439	0.056	-0.087	0.199	0.441
PSS					-0.119	-0.282	0.045	0.156	-0.112	-0.277	0.053	0.183
HCC					-0.036	-0.250	0.178	0.742	-0.031	-0.238	0.177	0.772
ADA					0.148	-0.007	0.303	0.061	0.175	-0.019	0.368	0.076
PSS x ADA									-0.017	-0.140	0.107	0.790
HCC x ADA									-0.098	-0.273	0.077	0.274
R^2		0.132				0.179				0.189		

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT-R = Life Orientation Test - Revised; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Table 3.3. *Moderate Physical Activity Three-Step Regression Analyses*

	Step 1 Observations: 130				Step 2				Step 3			
Variables	β	95% CI		*p*	β	95% CI		*p*	β	95% CI		*p*
Age	0.069	-0.174	0.313	0.577	0.049	-0.187	0.284	0.684	0.045	-0.173	0.264	0.685
Sex	**0.339**	**0.190**	**0.488**	**0.000**	**0.288**	**0.113**	**0.462**	**0.001**	**0.291**	**0.113**	**0.469**	**0.001**
BMI	-0.019	-0.166	0.129	0.805	0.005	-0.141	0.150	0.952	0.003	-0.141	0.147	0.969
PSS					-0.001	-0.208	0.207	0.996	0.000	-0.205	0.205	1.000
HCC					-0.036	-0.231	0.160	0.722	-0.041	-0.229	0.147	0.667
BRS					0.105	-0.080	0.291	0.265	0.102	-0.087	0.291	0.292
PSS x BRS									-0.001	-0.121	0.120	0.989
HCC x BRS									0.037	-0.157	0.231	0.709
R^2		0.116				0.127				0.128		
Age	0.069	-0.174	0.313	0.577	0.063	-0.172	0.298	0.599	0.063	-0.154	0.279	0.571
Sex	**0.339**	**0.190**	**0.488**	**0.000**	**0.317**	**0.153**	**0.480**	**0.000**	**0.316**	**0.154**	**0.477**	**0.000**
BMI	-0.019	-0.166	0.129	0.805	-0.018	-0.171	0.135	0.819	-0.023	-0.174	0.129	0.769
PSS					0.022	-0.163	0.207	0.815	0.030	-0.155	0.214	0.753
HCC					-0.035	-0.231	0.161	0.729	-0.041	-0.234	0.153	0.680
HOP					0.137	-0.031	0.305	0.111	0.181	-0.017	0.378	0.073
PSS x HOP									-0.092	-0.262	0.079	0.292
HCC x HOP									-0.007	-0.192	0.178	0.941
R^2		0.116				0.133				0.140		
Age	0.069	-0.174	0.313	0.577	0.066	-0.187	0.319	0.607	0.062	-0.182	0.305	0.618
Sex	**0.339**	**0.190**	**0.488**	**0.000**	**0.302**	**0.137**	**0.467**	**0.000**	**0.301**	**0.136**	**0.467**	**0.000**
BMI	-0.019	-0.166	0.129	0.805	-0.002	-0.150	0.146	0.976	0.006	-0.142	0.154	0.939
PSS					-0.099	-0.289	0.091	0.309	-0.085	-0.280	0.110	0.394
HCC					-0.047	-0.242	0.149	0.640	-0.048	-0.240	0.145	0.626
LOT					-0.079	-0.259	0.101	0.391	-0.066	-0.244	0.111	0.463
PSS x LOT-R									-0.042	-0.195	0.110	0.585
HCC x LOT-R									0.071	-0.124	0.266	0.475
R^2		0.116				0.125				0.130		
Age	0.069	-0.174	0.313	0.577	0.061	-0.190	0.311	0.635	0.062	-0.195	0.318	0.636
Sex	**0.339**	**0.190**	**0.488**	**0.000**	**0.310**	**0.144**	**0.476**	**0.000**	**0.300**	**0.129**	**0.472**	**0.001**
BMI	-0.019	-0.166	0.129	0.805	-0.009	-0.162	0.143	0.904	-0.009	-0.163	0.144	0.904
PSS					-0.039	-0.205	0.127	0.645	-0.042	-0.214	0.129	0.629
HCC					-0.037	-0.232	0.158	0.710	-0.043	-0.238	0.152	0.666
GSE					0.038	-0.097	0.173	0.582	0.068	-0.091	0.228	0.402
PSS x GSE									-0.060	-0.219	0.100	0.463
HCC x GSE									-0.054	-0.238	0.130	0.566
R^2		0.116				0.121				0.128		
Age	0.069	-0.174	0.313	0.577	0.059	-0.188	0.306	0.639	0.059	-0.183	0.300	0.634
Sex	**0.339**	**0.190**	**0.488**	**0.000**	**0.308**	**0.137**	**0.479**	**0.000**	**0.308**	**0.131**	**0.485**	**0.001**
BMI	-0.019	-0.166	0.129	0.805	-0.006	-0.155	0.142	0.936	-0.006	-0.156	0.143	0.936
PSS					-0.051	-0.223	0.122	0.566	-0.051	-0.223	0.121	0.564
HCC					-0.037	-0.233	0.158	0.708	-0.037	-0.231	0.156	0.705
ADA					0.015	-0.123	0.153	0.834	0.015	-0.157	0.187	0.866
PSS x ADA									-0.001	-0.128	0.126	0.983
HCC x ADA									0.003	-0.185	0.191	0.974
R^2		0.116				0.120				0.120		

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT-R = Life Orientation Test-Revised; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Table 3.4. *Walking Activity Three-Step Regression Analyses*

	Step 1 Observations: 111				Step 2				Step 3			
Variables	β	95% CI		*p*	β	95% CI		*p*	β	95% CI		*p*
Age	-0.133	-0.243	-0.023	0.018	**-0.148**	**-0.259**	**-0.038**	**0.008**	**-0.147**	**-0.255**	**-0.038**	**0.008**
Sex	0.226	0.022	0.429	0.030	0.146	-0.056	0.348	0.157	0.138	-0.070	0.346	0.193
BMI	0.068	-0.080	0.216	0.366	0.096	-0.056	0.249	0.216	0.108	-0.045	0.260	0.166
PSS					0.253	0.015	0.491	0.037	0.256	0.019	0.494	0.034
HCC					-0.084	-0.222	0.054	0.232	-0.088	-0.229	0.054	0.226
BRS					**0.282**	**0.084**	**0.481**	**0.005**	**0.266**	**0.075**	**0.456**	**0.006**
PSS x BRS									0.099	-0.078	0.275	0.272
HCC x BRS									-0.028	-0.157	0.100	0.665
R^2		0.079				0.137				0.146		
Age	-0.133	-0.243	-0.023	0.018	-0.116	-0.222	-0.010	0.032	-0.116	-0.220	-0.012	0.030
Sex	0.226	0.022	0.429	0.030	0.211	0.001	0.421	0.049	0.210	-0.002	0.423	0.052
BMI	0.068	-0.080	0.216	0.366	0.076	-0.081	0.234	0.343	0.079	-0.080	0.238	0.328
PSS					0.100	-0.115	0.316	0.361	0.097	-0.117	0.311	0.374
HCC					-0.084	-0.224	0.055	0.234	0.084	-0.223	0.055	0.237
HOP					0.015	-0.183	0.213	0.884	-0.010	-0.224	0.204	0.925
PSS x HOP									0.056	-0.128	0.239	0.553
HCC x HOP									-0.010	-0.151	0.132	0.893
R^2		0.079				0.092				0.094		
Age	-0.133	-0.243	-0.023	0.018	-0.122	-0.227	-0.016	0.024	-0.115	-0.219	-0.011	0.031
Sex	0.226	0.022	0.429	0.030	0.218	0.007	0.429	0.043	0.237	0.015	0.460	0.037
BMI	0.068	-0.080	0.216	0.366	0.077	-0.080	0.234	0.335	0.060	-0.092	0.212	0.441
PSS					0.136	-0.085	0.356	0.228	0.138	-0.093	0.368	0.242
HCC					-0.074	-0.214	0.065	0.296	-0.084	-0.234	0.065	0.269
LOT					0.090	-0.144	0.324	0.449	0.086	-0.146	0.318	0.470
PSS x LOT-R									-0.079	-0.309	0.151	0.501
HCC x LOT-R									-0.063	-0.238	0.112	0.479
R^2		0.079				0.098				0.110		
Age	-0.133	-0.243	-0.023	0.018	-0.116	-0.224	-0.008	0.035	-0.114	-0.226	-0.001	0.047
Sex	0.226	0.022	0.429	0.030	0.217	0.006	0.429	0.044	0.226	0.012	0.440	0.039
BMI	0.068	-0.080	0.216	0.366	0.083	-0.072	0.237	0.295	0.078	-0.081	0.236	0.336
PSS					0.061	-0.133	0.254	0.540	0.065	-0.131	0.261	0.513
HCC					-0.087	-0.227	0.054	0.226	-0.080	-0.222	0.062	0.269
GSE					-0.069	-0.267	0.129	0.494	-0.051	-0.264	0.163	0.642
PSS x GSE									-0.028	-0.257	0.201	0.812
HCC x GSE									0.080	-0.072	0.231	0.303
R^2		0.079				0.095				0.101		
Age	-0.133	-0.243	-0.023	0.018	-0.127	-0.240	-0.013	0.028	-0.124	-0.241	-0.008	0.036
Sex	0.226	0.022	0.429	0.030	0.184	-0.043	0.412	0.113	0.196	-0.037	0.430	0.100
BMI	0.068	-0.080	0.216	0.366	0.080	-0.081	0.240	0.330	0.076	-0.086	0.239	0.356
PSS					0.139	-0.078	0.355	0.209	0.131	-0.085	0.347	0.234
HCC					-0.082	-0.219	0.055	0.241	-0.086	-0.225	0.054	0.229
ADA					0.109	-0.078	0.296	0.252	0.080	-0.118	0.278	0.428
PSS x ADA									0.045	-0.088	0.178	0.508
HCC x ADA									0.073	-0.043	0.189	0.215
R^2		0.079				0.100				0.109		

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT-R = Life Orientation Test-Revised; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Table 3.5. *Sitting Time Three-Step Regression Analyses*

	Step 1 Observations: 127				Step 2				Step 3			
Variables	β	95% CI		*p*	β	95% CI		*p*	β	95% CI		*p*
Age	0.164	0.031	0.297	0.015	0.166	0.025	0.307	0.021	0.160	0.011	0.308	0.035
Sex	-0.124	-0.304	0.057	0.180	-0.143	-0.342	0.056	0.160	-0.135	-0.332	0.063	0.181
BMI	-0.053	-0.210	0.104	0.506	-0.040	-0.199	0.119	0.619	-0.035	-0.190	0.120	0.658
PSS					0.163	-0.105	0.430	0.233	0.161	-0.104	0.426	0.233
HCC					-0.026	-0.161	0.109	0.706	-0.042	-0.190	0.105	0.575
BRS					0.134	-0.128	0.395	0.316	0.112	-0.156	0.380	0.411
PSS x BRS									0.053	-0.095	0.200	0.485
HCC x BRS									0.088	-0.089	0.264	0.329
R^2	0.045				0.063				0.074			
Age	0.164	0.031	0.297	0.015	**0.181**	**0.049**	**0.313**	**0.007**	0.172	0.036	0.308	0.013
Sex	-0.124	-0.304	0.057	0.180	-0.106	-0.291	0.079	0.262	-0.107	-0.290	0.076	0.251
BMI	-0.053	-0.210	0.104	0.506	-0.045	-0.200	0.110	0.569	-0.041	-0.199	0.116	0.608
PSS					-0.032	-0.248	0.184	0.772	-0.032	-0.255	0.192	0.781
HCC					-0.029	-0.163	0.104	0.666	-0.028	-0.163	0.107	0.685
HOP					-0.223	-0.404	-0.043	0.015	-0.226	-0.446	-0.006	0.044
PSS x HOP									-0.009	-0.176	0.158	0.913
HCC x HOP									0.042	-0.091	0.175	0.533
R^2	0.045				0.088				0.089			
Age	0.164	0.031	0.297	0.015	**0.187**	**0.045**	**0.328**	**0.010**	0.182	0.037	0.326	0.014
Sex	-0.124	-0.304	0.057	0.180	-0.115	-0.303	0.073	0.231	-0.109	-0.295	0.078	0.253
BMI	-0.053	-0.210	0.104	0.506	-0.053	-0.213	0.107	0.516	-0.055	-0.218	0.109	0.511
PSS					0.057	-0.138	0.252	0.566	0.087	-0.120	0.294	0.412
HCC					-0.034	-0.167	0.098	0.611	-0.036	-0.169	0.097	0.598
LOT					-0.070	-0.235	0.095	0.407	-0.050	-0.218	0.118	0.559
PSS x LOT-R									-0.104	-0.261	0.053	0.193
HCC x LOT-R									0.071	-0.078	0.220	0.348
R^2	0.045				0.057				0.068			
Age	0.164	0.031	0.297	0.015	0.182	0.041	0.323	0.011	0.178	0.033	0.324	0.016
Sex	-0.124	-0.304	0.057	0.180	-0.107	-0.296	0.082	0.267	-0.104	-0.291	0.084	0.278
BMI	-0.053	-0.210	0.104	0.506	-0.051	-0.212	0.109	0.532	-0.052	-0.211	0.107	0.520
PSS					0.053	-0.161	0.267	0.628	0.063	-0.151	0.277	0.564
HCC					-0.030	-0.161	0.102	0.657	-0.025	-0.162	0.112	0.722
GSE					-0.083	-0.295	0.128	0.441	-0.060	-0.307	0.187	0.634
PSS x GSE									-0.051	-0.236	0.133	0.586
HCC x GSE									0.111	-0.054	0.276	0.186
R^2	0.045				0.058				0.071			
Age	0.164	0.031	0.297	0.015	**0.199**	**0.057**	**0.341**	**0.006**	0.180	0.034	0.327	0.016
Sex	-0.124	-0.304	0.057	0.180	-0.075	-0.261	0.111	0.428	-0.073	-0.261	0.115	0.446
BMI	-0.053	-0.210	0.104	0.506	-0.066	-0.227	0.096	0.426	-0.066	-0.224	0.092	0.414
PSS					0.024	-0.181	0.228	0.822	0.024	-0.181	0.229	0.819
HCC					-0.036	-0.165	0.093	0.588	-0.033	-0.160	0.094	0.608
ADA					-0.166	-0.365	0.032	0.101	-0.137	-0.376	0.102	0.261
PSS x ADA									-0.102	-0.314	0.109	0.343
HCC x ADA									0.095	-0.044	0.234	0.179
R^2	0.045				0.073				0.086			

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT-R = Life Orientation Test - Revised; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

that may have been hitherto overlooked due to amalgamated assessments of PA. Therefore, an interesting avenue for future research may be to explore the nature of the different intensities of PA that may be driving these associations with perceived stress.

Objectively measured stress displayed a similar trend to perceived stress whereby higher levels of HCC demonstrated small and non-significant associations with lower levels of PA. Previous research exploring this association is limited. For example, within Stults-Kolehmainen and Sinha's review, although there were studies recruiting objectively stressed populations (e.g., caregivers) only three utilised an objective measure of stress. Similar small and non-significant associations have also been reported in past cross-sectional research utilising HCC (e.g., Stalder et al., 2013; Steptoe, Easterlin, & Kirschbaum, 2017), as well as cross-sectional research specifically utilising the IPAQ as a measure of PA (Gidlow, Randall, Gillman, Silk, et al., 2016; Staufenbiel et al., 2015). The small and non-significant correlations with HCC extended to all self-report measures, with the exception of the bounce back resilience (BRS). Inconsistencies have often been observed in the findings between self-reported and physiological measures, adding to a growing body of literature advocating a "lack of psychoendocrine covariance" (Staufenbiel, Penninx, Spijker, Elzinga, & van Rossum, 2013, p. 1230). Specifically, with regard to perceived stress and HCC, small associations have been observed frequently (Gidlow, Randall, Gillman, Silk, et al., 2016; Gidlow, Randall, Gillman, Smith, et al., 2016) and confirmed in meta-analytic syntheses (Stalder et al., 2017; Staufenbiel et al., 2013). One explanation for these findings is the temporal component of the assessments. Many studies have looked at hair lengths of 2-3 cm, representing approximately 2-3 months of secretion, against self-reported stress (PSS) which assesses perceived stress over the previous month. We considered this temporal dimension of the assessment protocol so that perceived stress and HCC overlapped; however, consistent with past work, we revealed a small and non-significant association. A second explanation relates to the context in which studies have been conducted; that is, participants typically have been assessed during periods of relatively low stress levels thereby stress could have had minimal effects on longer term cortisol secretion (Stalder et al., 2017). Future research can address this methodological limitation by assessing participants longitudinally during naturally occurring or experimentally induced stressful periods (e.g. examination periods).

The direct effects between the individual-level resilience resources and PA intensities were mixed. Examination of the bivariate correlations shows the effects were generally positive in nature, suggesting higher levels of resilience resources are associated with higher levels of PA. These findings are in line with past research which has shown higher levels of these personal resources to be linked to higher levels of PA (e.g., hope, Gustafsson, Podlog, & Davis, 2017; self-efficacy, Lewis, Williams, Frayeh, & Marcus, 2016; optimism, Huffman et al. 2016; and resilience, Gerber, Jonsdottir, Lindwall, & Ahlborg, 2014). This observation was especially evident for VPA which demonstrated significant small to moderate associations with all resources, with the exception of optimism. However, this trend did not extend to sitting for which we observed a negative association. Intuitively, individuals with higher levels of resources who are taking part in more PA may in turn be spending less time sitting. It is possible that having higher levels of these resources may allow individuals to gain the benefits of PA and negate the deleterious effects of too much sedentary time. Although these findings suggest that higher levels of perceived resources are associated with greater levels of different PA intensities, the cross-sectional nature of this study precludes us from ruling out the alternative explanation that higher levels of PA are associated with increased perceptions of available resilience resources. Longitudinal studies are needed to establish the importance of the perceived availability of these resources, which could inform resource focused interventions that help individuals maintain PA levels during stressful periods.

Within the regression analyses three of the examined individual-level resilience resources were found to share salient associations with PA. First, when looking at VPA the resources of hope and self-efficacy were found to have salient positive weak to moderate associations. A possible mechanism by which hope demonstrated this positive association with VPA is via its two interactive components; pathway and agency. For example, individuals who have higher levels of hope may have an increased awareness of the various routes to be physically active (pathway), and the motivation to use these routes (agency). The finding that self-efficacy was also related positively with VPA is interesting as a central tenet of hope theory is that those who have higher levels of hope are instilled with an increased feeling of self-efficacy (Snyder, 2002), and therefore could reflect a by-product of their enhanced awareness of pathways to achieve their PA goals. Hope theory (Snyder, 2002) also suggests that hope is linked to one’s motivation towards a goal, thus the observed association between higher levels of hope and increased VPA can be seen to be in line with motivation towards a goal of being physically active. Furthermore, the negative association between hope and sitting time approached significance, and less time sitting could also be seen to be in line with a goal of being more physically active. Second, one's ability to bounce back from stress, as measured by the BRS, was found to share a significant positive weak to moderate association with walking activities. Research utilising the BRS has demonstrated that groups of individuals who display resilience are more physically active than those who had low levels of resilience (Gerber et al., 2014). Specifically, in relation to light PA (e.g., walking and light gardening), those who engaged in light PA had reduced odds of being classed as highly burdened or stressed, i.e. lower levels in the BRS. Bearing in mind the cross-sectional nature of these data, these findings suggest that individuals who are well resourced to bounce back from adversity are better equipped to engage in higher amounts of walking activity. Research exploring this association between resilience and PA has mainly been focused at higher intensities of PA (Thogersen-Ntoumani, Black, Lindwall, Whittaker, & Balanos, 2017); thus, further work is needed to disentangle the association at all intensities of PA. Together, these findings are important as moderate to vigorous PA is the most important form of activity for individuals to improve their fitness, and gain its related health benefits (Garber et al., 2011), and SB (sitting time) has consistently been shown to be associated with numerous deleterious outcomes (Australian National Preventive Health Agency, 2014). Therefore, the findings that these individual-level resilience resources are related to increased levels of PA are important and may offer a fruitful line of further enquiry.

When examining the moderation effects of individual-level resilience resources our hypothesis that these resources would moderate the association between stress and PA was unsupported. There are several possible explanations for the non-significant moderation effects observed in the current study. First, our selection of individual-level resilience resources may have been insensitive to the primary outcomes; future research should consider resilience sources that are contextually tailored to the outcomes of interest (e.g., exercise self-efficacy). Second, the degree to which individual-level resilience resources attenuate the effects of stress on PA may be small, yet practically meaningful, in which case the current study was likely underpowered to detect such an effect. Third, against the backdrop of the transactional perspective of stress (Lazarus & Folkman, 1984), our focus on secondary appraisals (i.e., perceptions of one's available resources to deal with stressors) in the absence of primary appraisals (i.e., interpretation of the stressor as a threat or challenge to personal functioning) could be considered a simplistic view of association between stress and PA. For example, individual-level resilience resources might moderate the effect of one's interpretations of the stressors, rather than the degree to which stress has been experienced. Finally, the cross-sectional nature of this study means we captured a static snapshot of the associations between stress, PA and individual-level resilience resources; the interactive effects among these variables may be dynamic in nature and therefore cannot be captured using a cross-sectional design. Despite its potential significance, previous research exploring possible moderators of the stress-PA association is limited. In a recent study examining the possible bi-directional association between stress and PA, moderation effects were also examined, including the resource of optimism; similarly to the current study no moderation effects were observed (Burg et al., 2017). The current study utilised a cross sectional design, whereas Burg et al. (2017) utilised only baseline measures of possible moderators; thus, future research may benefit from longitudinal designs with repeated assessments of participant's dispositional levels of individual-level resilience resources.

3.3.1. Strengths and limitations.

Notable strengths of this study were the assessment of stress via perceived and physiological indices, decomposition of PA into its different intensities rather than a global score, and consideration of stress-buffering individual-level resilience resources. Nevertheless, four limitations should be considered when interpreting our findings. First, the findings are based on a sample of university students (predominantly female) who engaged in relatively high levels of PA; therefore, caution should be taken if generalising to other populations, particularly as the bias in the sample (e.g., wide age range and incentives) may have decreased the likelihood of finding significant associations. For example, the higher percentage of females was likely due to our eligibility criterion of sufficient hair length (2 cm) on the posterior vertex region of the head. Relatedly, the largely healthy nature of our sample means that we observed relatively low levels of perceived stress, which affects longer-term cortisol secretion (Stalder et al., 2017). When compared with past investigations of HCC in student samples, for example, cortisol levels in the current study (3.91 ± 3.52 pg/mg) were considerably lower than values in past research (e.g., 19.9 ± 33.5 pg/mg, Karlén, Ludvigsson, Frostell, Theodorsson, & Faresjö, 2011). Nevertheless, levels were similar to previous studies utilising the same (ELISA) analysis within the same laboratory (3.51 ± 3.11 pg/mg, Simmons et al., 2016). Furthermore, liquid chromatography-mass spectrometry is seen as the gold-standard in cortisol extraction techniques (Gerber, Jonsdottir, et al., 2013), and in a sample of healthy adults levels of HCC were roughly equivalent (median = 3.18, range = 2.16 – 5.58 pg/mg; Staufenbiel et al., 2015). Second, as there was a small amount of missing data on the dependent variables, some of the analyses were insufficiently powered to detect the smallest effect size of interest in this study. Third, we excluded an assessment of stress appraisals, which may have mediated our findings, as they have been found to predict salivary cortisol levels in research in the physical domain (Quested et al., 2011). Relatedly, we are unable rule out the potential effects of possible depressive symptoms or time availability to partake in PA outside of university demands because we did not collect this information (e.g., number of hours of un/paid work). Finally, the reliance on the IPAQ as a self-report assessment of PA levels. The IPAQ measures an individual's perceptions of the amount of PA they take part in at different intensity levels, and these perceptions of PA intensities (e.g., moderate and vigorous) may vary greatly between individuals. Perhaps most salient, people tend to over report their activity levels on the IPAQ when compared to an objective measure of PA (e.g., accelerometer; Rääsk et al., 2017), thus future research may benefit from utilising objective measures of PA.

3.3.2. Conclusion.

There are theoretical reasons (e.g., buffering hypothesis) and empirical evidence (e.g., Gerber et al., 2014) to support the prediction that resilience resources buffer the effects of stress on PA. However, the results of this study are contrary to these expectations in that we found non-significant interaction associations between self-reported individual-level resilience resources and stress (self-reported and assessed via HCC) on PA intensities. Nevertheless, we did find that certain resources correlate with more PA time and less sitting time. These associations were observed in relation to VPA, which is an important intensity at which to exercise to attain improvements in fitness, and its related health benefits. We also found that all resilience resources were negatively associated with perceived stress, and in the case of the BRS with HCC, again adding support to the importance of these resources. In light of the significant burden stress has on mental and physical health globally, it is important that strategies, such as resilience resource development programs, are explored which may help mitigate this burden for individuals. However, additional research is required to disentangle the dynamic associations between individual-level resilience resources and PA intensities before definitive recommendations can be made regarding the nature of such interventions.

3.4. Chapter 3 - Supplementary Material

Table S 3.1. *Vigorous Physical Activity*

Variables	β	95% CI		*p*
Age	-0.140	-0.254	-0.026	0.016
Sex	0.225	0.040	0.410	0.017
BMI	0.023	-0.136	0.182	0.776
PSS	-0.029	-0.196	0.138	0.736
HCC	-0.125	-0.291	0.041	0.140
BRS	0.113	-0.139	0.365	0.378
HOPE	0.317	0.017	0.616	0.038
LOT	-0.149	-0.313	0.015	0.074
GSE	0.081	-0.178	0.340	0.538
ADA	-0.063	-0.339	0.212	0.652
PSS x BRS	-0.110	-0.336	0.117	0.342
HCC x BRS	0.216	0.005	0.426	0.045
PSS x HOPE	-0.103	-0.491	0.285	0.603
HCC x HOPE	0.127	-0.216	0.470	0.468
PSS x LOT-R	-0.026	-0.180	0.127	0.735
HCC x LOT-R	0.016	-0.256	0.288	0.910
PSS x GSE	-0.218	-0.527	0.090	0.166
HCC x GSE	-0.461	-0.890	-0.032	0.035
PSS x ADA	0.317	-0.039	0.673	0.081
HCC x ADA	-0.007	-0.250	0.236	0.955

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOPE = Hope Scale; LOT-R = Life Orientation Test - Revised; GSE = General Self-Efficacy; ADA = Adaptability.

Table S 3.2. *Moderate Physical Activity*

Variables	β	95% CI		*p*
Age	0.062	-0.140	0.263	0.548
Sex	0.252	0.055	0.449	0.012
BMI	0.026	-0.132	0.183	0.749
PSS	0.008	-0.217	0.233	0.945
HCC	-0.121	-0.288	0.046	0.157
BRS	0.111	-0.102	0.324	0.307
HOPE	0.307	0.010	0.605	0.043
LOT	-0.170	-0.382	0.042	0.116
GSE	-0.085	-0.310	0.139	0.456
ADA	-0.070	-0.318	0.178	0.579
PSS x BRS	0.136	-0.127	0.398	0.311
HCC x BRS	0.101	-0.105	0.306	0.336
PSS x HOPE	-0.339	-0.807	0.129	0.156
HCC x HOPE	0.114	-0.172	0.401	0.433
PSS x LOT-R	-0.068	-0.283	0.148	0.539
HCC x LOT-R	0.128	-0.156	0.412	0.377
PSS x GSE	-0.050	-0.435	0.336	0.801
HCC x GSE	-0.337	-0.715	0.041	0.081
PSS x ADA	0.250	-0.108	0.609	0.171
HCC x ADA	0.017	-0.245	0.279	0.898

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOPE = Hope Scale; LOT-R = Life Orientation Test - Revised; GSE = General Self-Efficacy; ADA = Adaptability.

Table S 3.3. Walking Activity

Variables	β	95% CI		*p*
Age	-0.115	-0.249	0.018	0.090
Sex	0.122	-0.132	0.375	0.347
BMI	0.134	-0.014	0.283	0.077
PSS	0.249	0.048	0.450	0.015
HCC	-0.091	-0.260	0.077	0.287
BRS	0.365	0.172	0.558	0.000
HOPE	-0.062	-0.337	0.212	0.655
LOT	0.153	-0.111	0.416	0.256
GSE	-0.312	-0.661	0.037	0.080
ADA	0.121	-0.152	0.394	0.385
PSS x BRS	0.251	-0.056	0.558	0.109
HCC x BRS	-0.149	-0.323	0.025	0.093
PSS x HOPE	0.224	-0.260	0.708	0.365
HCC x HOPE	-0.110	-0.390	0.169	0.439
PSS x LOT-R	-0.141	-0.367	0.084	0.220
HCC x LOT-R	-0.062	-0.342	0.218	0.664
PSS x GSE	-0.563	-1.062	-0.063	0.027
HCC x GSE	0.112	-0.274	0.497	0.570
PSS x ADA	0.301	-0.046	0.648	0.089
HCC x ADA	0.167	-0.086	0.419	0.196

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOPE = Hope Scale; LOT-R = Life Orientation Test - Revised; GSE = General Self-Efficacy; ADA = Adaptability.

Table S 3.4. *Sitting Activity*

Variables	β	95% CI		*p*
Age	0.178	0.017	0.339	0.031
Sex	-0.106	-0.288	0.077	0.256
BMI	-0.005	-0.164	0.155	0.954
PSS	0.069	-0.188	0.325	0.600
HCC	-0.022	-0.172	0.128	0.778
BRS	0.175	-0.085	0.434	0.187
HOPE	-0.355	-0.674	-0.037	0.029
LOT	0.039	-0.184	0.263	0.730
GSE	0.152	-0.229	0.534	0.434
ADA	-0.056	-0.343	0.231	0.701
PSS x BRS	0.365	0.009	0.720	0.044
HCC x BRS	0.048	-0.177	0.273	0.674
PSS x HOPE	-0.014	-0.523	0.494	0.956
HCC x HOPE	-0.255	-0.542	0.032	0.081
PSS x LOT-R	-0.088	-0.268	0.092	0.339
HCC x LOT-R	0.074	-0.141	0.289	0.501
PSS x GSE	0.070	-0.381	0.521	0.760
HCC x GSE	0.274	-0.098	0.645	0.149
PSS x ADA	-0.337	-0.767	0.094	0.125
HCC x ADA	0.001	-0.300	0.302	0.994

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOPE = Hope Scale; LOT-R = Life Orientation Test - Revised; GSE = General Self-Efficacy; ADA = Adaptability.

Table S 3.5. *Descriptive Statistics for Square Root Transformed PA*

	N	Mean	SD	Skew	Kurtosis
Vigorous PA	132	9.78	7.73	.39	-.53
Moderate PA	130	9.20	7.61	.90	.88
Walking Activity	111	14.40	7.61	.73	.36
Sitting Time	127	18.78	4.91	.14	.11

Table S 3.6. *Vigorous Physical Activity – Comparison of Original with Transformed Responses*

	Step 3 Original				Step 3 Transformed			
	β	95% CI		*p*	β	95% CI		*p*
Age	**-0.163**	**-0.287**	**-0.040**	**0.009**	-0.164	-0.308	-0.020	0.025
Sex	**0.241**	**0.058**	**0.425**	**0.010**	**0.264**	**0.095**	**0.434**	**0.002**
BMI	0.055	-0.089	0.199	0.457	0.063	-0.089	0.216	0.417
PSS	-0.082	-0.250	0.086	0.338	-0.030	-0.204	0.143	0.732
HCC	-0.037	-0.237	0.164	0.721	0.009	-0.178	0.197	0.921
BRS	0.193	-0.011	0.396	0.063	0.245	0.030	0.460	0.026
PSS x BRS	-0.077	-0.210	0.056	0.258	-0.019	-0.145	0.107	0.771
HCC x BRS	0.007	-0.151	0.165	0.931	0.041	-0.115	0.196	0.606
R^2		0.186				0.199		
Age	-0.113	-0.233	0.008	0.068	-0.102	-0.251	0.048	0.183
Sex	**0.287**	**0.123**	**0.452**	**0.001**	**0.321**	**0.170**	**0.473**	**0.000**
BMI	0.020	-0.122	0.163	0.780	0.021	-0.128	0.170	0.783
PSS	-0.016	-0.180	0.148	0.852	0.009	-0.162	0.181	0.914
HCC	-0.048	-0.251	0.156	0.645	0.007	-0.170	0.184	0.937
HOP	**0.340**	**0.147**	**0.532**	**0.001**	**0.335**	**0.140**	**0.530**	**0.001**
PSS x HOP	-0.105	-0.252	0.041	0.159	-0.020	-0.141	0.100	0.740
HCC x HOP	-0.128	-0.279	0.023	0.097	-0.143	-0.308	0.022	0.090
R^2		0.243				0.248		
Age	-0.139	-0.268	-0.010	0.035	-0.131	-0.288	0.026	0.102
Sex	**0.291**	**0.114**	**0.468**	**0.001**	**0.320**	**0.155**	**0.485**	**0.000**
BMI	0.037	-0.107	0.181	0.615	0.035	-0.115	0.185	0.648
PSS	-0.156	-0.309	-0.002	0.047	-0.146	-0.316	0.023	0.091
HCC	-0.038	-0.258	0.182	0.738	0.015	-0.186	0.215	0.884
LOT	0.048	-0.115	0.212	0.562	0.047	-0.118	0.212	0.579
PSS x LOT	-0.020	-0.147	0.106	0.753	0.028	-0.106	0.162	0.683
HCC x LOT	-0.049	-0.240	0.141	0.613	-0.063	-0.249	0.123	0.508
R^2		0.168				0.170		
Age	-0.130	-0.248	-0.012	0.030	-0.125	-0.264	0.013	0.077
Sex	**0.252**	**0.080**	**0.424**	**0.004**	**0.288**	**0.130**	**0.446**	**0.000**
BMI	0.033	-0.112	0.178	0.658	0.030	-0.119	0.178	0.693
PSS	-0.085	-0.249	0.079	0.311	-0.046	-0.219	0.126	0.598
HCC	-0.049	-0.244	0.147	0.627	0.006	-0.170	0.181	0.950
GSE	**0.275**	**0.106**	**0.445**	**0.001**	**0.300**	**0.127**	**0.474**	**0.001**
PSS x GSE	-0.125	-0.299	0.050	0.163	-0.075	-0.232	0.081	0.347
HCC x GSE	-0.178	-0.339	-0.018	0.030	-0.151	-0.310	0.007	0.061
R^2		0.247				0.246		
Age	-0.151	-0.284	-0.017	0.027	-0.135	-0.293	0.024	0.095
Sex	**0.240**	**0.062**	**0.419**	**0.008**	**0.276**	**0.107**	**0.446**	**0.001**
BMI	0.056	-0.087	0.199	0.441	0.053	-0.096	0.201	0.487
PSS	-0.112	-0.277	0.053	0.183	-0.093	-0.257	0.072	0.268
HCC	-0.031	-0.238	0.177	0.772	0.016	-0.175	0.208	0.866
ADA	0.175	-0.019	0.368	0.076	0.151	-0.047	0.349	0.134
PSS x ADA	-0.017	-0.140	0.107	0.790	0.073	-0.061	0.207	0.284
HCC x ADA	-0.098	-0.273	0.077	0.274	-0.084	-0.265	0.096	0.358
R^2		0.189				0.193		

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT = Life Orientation Test; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Table S 3.7. *Moderate Physical Activity – Comparison of Original with Transformed Responses*

	Step 3 Original				Step 3 Transformed			
	β	95% CI		*p*	β	95% CI		*p*
Age	0.045	-0.173	0.264	0.685	-0.031	-0.256	0.195	0.790
Sex	**0.291**	**0.113**	**0.469**	**0.001**	**0.346**	**0.175**	**0.517**	**0.000**
BMI	0.003	-0.141	0.147	0.969	0.010	-0.151	0.171	0.904
PSS	0.000	-0.205	0.205	1.000	-0.043	-0.246	0.159	0.674
HCC	-0.041	-0.229	0.147	0.667	0.005	-0.180	0.190	0.957
BRS	0.102	-0.087	0.291	0.292	0.077	-0.133	0.287	0.473
PSS x BRS	-0.001	-0.121	0.120	0.989	0.020	-0.114	0.155	0.768
HCC x BRS	0.037	-0.157	0.231	0.709	0.037	-0.169	0.243	0.725
R^2	0.128				0.157			
Age	0.063	-0.154	0.279	0.571	-0.006	-0.232	0.220	0.958
Sex	**0.316**	**0.154**	**0.477**	**0.000**	**0.369**	**0.212**	**0.527**	**0.000**
BMI	-0.023	-0.174	0.129	0.769	-0.020	-0.184	0.145	0.816
PSS	0.030	-0.155	0.214	0.753	0.009	-0.188	0.206	0.928
HCC	-0.041	-0.234	0.153	0.680	0.008	-0.177	0.193	0.931
HOP	0.181	-0.017	0.378	0.073	0.194	-0.017	0.405	0.071
PSS x HOP	-0.092	-0.262	0.079	0.292	-0.046	-0.218	0.125	0.596
HCC x HOP	-0.007	-0.192	0.178	0.941	-0.054	-0.254	0.145	0.592
R^2	0.140				0.175			
Age	0.062	-0.182	0.305	0.618	-0.015	-0.273	0.243	0.908
Sex	**0.301**	**0.136**	**0.467**	**0.000**	**0.357**	**0.199**	**0.515**	**0.000**
BMI	0.006	-0.142	0.154	0.939	0.004	-0.152	0.160	0.960
PSS	-0.085	-0.280	0.110	0.394	-0.134	-0.339	0.071	0.199
HCC	-0.048	-0.240	0.145	0.626	-0.005	-0.192	0.182	0.958
LOT	-0.066	-0.244	0.111	0.463	-0.092	-0.294	0.109	0.369
PSS x LOT	-0.042	-0.195	0.110	0.585	-0.070	-0.236	0.095	0.404
HCC x LOT	0.071	-0.124	0.266	0.475	0.001	-0.194	0.195	0.994
R^2	0.130				0.163			
Age	0.062	-0.195	0.318	0.636	-0.017	-0.281	0.248	0.903
Sex	**0.300**	**0.129**	**0.472**	**0.001**	**0.353**	**0.187**	**0.520**	**0.000**
BMI	-0.009	-0.163	0.144	0.904	0.000	-0.164	0.165	0.997
PSS	-0.042	-0.214	0.129	0.629	-0.086	-0.269	0.098	0.359
HCC	-0.043	-0.238	0.152	0.666	0.003	-0.181	0.188	0.971
GSE	0.068	-0.091	0.228	0.402	0.025	-0.158	0.208	0.787
PSS x GSE	-0.060	-0.219	0.100	0.463	-0.006	-0.183	0.171	0.948
HCC x GSE	-0.054	-0.238	0.130	0.566	-0.085	-0.267	0.096	0.357
R^2	0.128				0.159			
Age	0.059	-0.183	0.300	0.634	-0.016	-0.262	0.230	0.900
Sex	**0.308**	**0.131**	**0.485**	**0.001**	**0.360**	**0.191**	**0.529**	**0.000**
BMI	-0.006	-0.156	0.143	0.936	0.000	-0.161	0.160	0.996
PSS	-0.051	-0.223	0.121	0.564	-0.083	-0.262	0.096	0.364
HCC	-0.037	-0.231	0.156	0.705	0.009	-0.177	0.196	0.922
ADA	0.015	-0.157	0.187	0.866	0.003	-0.192	0.199	0.974
PSS x ADA	-0.001	-0.128	0.126	0.983	0.029	-0.110	0.169	0.680
HCC x ADA	0.003	-0.185	0.191	0.974	-0.007	-0.202	0.188	0.944
R^2	0.120				0.152			

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT = Life Orientation Test; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Table S 3.8. *Walking Activity – Comparison of Original with Transformed Responses*

	Step 3 Original				Step 3 Transformed			
	β	95% CI		*p*	β	95% CI		*p*
Age	**-0.147**	**-0.255**	**-0.038**	**0.008**	**-0.227**	**-0.366**	**-0.088**	**0.001**
Sex	0.138	-0.070	0.346	0.193	0.082	-0.125	0.288	0.437
BMI	0.108	-0.045	0.260	0.166	0.103	-0.054	0.261	0.198
PSS	0.256	0.019	0.494	0.034	0.218	0.000	0.436	0.050
HCC	-0.088	-0.229	0.054	0.226	-0.105	-0.252	0.042	0.161
BRS	**0.266**	**0.075**	**0.456**	**0.006**	0.259	0.055	0.464	0.013
PSS x BRS	0.099	-0.078	0.275	0.272	0.157	-0.029	0.344	0.099
HCC x BRS	-0.028	-0.157	0.100	0.665	-0.052	-0.197	0.093	0.480
R^2	0.146				0.168			
Age	-0.116	-0.220	-0.012	0.030	**-0.193**	**-0.327**	**-0.059**	**0.005**
Sex	0.210	-0.002	0.423	0.052	0.157	-0.052	0.367	0.141
BMI	0.079	-0.080	0.238	0.328	0.070	-0.092	0.233	0.396
PSS	0.097	-0.117	0.311	0.374	0.064	-0.141	0.268	0.540
HCC	0.084	-0.223	0.055	0.237	-0.100	-0.245	0.045	0.177
HOP	-0.010	-0.224	0.204	0.925	-0.027	-0.243	0.190	0.810
PSS x HOP	0.056	-0.128	0.239	0.553	0.161	-0.052	0.374	0.138
HCC x HOP	-0.010	-0.151	0.132	0.893	-0.050	-0.198	0.099	0.513
R^2	0.094				0.120			
Age	-0.115	-0.219	-0.011	0.031	**-0.198**	**-0.328**	**-0.068**	**0.003**
Sex	0.237	0.015	0.460	0.037	0.181	-0.035	0.397	0.101
BMI	0.060	-0.092	0.212	0.441	0.045	-0.111	0.200	0.573
PSS	0.138	-0.093	0.368	0.242	0.088	-0.162	0.339	0.490
HCC	-0.084	-0.234	0.065	0.269	-0.111	-0.269	0.047	0.168
LOT	0.086	-0.146	0.318	0.470	0.076	-0.152	0.305	0.512
PSS x LOT	-0.079	-0.309	0.151	0.501	-0.032	-0.245	0.182	0.771
HCC x LOT	-0.063	-0.238	0.112	0.479	-0.110	-0.285	0.065	0.219
R^2	0.110				0.118			
Age	-0.114	-0.226	-0.001	0.047	**-0.199**	**-0.351**	**-0.047**	**0.010**
Sex	0.226	0.012	0.440	0.039	0.175	-0.037	0.386	0.105
BMI	0.078	-0.081	0.236	0.336	0.069	-0.097	0.235	0.417
PSS	0.065	-0.131	0.261	0.513	0.039	-0.157	0.235	0.696
HCC	-0.080	-0.222	0.062	0.269	-0.099	-0.251	0.052	0.199
GSE	-0.051	-0.264	0.163	0.642	-0.058	-0.272	0.155	0.591
PSS x GSE	-0.028	-0.257	0.201	0.812	0.065	-0.183	0.312	0.608
HCC x GSE	0.080	-0.072	0.231	0.303	0.056	-0.096	0.207	0.470
R^2	0.101				0.107			
Age	-0.124	-0.241	-0.008	0.036	**-0.203**	**-0.356**	**-0.051**	**0.009**
Sex	0.196	-0.037	0.430	0.100	0.133	-0.092	0.359	0.247
BMI	0.076	-0.086	0.239	0.356	0.065	-0.105	0.236	0.454
PSS	0.131	-0.085	0.347	0.234	0.110	-0.096	0.317	0.293
HCC	-0.086	-0.225	0.054	0.229	-0.109	-0.258	0.040	0.153
ADA	0.080	-0.118	0.278	0.428	0.098	-0.105	0.301	0.343
PSS x ADA	0.045	-0.088	0.178	0.508	0.117	-0.050	0.284	0.170
HCC x ADA	0.073	-0.043	0.189	0.215	0.051	-0.082	0.184	0.454
R^2	0.109				0.132			

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT = Life Orientation Test; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Table S 3.9. *Sitting Time – Comparison of Original with Transformed Responses*

	Step 3 Original				Step 3 Transformed			
	β	95% CI		*p*	β	95% CI		*p*
Age	0.160	0.011	0.308	0.035	0.146	-0.002	0.294	0.053
Sex	-0.135	-0.332	0.063	0.181	-0.151	-0.343	0.040	0.121
BMI	-0.035	-0.190	0.120	0.658	-0.026	-0.179	0.127	0.737
PSS	0.161	-0.104	0.426	0.233	0.164	-0.087	0.416	0.200
HCC	-0.042	-0.190	0.105	0.575	-0.025	-0.173	0.123	0.742
BRS	0.112	-0.156	0.380	0.411	0.145	-0.121	0.410	0.287
PSS x BRS	0.053	-0.095	0.200	0.485	0.010	-0.138	0.158	0.895
HCC x BRS	0.088	-0.089	0.264	0.329	0.092	-0.088	0.272	0.316
R^2	0.074				0.075			
Age	0.172	0.036	0.308	0.013	0.166	0.026	0.307	0.020
Sex	-0.107	-0.290	0.076	0.251	-0.121	-0.301	0.060	0.190
BMI	-0.041	-0.199	0.116	0.608	-0.034	-0.191	0.123	0.671
PSS	-0.032	-0.255	0.192	0.781	-0.021	-0.242	0.200	0.850
HCC	-0.028	-0.163	0.107	0.685	-0.013	-0.147	0.122	0.853
HOP	-0.226	-0.446	-0.006	0.044	-0.174	-0.402	0.054	0.135
PSS x HOP	-0.009	-0.176	0.158	0.913	-0.041	-0.213	0.131	0.637
HCC x HOP	0.042	-0.091	0.175	0.533	0.027	-0.104	0.159	0.682
R^2	0.089				0.079			
Age	0.182	0.037	0.326	0.014	0.173	0.030	0.317	0.018
Sex	-0.109	-0.295	0.078	0.253	-0.119	-0.301	0.062	0.198
BMI	-0.055	-0.218	0.109	0.511	-0.044	-0.205	0.118	0.595
PSS	0.087	-0.120	0.294	0.412	0.076	-0.120	0.272	0.448
HCC	-0.036	-0.169	0.097	0.598	-0.019	-0.153	0.114	0.778
LOT	-0.050	-0.218	0.118	0.559	-0.049	-0.218	0.121	0.573
PSS x LOT	-0.104	-0.261	0.053	0.193	-0.109	-0.256	0.037	0.144
HCC x LOT	0.071	-0.078	0.220	0.348	0.063	-0.084	0.210	0.403
R^2	0.068				0.068			
Age	0.178	0.033	0.324	0.016	0.170	0.026	0.314	0.021
Sex	-0.104	-0.291	0.084	0.278	-0.118	-0.298	0.062	0.199
BMI	-0.052	-0.211	0.107	0.520	-0.041	-0.197	0.115	0.606
PSS	0.063	-0.151	0.277	0.564	0.056	-0.159	0.272	0.609
HCC	-0.025	-0.162	0.112	0.722	-0.008	-0.147	0.130	0.907
GSE	-0.060	-0.307	0.187	0.634	-0.036	-0.308	0.235	0.793
PSS x GSE	-0.051	-0.236	0.133	0.586	-0.085	-0.284	0.113	0.400
HCC x GSE	0.111	-0.054	0.276	0.186	0.117	-0.050	0.285	0.170
R^2	0.071				0.073			
Age	0.180	0.034	0.327	0.016	0.165	0.017	0.312	0.029
Sex	-0.073	-0.261	0.115	0.446	-0.092	-0.271	0.087	0.316
BMI	-0.066	-0.224	0.092	0.414	-0.052	-0.210	0.107	0.522
PSS	0.024	-0.181	0.229	0.819	0.022	-0.188	0.232	0.836
HCC	-0.033	-0.160	0.094	0.608	-0.014	-0.141	0.114	0.835
ADA	-0.137	-0.376	0.102	0.261	-0.099	-0.372	0.173	0.475
PSS x ADA	-0.102	-0.314	0.109	0.343	-0.142	-0.375	0.091	0.233
HCC x ADA	0.095	-0.044	0.234	0.179	0.103	-0.044	0.250	0.170
R^2	0.086				0.089			

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT = Life Orientation Test; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Chapter 4: Stress, Physical Activity, Sedentary Behaviour, and Resilience – The Effects of Naturalistic Periods of Elevated Stress: A Measurement Burst Study

Completing tertiary education presents a challenge to students' academic, social, and personal development, and as a result can be a stressful time in their life (Zimmaro et al., 2016). For example, in a large scale (N=3303) national well-being study of university students in Australia, 67% rated their mental health level as being 'fair' or 'poor', and 65% reported high or very high levels of psychological distress (Rickwood, Telford, O'Sullivan, Crisp, & Magyar, 2016). In terms of their tertiary education experiences, a small percentage of students reported experiencing no academic stressors (~1%), where the majority (64.2%) found their academic experience to be either 'very' or 'extremely' stressful. Among university students, stress is associated with poor academic performance, increased levels of episodic drinking, and unhealthy relationship behaviours (Houston et al., 2017). More broadly, stress is associated with numerous deleterious physical (e.g., obesity, cardiovascular disease, type 2 diabetes) and psychological (e.g., generalised anxiety disorder, depression) outcomes (Thoits, 2010). In 2016, there were nearly 1.5 million students enrolled in Australian universities (Universities Australia, 2018), making stress among university students an important concern for national well-being. As university students exhibit higher levels of stress than their non-student counterparts (Orygen, 2017), it is important to understand the downstream effects of this stress on important health behaviours (e.g., physical activity). Therefore, the overall objectives of this study were to examine the effects of stress on physical activity (PA) and sedentary behaviour (SB) over naturalistically different periods of stress, using physiological and self-report indices.

Examination periods have been commonly reported as stressful experiences by university students (Murphy, Denis, Ward, & Tartar, 2010). The aforementioned national well-being survey found exams to be the most stressful academic stressor, with 47.6% of students reporting them as extremely stressful (Rickwood et al., 2016). Examination periods are naturalistic stressors and offer investigators the opportunity to study temporal associations between variables of interest (Stults-Kolehmainen & Sinha, 2014). Researchers opportunistically using these naturalistic periods of elevated stress have demonstrated empirically that students report increases in perceived stress during examination periods when compared to a baseline nonexamination period (e.g., Oaten and Cheng, 2005; Steptoe et al., 1996). This increase in perceived stress has also been reported elsewhere, as have links with physiological markers of stress, such as salivary cortisol, during examination periods (e.g., Murphy et al., 2010; Weeks et al., 2006). Evidence suggests that examination periods increase activity in the hypothalamic-pituitary-adrenal (HPA) axis resulting in an increase in cortisol release (e.g., Lacey et al. 2000; Lucini, Norbiato, Clerici, & Pagani, 2002; Weeks et al., 2006).

Findings are inconsistent across research with some work demonstrating either no change or a decrease in cortisol secretion (Weeks et al., 2006). These findings are based on cortisol measured in saliva and blood serum, which provide a measure of acute cortisol levels at the time of sampling (Dettenborn, Tietze, Kirschbaum, & Stalder, 2012). However, acute measures of stress are problematic when assessing cortisol concentrations over a longer timeframe because HPA activity is highly variable (Stalder et al., 2017). Furthermore, these transient levels of cortisol can be affected by factors such as smoking, drinking alcohol, eating food, and PA prior to sampling (e.g., Gerber et al., 2013; Stalder & Kirschbaum, 2012; Stalder et al. 2017). These limitations have been addressed via an analysis of cortisol taken from hair samples, which capitalises on the incorporation of lipophilic hormones into the growing hair at the follicle (Stalder et al., 2013). Human hair grows on average approximately one centimetre per month (Wenning, 2000); therefore, hair cortisol concentration (HCC) can provide a reliable assessment of secretion over a period of up to six months (Kirschbaum, Tietze, Skolunda, & Dettenborn, 2009). The utility of HCC as a measure is becoming increasingly established, with empirical evidence in support of its overall validity, good levels of intra-individual stability, and high test re-test reliability (Stalder et al., 2017). In light of its growing support, HCC has been used to explore the effect of chronic stress on a number of behaviours such as PA (e.g., Gerber et al., 2013a), and SB (e.g., Teychenne, Olstad, Turner, Costigan, & Ball, 2018).

The beneficial effects of PA on physical and mental health are well recognised (Arem et al., 2016; Rhodes et al., 2017; Stults-Kolehmainen & Sinha, 2014). The Physical Activity Guidelines Committee (2018) recommends that adults take part in a minimum of 150 minutes of moderate intensity, or 75 minutes of vigorous intensity activity weekly to reap important health benefits. These benefits improve both physiological and psychological health, such that meeting the recommended guidelines reduces the risk of all-cause mortality by around 75% (Piercy & Troiano, 2018). Physiological benefits include reduced risk of cardiovascular disease, type 2 diabetes, obesity, stroke, and some cancers (e.g., breast cancer; Warburton & Bredin, 2016), and psychological benefits include lower levels of depression, post-traumatic stress, anxiety, and subjective stress (Stults-Kolehmainen & Sinha, 2014). Despite the wealth of information on the numerous benefits of PA, many people engage in insufficient levels. A recent report found that only 22% of adults meet PA guidelines, with 36% of adults reporting no leisure time activity at all (Piercy & Troiano, 2018). Among student populations, a meta-analysis reported that between 40% and 50% of college students were physically inactive (according to the American College of Sports Medicine's PA guidelines; Keating, Guan, Pinero, & Bridges, 2005). Similar findings of students failing to reach recommended levels of PA have been reported in a number of more recent studies (e.g., Cocca, Liukkonen, Mayorga-vega, & Viciana-Ramirez, 2014; Pengpid et al., 2015). As well as being physically inactive, research has found that students spend a large amount of their time on sedentary activities (e.g., studying, using the computer, watching TV), on average eight hours a day (Rouse & Biddle, 2010). Therefore, it is important to understand factors which perpetuate SB's and physical inactivity to identify possible intervention targets to promote a more active lifestyle for students (Deliens, Daforche, DeBourdeaudhuij, & Clarys, 2015).

Stress is considered an important factor in understanding why people take part in limited or no PA (Burg et al., 2017), with research typically examining the effects of PA on stress demonstrating its salubrious effect (Wipfli, Rethorst, & Landers 2008). However, in a large systematic review of 168 studies, higher levels of stress were associated with lower levels of PA or higher levels of SB in 72.8% of the studies (Stults-Kolehmainen & Sinha, 2014). These findings were present across studies that included self-reported and/or physiological measures of stress (e.g., salivary cortisol), though stress was assessed via physiological markers in only seven studies. The negative association between stress and PA, and positive association with SB was observed in chronically stressed populations (e.g., caregivers, cancer survivors, first-time mothers, medical students) and in naturalistically varying periods of elevated stress (e.g., examination periods vs a baseline control time point). Collectively, these findings indicate that stress represents an important precursor to poor PA levels and high levels of SB among healthy and clinical populations. Of the studies reviewed by Stults-Kolehmainen and Sinha, nearly 70% were conducted over a single time point, meaning longitudinal research is required to examine the temporal dynamics between stress, PA, and SB. Laboratory studies involving manipulations of stress using the Trier Social Stress test (e.g., Roemmich, Gurgol, & Epstein, 2003) have demonstrated that transient acute stress has a negative effect on PA. Although these laboratory manipulations of acute stress are important for controlled investigations, they are limited in terms of their ecological validity, in that multiple life stressors often accumulate over time, even within the space of one day. Therefore, the temporal dynamics of stress are an important consideration for a nuanced understanding of its effects on important health behaviours like PA and SB.

To alleviate these concern, researchers have employed quasi-experimental designs to examine stress and PA at two different time points, assessing individuals over naturalistically different periods of stress comparing those who are theoretically encountering a period of low stress and others who are experiencing high stress. For example, Oaten and Cheng (2005) explored the effect of real world stress (examination periods vs control group) on regulatory behaviours (e.g., PA, consumption behaviours, and study and self-care habits) among a sample of university students (N = 57). They found that when compared to a control group (assessed during normal term time), students in the exam stress group reported a significant increase in perceived stress from baseline measures (4 weeks prior to exam), which resulted in a significant decrease in PA levels. Specifically, they reported significant decreases in exercise frequency, duration, and perceived ease maintaining exercise regimes among those students who were exposed to examination stress. This study relied on self-reported PA levels, common in previous research (e.g., Stults-Kolehmainen & Sinha, 2014), though PA levels have been found to be over reported when compared with a device based measure of PA (e.g., Dyrstad et al., 2014). Therefore, despite the strengths of the longitudinal design, the methodological approach is limited in that it represents a single snapshot of one possible linear trend, rather than a dynamic perspective of the nature of stress and its effects on health behaviours over time. Longitudinal designs incorporating multiple physiological and self-report assessments of stress and related variables measured across time are required to provide insight into such temporal dynamics.

Measurement burst studies (Nesselroade, 1991) are one category of longitudinal design that have the potential to shed light on the temporal dynamics between stress and health behaviours such as PA and SB. The key characteristic and innovation of measurement bursts designs is that they incorporate two categories of longitudinal methodologies into a single framework; intensive, short-term (e.g., daily diary), and long-term assessments which examine intra-individual change over a wider time frame (e.g., months or years; Sliwinski, 2008). This type of design allows the examination of both intra- and inter-individual change over bursts of intense measurement, providing both fine-grained temporal associations between variables within bursts (e.g., daily effects), as well as the change in this association across bursts and individuals (Sliwinski, 2008). Measurement burst designs allow the examination of this complex association using resource intensive designs to capture the interaction of intra-individual processes, which happen over different temporal intervals. This approach may help to clarify the discrepancies in findings seen in previous research and shed light on the dynamic nature of the associations between stress, PA, and SB.

Literature suggests that the association between stress, PA, and SB is not universal; therefore, there is a need to examine factors that may protect individuals against the negative effects of stress (Stults-Kolehmainen & Sinha, 2014). This thinking is in keeping with a resilience framework (e.g., Masten, 2011; Windle, 2011), in which an individual may draw upon resources that can buffer the deleterious effects of stress on PA and SB. The last two decades has seen a surge of interest in psychological resilience, although debate remains around a universally accepted definition (Bonanno, Romero, & Klein, 2015). We ascribe to the view that resilience encapsulates an individual's trajectory of functioning over time within the context of exposure to a significant adversity or stressor, where the individual withstands the negative effects, or bounces back to relatively healthy levels of psychological and physical functioning from pre- to post-adversity (e.g., Gucciardi et al., 2018; Fletcher, 2018). Conceptualising resilience in this way helps to clarify the distinction between resources, processes, and outcomes. Resilience resources (commonly referred to as protective factors) are those factors that maximise the likelihood of individuals withstanding or bouncing back from the deleterious effects of a significant stressor, whereas processes represent the translation of an individual's potential for action via cognitive, emotional, or behavioural mechanisms into a demonstrable outcome. In this way, resilience as an emergent outcome is demonstrated when salient resources are used in response to a significant stressor to produce an adaptive response that enables individuals to withstand or bounce back from the negative effects of the experience. Thus, one would expect that some individuals have access to a greater quantity and/or quality of resilience resources than others, thereby enabling them to be more resilient to the deleterious effects of stress.

Research examining the moderating effect of resilience resources on the associations between stress and PA and SB is limited. To date, only one cross-sectional study has examined this conceptual proposition (Lines et al., in press). Among a sample of university students (N = 135), individuals who reported higher levels of resilience resources reported lower levels of psychological stress (though not physiological stress) and higher levels of vigorous PA. For the other PA intensities these associations were largely small and non-significant. The hypothesised buffering effect of resilience resources on the effect of stress – both self-reported and physiological – on PA and SB were unsupported. Given the cross-sectional nature of this study, additional research is required to examine the potential buffering effect of resilience resources on the effects of stress on PA and SB. Longitudinal designs, in particular, are essential because they align concept with methodology, where resilience is conceptualised as an individual's trajectory of functioning over time within the context of a specific stressor or adversity.

Against this backdrop, the objective of this study was to examine temporal associations between device measured PA and SB and two indices of stress (perceived and biological), and the possible buffering effect of individual-level resilience resources across naturalistically different periods of stress. We utilised a longitudinal measurement burst design (Sliwinski, 2008) to accomplish our objectives. In the current study, we conducted multiple bursts of daily sampling of students' perceived stress and device-based measured PA and SB levels over naturalistically different periods of stress separated by long intervals between bursts. In light of previous research, we expected that individuals would take part in less PA and spend more time in sedentary activities on days where they reported higher levels of stress. We also anticipated that higher levels of stress (both perceived and physiological) at commencement of the burst would be related to lower levels of PA and higher levels of SB during that burst. Informed by a resilience framework (Masten, 2011; Windle, 2011), we expected resilience resources to buffer the effect of stress on PA and SB, such that the deleterious effects of stress on PA and SB will be reduced for those individuals who report higher levels of resilience resources. Our efforts were focused on a sample of university students who were enrolled in courses where there was a defined 2-week period of written and/or practical examinations at the end of a 12-week semester. Doing so allowed us to capture assessments of the key study variables before, immediately prior to, and after a naturalistic period of stress. The utilisation of physiological measures of stress, PA, and SB and the longitudinal temporal pattern are unique to the current study. Collectively, these methods will address gaps in research regarding the dynamic temporal associations between stress and PA and SB and the possible buffering effect of resilience resources.

4.1. Methods

4.1.1. Participants and Procedures.

This study was approved by the Human Research Ethics Committee at the lead author's institution. University students from a university in Western Australia were recruited to take part in a measurement burst study. Recruitment occurred via two methods: (i) an online research participation pool, where students sign up to participate in studies in return for incentives; and (ii) invitations to participants who had consented to be contacted following a previous study conducted by our group (Lines et al., in press). In total, 52 participants completed at least 1 burst; 75% (n=39) completed all three bursts, 15.4% (n=8) completed 2 bursts, and 9.6% (n=5) completed 1 burst only. The participants were aged 18 – 38 years (M = 21.94, SD = 4.57), and 78.8% (n=41) of the sample was female. Of the sample, 50% (n=26) were born in Australia, 71.2% (n=37) speak English as their first language, and 57.7% (n=30) lived at home with their parents. Approximately 73% (n=38) spent time outside of university working in a paid job (mean ± SD; 10.29 ± 8.73 hrs), and 53.8% (n=28) of participants took part in unpaid or voluntary work (mean ± SD; 2.52 ± 3.47 hrs).

The study consisted of 3 bursts of 6 days of data collection, with each burst separated by an 8-week gap. The bursts took place before, immediately prior to, and after an examination period. The first burst took place in the middle of first semester (March/April); the second burst occurred in the study week prior to exams (May/June); and the final burst took place in the first week of second semester following the university holidays (July/August). The chosen design captured intensive data for each participant (6 days x 3 bursts x 52 participants = 936 possible days). Of the 936 possible days of data collection, there was 790 useable days of daily diary self-report data (84.4%), and 788 usable days of accelerometer data (84.2%).

Participants visited the lab at the beginning and end of each burst for a short session (around 10 minutes). In the initial meeting, participants were given a brief introduction to the study, provided an information sheet, and consented to the study. In this initial visit, participants completed a multi-section survey (i.e., demographic information, perceived stress, and resilience resources) online via Qualtrics (Qualtrics LLC, Utah, USA), collected their accelerometer, and provided a hair sample. Throughout each 6-day burst, participants completed a daily assessment of academic stress and general perceived stress on Qualtrics, with an individualised link sent out via e-mail at 8:00 pm each evening. A text message was also sent out to participants at 8:00 pm reminding them to complete their daily diary. A further two e-mail reminders were sent out to participants who had not completed the daily assessment; the first at 9:00 pm and the second at 10:00 pm. Each daily diary survey was closed at 4:00 am the following day. Seven days later participants returned to the lab to hand in their accelerometers, and receive their incentivisation ($25 voucher).

4.1.2. Measures.

4.1.2.1. Survey pack.

4.1.2.1.1. *Preceived stress.* The 10-item Perceived Stress Scale (PSS; Cohen, Kamark, & Mermelstein, 1983) was used to assess the degree to which situations in an individual's life over the past month were perceived as stressful (e.g., "In the last month, how often have you been upset because of something that happened unexpectedly?"). Items were assessed on a 5-point scale from 0 (*never*) to 4 (*very often*). Past work with student samples has provided reliability and validity evidence of test scores obtained with the PSS (Shapiro, Brown, Thoresen, & Plante, 2011). In the current sample, internal reliability evidence was sound (burst 1 $\alpha = .88$; burst 2 $\alpha = .88$; and burst 3 $\alpha = .86$).

4.1.2.1.2. *Resilience resources.* Our choice of resilience resources was informed by a conceptual and methodological review of 17 measures of resilience (Pangallo, Zibarras, Lewis, & Flaxman, 2015). The Psychological Capital Questionnaire (PsyCap; Luthans, Youssef, & Avolio, 2007) received the highest ratings of the assessed measures and is comprised of four broad resilience resources, namely hope, optimism, self-efficacy, and bounce back ability. Each of the surveys was measured on a 7-point scale ranging between 1 (*strongly disagree*) and 7 (*strongly agree*).

4.1.2.1.2.1. Hope. The Adult Hope Scale (AHS) (Snyder et al., 1991) is a 12-item measure of an individual's hope in regards to personally valued objectives. The scale is comprised of two factors, each measured by four items; the remaining four are fillers and were omitted from the current study. The *pathway* factor captures one's perception of their ability to overcome goal-related barriers to reach their goals (e.g., "I can think of many ways to get the things in life that are important to me"). The *agency* factor reflects one's goal-directed energy and motivation to use pathways to achieve their goal (e.g., "I meet the goals that I set for myself"). Previous research has supported the reliability and validity evidence of the AHS (e.g., Feldman & Kubota, 2015; Snyder et al., 1991). In the present sample, the internal reliabilities were sound (burst 1 $\alpha = .84$; burst 2 $\alpha = .87$; and burst 3 $\alpha = .84$).

4.1.2.1.2.2. Optimism. The Life Orientation Questionnaire – Revised (LOT-R) (Scheier, Carver, & Bridges, 1994) is a 10-item measure of an individual's perceived optimism (e.g., "Overall, I expect more good things to happen to me than bad") and pessimism (e.g., "If something can go wrong for me, it will"). Each of the two dimensions are measured with three items; the remaining four statements are fillers and were omitted from the current study. A composite score was created by combining the optimism and pessimism (reverse scored) items, with a larger score reflecting higher levels of optimism. Test scores on the LOT-R have demonstrated good internal consistency ($\alpha = .85$; Huffman et al., 2016) and test-retest reliability evidence (r = .73; Atienza, Stephens, & Townsend, 2004). Internal reliability evidence in the current study was sound (burst 1 $\alpha = .75$; burst 2 $\alpha = .75$; and burst 3 $\alpha = .87$).

4.1.2.1.2.3. General self-efficacy. The General Self-Efficacy Scale (GSE) (Chen, Gully, & Eden, 2001) is an 8-item unidimensional measure of one's belief in their ability to accomplish a desired goal (e.g., "I will be able to achieve most of the goals that I have set for myself"). Scores on the GSE are cumulative with a larger score indicating a higher level or general self-efficacy. Test scores on the GSE within student samples have shown good internal consistency ($\alpha = .86$ - .90) and test-retest reliability ($r = .62$ to .86) evidence (Chen et al., 2001). In the current sample, internal reliability evidence was excellent (burst 1 $\alpha = .91$; burst 2 $\alpha = .91$; and burst 3 $\alpha = .92$).

4.1.2.1.2.4. Bounce back ability. The Brief Resilience Scale (BRS) (Smith et al., 2008) is a 6-item measure of an individual's perceived ability to bounce back from stress. Three of the items are positively worded (e.g., "It does not take me long to recover from a stressful event"), and three are negatively worded (e.g., "I tend to take a long time to get over set-backs in my life"). The scale score is computed by reverse scoring the negatively worded items producing a cumulative score, with a larger score reflecting higher levels of bounce back ability. Previous research has demonstrated good levels of internal consistency (α = .81 - .91) and test-retest reliability (at 1 month r = .69 and at 3 months r = .62) evidence (Smith et al., 2008). Internal reliability evidence in the present sample was sound (burst 1 α = .84; burst 2 α = .88; and burst 3 α = .89).

4.1.2.2. Daily diary.

4.1.2.2.1. *Academic stressors.* We developed an 18 item scale to assess the frequency of academic stressors. Drawing from a review of 40 qualitative research papers (Hurst, Baranik, & Daniel, 2012), stressors were generated from the most frequently occurring sub-themes to emerge from the review (e.g., "Inadequate academic support from teaching staff"). Participants indicated whether or not they had experienced each stressor (0 = no, 1 = yes), and a composite score was created by summing the total number of different academic stressors experienced, with a possible range between 0 and 18. This scale assessed stressor frequency and should therefore theoretically exclude any influence of appraisals. Internal reliability evidence in the current study was sound (burst 1 α = .76; burst 2 α = .75; and burst 3 α = .79).

4.1.2.2.2. *Perceived stress.* The 4-item version of the Perceived Stress Scale (PSS-4) (Cohen & Williamson, 1988) was used to measure an individual's general perceived stress. Items were assessed on a 5-point scale from 0 (*never*) to 4 (*very often*). The internal consistency of the PSS-4 has been found to be acceptable in a review of 19 studies (Lee, 2012). In the current sample, internal reliability evidence was acceptable (burst 1 α = .69; burst 2 α = .71; and burst 3 α = .72).

4.1.2.3. Physical activity.

Participants wore a triaxial accelerometer (GENEActiv Original; Activinsights Ltd, Kimbolton, Cambs, UK) on their non-dominant wrist for 24 hours a day until the end of burst visit 1 week later. The GENEActiv accelerometer measures acceleration in three axes with a range between -8 g and +8 g. Consistent with previous research (e.g., Hildebrand et al., 2014; Hildebrand et al., 2016; White, Westgate, Wareham, & Brage, 2016), accelerometers were set to a sampling frequency of 60 Hz. The accelerometers were set to start recording at 8:00 am on the day of the beginning of burst session and were set to record for a maximum of 8 days.

4.1.2.3.1. *Data processing.* The accelerometers were set up and the data was downloaded using the GENEActiv software version 3.1, with raw .csv files converted into .bin files for data processing. Data was analysed using the R package GGIR version 3.3.3 (https://cran.r-project.org/web/packages/GGIR/GGIR.pdf). Raw accelerometry data processing in GGIR facilitates data cleaning using autocalibration with local gravity as reference (van Hees et al., 2014), detection of non-wear time (van Hees et al., 2013), detection of sustained abnormally high levels of acceleration, and extraction of defined levels of acceleration which can be set to reflect intensity levels of PA. As in previous studies (e.g., da Silva et al., 2014; Hildebrand et al., 2014; Menai et al., 2017; Rowlands et al., 2016), acceleration is expressed relative to gravity in *g* units (1 g=9.81 $m{\cdot}s^{-2}$; 1 mg = 0.00981 $m{\cdot}s^{-2}$). The summary measures used in the current study are time spent (in minutes) in the following PA intensities: sedentary (<50 m*g*), light (50 – 100 m*g*), moderate (100 – 400 m*g*), and vigorous (>400 m*g*), as utilised in past research (e.g., Hildebrand et al., 2014). Accelerometer data was confined to 6 full days and nights (4 weekdays and 2 weekend days), starting at waking time on the day after the devices were distributed. This decision was made so each data set represented the same window for analysis, as accelerometer return date sessions sometimes exceeded the 7 day measurement duration.

4.1.2.4. Hair cortisol concentration.

Hair samples were collected from the posterior vertex region of the head and were cut as close to the scalp as possible (Sauve et al., 2007). Hair samples were not collected in cases where participants had less than 3 cm of hair, minimising cosmetic impact, resulting in significantly more females taking part. Of those who did take part, two attended one of the initial burst sessions with hair length < 3 cm, and therefore were unable to provide a sample for that burst (136 of 138 or 98.6% of HCC measures available). As hair grows at approximately 1cm per month (Wennig, 2000), samples were cut to around 2 cm to represent cortisol secretion over the preceding two months (the gap between bursts). Individual samples were wrapped in aluminium foil with an elastic band around the root end of the sample, and stored at room temperature before being sent to a specialist lab for analysis (Stratech Scientific APAC Pty Ltd (Sydney, Australia)). Samples were cut to 2 cm in length before processing in accordance with the previously described ELISA procedure (e.g., Davenport, Tiefenbacher, Lutz, Novak, & Meyer, 2006), using commercially available Salimetrics, LLC (Carlsbad, USA) ELISA immunoassays. The intra-assay variabilities were 5.8%, 6.1%, and 5.6%, and the inter-assay variabilities were 6.4%, 6.6%, and 6.3% (for bursts 1, 2, and 3 respectively). These levels are below the manufactures acceptable limits of < 15% for inter-assay and < 10% for intra-assay variability (Salimetrics, 2019)

4.1.3. Statistical analysis.

Due to the nested nature of the data we used multilevel modelling in Mplus 8 (Muthén & Muthén, 2017) to (i) analyse the effect of stress (academic and perceived) on PA intensities, and (ii) to examine whether burst-level and person-level resilience resources, and subjectively and objectively measured stress moderated this association. The data consisted of daily measurements (level 1) nested within bursts (level 2) nested within individuals (level 3); we refer to this nesting structure as day level, burst level, and person level. Initially, we computed empty models of the variables of interest (PA, daily stress), allowing for decomposition of variance into day, burst, and person levels. A 3-level model was employed to examine the primary research questions. At level 1, daily stress assessments (academic or general) were included as a predictor of PA intensities. Daily stress variables were person mean centred and modelled as random effects (Callum et al., 2012). At level 2, burst level resilience resources (hope, optimism, self-efficacy, and bounce back ability) and subjective and objective stress were included as predictors of the random within-person slope to test cross-level moderation effects of daily stress on PA intensities. The effect of stress (burst mean centred) on PA intensities across bursts was modelled as a random slope at level 2. We controlled for the linear effect of burst (coded 0, 1, 2) on PA intensities. At level 3, person level covariates (age, sex, BMI, work, and voluntary/unpaid work hours) were grandmean centred and modelled as fixed effects on PA intensities (Armeli et al., 2010). Finally, we modelled cross-level interactions between person-level resilience resources and stress (grandmean centred) via a direct effect on the random between-burst effect of stress on PA intensities. Random variance in PA and stress slopes were tested, and random intercepts of outcomes were allowed to covary.

Table 4.1. *Descriptive Statistics for Burst 1*

Variables	Between-Person Correlations																		
	1	2	3	4	5	6	7	8	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*M*	*SD*
1. Age	-																	21.94	4.528
2. Gender	-.09	-																-	-
3. BMI[a]	.29**	.06	-															23.23	3.58
4. Work[b]	.16**	.01	.24**	-														10.29	8.66
5.Volunteer[b]	-.02	.08	.27**	.24**	-													2.52	3.45
6.HCC[c]	.05	.10	.14*	.27**	-.16**	-												5.81	4.96
7. Perceived Stress[d]	-.09	.18**	-.14*	.13*	-.05	-.09	-											2.91	.63
8.Resilience[e]	.10	-.35**	.02	.11	-.09	.09	-.50**	-										4.38	1.01
9.Hope[e]	.10	-.13*	.27**	.06	.20**	-.10	-.43**	.34**	-									5.10	.85
10.Optimism[e]	.07	-.12*	.15*	-.08	-.04	-.09	-.44**	.21**	.62**	-								4.53	1.04
11. Self-Efficacy[e]	-.08	-.16**	.30**	.12	.08	-.06	-.31**	.45**	.68**	.45**	-							5.13	.92
12. DAS	.25**	.02	.14*	.03	.18**	.08	.14*	-.24**	-.16**	-.31**	-.23**	-						3.28	2.11
13.DGS	-.07	.07	-.08	.05	.09	-.01	.48**	-.42**	-.34**	-.45**	-.26**	.47**	-					2.52	.53
14.Sedentary[f]	-.15*	.10	-.40**	-.55**	-.17**	-.37**	.23**	-.35**	-.16**	-.04	-.21**	-.11	.06	-				1206.60	62.61
15.Light[f]	.25**	.13*	.39**	.58**	.09	.41**	-.12	.26**	.10	.09	.24**	.11	-.02	-.85**	-			123.00	29.24
16. Moderate[f]	.04	-.20**	.32**	.48**	.22**	.27**	-.25**	.33**	.18**	-.01	.15*	.09	-.07	-.94**	.64**	-		104.16	36.70
17.Vigorous[f]	.15*	-.40**	.24**	-.05	.04	.23**	-.33**	.31**	.11	.09	.06	.04	-.13*	-.50**	.14*	.58**	-	6.24	6.27

Note. N = 48; BMI = Body mass index; HCC = Hair cortisol concentration; DAS = Daily academic stress; DPS = Daily general stress; [a] BMI scores in kg·m^2; [b] Measured in hours per week; [c] HCC in pg·mg^{-1}; [d] Range 1 – 5; [e] Range 1 – 7; [f] min·day^{-1}; * = Correlation is significant at the 0.05 level (2-tailed); ** = Correlation is significant at the 0.01 level (2-tailed).

Table 4.2. *Descriptive Statistics for Burst 2*

Variables	Between-Person Correlations 1	2	3	4	5	6	7	8	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*M*	*SD*
1. Age	-																	21.94	4.53
2. Gender	-.09	-																-	-
3. BMI[a]	.29**	.06	-															23.23	3.58
4. Work[b]	.16**	.01	.24**	-														10.29	8.66
5.Volunteer[b]	-.02	.08	.27**	.24**	-													2.52	3.45
6.HCC[c]	-.03	.12*	.03	.20**	-.03	-												4.80	7.52
7. Perceived Stress[d]	-.35**	.06	-.32**	.06	.04	.00	-											2.88	.66
8.Resilience[e]	.20**	-.16**	.03	.01	-.13*	.06	-.65**	-										4.61	1.07
9.Hope[e]	.10	-.17**	-.05	.06	.11	.00	-.24**	.37**	-									5.19	.85
10.Optimism[e]	.04	-.08	.21**	-.01	.09	.14*	-.26**	.25**	.58**	-								4.59	1.03
11. Self-Efficacy[e]	-.02	-.13*	.15**	.08	.05	-.14*	-.17**	.37**	.68**	.51**	-							5.26	.84
12. DAS	.28**	-.22**	.03	.01	.12*	-.09	.37**	-.25**	-.13*	-.23**	-.13*	-						2.56	1.94
13.DGS	-.25**	-.08	-.13*	-.05	-.06	.00	.63**	-.59**	-.39**	-.36**	-.39**	.40**	-					2.42	.56
14.Sedentary[f]	.02	-.12	-.19**	-.44**	-.13*	-.20**	-.02	-.16**	-.08	-.06	-.08	-.07	.15*	-				1202.69	69.03
15.Light[f]	.06	.21**	.16**	.46**	.07	.31**	.02	.18**	.01	.07	.02	.05	-.15*	-.91**	-			123.14	29.76
16. Moderate[f]	-.07	.06	.16**	.39**	.19**	.10	.03	.13*	.12*	.04	.09	.07	-.14*	-.97**	.78**	-		108.58	40.63
17.Vigorous[f]	.02	-.13*	.30**	.08	-.07	.12*	-.12	.10	-.04	.13*	.20**	.01	-.03	-.52**	.29**	.54**	-	5.59	5.17

Note. $N = 48$; BMI = Body mass index; HCC = Hair cortisol concentration; DAS = Daily academic stress; DPS = Daily general stress; [a] BMI scores in $kg{\cdot}m^2$; [b] Measured in hours per week; [c] HCC in $pg{\cdot}mg^{-1}$; [d] Range 1 – 5; [e] Range 1 – 7; [f] $min{\cdot}day^{-1}$; * = Correlation is significant at the 0.05 level (2-tailed); ** = Correlation is significant at the 0.01 level (2-tailed).

Table 4.3. *Descriptive Statistics for Burst 3*

Variables	Between-Person Correlations 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	*M*	*SD*
1. Age	-																	21.94	4.53
2. Gender	-.09	-																-	-
3. BMI[a]	.29**	.06	-															23.23	3.58
4. Work[b]	.16**	.01	.24**	-														10.29	8.66
5.Volunteer[b]	-.02	.08	.27**	.24**	-													2.52	3.45
6.HCC[c]	.29**	.02	.25**	.01	-.34**	-												4.22	2.39
7. Perceived Stress[d]	-.16*	.10	-.07	-.06	.11	-.02	-											2.57	.64
8.Resilience[e]	.12	-.16*	.04	-.09	-.23**	.14*	-.71**	-										4.79	1.17
9.Hope[e]	.10	-.14*	.21**	.14*	.05	.04	-.55**	.60**	-									5.32	.84
10.Optimism[e]	.09	-.12	.16*	-.17**	-.00	.01	-.69**	.65**	.76**	-								4.64	1.23
11. Self-Efficacy[e]	.03	-.08	.16**	.12	-.02	.12	-.60**	.74**	.84**	.66**	-							5.31	.84
12. DAS	.41**	-.22**	.01	.04	.28**	-.09	.18**	-.31**	-.24**	-.28**	-.21**	-						2.19	2.27
13.DGS	-.01	.08	-.02	.08	.05	-.16*	.60**	-.65**	-.50**	-.54**	-.62**	.26**	-					2.28	.58
14.Sedentary[f]	-.14*	.02	-.37**	-.32**	-.04	-.26**	.26**	-.12	-.15*	-.04	-.28**	-.05	.10	-				1208.98	73.10
15.Light[f]	.20**	-.01	.42**	.30**	-.02	.17**	-.32**	.09	.13*	.07	.23**	.06	-.08	-.92**	-			120.81	30.00
16. Moderate[f]	.09	-.02	.32**	.32**	.10	.24**	-.23**	.12	.16*	.02	.30**	.05	-.10	-.98**	.83**	-		103.87	43.27
17.Vigorous[f]	.07	-.13*	.05	.11	-.12	.48**	.05	.09	.01	-.01	.19	-.09	-.08	-.49**	.23**	.53**	-	6.35	6.35

Note. N = 48; BMI = Body mass index; HCC = Hair cortisol concentration; DAS = Daily academic stress; DPS = Daily general stress; [a] BMI scores in $kg{\cdot}m^2$; [b] Measured in hours per week; [c] HCC in $pg{\cdot}mg^{-1}$; [d] Range 1 – 5; [e] Range 1 – 7; [f] $min{\cdot}day^{-1}$; * = Correlation is significant at the 0.05 level (2-tailed); ** = Correlation is significant at the 0.01 level (2-tailed).

4.2. Results

4.2.1. Descriptive statistics.

The descriptive statistics for the sample are presented by burst in Tables 4.1 – 4.3. Briefly, across all bursts the three PA intensities demonstrated significant weak to strong positive correlations with each other (.14 < r < .83); each of the three intensities also demonstrated significant moderate to strong negative correlations with sedentary activities (light = -.85 < r < -.92; moderate = -.94 < r < -.98; vigorous = -.49 < r < -.52). The individual-level resilience resources demonstrated significant weak to strong positive correlations with each other across all bursts (.21 < r < .84). When considering stress measures, objectively measured stress (HCC) shared significant weak to moderate positive correlations with PA intensities (.12 < r < .48) across bursts (with the exception of burst 2 moderate PA), and significant negative correlations with sedentary activity (-.20 < r < -.37). Both day level measures of stress demonstrated significant weak to moderate negative correlations with individual-level resilience resources across all bursts (academic = -.13 < r < -.31; general = -.26 < r < -.65), and a significant positive correlation with each other (.26 < r < .47).

4.2.2. Empty means models.

The decomposition of variance of study variables across the three levels of analysis are presented in Table 4.4. With the exception of academic stress, for all study variables the between day-level (level 1) demonstrated the most variation (ranging from 51.1% to 73.8% of total variance). Variation at the between person level (level 3) was smaller than that of the between day level (ranging from 20.5% to 45.1%). Variance across bursts being substantially smaller across all variables, ranging between 2.4% – 11.8%. In terms of academic stress, the most variation was observed at the between person level (48.9%), followed by the between days (level 1, 39.3%).

Table 4.4. *Variance Decomposition in Empty Three-Level Models.*

	Physical Activity				Stress	
	Sedentary	Light	Moderate	Vigorous	Academic	General
Level 3	3552.63	640.65	1249.93	20.86	3.19	0.21
(Across People)	(41.3%)	(33.4%)	(45.1%)	(20.5%)	(48.9%)	(34.3%)
Level 2	245.73	46.25	104.56	5.82	0.77	0.03
(Across Bursts)	(2.9%)	(2.4%)	(3.8%)	(5.7%)	(11.8%)	(4.5%)
Level 1	4801.22	1228.85	1415.01	74.97	2.56	0.38
(Across Days)	(55.8%)	(64.1%)	(51.1%)	(73.8%)	(39.3%)	(61.2%)

Note. Proportion of total variance in bracket.

4.2.3. Academic stress.

4.2.3.1. Covariates.

Results of the multilevel analyses with academic stress as the predictor of PA and SB are detailed in Tables 4.5 – 4.8. An inverse association was observed between BMI and sedentary time in the models for hope, optimism, and HCC, such that individuals with a higher BMI spent less time in SB. Conversely, BMI was positively associated with vigorous activity in the model for hope, suggesting that individuals with higher levels of BMI take part in more vigorous activity. Work hours were also inversely associated with SB, such that those individuals who worked more hours spent less time being sedentary. In contrast, work hours were positively associated with light and moderate intensity PA minutes, with those who spent more time working also spending more time in these activity intensities. All other effects of age, sex, BMI, work hours, and time spent volunteering were non-significant.

4.2.3.2. Direct effects.

The day-level effect of academic stress was positive and significant for SB across all models, indicating that the time spent in SB was higher on days when students experienced a greater number of study-related stressors. In contrast, the day-level effect of academic stress was negative and significant for light intensity activity in the models for all resilience resources. This inverse effect indicates that the time spent in light intensity activities was lower on days when students experienced a greater number of study-related stressors. There was also a significant negative effect of day-level academic stress on moderate activity for models including bounce back ability, and optimism, suggesting that on days when more academic stressors were experienced less time was spent in moderate intensity activities. At the burst level, the effects of academic stress on PA were not significantly different from zero.

4.2.3.3. Cross-level interactions.

There was a single significant cross-level interaction, namely the moderating effect of person-level HCC on the burst-level association between academic stressors and SB ($B = -1.447$, $SE = .428$, $p = .001$). This finding indicates that the within-person effect of academic stressors on SB across bursts was lower for those students with lower levels of cortisol averaged across all three measurement periods. All other cross-level interactions were not significantly different from zero.

Table 4.5. *Results of Three-Level Model for Sedentary Behaviour and Academic Stress*

Variables	BRS	HOPE	LOT-R	GSE	HCC	PSS
Within Level (Day)						
SB RV	4584.69 (617.58)***	4564.79 (622.07)***	4566.47 (621.56)***	4584.79 (625.58)***	4550.00 (604.85)***	4581.90 (624.49)***
Between Level (Burst)						
Slope1 R-ON L2_Res	5.11 (5.37)	2.54 (5.26)	2.58 (5.16)	0.86 (4.86)	0.15 (0.63)	-3.47 (4.10)
Burst	6.96 (5.42)	7.00 (3.98)	7.27 (3.91)	6.94 (3.73)	6.71 (3.72)	6.76 (3.65)
AS & Slope1 COR	-63.80 (161.58)	-85.39 (117.78)	-87.79 (107.06)	-88.76 (107.04)	-34.04 (68.42)	-87.51 (98.56)
Mean L2_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.15)	0.00 (0.12)	-0.00 (0.64)	0.00 (0.08)
Variance L2_Res	1.20 (0.19)***	0.72 (0.14)***	1.21 (0.20)***	0.76 (0.27)**	30.36 (21.50)	0.43 (0.05)***
SB RV	192.26 (270.34)	207.53 (258.95)	215.87 (261.67)	215.10 (255.37)	234.07 (209.61)	249.81 (260.76)
Slope1 RV	24.24 (81.55)	43.05 (77.17)	39.61 (74.65)	39.23 (77.16)	35.92 (83.46)	34.37 (56.14)
Between Level (Person)						
Slope1 R-ON L3_Res	-1.77 (6.33)	-0.29 (6.18)	0.12 (5.45)	-0.24 (4.92)	0.25 (0.60)	0.00 (5.18)
Slope2 R-ON L3_Res	-5.64 (4.58)	-2.89 (4.15)	-0.72 (3.25)	-1.54 (2.88)	-1.45 (0.43)**	2.60 (5.38)
AGE	2.36 (2.51)	1.91 (2.19)	1.72 (2.11)	1.72 (2.08)	1.98 (2.09)	1.65 (2.06)
SEX	-5.78 (21.37)	-5.25 (18.03)	-5.73 (18.71)	-4.01 (18.22)	-4.93 (18.41)	-7.28 (19.70)
BMI	-4.61 (2.53)	-4.75 (2.39)*	-4.95 (2.40)*	-4.66 (2.43)	-4.60 (2.23)*	-4.78 (2.48)
WRK	-3.48 (0.93)***	-3.15 (0.90)***	-3.07 (0.92)**	-3.19 (0.91)***	-3.29 (0.89)***	-3.29 (0.97)**
VOL	-1.14 (2.59)	-1.02 (2.81)	-0.83 (2.70)	-0.95 (2.65)	-1.20 (2.29)	-0.10 (2.78)
Slope1 & Slope2 COR	-1.04 (181.44)	-5.69 (76.30)	-5.63 (50.64)	-5.29 (44.55)	-0.68 (33.98)	-0.91 (16.06)
Slope1 & SB COR	-132.50 (177.02)	-173.88 (119.87)	-160.61 (117.99)	-167.90 (115.76)	-179.80 (129.17)	-62.04 (121.72)
Slope1 COR	17.80 (157.34)	79.41 (103.82)	84.02 (91.40)	75.23 (94.92)	7.80 (106.52)	34.49 (110.11)
Mean L3_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.14)	0.00 (0.12)	0.00 (0.56)	0.00 (0.08)
SB Intercept	1199.62 (8.05)***	1201.15 (7.97)***	1201.25 (8.01)***	1201.41 (7.80)***	1201.07 (7.62)***	1201.34 (7.77)***
Slope1 Intercept	4.11 (1.98)*	3.80 (1.80)*	4.12 (1.79)*	3.59 (1.82)*	3.50 (1.72)*	3.91 (1.63)*
Slope2 Intercept	-0.89 (5.54)	-0.50 (3.29)	-0.26 (3.17)	-0.52 (3.12)	-0.08 (3.37)	-0.93 (2.80)
Variance L3_Res	0.94 (0.19)***	0.62 (0.13)***	1.01 (0.18)***	0.71 (0.27)**	16.17 (10.91)	0.32 (0.06)***
SB RV	2375.10 (905.67)**	2451.94 (707.02)**	2416.12 (587.06)***	2411.96 (574.83)***	2194.67 (457.76)***	2364.53 (494.09)***
Slope1 RV	7.49 (126.82)	12.48 (83.70)	10.80 (95.52)	11.84 (83.75)	14.83 (89.04)	1.63 (6.35)
Slope2 RV	0.58 (307.79)	3.15 (147.71)	3.53 (102.20)	2.93 (92.44)	0.33 (27.25)	0.97 (50.76)

Note: RV = Residual Variance; SB = Sedentary Behaviour; R-ON = Regressed On; COR = Correlation; Slope1 = Slope between daily academic stress and SB; Slope2 = Slope between burst mean academic stress and SB; L2 = Level 2; L3 = Level 3; AS = Academic Stress; BMI = Body Mass Index; WRK = Hours worked in a paid job (per week); VOL = Hours spent volunteering (per week); AS = Academic Stress; Res = Resilience Resource; * = p < .05; ** = p < .01; *** = p < .001.

Table 4.6. *Results of Three-Level Model for Light Intensity Activity and Academic Stress*

Variables	BRS	HOPE	LOT-R	GSE	HCC	PSS
Within Level (Day)						
PA RV	1126.89 (154.00)***	1118.49 (144.54)***	1118.81 (149.11)***	1121.54 (145.75)***	1119.92 (142.40)***	1117.97 (155.08)***
Between Level (Burst)						
Slope1 R-ON L2_Res	-2.98 (2.83)	-2.15 (2.83)	-3.01 (2.67)	-1.09 (3.16)	-0.14 (0.62)	3.63 (6.50)
Burst	-3.25 (1.93)	-3.30 (1.95)	-3.47 (1.82)	-3.27 (2.19)	-3.24 (1.93)	-3.27 (1.87)
AS & Slope1 COR	-28.58 (31.03)	-35.40 (33.95)	-35.44 (52.91)	-35.83 (35.22)	-27.07 (34.49)	-36.97 (44.52)
Mean L2_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.15)	0.00 (0.12)	-0.01 (0.65)	0.00 (0.08)
Variance L2_Res	1.20 (0.19)***	0.72 (0.14)***	1.21 (0.20)***	0.76 (0.27)**	30.37 (21.52)	0.43 (0.05)***
PA RV	42.53 (59.30)	49.31 (63.42)	52.00 (88.83)	50.17 (63.03)	46.44 (56.54)	52.97 (104.84)
Slope1 RV	20.28 (19.30)	26.73 (25.99)	24.83 (22.68)	26.93 (28.58)	25.65 (28.12)	26.80 (47.17)
Between Level (Person)						
Slope1 R-ON L3_Res	0.93 (2.81)	0.61 (3.29)	1.53 (2.58)	0.47 (3.28)	-0.03 (0.71)	-2.52 (13.62)
Slope2 R-ON L3_Res	3.01 (1.55)	2.26 (1.35)	1.95 (2.00)	2.17 (1.30)	0.51 (0.44)	-1.18 (5.43)
AGE	-0.41 (1.05)	-0.12 (1.01)	-0.11 (1.16)	0.06 (1.01)	-0.06 (1.03)	0.04 (1.03)
SEX	-8.08 (7.34)	-7.99 (7.40)	-7.37 (7.30)	-8.98 (7.54)	-7.65 (8.09)	-9.16 (10.29)
BMI	1.76 (1.09)	1.78 (1.05)	1.83 (1.48)	1.59 (1.06)	1.72 (1.45)	1.81 (1.94)
WRK	1.71 (0.46)***	1.54 (0.45)**	1.55 (0.44)***	1.60 (0.46)**	1.54 (0.54)*	1.53 (0.58)**
VOL	-0.45 (1.29)	-0.52 (0.91)	-0.52 (2.20)	-0.43 (0.85)	-0.44 (1.31)	-0.56 (2.21)
Slope1 & Slope2 COR	0.39 (24.95)	-0.01 (10.96)	0.10 (63.23)	0.17 (15.00)	0.42 (35.40)	-0.07 (27.33)
Slope1 & PA COR	-10.92 (39.20)	-21.26 (31.61)	-18.70 (97.95)	-20.78 (41.68)	-19.61 (56.39)	-19.29 (176.35)
Slope1 COR	-14.63 (33.09)	-0.24 (22.46)	-2.55 (57.12)	-3.89 (20.89)	-9.37 (68.12)	1.28 (64.03)
Mean L3_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.14)	0.00 (0.12)	0.00 (0.56)	0.00 (0.08)
PA Intercept	126.25 (3.61)***	125.77 (3.60)***	126.39 (3.81)***	125.89 (3.67)***	125.43 (3.77)***	125.28 (3.66)***
Slope1 Intercept	-2.07 (0.87)*	-1.93 (0.89)*	-2.07 (0.97)*	-1.82 (0.88)**	-1.77 (1.00)	-1.90 (1.45)
Slope2 Intercept	1.05 (1.50)	0.75 (1.31)	0.69 (1.91)	0.78 (1.45)	0.40 (1.19)	0.70 (1.55)
Variance L3_Res	0.94 (0.19)***	0.62 (0.13)***	1.01 (0.18)***	0.71 (0.27)**	16.17 (10.91)	0.32 (0.06)***
PA RV	403.52 (138.25)**	419.92 (119.38)***	412.67 (165.58)*	408.65 (128.45)**	414.43 (212.64)	417.79 (207.08)*
Slope1 RV	0.34 (33.28)	1.14 (47.66)	0.89 (51.82)	1.13 (61.23)	1.01 (63.40)	0.94 (160.98)
Slope2 RV	0.80 (18.93)	0.29 (9.71)	0.28 (44.35)	0.36 (15.30)	0.60 (59.27)	0.48 (73.94)

Note: RV = Residual Variance; PA = Physical Activity; R-ON = Regressed On; COR = Correlation; Slope1 = Slope between daily academic stress and SB; Slope2 = Slope between burst mean academic stress and SB; L2 = Level 2; L3 = Level 3; AS = Academic Stress; BMI = Body Mass Index; WRK = Hours worked in a paid job (per week); VOL = Hours spent volunteering (per week); AS = Academic Stress; Res = Resilience Resource; * = p < .05; ** = p < .01; *** = p < .001.

Table 4.7. *Results of Three-Level Model for Moderate Intensity Activity and Academic Stress*

Variables	BRS	HOPE	LOT-R	GSE	HCC	PSS
Within Level (Day)						
PA RV	1354.27 (202.25)***	1356.02 (203.88)***	1355.20 (202.62)***	1358.64 (204.72)***	1353.98 (203.63)***	1357.99 (204.54)***
Between Level (Burst)						
Slope1 R-ON L2_Res	-2.56 (2.08)	-1.21 (2.46)	-0.62 (2.76)	0.42 (2.30)	0.14 (0.56)	1.46 (2.17)
Burst	-3.38 (2.48)	-3.54 (2.57)	-3.66 (2.75)	-3.51 (2.58)	-3.29 (4.39)	-3.45 (2.67)
AS & Slope1 COR	-6.82 (25.24)	-9.64 (24.12)	-11.74 (26.97)	-10.84 (25.18)	-1.52 (50.99)	-11.22 (26.64)
Mean L2_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.15)	0.00 (0.12)	-0.00 (0.64)	0.00 (0.08)
Variance L2_Res	1.20 (0.19)***	0.72 (0.14)***	1.21 (0.20)***	0.76 (0.27)**	30.36 (21.50)	0.43 (0.05)***
PA RV	82.54 (82.10)	84.86 (81.42)	82.37 (83.62)	86.16 (81.29)	92.90 (146.84)	86.22 (81.94)
Slope1 RV	1.41 (16.32)	2.61 (13.61)	2.71 (15.20)	2.78 (14.10)	1.84 (34.81)	2.61 (15.72)
Between Level (Person)						
Slope1 R-ON L3_Res	1.07 (2.16)	-0.06 (2.69)	-0.88 (2.90)	-0.82 (2.34)	-0.41 (0.49)	-0.22 (3.08)
Slope2 R-ON L3_Res	3.32 (2.03)	1.49 (2.07)	-0.18 (2.02)	0.24 (1.93)	0.82 (1.08)	-1.51 (3.49)
AGE	-2.16 (1.16)	-1.94 (1.25)	-1.79 (1.33)	-1.88 (1.28)	-1.93 (3.01)	-1.82 (1.31)
SEX	9.07 (10.36)	8.60 (10.61)	8.61 (10.71)	7.96 (10.62)	8.12 (10.21)	7.63 (10.85)
BMI	2.36 (1.42)	2.53 (1.36)	2.68 (1.40)	2.56 (1.35)	2.42 (2.02)	2.49 (1.44)
WRK	1.83 (0.46)***	1.63 (0.46)***	1.55 (0.48)**	1.64 (0.48)**	1.74 (0.50)***	1.64 (0.48)***
VOL	1.56 (1.45)	1.45 (1.54)	1.28 (1.46)	1.31 (1.50)	1.50 (3.91)	1.35 (1.46)
Slope1 & Slope2 COR	-1.03 (17.96)	-3.34 (23.48)	-3.52 (29.20)	-3.60 (28.12)	-1.58 (179.22)	-2.68 (33.02)
Slope1 & PA COR	-63.15 (37.32)	-75.16 (36.78)*	-72.07 (37.91)	-74.53 (36.26)*	-74.87 (49.49)	-69.39 (39.05)
Slope1 COR	13.35 (45.69)	39.14 (43.83)	42.79 (61.30)	42.35 (50.44)	16.07 (458.06)	33.66 (71.70)
Mean L3_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.14)	0.00 (0.12)	0.00 (0.56)	0.00 (0.08)
PA Intercept	108.29 (4.66)***	107.35 (4.64)***	106.95 (4.78)***	107.00 (4.66)***	107.34 (4.69)***	107.30 (4.66)***
Slope1 Intercept	-2.07 (0.97)*	-2.02 (1.05)	-2.14 (1.07)*	-1.82 (1.04)	-1.74 (2.63)	-1.87 (0.99)
Slope2 Intercept	0.32 (2.29)	-0.06 (3.12)	-0.25 (2.83)	-0.10 (3.09)	-0.26 (4.47)	-0.01 (3.12)
Variance L3_Res	0.94 (0.19)***	0.62 (0.13)***	1.01 (0.18)***	0.71 (0.27)**	16.17 (10.91)	0.32 (0.06)***
PA RV	873.05 (205.92)***	908.73 (219.63)***	902.55 (195.36)***	899.00 (208.36)***	787.86 (623.82)	900.79 (202.33)***
Slope1 RV	4.67 (16.27)	6.44 (11.93)	5.92 (12.77)	6.36 (13.11)	7.23 (65.51)	5.53 (15.22)
Slope2 RV	0.62 (18.50)	2.27 (20.68)	2.58 (29.99)	2.57 (24.21)	0.55 (145.04)	1.85 (32.06)

Note: RV = Residual Variance; PA = Physical Activity; R-ON = Regressed On; COR = Correlation; Slope1 = Slope between daily academic stress and SB; Slope2 = Slope between burst mean academic stress and SB; L2 = Level 2; L3 = Level 3; AS = Academic Stress; BMI = Body Mass Index; WRK = Hours worked in a paid job (per week); VOL = Hours spent volunteering (per week); AS = Academic Stress; Res = Resilience Resource; * = p < .05; ** = p < .01; *** = p < .001.

Table 4.8. *Results of Three-Level Model for Vigorous Intensity Activity and Academic Stress*

Variables	BRS	HOPE	LOT-R	GSE	HCC#	PSS
Within Level (Day)						
PA RV	73.86 (26.75)**	73.70 (26.61)**	73.50 (27.57)**	73.87 (26.39)**		73.81 (27.20)**
Between Level (Burst)						
Slope1 R-ON L2_Res	0.26 (0.38)	0.61 (0.86)	0.35 (0.55)	0.13 (0.69)		-0.31 (0.48)
Burst	-0.26 (0.67)	-0.29 (0.65)	-0.30 (0.84)	-0.28 (0.70)		-0.30 (0.76)
AS & Slope1 COR	0.09 (4.42)	0.04 (3.60)	0.08 (5.07)	0.11 (4.51)		0.08 (5.35)
Mean L2_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.15)	0.00 (0.12)		0.00 (0.08)
Variance L2_Res	1.20 (0.19)***	0.72 (0.14)***	1.21 (0.20)***	0.76 (0.27)**		0.43 (0.05)***
PA RV	0.28 (4.18)	0.12 (5.67)	0.23 (4.78)	0.33 (5.59)		0.26 (4.77)
Slope1 RV	0.04 (2.33)	0.02 (3.50)	0.03 (1.44)	0.04 (4.26)		0.03 (2.42)
Between Level (Person)						
Slope1 R-ON L3_Res	-0.12 (0.36)	-0.23 (0.95)	-0.09 (0.63)	0.07 (0.78)		-0.16 (0.53)
Slope2 R-ON L3_Res	-0.10 (0.30)	-0.62 (0.56)	-0.59 (0.46)	-0.43 (0.57)		0.31 (0.52)
AGE	-0.04 (0.24)	0.01 (0.27)	-0.01 (0.26)	-0.05 (0.24)		-0.06 (0.21)
SEX	3.91 (2.17)	3.76 (2.69)	3.28 (3.06)	3.91 (2.76)		3.94 (2.12)
BMI	0. 39 (0.21)	0.40 (0.20)*	0.40 (0.32)	0.41 (0.24)		0.39 (0.29)
WRK	0.01 (0.06)	0.01 (0.06)	0.00 (0.08)	0.00 (0.06)		0.02 (0.06)
VOL	-0. 12 (0.21)	-0.11 (0.21)	-0.22 (0.25)	-0.14 (0.22)		-0.19 (0.27)
Slope1 & Slope2 COR	0. 27 (2.47)	-0.24 (2.22)	0.04 (2.76)	-0.18 (2.87)		0.03 (2.45)
Slope1 & PA COR	1.00 (1.46)	1.02 (1.55)	1.25 (1.82)	0.96 (1.80)		1.10 (2.04)
Slope1 COR	0.31 (2. 97)	-0.40 (2.34)	0.52 (2.95)	-0.07 (2.80)		0.66 (2.44)
Mean L3_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.14)	0.00 (0.12)		0.00 (0.08)
PA Intercept	5.96 (0.87)***	5.88 (1.06)***	5.67 (1.11)***	5.86 (1.08)***		5.92 (0.89)***
Slope1 Intercept	0.14 (0.19)	0.18 (0.24)	0.15 (0.24)	0.14 (0.18)		0.12 (0.17)
Slope2 Intercept	-0.16 (0.38)	-0.23 (0.42)	-0.26 (0.44)	-0.20 (0.41)		-0.22 (0.39)
Variance L3_Res	0.94 (0.19)***	0.62 (0.13)***	1.01 (0.18)***	0.71 (0.27)**		0.32 (0.06)***
PA RV	10.92 (7.27)	10.61 (6.64)	15.81 (9.28)	11.56 (5.89)*		15.61 (11.34)
Slope1 RV	0.15 (2.92)	0.14 (1.93)	0.10 (3.23)	0.12 (2.59)		0.08 (3.50)
Slope2 RV	1.03 (2.18)	0.92 (1.55)	0.06 (2.11)	0.81 (2.18)		0.14 (1.64)

Note. RV = Residual Variance; PA = Physical Activity; R-ON = Regressed On; COR = Correlation; Slope1 = Slope between daily academic stress and PA; Slope2 = Slope between burst mean academic stress and PA; L2 = Level 2; L3 = Level 3; AS = Academic Stress; BMI = Body Mass Index; WRK = Hours worked in a paid job (per week); VOL = Hours spent volunteering (per week); AS = Academic Stress; Res = Resilience Resource; # Model estimation did not terminate normally due to an error in computation; * = p < .05; ** = p < .01; *** = p < .001.

4.2.4. General stress.

4.2.4.1. Covariates.

Results of the multilevel analyses with general stress as the predictor of PA and SB are detailed in Tables 4.9 – 4.12. As in models including academic stressors as the primary predictor, work was significantly inversely associated with sedentary time, such that individuals who spent more time working spent less time in SB. Conversely, work hours were positively associated with light, and moderate PA minutes, with people spending more time in these activity intensities the longer they spent working. A significant positive association was demonstrated between BMI and vigorous activity in the models for bounce back ability, optimism, self-efficacy, and perceived stress, such that those who had higher BMI levels spent more time in vigorous intensity activities. All other effects of age, sex, BMI, work hours, and time spent volunteering were non-significant.

4.2.4.2. Direct effects.

Results showed a significant positive day-level effect of general stress on sedentary activity across all models, with the exception of hope, indicating that on days in which students reported a higher levels of general stress they were more sedentary. Conversely, a significant inverse day-level effect of general stress was observed with moderate intensity activity in models including optimism, self-efficacy, and HCC, such that students participated in less moderate intensity activities on days where they experienced higher levels of general stress. There were a significant positive linear effect of burst on SB in the model where HCC was modelled as the cross-level moderator, indicating a constant increase in SB across the three bursts. At the burst level, the effects of general stress on PA were not significantly different from zero.

4.2.4.3. Cross-level interactions.

None of the cross-level interaction effects were significantly different from zero when general stress was the predictor of PA intensities and SB.

4.3. Discussion

Previous research examining the effects of stress on PA and SB has demonstrated the deleterious effects of stress; however, past research has mainly relied upon self-report and cross-sectional methods to explore this association. The aim of

Table 4.9. *Results of Three-Level Model for Sedentary Behaviour and General Stress*

Variables	BRS	HOPE	LOT-R	GSE	HCC	PSS
Within Level (Day)						
SB RV	4699.17 (642.81)***	4676.95 (637.47)***	4701.99 (645.08)***	4706.07 (644.04)***	4712.59 (688.27)***	4704.41 (645.43)***
Between Level (Burst)						
Slope1 R-ON L2_Res	1.63 (10.17)	5.70 (11.36)	1.09 (11.22)	1.74 (16.68)	-0.95 (0.98)	-0.95 (13.73)
Burst	7.52 (4.09)	7.45 (4.17)	7.47 (4.03)	7.14 (4.29)	9.78 (4.66)*	7.54 (4.23)
GS & Slope1 COR	-40.20 (250.22)	-38.48 (240.91)	-40.50 (243.80)	-34.25 (248.51)	-55.00 (246.22)	-43.85 (231.81)
Mean L2_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.15)	0.00 (0.12)	-0.04 (0.64)	0.00 (0.08)
Variance L2_Res	1.20 (0.19)***	0.72 (0.14)***	1.21 (0.20)***	0.76 (0.27)**	30.49 (21.61)	0.43 (0.05)***
SB RV	219.32 (247.75)	218.61 (258.75)	217.65 (245.56)	212.53 (257.72)	195.58 (461.83)	219.71 (250.76)
Slope1 RV	8.26 (272.17)	7.58 (263.24)	8.45 (262.13)	6.44 (241.17)	18.60 (163.65)	9.68 (264.72)
Between Level (Person)						
Slope1 R-ON L3_Res	1.69 (9.68)	4.64 (12.59)	1.22 (12.08)	0.98 (15.94)	0.02 (1.55)	2.91 (17.76)
Slope2 R-ON L3_Res	-1.31 (7.70)	-6.07 (10.40)	-1.62 (6.62)	-5.06 (9.11)	-0.50 (10.77)	-3.34 (25.13)
AGE	1.85 (2.34)	1.83 (2.46)	1.79 (2.35)	1.72 (2.45)	1.83 (2.80)	1.90 (2.35)
SEX	-9.93 (17.67)	-10.37 (17.85)	-9.27 (17.35)	-9.30 (17.71)	-9.15 (18.35)	-9.11 (17.38)
BMI	-4.64 (2.60)	-4.60 (2.72)	-4.63 (2.52)	-4.53 (2.64)	-4.75 (2.84)	-4.75 (2.73)
WRK	-3.50 (1.05)**	-3.45 (1.17)**	-3.49 (1.10)**	-3.44 (1.11)**	-3.51 (1.31)**	-3.55 (1.05)**
VOL	0.14 (2.35)	0.15 (2.37)	0.13 (2.37)	0.16 (2.35)	0.23 (2.44)	0.28 (2.36)
Slope1 & Slope2 COR	-9.27 (863.25)	-3.36 (1170.48)	-3.19 (738.94)	-1.81 (981.21)	2.35 (1079.43)	-1.84 (1048.99)
Slope1 & SB COR	63.71 (382.86)	23.47 (365.98)	24.48 (341.03)	15.35 (383.88)	-19.97 (471.48)	15.76 (513.28)
Slope1 COR	-347.07 (1025.79)	-345.38 (1041.55)	-315.78 (1000.08)	-290.12 (1058.90)	-270.33 (1839.83)	-288.41 (1530.40)
Mean L3_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.14)	0.00 (0.12)	0.00 (0.56)	0.00 (0.08)
SB Intercept	1200.83 (8.06)***	1200.19 (8.12)***	1200.81 (8.08)***	1200.52 (8.50)***	1199.12 (11.31)***	1201.75 (9.36)***
Slope1 Intercept	8.35 (3.85)*	7.53 (4.25)	8.63 (3.61)*	8.55 (3.49)*	8.87 (3.58)*	9.10 (3.93)**
Slope2 Intercept	8.06 (11.87)	8.09 (13.47)	7.79 (11.69)	6.89 (14.00)	6.39 (10.43)	8.06 (12.00)
Variance L3_Res	0.94 (0.19)***	0.62 (0.13)***	1.01 (0.18)***	0.71 (0.27)**	16.17 (10.91)	0.32 (0.06)***
SB RV	2372.35 (597.46)***	2372.83 (613.79)***	2372.59 (607.77)***	2364.21 (667.49)***	2355.62 (1230.08)	2346.66 (689.58)**
Slope1 RV	2.19 (486.87)	0.65 (756.44)	0.81 (411.41)	0.67 (521.40)	0.80 (450.56)	0.68 (546.83)
Slope2 RV	51.46 (477.03)	50.97 (433.43)	42.72 (446.09)	36.33 (486.62)	31.81 (1858.57)	36.14 (698.08)

Note: RV = Residual Variance; SB = Sedentary Behaviour; R-ON = Regressed On; COR = Correlation; Slope1 = Slope between daily general stress and SB; Slope2 = Slope between burst mean academic stress and SB; L2 = Level 2; L3 = Level 3; GS = General Stress; BMI = Body Mass Index; WRK = Hours worked in a paid job (per week); VOL = Hours spent volunteering (per week); AS = Academic Stress; Res = Resilience Resource; * = p < .05; ** = p < .01; *** = p < .001.

Table 4.10. *Results of Three-Level Model for Light Intensity Activity and General Stress*

Variables	BRS	HOPE	LOT-R #	GSE	HCC	PSS
Within Level (Day)						
PA RV	1190.04 (158.15)***	1190.40 (158.92)***		1193.78 (159.21)***	1195.39 (172.62)***	1190.03 (158.10)***
Between Level (Burst)						
Slope1 R-ON L2_Res	-3.31 (5.57)	-6.49 (5.33)		-3.33 (8.60)	0.87 (0.87)	4.58 (7.27)
Burst	-3.61 (2.07)	-3.38 (2.02)		-3.37 (2.08)	-3.74 (2.33)	-3.58 (2.08)
GS & Slope1 COR	-27.36 (64.51)	-18.19 (56.81)		-22.70 (70.24)	-22.69 (109.87)	-30.15 (74.34)
Mean L2_Res	0.00 (0.14)	0.00 (0.11)		0.00 (0.12)	-0.03 (0.60)	0.00 (0.08)
Variance L2_Res	1.20 (0.19)***	0.72 (0.14)***		0.76 (0.27)**	30.42 (21.62)	0.43 (0.05)***
PA RV	41.68 (64.81)	40.23 (63.22)		39.19 (65.02)	34.86 (113.98)	42.01 (69.05)
Slope1 RV	20.72 (133.56)	10.38 (110.16)		16.09 (126.33)	18.16 (77.84)	24.60 (145.69)
Between Level (Person)						
Slope1 R-ON L3_Res	2.13 (5.10)	1.99 (5.69)		1.35 (8.35)	-0.64 (0.92)	-5.87 (7.91)
Slope2 R-ON L3_Res	1.22 (4.07)	1.96 (2.84)		1.41 (2.05)	0.07 (4.45)	3.08 (11.96)
AGE	-0.19 (1.22)	-0.13 (1.30)		-0.11 (1.31)	-0.03 (1.53)	-0.21 (1.32)
SEX	-4.50 (6.71)	-4.51 (6.44)		-4.36 (6.86)	-4.33 (8.67)	-4.20 (7.13)
BMI	2.01 (1.28)	1.96 (1.14)		1.93 (1.19)	1.98 (1.31)	2.05 (1.33)
WRK	1.64 (0.46)***	1.59 (0.49)**		1.59 (0.49)**	1.57 (0.57)**	1.64 (0.45)***
VOL	-0.87 (0.81)	-0.87 (0.84)		-0.82 (0.82)	-0.85 (0.82)	-0.91 (0.79)
Slope1 & Slope2 COR	-19.25 (185.46)	-16.61 (135.71)		-16.62 (148.91)	-4.95 (155.71)	-15.65 (183.30)
Slope1 & PA COR	84.00 (152.68)	74.45 (130.02)		77.49 (150.95)	63.88 (198.49)	76.29 (207.37)
Slope1 COR	-90.83 (360.45)	-89.27 (351.16)		-86.45 (360.90)	-31.39 (357.08)	-80.87 (506.57)
Mean L3_Res	0.00 (0.14)	0.00 (0.11)		0.00 (0.12)	0.00 (0.56)	0.00 (0.08)
SB Intercept	125.18 (3.54)***	125.73 (3.51)***		125.67 (3.55)***	125.65 (4.86)***	124.97 (4.21)***
Slope1 Intercept	-3.80 (2.23)	-3.24 (2.22)		-3.59 (2.17)	-3.89 (2.15)	-4.10 (2.35)
Slope2 Intercept	-4.37 (4.52)	-3.71 (4.41)		-3.70 (4.62)	-1.61 (5.34)	-4.48 (4.46)
Variance L3_Res	0.94 (0.19)***	0.62 (0.13)***		0.71 (0.27)**	16.17 (10.91)	0.32 (0.06)***
PA RV	393.92 (96.84)***	395.93 (100.73)***		395.41 (100.77)***	398.68 (221.83)	387.10 (96.47)***
Slope1 RV	18.71 (166.91)	14.84 (111.11)		16.65 (137.28)	12.13 (131.79)	16.39 (167.44)
Slope2 RV	21.37 (412.71)	20.62 (399.00)		19.44 (416.71)	3.32 (544.64)	17.39 (612.31)

Note. RV = Residual Variance; PA = Physical Activity; R-ON = Regressed On; COR = Correlation; Slope1 = Slope between daily general stress and PA; Slope2 = Slope between burst mean academic stress and PA; L2 = Level 2; L3 = Level 3; GS = General Stress; BMI = Body Mass Index; WRK = Hours worked in a paid job (per week); VOL = Hours spent volunteering (per week); AS = Academic Stress; Res = Resilience Resource; # Model estimation did not terminate normally due to an error in computation; * = p < .05; ** = p < .01; *** = p < .001.

Table 4.11. *Results of Three-Level Model for Moderate Intensity Activity and General Stress*

Variables	BRS	HOPE	LOT-R	GSE	HCC	PSS
Within Level (Day)						
PA RV	1375.53 (194.47)***	1369.88 (192.47)***	1374.65 (195.01)***	1376.93 (195.56)***	1374.04 (187.62)***	1375.58 (201.82)***
Between Level (Burst)						
Slope1 R-ON L2_Res	-0.48 (5.23)	-4.79 (5.98)	-0.75 (5.58)	-0.59 (7.74)	0.15 (1.08)	0.03 (7.28)
Burst	-3.92 (2.54)	-3.89 (2.53)	-4.00 (2.48)	-3.66 (2.53)	-5.06 (3.34)	-4.03 (3.76)
GS & Slope1 COR	-21.59 (89.12)	-22.18 (95.41)	-23.17 (89.74)	-19.96 (83.86)	-11.97 (43.12)	-24.18 (97.62)
Mean L2_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.15)	0.00 (0.12)	-0.01 (0.65)	0.00 (0.08)
Variance L2_Res	1.20 (0.19)***	0.72 (0.14)***	1.21 (0.20)***	0.76 (0.27)**	30.37 (21.49)	0.43 (0.05)***
PA RV	82.66 (76.37)	81.27 (80.27)	83.45 (76.22)	80.65 (77.42)	82.64 (87.64)	84.70 (93.96)
Slope1 RV	6.29 (90.81)	6.55 (88.28)	7.06 (89.71)	5.62 (84.71)	17.27 (39.09)	7.55 (126.52)
Between Level (Person)						
Slope1 R-ON L3_Res	-0.80 (6.22)	0.07 (6.39)	-0.83 (5.89)	0.50 (7.66)	0.10 (1.23)	-1.55 (16.57)
Slope2 R-ON L3_Res	1.91 (4.22)	4.06 (7.11)	0.93 (4.55)	3.56 (6.07)	0.70 (3.82)	3.71 (22.93)
AGE	-1.66 (1.32)	-1.68 (1.48)	-1.67 (1.29)	-1.60 (1.31)	-1.72 (1.37)	-1.79 (1.24)
SEX	9.65 (9.52)	10.33 (9.75)	9.02 (9.14)	9.04 (9.35)	9.34 (9.34)	8.79 (13.42)
BMI	2.38 (1.30)	2.36 (1.32)	2.41 (1.28)	2.32 (1.33)	2.45 (1.36)	2.48 (1.58)
WRK	1.89 (0.69)**	1.87 (0.80)*	1.90 (0.71)**	1.85 (0.69)**	1.92 (0.75)*	1.97 (0.91)*
VOL	0.90 (1.56)	0.92 (1.54)	0.88 (1.52)	0.86 (1.53)	0.88 (1.73)	0.76 (2.25)
Slope1 & Slope2 COR	7.38 (424.27)	8.72 (528.47)	8.94 (374.84)	7.73 (492.53)	11.02 (366.98)	7.81 (1008.62)
Slope1 & PA COR	-39.46 (172.70)	-47.73 (178.82)	-51.61 (147.18)	-51.43 (153.29)	-63.13 (121.05)	-52.00 (379.61)
Slope1 COR	-162.71 (335.39)	-158.56 (360.27)	-150.22 (323.87)	-130.25 (317.67)	-148.84 (485.79)	-127.84 (849.99)
Mean L3_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.14)	0.00 (0.12)	0.00 (0.56)	0.00 (0.08)
SB Intercept	108.12 (5.01)***	108.26 (4.80)***	107.87 (4.82)***	108.03 (5.12)***	108.68 (5.04)***	107.00 (9.43)***
Slope1 Intercept	-4.29 (2.22)	-3.83 (2.53)	-4.25 (1.90)*	-4.59 (1.92)*	-4.61 (2.07)*	-4.61 (2.44)
Slope2 Intercept	-6.49 (6.77)	-6.74 (8.22)	-6.67 (7.01)	-5.67 (8.48)	-5.77 (7.07)	-6.62 (7.29)
Variance L3_Res	0.94 (0.19)***	0.62 (0.13)***	1.01 (0.18)***	0.71 (0.27)**	16.17 (10.91)	0.32 (0.06)***
PA RV	872.04 (270.42)***	870.96 (291.87)**	869.94 (266.39)**	868.59 (308.50)**	853.57 (345.47)*	857.38 (590.28)
Slope1 RV	2.08 (224.94)	2.83 (307.20)	3.37 (201.48)	3.37 (236.33)	5.02 (201.30)	3.47 (497.30)
Slope2 RV	30.99 (152.20)	29.48 (104.67)	26.56 (122.92)	20.192 (122.44)	26.68 (279.20)	19.69 (299.28)

Note: RV = Residual Variance; PA = Physical Activity; R-ON = Regressed On; COR = Correlation; Slope1 = Slope between daily general stress and SB; Slope2 = Slope between burst mean academic stress and SB; L2 = Level 2; L3 = Level 3; GS = General Stress; BMI = Body Mass Index; WRK = Hours worked in a paid job (per week); VOL = Hours spent volunteering (per week); AS = Academic Stress; Res = Resilience Resource; * = p < .05; ** = p < .01; *** = p < .001.

Table 4.12. *Results of Three-Level Model for Vigorous Intensity Activity and General Stress*

Variables	BRS	HOPE	LOT-R	GSE	HCC	PSS
Within Level (Day)						
PA RV	74.09 (25.78)**	73.85 (25.88)**	74.24 (26.02)**	74.16 (25.75)**	74.13 (24.13)**	74.17 (25.81)**
Between Level (Burst)						
Slope1 R-ON L2_Res	-0.16 (1.16)	1.15 (2.78)	0.38 (0.95)	-0.19 (1.66)	-0.02 (0.31)	0.09 (1.02)
Burst	-0.35 (0.45)	-0.39 (0.46)	-0.36 (0.45)	-0.37 (0.45)	-0.39 (0.60)	-0.33 (0.45)
GS & Slope1 COR	-0.05 (7.18)	-0.02 (7.51)	-0.04 (6.37)	-0.05 (8.67)	-0.02 (0.51)	-0.05 (7.68)
Mean L2_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.15)	0.00 (0.12)	-0.00 (0.66)	0.00 (0.08)
Variance L2_Res	1.20 (0.19)***	0.72 (0.14)***	1.21 (0.20)***	0.76 (0.27)**	30.36 (21.50)	0.43 (0.05)***
PA RV	0.09 (6.26)	0.04 (6.25)	0.07 (5.84)	0.09 (6.60)	1.20 (0.75)	0.10 (6.63)
Slope1 RV	0.08 (24.54)	0.03 (46.47)	0.07 (18.76)	0.08 (30.74)	0.05 (0.78)	0.09 (24.52)
Between Level (Person)						
Slope1 R-ON L3_Res	-0.65 (1.32)	-2.22 (3.49)	-0.68 (1.00)	-0.74 (1.70)	0.10 (0.30)	0.58 (1.64)
Slope2 R-ON L3_Res	0.32 (1.63)	-0.34 (2.30)	-0.46 (0.92)	-0.14 (1.02)	0.71 (2.61)	-0.80 (2.94)
AGE	-0.12 (0.20)	-0.14 (0.22)	-0.15 (0.21)	-0.14 (0.21)	-0.13 (0.41)	-0.11 (0.25)
SEX	4.12 (4.40)	3.77 (8.24)	3.82 (4.43)	3.81 (4.61)	2.85 (5.65)	3.91 (3.99)
BMI	0.43 (0.19)*	0.43 (0.22)	0.45 (0.19)*	0.44 (0.19)*	0.47 (0.42)	0.43 (0.18)*
WRK	0.02 (0.05)	0.03 (0.05)	0.03 (0.05)	0.02 (0.05)	0.03 (0.06)	0.01 (0.05)
VOL	-0.18 (0.20)	-0.18 (0.28)	-0.20 (0.22)	-0.18 (0.23)	-0.15 (0.20)	-0.17 (0.20)
Slope1 & Slope2 COR	-0.26 (18.45)	-0.38 (35.91)	-0.44 (17.50)	-0.43 (19.23)	0.05 (24.50)	-0.35 (15.40)
Slope1 & PA COR	-0.91 (5.87)	-1.41 (6.19)	-1.50 (5.06)	-1.55 (6.38)	-3.13 (5.88)	-1.30 (6.14)
Slope1 COR	4.75 (9.56)	4.54 (17.68)	4.86 (10.57)	4.64 (11.59)	-0.26 (48.83)	4.61 (9.77)
Mean L3_Res	0.00 (0.14)	0.00 (0.11)	0.00 (0.14)	0.00 (0.12)	0.00 (0.56)	0.00 (0.08)
SB Intercept	6.15 (0.97)***	6.04 (1.11)***	5.98 (0.95)***	6.06 (0.88)***	6.16 (1.11)***	6.19 (1.02)***
Slope1 Intercept	-0.34 (0.34)	-0.34 (0.60)	-0.44 (0.47)	-0.31 (0.49)	-0.40 (0.56)	-0.43 (0.39)
Slope2 Intercept	-0.20 (0.96)	-0.33 (1.08)	-0.15 (0.94)	-0.21 (0.99)	0.08 (1.67)	-0.15 (0.88)
Variance L3_Res	0.94 (0.19)***	0.62 (0.13)***	1.01 (0.18)***	0.71 (0.27)**	16.17 (10.91)	0.32 (0.06)***
PA RV	17.07 (6.80)*	16.91 (7.27)*	16.79 (7.03)*	16.92 (6.42)**	13.88 (5.36)*	17.27 (6.81)*
Slope1 RV	0.08 (13.13)	0.13 (17.54)	0.16 (9.11)	0.18 (12.34)	0.73 (6.59)	0.14 (11.37)
Slope2 RV	1.45 (4.39)	1.30 (5.95)	1.51 (2.86)	1.39 (8.22)	0.04 (71.10)	1.35 (7.95)

Note: RV = Residual Variance; PA = Physical Activity; R-ON = Regressed On; COR = Correlation; Slope1 = Slope between daily general stress and SB; Slope2 = Slope between burst mean academic stress and SB; L2 = Level 2; L3 = Level 3; GS = General Stress; BMI = Body Mass Index; WRK = Hours worked in a paid job (per week); VOL = Hours spent volunteering (per week); AS = Academic Stress; Res = Resilience Resource; * = p < .05; ** = p < .01; *** = p < .001.

the current study was to investigate the dynamic associations between daily perceptions of stress (academic and general) and device-measured PA and SB over naturalistically differing periods of stress using a longitudinal measurement burst design. We expected that higher levels of daily self-reported stress would be associated with lower time spent being physically active and more time spent being sedentary. Our expectations were partially supported in that higher levels of daily academic and general stress were associated with more SB and lower levels of some intensities of PA (light and moderate). We also examined the effect of physiological and psychological stress at the beginning of bursts on PA and SB and anticipated the same deleterious effect, though our expectations were unsupported. In addition, we tested the possible buffering effects of burst level individual resilience resources on the associations between daily stress and PA and sedentary activity. Specifically, for those individuals who have higher levels of resilience resources, the negative effect of stress would be attenuated and they will, therefore, take part in higher levels of PA and less SB. Our expectations regarding possible moderating effects of resilience resources were unsupported.

Daily reports of academic and general stress were positively associated with SB. Previous cross-sectional research has revealed a similar pattern, with higher levels of stress related to more time spent in sedentary activities (e.g., Carter, 2018; He, Harris, Piche, & Beynon, 2009; Ortega-Montiel et al., 2015). The association has also been seen longitudinally, with higher levels of stress associated with an increase in television viewing time (Mouchacca et al., 2013). When looking specifically at academic stress in student populations, in times of increased stress (Cruz et al., 2013) or when they perceived higher levels of academic burden (Zhu, Haegele, Tang, & Wu, 2017), students take part in more sedentary activity. The findings from the present study may be an important advance in the literature as an inverse association was observed between both indices of stress (general and academic) and device measured sedentary activity. In cases where individuals have higher levels of perceived stress, SB's such as TV viewing or video game playing may be used as a coping strategy to relieve stress (Mouchacca et al., 2013). Therefore, future research may benefit from investigating intervention options, such as education on active coping strategies (e.g., going for a walk), to attenuate the deleterious effects of stress on SB.

In contrast to SB, the associations between daily reports of stress and PA intensities were mixed. Perceptions of daily academic stressors were associated negatively with light and moderate intensity activity, indicating less time was spent in these activity intensities on days when students perceived more academic stressors. General stress shared an inverse association with moderate intensity activity only. No significant associations were observed between academic or general stress and vigorous activity. Past research looking at the relationship between stress and vigorous PA has, for the main, used an amalgamated measure of moderate-to-vigorous physical activity with mixed findings (e.g., Stults-Kolehmainen & Sinha, 2014). Therefore, the current findings of a negative association between stress and moderate PA and lack of association with vigorous PA may suggest that this association is more important at moderate intensities. Although previous research has typically found stress to have a deleterious effect on PA levels, the majority has used cross-sectional designs and self-report measures of PA to assess this effect (Stults-Kolehmainen & Sinha, 2014). However, a limited amount of research has investigated the association between stress and PA utilising intensive longitudinal designs. In a yearlong longitudinal ecological momentary assessment among university students, for example, it was found that overall self-reported anticipated stress for a given day, whether reported in the morning or the previous evening, was significantly associated with fewer device measured (Fitbit) continuous bouts of moderate to vigorous PA lasting at least 30 minutes (Berg et al., 2017). The deleterious effect of stress on PA has also been demonstrated specifically in regards to academic stress, with higher levels of self-reported academic stress associated with less time spent in self-reported moderate and vigorous PA (Cruz et al., 2013). Similar findings were reported in a recent ecological momentary assessment study utilising an examination period as a naturalistic stressor for university students (Schultchen et al., 2019). Specifically, self-reported PA levels were found to be lower following more stressfully perceived moments. The majority of previous research has utilised self-reported PA which are associated with over reporting (Rääsk et al., 2017). Therefore, the use of device-based measures of PA intensities in the current study add support to the negative effects of stress on PA. As the effects of stress appear detrimental to PA participation, interventions aimed at stress reduction may not only have a direct effect on the deleterious downstream effects of stress (e.g., depression, anxiety) and increase PA levels, but they could also have long-term health outcomes, such as decreased BMI. Furthermore, as academic stressors were found to have stronger associations with PA than general perceived stress, in student populations it may be important to aim future interventions at the alleviation of stressors directly related to their academic experience.

Guided by a resilience framework (Masten, 2011; Windle, 2011), we tested the expectation that the deleterious effects of stress on PA and SB will be reduced for those individuals who report higher levels of resilience resources. We found none of the psychosocial resilience resources to moderate the effects of stress on PA and SB. A possible reason for this null effect may be that participant's daily reports of both stress (general and academic) incorporated elements of these moderating variables (Berg et al., 2017). For example, participants' perceptions of their resilience resources at the beginning of each burst could have influenced their daily assessments of the intensity and interpretation of stress experienced during the weekly period. This makes it difficult to disentangle the effects of these burst level resources from daily reports. In considering the process whereby self-reported stress affects PA and sedentary activity, it may be important to draw upon the transactional theory of stress (Lazarus & Folkmanm, 1984). Specifically, there is a need to disentangle primary (i.e., the interpretation of the stressor as posing a harm/loss, threat, or a challenge) and secondary (i.e., one's perceptions about their resources to be able to cope with the stressor) appraisals of stressors. Within the current study, it could be argued that in measuring perceived stress via the PSS (4 and 10 item) our focus was primarily on participants' secondary appraisals of stress, where our measure of academic stressors excluded any element of appraisals. Primary appraisals are a key mechanism linking stressors to outcomes via perceptions of the stimulus as a challenge or a threat, yet methodological designs often make assumptions that a stressor is perceived as either a challenge or a threat (Webster, Beehr, & Love, 2011). Excluding an individual's primary appraisal of a stressor in the current study may have obfuscated our ability to examine the moderating effect of resilience resources. Specifically, it may be that resilience resources buffer the effects of stressors primarily when stressors are appraised as threats rather than challenges to healthy functioning. Therefore, future work may benefit from assessing participants' primary and secondary appraisals of stress to understand fully the buffering effects of resilience resources.

In terms of daily perceptions of academic stressors, the measure used in the current study assessed the frequency of such events and should therefore theoretically exclude any influence of appraisals. In regards to academic stressors, the null moderating effect of resilience resources could be explained by the specificity matching principle in that there was incongruence in the degree of specificity between the predictor and outcome (Swann, Chang-Schneider, & McClarty, 2007). Specifically, we used a narrow measure of stressors for the educational context, yet relied on a broad assessment of resilience resources (e.g., general self-efficacy) rather than operationalisations that matched the key determinant (e.g., academic self-efficacy). It is important in future research that investigators take heed of the specificity principle matching to clarify the moderating effect of resilience resources on the effect of stress on PA and SB.

We also examined chronic or accumulated stress – both physiological and self-reported – as moderators of the effects of daily stress. Hair cortisol concentration was identified as a salient moderator variable for SB only, such that in bursts where lower levels of cortisol were present, the daily positive effect of academic stress on SB was lower. Past research has revealed inconsistent results regarding the associations between physiological markers of stress and PA and SB (Staufenbiel et al., 2015). Few studies to date have examined the associations between physiological measures of stress (e.g., saliva, blood plasma, or hair cortisol) and SB (Teychenne et al., 2018). This work has revealed inconsistent results; some studies have found null effects (Ivarson, Anderson, Akerstedt, & Lindblad, 2009), whereas others reported positive (Nabi, Prestin, & So, 2016) associations with SB's (i.e., watching TV and playing video games). When using HCC as a measure of chronic stress, results have found no association with SB (e.g., Teychenne et al., 2018). Although, inconsistencies have also been observed between HCC and PA (Staufenbiel et al., 2015), research suggests that exposure to physical stressors (e.g., vigorous PA) can evoke a similar stress response to psychological stress, i.e., increasing HCC (Gerber et al., 2017). For example, in a sample of university students (Mage = 21.2 ± 1.87), HCC was significantly positively correlated with a device based measure of vigorous activity though not with moderate activity (Gerber et al., 2013), indicating that perhaps a threshold of intensity needs to be reached to be stressful enough to elicit a response. These findings underscore a challenge with using HCC as a measure of chronic stress in that PA itself may act as a stressor, with acute bouts of vigorous exercise increasing cortisol levels leading to higher concentrations found in hair samples (Gerber et al., 2012). In the context of the current study, it may be that the lower levels of HCC is an indication that less PA took place, consequently more time might have been spent in SB's. Therefore, caution may need to be taken when using HCC as a measure of chronic stress in active samples as elevated levels may not truly reflect pathological levels of stress (Gerber et al., 2012). Future work would benefit from temporally aligned longitudinal studies using device-based measures of PA and SB with physiological measures of stress to provide guidelines on the interpretation of chronic stress within the context of regular PA (e.g., frequency, intensity).

There were a number of notable strengths of the current study, namely the assessment of stress via self-report and physiological indices, utilisation of a device-based measure of PA and sedentary activities with decomposition of PA into different intensities. The examination of the possible effects of resilience resources, and using a longitudinal measurement burst design to capture both intra-and inter-individual differences also strengthened the study. Despite these strengths, several limitations must be considered when interpreting the findings, in addition to those points mentioned previously (e.g., specificity matching principle). First, the second burst representing the naturalistic examination condition took place a week prior to the examination period. Although previous research has demonstrated that students' self-reported stress increases in the lead up to an examination period (e.g., Steptoe et al., 1996), we found that average levels of daily self-reported stress decreased from the first to the last burst. This pattern was also observed for burst level measures of physiological (HCC) and perceived stress. The week prior to exams was used in the current study due to ethical considerations regarding participant burden during an examination period that has implications for students' grades and progression through their degree. Although past research has shown perceived stress to increase in the lead up to an examination period (e.g., Steptoe et al., 1996), measurement of study variable in the actual exam week would give a more complete picture. Second, caution is required when generalising the findings to other populations. For example, the sample was predominantly female (78.8%), which was most likely due to the eligibility criteria of sufficient hair length for analysis (2 cm). This limitation is not specific to the current study, previous research has reported issues with collecting hair samples from males and reported similar percentages of female participation (e.g., 72%, Fischer et al., 2017; 81%, Gidlow, Randall, Gillman, Smith, & Jones, 2016; 72%, Staufenbiel et al., 2015). Furthermore, we were unable to rule out the possible effects of mental health problems (e.g., depression) as we did not collect such information. Previous research has identified associations between depression and PA and SB (e.g., Vallance et al., 2011), and with stress (e.g., Gerber et al., 2013). Therefore, it would be beneficial for future studies to include additional measures such as the Beck Depression and Beck Anxiety inventories (Beck & Steer, 1987; Beck & Steer, 1990) to control for possible effects. Finally, although the current study reports similar sample size to those used in previous intensive longitudinal designs (e.g., Burns et al., 2015; Rocke, Hoppmann, & Klumb, 2011; Rocke, Li, & Smith, 2009), we were likely underpowered to detect moderation effects. Power simulations would be required to provide further clarification on this matter.

4.3.1. Conclusion.

In summary, we implemented an innovative methodological approach (e.g., device-based measures, measurement burst design) to examine the temporal dynamics between stress and PA and SB during varying periods of naturalistic stress. The finding that higher levels of both academic and general stress are dynamically associated with lower levels of light and moderate PA and higher levels of SB measured via accelerometers, is an important extension to previous research, which has relied heavily on cross-sectional snapshots and self-reported data. As both physical inactivity and SB's are consistently linked with a number of deleterious physical and psychological health consequences (e.g., Thoits, 2010), interventions aimed at reducing primary and secondary appraisals of stress may help students to meet PA guidelines and reduce time spent in SB, thereby protecting them from associated deleterious outcomes (e.g., cardiovascular disease and obesity).

Chapter 5: General Discussion

The importance of advancing knowledge of stress and adversity, and the associated effects on people cannot be understated. We confront many stressors throughout daily life, and most if not all people will face several significant adversities within their lifetime. The deleterious downstream effects of stress and adversity are well established and encompass both psychological (e.g., generalised anxiety disorder, post-traumatic stress disorder) and physiological consequences (e.g., cardiovascular disease, type 2 diabetes; Thoits, 2010). One such consequence is a reduction in physical activity (PA), or an increase in the time spent in sedentary behaviours (SB) during and/or after stressful periods (Stults-Kolehmainen & Sinha, 2014). A number of deleterious outcomes have also been associated with lower levels of PA (e.g., obesity, hypertension, osteoporosis; Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017) and higher levels of SB (e.g., cardiovascular disease, cancer mortality; Ekelund et al., 2018), possibly compounding the effects of stress and adversity. Therefore, it is vital that we understand factors by which the negative effects of stress and adversity can be attenuated. Research in the remit of resilience offers a promising avenue, and the salubrious effects of resilience are well documented (e.g., Chmitorz et al., 2018; Helmreich et al., 2017). Resilience resources are one such group of factors that may protect individuals against the negative effects of stress in relation to PA and SB. It is also possible that the experience of adversity, in manageable amounts, has an adaptive element allowing people to build their resilience to future stressors or adversities (e.g., Holtge et al., 2018; Seery & Quinton, 2016). However, these two considerations remain largely untested from an empirical standpoint.

The overarching objective of this thesis was to examine the effects of stress on PA and SB, and the moderating role of resilience resources. Three empirical studies were conducted to provide insight on this objective. We first investigated the degree to which adversity exposure provides individuals with salient experiences by which to develop and/or refine resilience resources for use when faced with future stressful situations. The focus then shifted from major adverse events towards everyday stressors, which are experienced frequently and may be most likely to influence people's activity patterns. Across two empirical studies, we examined the cross-sectional and longitudinal dynamics of stress, PA, and SB alongside the moderating role of resilience resources. The culmination of this thesis was a measurement burst study that capitalised on subjective and physiological indices of stress, and device-based assessments of PA and SB. Collectively, this methodological approach provides multiple vantage points to understanding the interplay among stress, PA, SB, and resilience resources.

Against this methodological backdrop, we examined several conceptual expectations. In Study 1, we hypothesised that individuals who reported having experienced moderate amounts of adversity would report higher levels of resilience resources in comparison to those who had experienced either high or low amounts of adversity. This expectation was underpinned by an examination of the way by which adversity experiences cluster together among individuals. Based on previous research (Contractor et al., 2018), we expected to find three classes of individuals characterised by (i) a high likelihood of experiencing most or all of the assessed adversities, (ii) a class characterised by a lower likelihood of experiencing most or all of the assessed adversities, and (iii) a class characterised by a high likelihood of experiencing a specific adversity. Across Studies 2 and 3, we hypothesised that stress would have a deleterious effect on PA and SB, such that increased levels of subjective and physiologically measured stress would be associated with a decreased amount of time spent being physically active and an increase in time spent in SB. Aligned with a resilience perspective (Luthar, Cicchetti, & Becker, 2000; Masten, 2011; Windle, 2011), we also expected resilience resources to buffer the effects of stress on PA, such that the negative association between stress and PA would be attenuated for individuals with higher levels of these resources. Owing to the unavailability of past work on the longitudinal dynamics between stress, PA, SB, and resilience resources, we took an exploratory approach to the temporal associations between these variables.

We focused on university students for a three main reasons. First, student's experience at university can be a highly stressful period in which they face numerous stressors across different areas of their life, such as academic (e.g., examinations), personal (e.g., relationship difficulties), and occupational (e.g., career aspirations) (Hurst, Baranik, & Daniel, 2012). Second, we utilised the end of semester examination period as a naturalistic period of elevated stress. This period permitted an examination of the study variables before, during, and after a period known to be associated with elevated levels of stress (e.g., Oaten & Cheng, 2005; Sherman, Bunyan, Creswell, & Jaremka, 2009; Steptoe, Wardle, Pollard, Canaan, & Davies, 1996). Finally, research has found that 40 - 50% of students are physically inactive and spend up to eight hours a day engaged in sedentary activities (Deliens, Deforche, De Bourdeaudhuij, & Clarys, 2015). For these reasons, we considered university students as an ideal population to shed light on conceptual issues related to the interplay among stress, PA, SB, and resilience resources.

5.1. Main Interpretations and Explanations

5.1.1. Adversity and resilience resources.

The focus in Study 1 was on people's experiences of a broad range of adversities across two samples (student and community). The primary objectives were to identify meaningful classes of individuals who have experienced similar patterns of adversities, and examine how these classes differed with regard to individual-level resilience resources (i.e., optimism, hope, self-efficacy, and bounce-back ability). The findings regarding the individual classes of adversity exposure were largely consistent with expectations (Contractor, Caldas, Fletcher, Shea, & Armour, 2018). We identified one class representative of high and one of low polyadversity, though the samples differed in regards to the third class. Specifically, we identified a class among the students that was representative of a specific type of adversity (vicarious polyadversity), while in the community sample a class that was representative of a moderate amount of polyadversity emerged. This difference may be due to the nature of the samples, with one a young university student (Mage = 22.09 years) and the second a middle-aged community (Mage = 52.77 years) sample. Experiences of adversity change throughout the life course, such that different adversities are most pertinent at different stages in our lives (Benjet et al., 2016). For example, younger people (18 - 34 years) are more likely than their older counterparts (65+ years) to report the unexpected death of a loved one. Future research may benefit from a longitudinal analysis of the experience of adversity over a lifetime to identify which adversities may be most salient at different points in people's lives. Knowledge of the significance of adversities at different points in people's lives may help clinicians and healthcare services tailor effective treatment programs, or scaffold them across common developmental trajectories.

The findings regarding the salience of adversity experiences and differences in resilience resources were mixed across both samples. Informed by concepts such as stress inoculation (Meichenbaum, 1976, 1977), the steeling effect (Rutter, 1987), immunisation (Başoğlu et al., 1997), and the theory of toughness (Dienstbier, 1989, 1992), we expected that exposure to a challenging yet manageable amount of adversity provides individuals with the opportunity to develop and/or refine resources (e.g., self-efficacy), and in so doing builds one's capacity to demonstrate resilience to future adversities via personal resources. Previous empirical work supports these theoretical assertions, revealing an inverted U-shaped association between adversity and indices of functioning (e.g., Höltge et al., 2018; Kondrak & Seery, 2015; Seery, Holman et al., 2010; Seery et al., 2013; Seery, Leo et al., 2010). This body of work has consistently demonstrated that the experience of some adversity is associated with adaptive levels of a number of outcomes of psychological (e.g., positive and negative affect) and physiological (e.g., cortisol reactivity) functioning, when compared to either high or no adversity. We revealed support for this inverted U-shaped association between adversity experiences and resilience resources in the community sample, but not among the students. Related to the (inverted) U-shaped association between adversity and indices of functioning is the expectation that individuals who have the highest experiences of adversity are characterised by the worst well-being outcomes (e.g., Contractor et al., 2018, Seery, Holman et al., 2010). The deleterious effects of high levels of adversity were also present in the current findings. Within the community sample, those individuals in the high polyadversity sample reported the lowest levels of all resilience resources, significantly lower than both the moderate and low classes. This finding suggests that a large degree of adversity exposure is detrimental for the development of or the perceived availability of such personal resources. Taken together, these findings suggest that interventions focused on building resilience resources may be most important for individuals who have experienced high levels of adversity.

5.1.2. Stress, PA and SB.

Both acute and chronic stress, as well as everyday life demands, can act as barriers to the uptake and maintenance of a healthy lifestyle (Burg et al., 2017). Of particular relevance to this thesis is a systematic review which found that stressful periods predicted decreased PA and increased SB across 168 studies (Stults-Kolehmainen & Sinha, 2014). As such, one of the main assumptions in the current work was that those individuals who report high levels of stress will in turn report/engage in lower levels of PA and more time spent in SB. Contrary to this expectation, the cross-sectional associations reported in Studies 2 and 3 were largely mixed, such that the magnitude and direction of the correlation depended on the measurement method (self-reported, physiological, devised-based), PA intensity, and timing of assessment (before, during, or after exams). In contrast, the longitudinal data in Study 3 supported the direction of these hypotheses regarding the associations between subjective stress and PA and SB, specifically when modelled as random daily effects, yet in terms of magnitude was most compatible with an interpretation of no important effect.

In terms of the effects of stress on PA, we found a significant negative association between perceived stress and vigorous PA in Study 2, suggesting that the association may be more important at the vigorous end of the PA spectrum. In contrast, findings from Study 3 suggest that the association may be most salient for moderate and light activity. Differences were observed between indices of stress, with academic stress associated with lower levels of both moderate and light activity, and general stress associated with lower levels of moderate activity. Though these indices were significantly positively related across bursts, differences may be due to academic stressors being more pertinent than general stress within student samples. The limited longitudinal research to date examining the association between stress and PA has similarly demonstrated the negative effects of stress on PA (e.g., Berg et al., 2017; Schultchen et al., 2019). In terms of SB, we reported a small and non-significant association in Study 2, yet demonstrated significant positive associations between perceived stress (general, academic) and SB in Study 3. These findings are also in line with longitudinal evidence regarding the detrimental effect of stress on SB (e.g., Carter, 2018; Mouchacca, Abbott, & Ball, 2013). Taken together, the current work highlights the potentially damaging effects of stress on PA and SB, though clarity is required regarding these effects on different intensities of PA. Clarification on this matter can help inform future interventions in terms of which intensities of PA should be targeted as part of programs aimed at developing the greatest protection from stress.

It is important to consider methodological characteristics of empirical work for the interpretation of the findings in this thesis. First, past work has typically relied on a composite measure of PA, whereby the different intensities are amalgamated into a single metric of PA (Stults-Kolehmainen & Sinha, 2014). The findings reported in this thesis suggest that distinctions in PA intensity are critical to understanding the nature of stress on this health behaviour, because the magnitude and direction of the point estimate most compatible with the data varied across intensities. Thus, the amalgamation of PA intensities in past work has likely obscured the nature of the effect of stress on PA. An important consideration for future work is to employ compositional analyses of activity data, as PA, SB, and sleep are co-dependent and relative to the total amount of time in a day (e.g., Chastin, Palarea-Albaladejo, Dontje, & Skelton, 2015). Also relevant in this regard is how PA is assessed, as people tend to over report levels of PA when using self-report measures (Raask et al., 2017). Consider the IPAQ, perhaps the most widely employed self-report tool of PA and SB, where participants typically report higher levels of vigorous activity when compared with a device-based measure (Dyrstad, Hansen, Holme, & Anderssen, 2014). The utility of the IPAQ in measuring SB has also been questioned, with research showing SB to be underreported when compared to device-based measures (Prince, Reid, Bernick, Clarke, & Reed, 2018). This finding may be due to difficulty differentiating between different PA intensities or activities, as people have no inbuilt differentiation mechanism, therefore interpretations will vary considerably between people (Raask et al., 2017).

Second, a combination of subjective and objective measures is the preferred approach to assessing stress (Weckesser, Dietz, Schmidt, Grass, Kirschbaum, & Miller, 2019). However, the findings reported here indicated that the effects of stress on PA and SB appear sensitive to the manner in which stress is measured. One potential explanation for this finding is that physiological measures of stress tend to 'lag behind' subjective interpretations of environmental demands (e.g., Schlotz, Kumsta, Layes, Entringer, Jones, & Wüst, 2008; Weckesser et al., 2019). Third, the findings of this thesis support the conclusion that static snapshots of associations between stress and important outcomes represent a suboptimal method by which to understand the nature of stress. Consider any one of the measurement bursts of Study 3 in isolation; depending on which burst was sampled, we could arrive at a completely different interpretation of the data. Recent work has acknowledged this limitation by considering the temporal dynamics between stress and moderate-to-vigorous PA over short (7 days; Schultchen et al., 2019) and long periods (12 months; Berg et al., 2017). Fourth, the specificity or generality of subjective stress assessments matter. In Study 3 we demonstrated that the magnitude and direction of the effect of stress reported daily (level 1) or averaged across a 7-day period (level 2) on PA and SB is largely congruent for global stress, yet differs when the focus is on academic stressors.

5.1.3. Resilience resources as a buffer of stress on PA and SB.

One of the main aims examined in this thesis was the possible buffering effect of resilience resources on the deleterious association between stress and PA and SB. Put simply, we expected that those who have access to greater levels of these resources will take part in more PA and less SB when faced with increases in stress. Across both the cross-sectional and longitudinal studies, our results were most compatible with an interpretation of no important moderating effect of resilience resources. There are three possible reasons for this finding. First, our selection of individual-level resilience resources may have been insensitive to the primary outcomes. The selection of resources for the current work was informed by a recent conceptual and methodological review of resilience measures (Pangallo, Zibarras, Lewis, & Flaxman, 2015). The review assessed the psychometric properties of 17 resilience measures, identifying the Psychological Capital Questionnaire (PsyCap; Luthans, Youssef, & Avolio, 2007) to have the highest psychological rating across seven quality assessment criteria, namely theory formulation, internal consistency, replicability, convergent validity, discriminant validity, and application. Despite research supporting the importance of the elements of the PsyCap (optimism, hope, ‘bounce-back’ resilience, and self-efficacy) across a number of samples and contexts (e.g., Chmitorz et al., 2018; Fletcher, 2018), the current findings may suggest that in a university sample other factors may need to be examined. For example, a number of other resilience resources or resilience factors have been identified and studied within the literature, providing evidence of their utility in the resilience process, such as active coping (e.g., problem solving), social support, cognitive flexibility (e.g., positive reappraisal), spirituality, hardiness, and positive emotions or positive affect (Helmreich et al., 2017). Among university students, therefore, other factors may be most important for students’ resilience. For example, a student may benefit from having a strong network of social support to fall back on to help them effectively cope with stressful periods, rather than a higher level of optimism. As such, future research may benefit from broadening potential resilience resources from the individual to other ecologies (e.g., social, environmental).

Second, the specificity matching principle offers a logical explanation for an interpretation of no important moderating effect of resilience resources (Swann, Chang-Schneider, & McClarty, 2007). Central to this principle is the notion that an outcome is normally caused by numerous factors, and that congruency between predictor and outcome is essential to compensate for the possible influence of rival predictors. An example of this principle may be that an individual's attitude towards football may help to predict how much they engage with football during the football season, though not the total amount of PA they complete outside of their football pursuits. Therefore, the current study may have benefitted from matching resilience resources within the context in which they are used. For example, it may have been more appropriate to measure students' efficacy to deal with academic stressors, rather than a global measure of self-efficacy. Additionally, the importance of specific resilience resources will vary across time and contexts, and therefore certain resources may be more suited to withstand and adapt to certain stressors than others depending on the context (Fletcher, 2018). A consideration for future research, therefore, is the "traitness" of resilience resources.

Finally, the transactional theory of stress (Lazarus & Folkmanm, 1984) places an individual's appraisal of a stressor at the centre of the stress process. From a transactional perspective, the individualised experience of stress is moderated by primary (i.e., the interpretation of the stressor as posing a harm/loss, threat, or a challenge) and secondary (i.e., one's perceptions about their resources to be able to cope with the stressor) appraisals of a stressor. Within the current research, it could be argued that in using a global measure of perceived stress the focus was on participant's secondary appraisals of stress. Primary appraisals are considered a key mechanism in linking a stressor to an outcome via perception of the stressor as either a challenge or threat. Despite this recommendation, study designs often presume a priori that a stressor has been perceived as either a challenge or a threat (Webster, Beehr, & Love, 2011). Not considering an individual's primary appraisal of a stressor when examining the associations between stress and PA and SB could be considered an over simplification. It may be that resilience resources primarily buffer the effects of a stressor when that stressor is appraised as a threat to functioning rather than as a challenge. For example, an individual with a higher level of optimism will generally have a more positive outlook on the future, which may in turn affect how they appraise the stressor. Excluding a measure of participants' primary appraisals of stressors may have hampered the ability to detect the buffering effects of resilience resources. Therefore, future work would benefit from an assessment of both primary and secondary appraisals of stress, which may help identify if indeed their utility is more important when faced with an appraisal of a threat.

5.2. Secondary Interpretations and Explanations

5.2.1. Resilience resources and stress.

Though the examined resilience resources were not found to buffer the deleterious effect of stress on PA and SB, they did demonstrate some salubrious effects. Resilience resources consistently demonstrated negative associations with all indices of perceived stress (PSS 10, PSS 4, and academic stressors). Bivariate correlations demonstrated relatively large (Gignac & Szodorai, 2016) significant negative associations between all resources and perceived stress (PSS 10, $r > -.47$). A similar pattern was observed longitudinally across all bursts with resilience resources demonstrating significant negative correlations with all indices of stress (PSS 10, $r = -.17$ to $-.71$; PSS 4, $r = -.26$ to $-.65$; academic stress, $r = -.13$ to $-.31$). These findings suggest that individuals who had higher levels of resilience resources had lower levels of perceived stress. Intuitively these findings fit within a resilience framework (Masten, 2011; Windle, 2011), whereby individuals who have access to resources in greater quantity and/or quality will be resilient to stress. The negative association has been observed between the PsyCap and stress in a meta-analysis ($r = -.29$; Avey et al., 2011), and in relation to the individual resources, including optimism (Kowk, Ning, & Lee, 2014), hope (Dixson, Worrell, & Mello 2017), self-efficacy (Ersan, Fişekçioğlu, Dölekoğlu, & İlgüy, 2017), and bounce back resilience (Smith et al., 2008). The current findings support previous work and may advocate for the utility of focusing interventions on resilience resources to help reduce stress. An advantage of focusing interventions on these resilience resources is that research has shown them to be malleable (e.g., self-efficacy, Burger & Samuel, 2017; hope, Kwon, Birrueta, Faust, & Brown, 2015; optimism, Malouff & Schutte, 2017; and bounce-back resilience, Joyce et al., 2017) and they can therefore be strengthened. This strengthening of resources could bring with it a reduction in levels of perceived stress, having positive benefits on the downstream deleterious effects of stress.

5.2.2. Resilience resources, PA and SB.

The beneficial effects of resilience resources were also found to be present in regards to PA and SB. An examination of the bivariate correlations between resources and PA and SB show predominantly positive effects across the cross-sectional and longitudinal data with device-based measurements. The findings suggest that higher levels of resilience resources are associated with higher levels of PA and less time spent in SB. Previous research has supported links between the individual resources of hope (Gustafsson, Podlog, & Davis, 2017), optimism (Huffman et al. 2016), self-efficacy (Lewis, Williams, Frayeh, & Marcus, 2016), and bounce-backability (Ozkara, Kalkavan, Alemdag, & Alemdag, 2016) and increased levels of PA. The current findings fit intuitively, as individuals who are taking part in higher levels of PA, in turn spend less time being sedentary. Therefore, resilience resources may help individuals to benefit from the positive effects of PA whilst protecting them from the deleterious effects of SB. Future research may benefit from broadening potential resilience resources from the individual to other ecologies (e.g., social) to clarify the nature of the associations with PA and SB.

5.2.3. Hair cortisol and perceived stress.

An examination of the associations between physiological and psychological indices of stress revealed predominantly small and non-significant associations. This finding is common within the literature, with inconsistencies often reported between self-reported and physiological measures, adding to support of a "lack of psychoendocrine covariance" (Staufenbiel, Penninx, Spijker, Elzinga, & van Rossum, 2013, p. 1230). Specifically, considering research using the PSS and HCC, similar non-significant findings have been reported (e.g., Gidlow, Randall, Gillman, Silk et al., 2016; Gidlow et al., 2016), as well as confirmation in meta-analytic syntheses (Stalder et al., 2017; Staufenbiel et al., 2013). A possible reason for these findings may be that subjective and objective measures of stress are not temporally synchronised. For example, recent research has demonstrated that the association between self-reported mood and salivary cortisol reaches its peak association when a 12 minute temporal offset is accounted for (Miller et al., 2018). This evidence of a lagged association has more recently been demonstrated between HCC and self-reported stress (Weckesser et al., 2019). Weckesser et al. reported that correlations between self-reported stress and HCC demonstrated the highest association with a lag of ~4 weeks, accounting for 16% of the total variance in HCC. Additionally, of the three self-report measures of stress examined, only a single measure demonstrated a significant association with HCC ($r = 0.27$). This suggests that a large proportion of the variation in objective measures of stress may be attributed to factors other than subjective stress, such as genetic influences. For example, twin studies have found a majority of variation in HCC can be attributed to genetic differences and is largely unrelated to self-reported stress (e.g., Tucker-Drob et al., 2017). In light of these findings, future research would benefit from using both self-report and HCC, taking into account both the lagged effect of self-reported stress on HCC and account for the advantages and disadvantages associated with each of these methods.

5.2.4. Hair cortisol, PA and SB.

Associations between HCC and PA and SB within Studies 2 and 3 were mixed. Study 2 found HCC to share relatively small negative correlations with all intensities of PA (r = -.14 to -.16) and a negligible positive correlation with SB. Within the measurement-burst paper, this association was reversed with HCC demonstrating predominantly positive small to large correlations with all intensities of PA (r = .10 to .48), and negative moderate to relatively large correlations with sedentary activity (r = -.20 to -.37). A possible reason for observed differences may be due to the measurement of PA via self-report in Study 2 and a device-based measure in Study 3. Findings regarding the utility of self-reported PA when compared to device-based measures of PA have been equivocal (Raask et al., 2017), with self-report measures suffering from both under and over reporting (Skender et al., 2016). Device-based measures of PA are recognised for their ability to provide a more precise estimate of PA levels over self-report measures (Kim, Park, & Kang, 2013). Therefore, the current findings would suggest that higher levels of HCC are associated with higher levels of PA and more time spent in SB. Though caution must be exercised when interpreting these findings as inconsistencies have been observed between HCC and PA and SB (e.g., Staufenbiel et al., 2015; Teychenne et al., 2018). In terms of SB, researchers have reported both null associations (Ivarson, Anderson, Akerstedt, & Lindblad, 2009) and positive associations (Nabi, Prestin, & So, 2016). Inconsistencies have also been found between HCC and PA (Staufenbiel et al., 2015), though researchers tend to subscribe to the view that physical stressors (e.g., vigorous PA) can bring about a similar stress response to psychological stressors (Gerber et al., 2017). Findings from the current work are in line with this view, where elevated levels of HCC were associated with increased PA and lower levels of SB. In light of past work and the current findings, caution must be taken when using HCC as a measure of stress because higher levels of HCC may not truly represent pathological levels of stress (Gerber et al., 2012). To clarify our understanding, future work would benefit from an assessment of temporally aligned longitudinal studies of individuals who typically take part in different levels of PA. This would help to shed light of the effects of physiological stressors on HCC and provide guidelines to aid interpretation of HCC as a measure of chronic stress within the context of PA.

5.3. Implications

Stress and adversity are associated with numerous deleterious health outcomes, and interfere with people's desires to be healthy. With the younger generations (e.g., millennials) reporting the highest levels of stress (American Psychological Association, 2018), strategies that can help reduce the burden of stress are of paramount importance. The findings within this thesis provide an initial insight into two potential implications for helping people to maintain a healthy lifestyle and better cope with stressful periods they encounter.

First, the finding that individuals who experienced moderate levels of polyadversity reported higher levels of resilience resources than those who had experienced either high or low levels suggest that adversity exposure is potentially important for fostering resilience. If supported via replications and extensions in future research (e.g., longitudinal trajectories of adversity clusters), there may be a need to direct efforts towards those individuals who have experienced high levels of polyadversity and little or no experience of adversity. Indeed, previous research has demonstrated that individuals who have been over protected from stress by their parents present with maladaptive coping patterns and higher levels of distress in later life (Bayer, Sanson, & Hemphill, 2006). Therefore, as work usually focuses on individuals who have experienced a large amount of adversity, individuals who have encountered few exposures to adversity represent an unrecognised, but potentially at-risk population (Holtge et al., 2018). The current findings are in line with concepts such as toughening, whereby exposure to nominal amounts of stress may not be sufficiently challenging to develop one's individual level resilience resources (Dienstbier, 1989; 1992). Therefore, interventions aimed at fostering resilience resources would be beneficial for those at both ends of the polyadversity spectrum. To facilitate development of these resources, programs might focus on helping individuals to perceive encountered stressors as challenging rather than threatening in order to stimulate the development or refinement of resources.

Second, although resilience resources were not found to moderate the association between stress and PA and SB, they were associated with lower levels of self-reported stress and SB and higher levels of PA. These findings suggest that interventions aimed at strengthening students' resilience resources may be beneficial for reducing levels of perceived stress and time spent being sedentary as well as increasing PA. Within an educational context, universities may benefit from the incorporation of resilience resource building strategies into the student experience. Considered in conjunction with the polyadversity findings, it would be most effective if programs were incorporated from the beginning of the student journey, taking a multifaceted approach so that students can 'test out' the utility of learned skills or strategies when they experience stress. These programs could encompass elements of the individual-level resilience resources examined in the present work, as well as other types of previously identified resilience factors including social and environmental factors (Helmreich et al., 2017). In terms of the individual level resources used in the current work, previous research has shown that they can be developed effectively in both classroom (Luthans et al., 2006) and via online settings (Luthans, Avey, & Patera, 2008). The ease of use and accessibility of an online program may appeal to the student population; indeed, online programs have been found to be effective for improving health behaviours, can target specific subgroups of students, and can reach larger groups of students than traditional in person interventions (Kleinsasser, Jouriles, McDonald, & Rosenfield, 2015).

5.4. Strengths and Limitations

5.4.1. Strengths.

A notable strength of the present body of work was the use of both subjective and objective measures of stress, PA, and SB. Subjectively, measures were used to assess perceived general stress over a month (PSS-10) and a day (PSS-4), as well as a measure of daily academic stress. This measurement approach enabled an examination of participants' perceptions of different types of stress over differing temporal periods. In terms of measures of subjective stress, the PSS is considered the most popular and is widely used (Taylor, 2015), with past work supporting reliability evidence (e.g., Lee, 2012). Despite this body of work, self-report measures inherently suffer from method biases (e.g., recall bias), which can affect their predictive validity in spite of good reliability (Weckesser et al., 2019). Furthermore, stress measures have been found to be affected by psychological traits (e.g., neuroticism; Schlotz, Yim, Zoccola, Jansen, & Schulz, 2011). To account for the limitations associated with subjective measures of stress within this thesis, stress was measured physiologically through HCC. Objective measures of stress are typically characterised by higher reliabilities and a lower likelihood of suffering from measurement bias than subjective measures of stress (Weckesser et al., 2019). Specifically, when using HCC as a measure of long term stress exposure, it has been found to address limitations (e.g., circadian rhythmicity) associated with other objective measures of stress (e.g., salivary and plasma cortisol concentrations; Stalder et al., 2017). There is also strong evidence of the overall validity of HCC (e.g., Short et al., 2016; Stalder & Kirschbaum, 2012), including good test re-test reliability and high levels of intraindividual stability (Stalder et al., 2017). Despite the growing evidence for the utility of objective measures of stress, it may be inadvisable to rely on their findings in isolation as they are not free of limitations and are sensitive to psychophysiological traits unrelated to stress levels (Weckesser et al., 2019). Therefore, future research should look to use both subjective and objective measures of stress in tandem to provide a comprehensive picture of an individual's stress response.

In recent years, there has been a shift towards device-based measurement of PA and SB using wearable accelerometers (Farrahi, Niemela, Kangas, Korpelainen, & Jamsa, 2019). We used a GENEActiv Original triaxial accelerometer (Activinsights Ltd, Kimbolton, Cambs, UK) within this research program. The GENEActive has been widely used in a number of large-scale studies (e.g., da Silva et al., 2014; Sabia et al., 2013) and validated for measurement of both PA (e.g., Esliger et al., 2011) and SB (e.g., Pavey, Gomersall, Clark, & Brown, 2015). Although the IPAQ is a widely used and validated self-report measure of PA and SB (e.g., Kim, Park, & Kang, 2013), there are inherent problems associated with self-report measures including retrospection bias and social desirability, which can lead to a less accurate assessment than an objective measure (Podsakoff, MacKenzie, & Podsakoff, 2012). Therefore, measurement of PA and SB levels with accelerometers provide a more accurate measure of activity levels addressing the limitations associated with the IPAQ. However, device-based measures are not infallible and can suffer from problems, such as body location and assigned intensity cut points (influences amount of time recorded in each intensity; Sylvia, Bernstein, Hubbard, Keating, & Anderson, 2014). Future research may benefit from using both indices in tandem to offer a more complete picture of all facets of people's activity levels. An additional strength in regards to PA measurement in the current work was the decomposition of PA into its different levels of intensity. A number of studies have reported results in terms of absolute levels of PA, categorised individuals as either active or not, or failed to assess intensity (Stults-Kolehmainen & Sinha, 2014). This compound assessment may not paint a true picture of PA and clarity could be gained from the examination of PA intensities, offering a more nuanced understanding on how factors may have differential effects at different intensities of PA.

The use of a measurement burst design to examine the associations between stress and PA and SB in Study 3 is a key strength of this research program. Measurement burst designs allow us to observe processes that occur over short intervals (e.g., hours, days, weeks) and how these processes may change over a longer timeframe (e.g., months, years) (Sliwinski, 2008). Therefore, this method was ideally suited to study the temporal associations between stress and PA and SB, as these associations are likely dynamic in nature. The design allowed for the examination of both inter- and intra-individual change over each 6 day burst of intensive measurement, providing a picture of the daily effects of stress on PA and SB, as well as the changes in these associations across the three bursts and across individuals. More traditional single wave longitudinal studies usually rely on a single measurement at each period, which can be problematic if the variable of interest is highly variable (e.g., perceived stress) (Sliwinski, 2008). Measurement burst design reliability in detecting long-term changes in the variable of interest is enhanced through examining changes in the average levels of variables of interest within each burst. Therefore, they offer researchers the opportunity to explore interactions of inter-individual processes that occur over different time periods. As people's perceived stress and PA and SB levels can be highly variable, measurement bursts offer an ideal medium by which to examine these dynamic associations.

5.4.2. Limitations.

Despite these strengths, there are several limitations of this of work which may inspire future research. First, the choice of measure for adversity in Study 1 was informed by an important body of work by Seery and colleagues, who examined how the experience of cumulative lifetime adversity is related to resilience (e.g., Seery, 2011; Seery, Leo et al., 2010; Seery, Holman et al., 2010; Seery et al., 2013; Seery & Quinton, 2016). Though the utility of the scale has been demonstrated within this research, it may not capture all of the important aspects of people's adversity experience. Recent research in the area of adversity exposure has suggested that it is critical to assess what adversities people have experienced alongside the way in which the adversity is perceived by the individual (Slavich & Shields, 2018). For example, two individuals may report experiencing the death of a parent, though one may be estranged from their family and the other may have a very close-knit family. One could then presume that these experiences of the same adversity may be very different for these two individuals. A recent development in the measurement of lifetime stress exposure is the Stress and Adversity Inventory for Adults (Adult STRAIN; Slavich & Sheilds, 2018). The STRAIN is an online automated measure, assessing a total of 55 stressors including both acute (26) and chronic (29) difficulties. The stressors cover major life domains, such as relationships, health, work, and education, and encompass a number of key social-psychological characteristics, including interpersonal loss, humiliation, and physical danger (Sheilds & Slavich, 2017). The measure allows researchers to investigate both objective (e.g., number of stressors/adversities) and subjective (e.g., perceived severity of stressors/adversities) experiences of stress and adversity exposure. Research using the STRAIN is promising and it has been found to predict psychological (e.g., memory), biological (e.g., biological reactivity to acute stress) and clinical (e.g., mental health problems) outcomes (Sheilds & Slavich, 2017). Additionally, it had demonstrated good validity and test-retest reliability evidence and better predictive utility in regards to health related outcomes (e.g., doctor-diagnosed general health problems) compared to other commonly used measures (Slavich & Shields, 2018). Therefore, future research may benefit in using the STRAIN to further our understanding on the cumulative effects of lifetime stress and adversity exposure.

A second limitation related to the measures used in this thesis, as alluded to earlier, is that the PsyCap concept may not encapsulate salient resilience resources for the studied population. The choice within this research was informed by a recent conceptual and methodological review of resilience measures (Pangallo et al., 2015) which assessed the psychometric properties of 17 resilience measures, identifying the PsyCap to have the highest psychological rating across seven quality assessment criteria. Therefore, though the utility of this concept for operationalising resilience resources may be justified, there is a need to consider other possibly salient resources. Research has identified a number of resources which may warrant further investigation within the current context, covering both internal (e.g., hardiness) and external (e.g., social support) resources (Helmreich et al., 2017). Furthermore, some of these resources have been found to have utility within university student populations, such as social support (e.g., Dyrbye et al., 2010) and coping flexibility (Galatzer-Levy, Burton, & Bonanno, 2012). In light of this limitation, future research could benefit from broadening the scope of potential resilience resources and include both internal and external (e.g., social, environmental) resources.

The lack of assessment of certain demographic details also may be considered a limitation within this thesis. First, we did not assess participant's ethnicity throughout the studies. Race has previously been found to be associated with differences in HCC, with the higher levels reported in black, Hispanic and non-white people (Abell et al., 2016; Fischer et al., 2017; Wosu et al., 2015) when compared with white people. Furthermore, significant associations have also been reported between skin colour and perceived stress (Perreira, Wassink, & Harris, 2017). Therefore, future work may want to assess ethnicity within samples and control for it as a possible covariate. Second, we did not assess hair related factors such as hair washing frequency and hair treatment (e.g., dye). Findings related to these characteristics are equivocal with evidence for and against effects. For example, hair treatment has been reported to be associated with lower levels of HCC (e.g., Manenschijn et al., 2011; Stalder et al., 2013; Staufenbiel et al., 2015) as well as no effect (e.g., Fischer et al., 2017). As such, it may have been beneficial to include a measure of these characteristics to account for their influence across all statistical models. A related limitation of the current study is the high proportion of females compared to males. With regard to Studies 2 and 3, in particular, a disproportionately high percentage of females is a common issue in studies using HCC, with previous work reporting a similar proportion of female participation (e.g., 72%, Fischer et al., 2017; 81%, Gidlow, Randall, Gillman, Smith, & Jones, 2016; 72%, Staufenbiel et al., 2015). This finding may be due to the requirements in hair length, as men traditionally have shorter hair than women in the posterior vertex region of the scalp, the location which shows the least variability in growth rates (Cooper, Kronstrand, & Kintz, 2012). Coupled with a volunteer bias for research within this field (Fischer et al., 2017), this may exacerbate female dominated studies in this area.

Third, we were unable to rule out the possible effects of mental health problems across all studies, as such information was not collected (bearing in mind participant burden). Past research has demonstrated meaningful associations between mental health problems and variables of interest within the present work. For example, depressive symptoms are typically associated with higher levels of perceived stress (e.g., Hewitt, Flett, & Mosher, 1992), linked with higher levels of HCC (Belvederi et al., 2014), lower levels of PA (Vancampfort et al., 2015), and higher levels of SB (Vallance et al., 2011). Therefore, it may be important in future research to assess possible mental health correlates, potentially as a screening tool. Finally, although the work within this thesis offers insights into the dynamic associations between stress, PA and SB within a university setting, the generalisability across other environments remains unknown (e.g., work). As stress represents the interplay between internal and external demands, and people's internal appraisal of these demands, stressors associated with different environments may have a differential effect on outcomes. Therefore, additional research is required with diverse samples, such as health professionals, or military personnel to offer insight as to the generalisability of these findings.

Fourth, as stress, PA, and SB are all essentially dynamic concepts, it makes sense to adapt the longitudinal measurement burst protocol used in the current project to examine different temporal resolutions. Ecological Momentary Assessment (EMA) allows for repeated monitoring of variables (e.g., stress) in real-time in an ecologically valid setting (e.g., home, university, work; Schwartz & Stone, 1998). This technique addresses limitations associated with a single daily retrospective measure of perceived stress, such as transient level at the time of measurement, time of day that the measure was completed, and where the measure is completed (Jones et al., 2017). As EMA collects measurements in real-time and in natural environments, it is therefore able to capture moment to momentary changes in levels of the observed variables. Research suggests that EMA designs are most appropriate for predicting negative health behaviours, when compared with more traditional retrospective assessment techniques (e.g., Anestis et al., 2010; Jones et al., 2017; Steptoe, Gibson, Hamer, & Wardle, 2007). Furthermore, recent work has provided excellent examples of how EMA can be used to investigate the associations between stress and PA and SB (e.g., Burg et al., 2017; Jones et al., 2017). Therefore, the incorporation of EMA within the measurement burst design alongside device-based assessment of PA and SB would help to provide an accurate picture and add to our understanding of the dynamic associations between stress and PA and SB.

A final consideration for future research could include the time frame through which students stress may change and exert negative effects on PA and SB. Therefore, it would be beneficial to incorporate multiple time frames (e.g., across weeks, semesters, years) to further our understanding of the time course through which changes in stress effect PA and SB levels. This suggestion is consistent with the need for an improved consideration of time within empirical research (e.g., Shipp & Cole, 2015). The research highlights the need to take into consideration issues such as patterns, duration, cycles, and time lags. An optimal design would be to conduct a measurement burst design over the course of student's whole university experience (e.g., 3 year degree), enabling the identification of patterns and cycles of the temporal effects of stress on PA and SB. This enhanced temporal resolution could provide important information to university services on when students may require additional support, and what training or services may be required (e.g., building social resources early in their degree). For example, it may be that self-efficacy is most important within examination periods, whereas social support is most important during regular term time. Therefore, procedures could be set in place, or interventions implemented to help develop or support the most salient resources at the most appropriate time. This research could help make the students time at university a less stressful and more fruitful experience.

5.5. Conclusion

Too much stress or adversity, too little PA and too much SB are all associated with numerous deleterious psychological and physiological health outcomes. Therefore, clarity in our understanding of these factors and how they are interrelated is essential in our efforts to try to mitigate their harmful effects. It is also necessary to understand other factors, such as resilience, which may have a salubrious effect on the stress-outcome pathway. This thesis provides a number of important insights. Study 1 provides initial evidence of how exposure to lifetime adversities cluster together in two samples, and how class membership is associated with individual-level resilience resources. Study 2 found that resilience resources were related to more PA time and less time spent in SB, and demonstrated that higher levels of resilience resources were associated with lower levels of perceived stress. Finally, Study 3 found that higher levels of daily academic and general stress are dynamically associated with lower levels of light and moderate PA and higher levels of SB. Collectively, therefore, the research program detailed in this thesis provides an important first look at the interplay among stress, PA, SB, and resilience resources. It is hoped the strengths of this work and lessons learned will inspire others to extend the foundation that has been laid here.

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Appendix A: Published Article

Published Article

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Profiles of adversity and resilience resources: A latent class analysis of two samples

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Adversities refer to events that are characterized by perceived or actual threat to human functioning. Often considered deleterious for health and well-being, recent work supports an alternative picture of the effects of adversity on human functioning, such that a moderate amount of adversity – when compared with none or high levels – can be beneficial. We extend this body of work in the current study by considering the breadth or type of adversities experienced simultaneously (referred to as polyadversity), with a focus on individual profiles of lifetime adversities. Latent class analysis was employed to explore different configurations of lifetime adversity experiences in two independent samples and examine how these latent classes differed with regard to resilience resources (i.e., optimism, hope, self-efficacy, and bounce-back ability). University students ($N = 348$) and members from the broader community ($N = 1{,}506$) completed measures of lifetime adversity exposure and resilience resources. Three polyadversity classes were revealed in each sample, with both producing a high and a low polyadversity class. The third class differed between samples; in the student sample, this class represented experiences of vicarious adversity, whereas in the community sample, it represented moderate levels of exposure to adversity. Support for the adaptive nature of a moderate amount of adversity exposure was found in the community sample but not in the student sample. This study produces initial evidence of how lifetime adversity experiences group together and how class membership is related to resilience resources.

Bad things can and do happen to people; whether it is being struck down by serious illness, being exposed to a natural disaster, or experiencing the death of a loved one, most if not all people will experience one or more of these highly aversive events during their lives. Adversities refer broadly to 'negative life circumstances that are known to be

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statistically associated with adjustment difficulties' (Luthar & Cicchetti, 2000, p. 858). Epidemiological studies show the worldwide prevalence rates of exposure to lifetime adversities to be relatively high. For example, in a study covering 24 countries over six continents, 70.4% of respondents (N = 68,894) reported experiencing at least one traumatic event, with 30.5% reporting four or more different events (Benjet *et al.*, 2016). National rates varied between 28.6% (Bulgaria) and 84.6% (Ukraine). The most commonly experienced traumatic events included unexpected death of a loved one (31.4%), witnessing death, a dead body or someone seriously injured (23.7%), and being mugged (14.5%). In general, adversity and potentially traumatic events (PTEs)[1] are statistically associated with various negative psychological and physiological health outcomes such as depression (Burns, Lagdon, Boyda, & Armour, 2016), post-traumatic stress disorder (Burns *et al.*, 2016; Cavanaugh, Martins, Petras, & Campbell, 2013), and substance abuse (Armour & Sleath, 2014; Young-Wolff *et al.*, 2013). Research within the field of stress and adversity usually focuses on these and other deleterious outcomes. However, not everyone who experiences adversity is afflicted with such negative consequences (e.g., Bonanno, Westphal, & Mancini, 2011).

Different theories suggest that, in the right amount, exposure to stressors or adversities may actually foster resilience. For example, Dienstbier's proposed theory of toughness (1989, 1992) postulates that exposure to stress can have a toughening effect when this exposure is limited and there is opportunity for recovery. Similar concepts to toughness have been referred to as stress inoculation (i.e., Meichenbaum, 1976, 1977), steeling (e.g., Rutter, 1987), and immunization (e.g., Başoğlu *et al.*, 1997). A common theme among these perspectives is that exposure to moderate amounts of stress/adversity that are sufficiently challenging to be successfully coped with creates an opportunity for an individual to develop resources (e.g., self-efficacy) which will help them cope with future adversities. Indeed, it has been suggested that to develop the resilience necessary for high performance, individuals may first need to be vulnerable to adversity to subsequently benefit from the psychological and behavioral changes that only this level of trauma can bring (Fletcher, 2018; Fletcher & Sakar, 2016). In this view, toughness can be seen as analogous to physical fitness, in that improvement in physical fitness requires physical exertion followed by a period of recovery to build one's capacity. Though too much exposure to stressors can have debilitating effects on toughness just as overtraining can for physical fitness (Seery, Leo, Lupien, Kondrak, & Almonte, 2013). This developed toughness is also proposed to be transferable to other domains, both familiar and novel, which has positive implications for resilience to future adversity (Seery & Quinton, 2016). Toughening may occur via self-reflection, whereby exposure to adversity offers the opportunity to reflect on one's initial response to a stressor and develop resilient capacities (e.g., coping resources) that maximize the likelihood of resilience to future events (Crane, Searle, Kangas, & Nwiran, 2019). Furthermore, similar to the previously mentioned concepts, this reflective process is most effective during moderate exposure to adversity (Crane *et al.*, 2019). Therefore, moderate levels of adversity offer more opportunity to systematically self-reflect than experiencing no or high levels of adversity, resulting in the strengthening of resilience to future adversities.

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[1] *We acknowledge that events are termed traumatic when they involve perceived or real threat to one's or another person's life or limb (American Psychiatric Association, 2013). Here, we use the term adversity to capture the breadth of possible events that might disrupt the functioning of a system, yet adopt traumatic where appropriate (e.g., study cited focused solely on traumatic events).*

Over the last 20 years, there has been a surge of interest examining psychological resilience, and with this, numerous definitions have been presented leading to debate around a universally accepted definition (Bonanno, Romero, & Klein, 2015). We ascribe to the view that resilience is a system's (e.g., individual, team) trajectory of functioning over time within the context of adversity exposure, whereby the system (e.g., individual, team) might withstand the potentially negative effects, or bounce back quickly to normal (i.e., pre-adversity) or healthy levels of functioning (e.g., Fletcher, 2018; Gucciardi *et al.*, 2018). This conceptualization helps clarify the distinction between resilience resources (often referred to as protective factors), processes, and outcomes. Resources help maximize the likelihood of a system withstanding or bouncing back from the negative effects of adversity exposure, whereas processes reflect the translation of one's potential for action via cognitive, emotional, or behavioural mechanisms into a demonstrable outcome. Thus, resilience as an emergent outcome is displayed when salient resources are activated in response to an adverse event to enact adaptive processes that result in optimal functioning either in terms of withstanding the negative effects of the adversity or bouncing back from deteriorations in functioning.

Broadly speaking, resilience resources encompass individual (e.g., personality, biological), community (e.g., social support), and societal (e.g., health and social services) factors (Masten, 2011; Windle, 2011). Our focus on individual resources in the current study was informed by a recent conceptual and methodological review of resilience measures that are designed to operationalize such resources (Pangallo, Zibarras, Lewis, & Flaxman, 2015). The Psychological Capital Questionnaire (PsyCap; Luthans, Youssef, & Avolio, 2007) received the highest rating of 17 resilience measures reviewed against seven quality assessment criteria, namely theory formulation, internal consistency, replicability, convergent validity, discriminant validity, and application. PsyCap, which is designed to assess four resilience resources, was awarded maximum marks in all but one criteria (replicability). First, the resilience component assesses one's ability to bounce back or recover from stress or adversity. The other three resources of hope, self-efficacy, and optimism share a commonality in that they are related to one's thoughts and beliefs about the attainment of future positive states (Feldman & Kubota, 2015). Hope refers to a cognitive process of self-determined motivation towards personally valued objectives and ways by which to achieve them (Snyder *et al.*, 2002). Self-efficacy is defined as a belief in one's ability to accomplish a desired goal; these beliefs instil individuals with the motivation to face new challenges and persist in the face of barriers (Bandura, 1997). Finally, optimism reflects an individual's expectancy that positive things will happen (Scheier, Carver, & Bridges, 1994). Each of these concepts has gained substantial support as key resilience resources across a broad range of samples and contexts (e.g., Chmitorz *et al.*, 2018; Fletcher, 2018). Together, these beliefs can influence behaviours towards a goal, in turn affecting achievement of goals and one's psychological well-being (Rand, Martin, & Shea, 2011). As beliefs are largely founded in experience, encountering many difficulties (adversities) that are perceived as overwhelming may lead to formation of a belief that we have low agency in the world. In contrast, if we overcome something, then we may believe that we are able to overcome difficulties. Thus, forming positive beliefs about your efficacy to overcome demands may be challenging unless you have experienced such adversities. Therefore, the experience of adversities may help one to develop adaptive beliefs through these examined resources.

Scholars have examined the effects of exposure to lifetime adversities on resilience outcomes across various life contexts and indices of functioning (Höltge, Mc Gee, Maercker, & Thoma, 2018). For example, Seery, Holman, and Silver (2010) found a U-shaped association between the number of lifetime adversities experienced and mental health and well-being. Specifically, individuals who had been exposed to some adversity reported better mental health and well-being (e.g., lower global distress, and higher life satisfaction) than people who had experienced either no (0 adversities) or high levels (mean + 1 *SD*) of lifetime adversity. In a subsample of sufferers of chronic back pain, individuals who had experienced some lifetime adversity (just below the logarithmic mean of 2.22; raw score median = 9 lifetime adverse events) reported lower levels of functional impairment (i.e., extent to which mental/physical health affected social/work activities) and use of health care than people who had experienced either no or high levels of adversity (defined as +1 *SD* [0.73] above the logarithmic mean of 2.22; Seery, Leo, Holman, & Silver, 2010). These findings have also been supported in response to laboratory stressors requiring passive endurance and active instrumental performance, in student samples (Seery *et al.*, 2013). In Seery and colleagues' research, lifetime adversities were operationalized using a cumulative measure (i.e., a score of 4 could represent four different adversities or the same adversity four times). Recent work has differentiated between cumulative acute and chronic adversities and found that breast cancer survivors who experienced moderate levels of acute lifetime adversities (i.e., time limited events, e.g., death of a loved one) reported higher levels of positive affect and fewer cancer-related intrusions (i.e., intrusive thoughts, nightmares, intrusive feelings, and imagery) than survivors who had experienced either low or high levels of acute adversities (Dooley, Slavich, Moreno, & Bower, 2017). Taken together, these findings provide evidence that moderate exposure to adversities may help protect individuals from the negative psychological effects of future stressors/adversities via the selection and development or refinement of resilience resources.

Though research has examined how different degrees of adversity exposure affect functioning, less attention has been paid to how adversities may cluster together (Holt *et al.*, 2017). Considering multiple types of adversities in tandem allows for an examination of differing combinations of adversity experiences, and how such distinct typologies might be differentially associated with various indicators of functioning. For example, multiple adversities can better predict outcomes, such as college adjustment (Elliott, Alexander, Pierce, Aspelmeier, & Richmond, 2009) and trauma symptoms (Finkelhor, Ormrod, & Turner, 2007), than single adversities in isolation. The term 'polytraumatization' (Gustafsson, Nilsson, & Svedin, 2009) was developed to represent this notion of exposure to multiple types of adversities, rather than repeated instances of single or chronic adversity. Compared to a single or repeated instance of the same adversity, polytraumatization has a negative effect on mental and physical indices of health (e.g., Briere, Agee, & Dietrich, 2016; Finkelhor *et al.*, 2007; Gustafsson *et al.*, 2009; Hughes *et al.*, 2017).

To study polytraumatization or, in the current study 'polyadversity', a person-centred approach is required to identify homogenous groups of individuals based on their adversity experiences. For the assessment of polyadversity classes, latent class analysis (LCA) is considered to be an optimal statistical method (Contractor, Caldas, Fletcher, Shea, & Armour, 2018). Unlike variable-centred approaches (e.g., regression), in LCA the sample is organized into a finite number of meaningful latent subgroups comprised of individuals who have similar response patterns on a set of variables, yet maximizes differences between these individuals with people assigned to other clusters (Lanza & Cooper, 2016). Simply put, there is a focus on the similarities and differences among people, rather than associations between variables. In LCA, individuals are probabilistically assigned to classes based on the probability of their membership in all identified classes (Berlin, Williams, & Parra, 2014), often with no *a priori* decisions about the number of classes, though decision-making is led by theory and evidence (Holt *et al.*, 2017). Past work focused on classes of trauma experiences among adult samples has underscored the importance of person-centred analyses. Contractor *et al.* (2018) identified nine studies via a systematic search of the literature and found three common types of trauma profiles across this work: individuals who had experienced low or high counts of trauma, and specific types of traumas (e.g., childhood maltreatment). These trauma groupings differed on a range of mental health indicators (e.g., depression), with the high-trauma class characterized by the poorest degree of mental health.

Though some research has utilized LCA to examine associations of polyadversity class membership with indicators of resilience outcomes such as depression, anxiety, and post-traumatic stress disorder (e.g., Burns *et al.*, 2016; Holt *et al.*, 2017; Young-Wolff *et al.*, 2013), there has been little consideration of the associations between polyadversity class membership and resilience resources or determinants. As resilience involves adjustment to adversity, it is important to understand how polyadversity classes are associated with resilience resources, which in turn may affect an individual's response to future adversities. To do so, we used a person-centred approach to explore polyadversity in two samples (student and community) and examined how the identified classes differ with regard to individual-level resilience resources (i.e., optimism, hope, self-efficacy, and bounce-back ability). In accordance with the findings of a recent meta-analysis of studies utilizing person-centred analyses for polytraumatization class analyses (Contractor *et al.*, 2018), we hypothesized that we would find a class characterized by a higher likelihood to have experienced most or all of the assessed adversities (H1), a class characterized by a lower likelihood of experiencing most or all of the assessed adversities (H2), and a class/classes characterized by a high likelihood of experiencing a specific adversity (H3). We also hypothesized that individuals who have experienced moderate levels of polyadversity (relative to the other classes identified) will report higher levels of individual-level resilience resources when compared to those who have experienced no/low or high levels of polyadversity (H4).

STUDY 1

Methods

Participants

A convenience sample of 348 undergraduate university students (61.5% female) aged 18–52 years (mean ± *SD*; 22.09 ± 4.97) was recruited from universities in Western Australia (77%) and the United Kingdom (33%).

Procedure

Approval for the study was granted by an accredited Human Research Ethics Committee prior to data collection. Participants were recruited via three methods: (1) an online research participation pool, where students completing health science degrees sign up to participate in studies in return for course credit; (2) posters placed around the university campus inviting participants to take part in the study; and (3) announcements about the study, including the information sheet and survey link, distributed by unit co-ordinators to students enrolled within their units. The students who chose to participate in the study completed a multi-section survey online via Qualtrics (Provo, UT, USA). All participants provided informed consent to take part in the study, via a checkbox at the beginning of the survey.

Measures

Adversity exposure

Participants' exposure to adversity across their lifetime was assessed using an adapted version of Seery, Holman, *et al.* (2010) and Seery, Leo, *et al.* (2010) cumulative lifetime adversity measure. The adapted measure consisted of 15 negative events that captured the following six broad categories: own illness or injury, loved ones illness or injury, violence, bereavement, social/environmental stress, and relationship stress. An additional two categories were included within our adapted version to capture common experienced adversities: threat or harassment, and others' death or injury. Respondents indicated whether or not they had ever experienced the adversity (0 = no, 1 = yes) and, if so, how many times. For the purposes of this study, a single dichotomous (yes or no) variable was created to represent each of the eight categories of adversity. For example, if participants indicated that they had experienced a 'major illness' but not a 'life threatening accident' (or vice versa), they would be scored as yes (1) to the adversity category own illness or injury. In cases where participants experienced both of these adversities, they were also coded as yes (1) to the adversity category own illness or injury. The combining of conceptually similar items to create a single binary category has been used in previous studies (e.g., Holt *et al.*, 2017; Young-Wolff *et al.*, 2013).[2]

Resilience resources

Informed by findings from a recent conceptual and methodological review of resilience measures (Pangallo *et al.*, 2015), we assessed four broad resilience resources encapsulated by the concept of psychological capital, namely hope, efficacy, resilience, and optimism (Luthans *et al.*, 2007). For each of the four scales, items were measured on a 7-point scale anchored by 1 *strongly disagree* and 7 *strongly agree*.

Bounce-back ability (Smith et al.*, 2008).* The Brief Resilience Scale (BRS) is a measure of one's perceived ability to bounce back or recover from stress. The scale is comprised of six items, three of which are positively worded (e.g., 'I tend to bounce back quickly after hard times') and three are negatively worded (e.g., 'It is hard for me to snap back when something bad happens'). Scores on the BRS have demonstrated good levels of internal consistency (α = .81–.91) and test–retest reliability (1 month r = .69 and 3 months r = .62) evidence in past work (Smith *et al.*, 2008). Internal reliability evidence in the current sample was excellent (α = .91).

Adult Hope Scale (Snyder et al.*, 1991).* The Adult Hope Scale (AHS) is a measure of an individual's cognitive and motivation towards personally valued objectives. The scale is comprised of 12 items consisting of two factors, each of which is measured by four items;

[2] *One reviewer asked why we used a binary score (yes/no) to operationalize adversity exposure rather than a continuous or summative score to indicate the number of times participants had experienced each adverse event category. As explained in the Supporting Information, this decision was largely statistical in nature rather than substantively informed (e.g., model fit statistics were unclear about the optimal number of classes, classes contained <5% of the total sample).*

the four filler items were omitted in this study to minimize participant burden. The *pathway* items measure one's perception of their ability to overcome goal-related barriers to their goals (e.g., 'There are lots of ways round any problem'), whereas the *agency* items reflect people's motivation and goal-directed energy to use pathways to reach their goal (e.g., 'My past experiences have prepared me well for my future'). Scores on the AHS have demonstrated good reliability (α = .79; Feldman & Kubota, 2015) and test–retest reliability evidence (3 weeks, r = .85 up to 10 weeks, r = .82; Snyder *et al.*, 1991). Internal reliability evidence in the current sample was sound (α = .86).

General Self-Efficacy Scale (Chen, Gully, & Eden, 2001). The General Self-Efficacy Scale (GSE) is an 8-item measure of one's belief in their capabilities to perform the courses of action required to meet situational demands (e.g., 'When facing difficult tasks, I am certain that I will accomplish them'). Scores on the GSE have demonstrated good internal consistency (α = .82; Chen, Li, & Leung, 2016) and test–retest reliability evidence (r = .62–.86; Chen *et al.*, 2001). Internal reliability evidence in the current sample was excellent (α = .92).

Life Orientation Test-Revised (Scheier et al.*, 1994).* The Life Orientation Test-Revised (LOT-R) is a 10-item measure of an individual's perceived optimism (e.g., 'I'm always optimistic about my future') and pessimism (e.g., 'I rarely count on good things happening to me'). The two dimensions are measured with three items; the four filler items were omitted in the current study to minimize participant burden. Scores on the LOT-R have demonstrated good levels of internal consistency (α = .85; Feldman & Kubota, 2015; α = .85; Huffman *et al.*, 2016) and test–retest reliability evidence (r = .73; Atienza, Stephens, & Townsend, 2004). Internal reliability evidence in the current sample was sound (α = .81).

Data analysis

Latent class analyses (LCA) were conducted to identify subgroups or clusters of individuals based on their breadth (categorical indicator) of lifetime adversity exposure, that is, the total number of unique adversity experiences. These analyses are useful in reducing indicator variables into latent subgroups (Oberski, 2016). In the present study, we utilized the automatic 3-step method within M*plus* (Muthén & Muthén, 1998–2017) to model auxiliary variables (e.g., covariates and distal outcomes). First, the 3-step method determines the number of latent classes based on the indicator variables, which in our case included eight broad categories of unique adverse events. Second, the most likely class membership for participants is determined based upon the posterior distribution obtained in step one. Finally, this classification scheme is related to covariates and distal outcomes. The 3-step method was chosen because it takes into account error in classification when estimating associations with other variables (Gabriel, Daniels, Diefendorff, & Greguras, 2015), and class identification is uninfluenced by covariates or outcomes variables (Asparouhov & Muthen, 2013). We initially fitted a 2-class model, then increased the number of classes by one, comparing the model fit statistics to ascertain if the increase in classes produced groups that were substantively meaningful and had a good fit statistically. A high number of initial stage random starts (1,000) were utilized to avoid local solutions (i.e., a false maximum likelihood), which is a common problem with

LCA models (Holt *et al.*, 2017). All analyses were run using M*plus* 8 (Muthén & Muthén, 1998–2017).

Different sources of information should be considered when assessing the optimum number of latent classes, including the substantive meaningfulness and the level of statistical fit of the possible solutions (Gillet, Morin, Cougot, & Gagné, 2017; Marsh, Lüdtke, Trautwein, & Morin, 2009). Multiple statistical indicators can be used to aid decision-making (McLachlan & Peel, 2000) and include (1) Akaike's information criteria (AIC), (2) consistent AIC (CAIC), (3) Bayesian information criteria (BIC), (4) sample size adjusted Bayesian information criteria (ABIC), (5) Lo–Mendell–Rubin likelihood ratio test (LMR), (6) adjusted Lo–Mendell–Rubin likelihood ratio test (aLMR), and (7) bootstrap likelihood ratio test (BLRT). For the four information criteria (AIC, CAIC, BIC, and ABIC), a lower value indicates better model fit. The two likelihood ratio tests (aLMR and BLRT) are accompanied by a p value for a comparison of model fit with a model with one less class, where a non-significant p value indicates the model with one less profile should be retained (Morin & Wang, 2016). Finally, entropy is an indicator of model precision with regard to classifying individuals into their most likely classes. Scores range from 0 to 1 with a higher value representing greater accuracy (Diallo, Morin, & Lu, 2016).

Simulation work has found four statistical indicators (CAIC, BIC, ABIC, and BLRT) to be most informative in identifying the correct number of classes (Nylund, Asparouhov, & Muthén, 2007; Peugh & Fan, 2013; Tofighi & Enders, 2008). Conversely, the AIC, LMR, and aLMR are suboptimal for informing decisions regarding the number of classes because they tend to support the extraction of the incorrect number of classes (Diallo *et al.*, 2016; Nylund *et al.*, 2007; Peugh & Fan, 2013). All model fit indicators are reported here for clarity, though only the CAIC, BIC, ABIC, and BLRT were used to decide upon the optimal number of classes. Simulation work (Diallo *et al.*, 2016) suggests that the ABIC and BLRT are preferred when entropy is lower (closer to .50), and the BIC and CAIC preferred when entropy levels are higher (closer to .90). Sample size is another important consideration for selecting the final model, because with a sufficiently large sample size the observed indicators may carry on suggesting the addition of more classes without reaching a minimum (Morin & Wang, 2016). In such cases, the information criteria can be presented in elbow plots to show the gains offered by additional classes; the point at which the line flattens shows the optimum number of classes (Wang, Morin, Ryan, & Liu, 2016).

Once the optimal solution had been identified, the covariates and outcomes were examined. For the covariates of age and sex, we used the R3STEP command (Asparouhov & Muthen, 2013). To explore the outcomes as auxiliary variables, we utilized the automatic BCH approach (Bakk & Vermunt, 2016). The BCH approach was chosen because it accounts for classification error and unequal variance across classes (Asparouhov & Muthén, 2014). Means for outcomes were computed for each class and compared. The analyses of the covariates (R3STEP) and outcomes (BCH) were conducted separately, as these two methods cannot be run simultaneously in M*plus* (Asparouhov & Muthén, 2014).

Results

Descriptive statistics

The proportions of the sample who had experienced a lifetime adversity category as well as descriptive statistics of the psychosocial factors by sex are detailed in Table 1. Sex differences were examined using chi-squared and t-tests. Adversities related to 'loved one's illness/injury' (49.7%) and 'bereavement' (48.5%) were the most commonly

Table 1. Descriptive statistics by sex

Study 1 (N = 324[#])				
Variables	Total (%)	Male (%)	Female (%)	χ^2
LCA Indicators				
Illness/Injury	39.8	36.4	41.6	0.36
Threat/Harassment	31.2	40.9	26.2	7.36**
Violence	31.2	31.8	30.8	0.30
Bereavement	48.5	54.5	45.3	2.47
Loved Ones Illness/Injury	49.7	51.8	48.6	0.30
Others Death/Injury	35.2	40.9	32.2	2.39
Social/Environmental Stress	29.6	31.8	28.5	0.38
Relationship Stress	27.5	21.8	30.4	2.67
Outcomes	Overall *M* (*SD*)	Male *M* (*SD*)	Female *M* (*SD*)	*T*
BRS	3.44 (1.29)	3.85 (1.16)	3.22 (1.30)	−4.29***
HOPE	4.08 (0.97)	4.04 (0.96)	4.09 (0.97)	0.47
LOT	3.64 (1.06)	3.74 (1.03)	3.60 (1.07)	−1.14
GSE	4.15 (0.97)	4.22 (0.98)	4.11 (0.96)	−0.96

Study 2 (N = 1,506)				
Variables	Total (%)	Male (%)	Female (%)	χ^2
LCA Indicators (number of missing values)				
Illness/Injury (133)	46.1	48.9	42.5	5.48*
Threat/Harassment (141)	12.7	12.8	12.7	.01
Violence (135)	23.0	24.1	21.6	1.16
Bereavement (130)	85.9	85.5	86.4	.27
Loved Ones Illness/Injury (136)	55.9	51.2	62.0	15.93***
Others Death/Injury (138)	24.0	29.4	17.2	27.41***
Social/Environmental Stress (135)	42.7	39.6	46.5	6.55**
Relationship Stress (133)	40.9	38.9	43.5	3.04
Outcomes	Overall *M (SD)*	Male *M (SD)*	Female *M (SD)*	*T*
BRS	4.49 (1.21)	4.68 (1.15)	4.26 (1.24)	−5.76***
HOPE	2.93 (0.52)	2.99 (0.50)	2.85 (0.54)	−4.51***
LOT	3.25 (0.78)	3.29 (0.74)	3.20 (0.83)	−1.86
GSE	5.16 (1.18)	5.29 (1.11)	5.00 (1.23)	−4.11***

Notes. BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LCA = latent class analysis; LOT = Life Orientation Test.
*p < .05; **p < .01; ***p < .001; [#]missing 24.

reported. Males reported significantly higher proportions of being threatened/harassed than females (p = .007), with no other significant differences observed between groups for adversities (p = .102–.857). In terms of psychosocial factors, males reported significantly higher levels of perceived bounce-back resilience than females (p = .000).

Table 2. Model fit statistics for all latent class models tested

Model	LL	AIC	CAIC	BIC	ABIC	ALMRT (*p*)	BLRT (*p*)	Entropy
Study 1								
1-class	−1,769.967	3,555.935	3,568.267	3,586.753	3,561.374	Na	Na	Na
2-class	−1,703.837	3,441.674	3,467.881	**3,507.161**	3,453.232	.000	.000	0.562
3-class	−1,683.664	**3,419.328**	**3,459.409**	3,519.485	**3,437.004**	.002	.000	0.787
4-class	−1,676.728	3,423.457	3,477.411	3,558.284	3,447.253	**.050**	**.775**	0.828
5-class	−1,670.012	3,428.024	3,495.854	3,597.521	3,457.939	.191	.840	0.854
6-class	−1,663.371	3,432.741	3,514.446	3,636.908	3,468.775	.205	.745	**0.860**
Study 2								
1-class	−6,326.156	12,668.312	12,685.429	12,710.145	12,684.732	Na	Na	Na
2-class	−5,892.634	11,819.269	11,855.641	11,908.164	11,854.162	.000	.000	0.667
3-class	−5,805.008	11,662.017	**11,717.645**	**11,797.974**	**11,715.382**	.000	.000	**0.704**
4-class	−5,788.248	11,646.495	11,721.381	11,829.514	11,718.333	**.727**	.000	0.633
5-class	−5,772.175	11,632.349	11,726.491	11,862.430	11,722.660	.462	.000	0.593
6-class	−5,760.745	**11,627.490**	11,740.887	11,904.633	11,736.273	.021	**.065**	0.602

Notes. ABIC = adjusted BIC; AIC = Akaike information criteria; ALMRT = adjusted Lo–Mendell–Rubin likelihood ratio test; BIC = Bayesian information criteria; BLRT = bootstrap likelihood ratio test; CAIC = consistent AIC; LL = log-likelihood.
Boldface represents optimal fit.

Class identification

Model fit statistics are detailed in Table 2. The CAIC, ABIC, and BLRT supported the superiority of the 3-class solution, whereas the BIC reached its minimum value at the 2-class solution. As the entropy value was high, we preferred the CAIC and BIC values over the ABIC and BLRT. An examination of the elbow plot (see Figure 1) shows that with the exception of BIC, the lowest values were at the 3-class solution and the slopes began to increase with the addition of classes. These data suggest a preference for the 2-class and 3-class solutions; we accepted the 3-class solution as the most viable because of the higher entropy value. Substantively, although the 2-class solution produced distinct classes in line with the study hypotheses, the addition of the third class clearly identified members who had experienced a different profile of adversities than the other classes. Notably, the 4-class solution produced a class consisting of only 12 members (3.4%), which evidenced a similar pattern to the third class.

The estimated probabilities of the 3-class model are depicted in Figure 2. These plots display the probability that an individual within a latent class has experienced one of the lifetime adversity categories, and therefore, how different latent classes are from each other across the lifetime adversity categories. The first class along the bottom of the plot, denoted by the dashed line, is characterized by relatively low probabilities (<.33) of having experienced each of the lifetime adversity categories. This class was labelled *Low Polyadversity* and accounted for 41.1% of the sample. The second class, identified by the dotted line, had a low probability (<.33) of experiencing all but two categories, where individuals reported moderate to high probabilities of experiencing bereavement (.60) and a loved one's illness/injury (1). This class contained 17.8% of the sample and was called *Vicarious Adversity*. The final class, denoted by the solid line, constituted the remaining 41.1% of the sample.

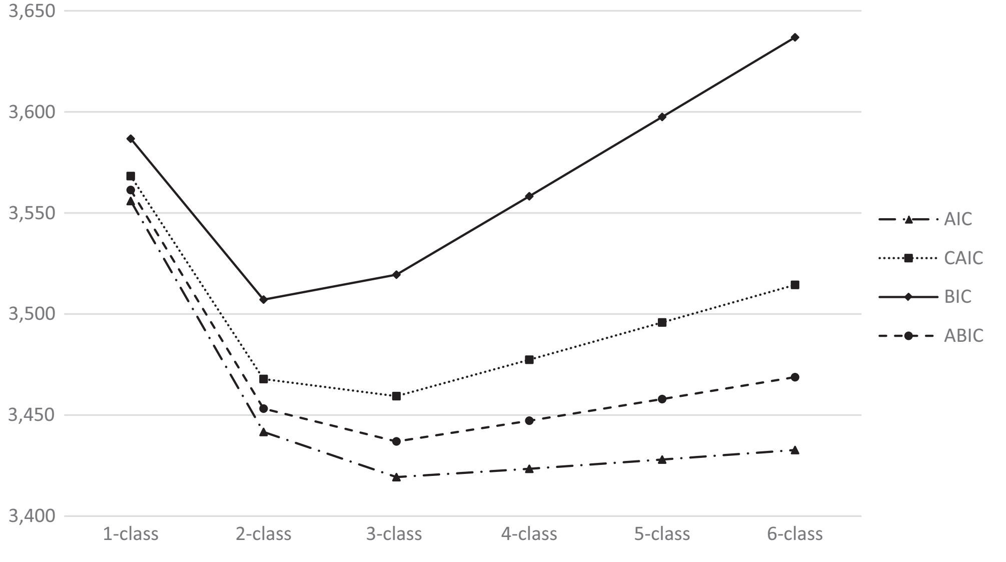

Figure 1. Elbow plot of the information criteria for latent class models in Study 1. *Note.* ABIC = adjusted BIC; AIC = Akaike's information criteria; BIC = Bayesian information criteria; CAIC = consistent AIC.

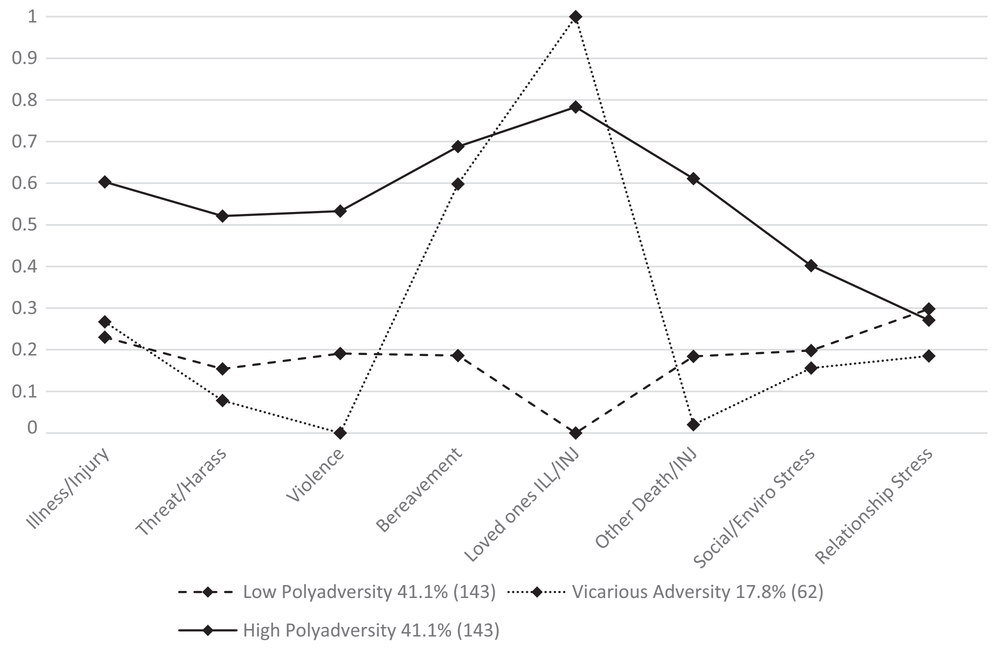

Figure 2. Category probability plot of the three LTA classes in Study 1. *Note.* Enviro = environmental; Harass = harassment; ILL = illness; INJ = injury.

This class was characterized by moderate to high probability of experiencing all categories, with the exception of relationship stress (.27); as such, we labelled this class as *High Polyadversity*.

Covariates

Sex and age differences were observed across the three classes. With regard to sex, females were more likely than males to be in the *High Polyadversity* class than the *Vicarious Adversity* (−.95, SE = .47, p = .04) and *Low Polyadversity* classes (−.63, SE = .31, p = .04). With regard to age, participants in the *High Polyadversity* class were older than individuals in both the *Vicarious Adversity* (−.21, SE = .08, p = .01) and *Low Polyadversity* (−.09, SE = .03, p = .01) classes.

Outcomes

An examination of differences across classes in terms of psychosocial factors (see Table 3) shows a single statistically significant difference, with those students in the *Vicarious Adversity* class reporting lower levels of optimism than individuals in the *Low Polyadversity* class. The standardized outcome scores across the three classes are depicted in Figure 3.

STUDY 2

The results of the first study provided initial support for our expectations regarding classes of individuals who experienced low or high amounts of adversities (H1 and H2), or one

Table 3. Means and mean-level class difference of outcome variables in Study 1

Reference class	Mean	High polyad	Vicarious Ad	Low polyad
High polyad				
BRS	3.44 (0.13)		1.21	0.08
HOPE	4.14 (0.10)		0.78	0.43
LOT	3.58 (0.10)		0.95	2.15
GSE	4.14 (0.09)		0.32	0.29
Vicarious Ad				
BRS	3.19 (0.16)			2.23
HOPE	3.98 (0.14)			0.19
LOT	3.38 (0.16)			4.87*
GSE	4.03 (0.16)			1.08
Low polyad		Overall test		
BRS	3.49 (0.12)	2.28		
HOPE	4.05 (0.09)	0.83		
LOT	3.80 (0.10)	5.64		
GSE	4.21 (0.09)	1.17		

Notes. Ad = adversity; BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LOT = Life Orientation Test; Polyad = polyadversity.

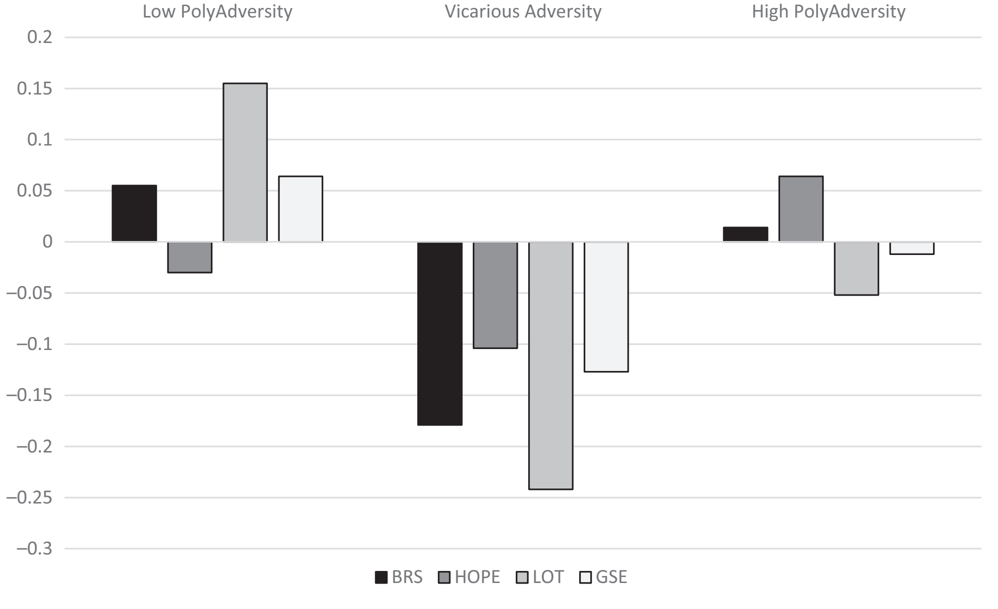

Figure 3. Standardized outcome variable scores across classes in Study 1. *Note.* BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LOT = Life Orientation Test.

specific type of adversity (H3). However, there were minimal differences between these classes in terms of self-reported resilience resources (H4). In this study, we replicated the aforementioned methodological approach with a larger sample and broader representation of the community than university students, particularly with regard to lifetime adversity exposure.

Methods

Participants

A sample of 1,506 participants (51.8% male) aged between 18 and 90 years (mean ± *SD*; 52.77 ± 17.01) were recruited through the On-line Research Unit (ORU), Australia's largest online research panel. Simulation work suggests that a sample of this size should provide 80% power to detect small effects ($\sim w = .15$) for a three or four class solution (Dziak, Lanza, & Tan, 2014).

Procedure

Approval for the study was granted by an accredited Human Research Ethics Committee prior to data collection. Participants were recruited using an online data collection agency (http://theoru.com). From a population of approximately 400,000 participants, the data collection agency distributed our survey via email to a random subsample representative of the general population in terms of age, gender and geographical location. Those participants who opted to participate in the study completed the survey online via Qualtrics (Qualtrics LLC). The survey included questions regarding basic demographic information, the occurrence of past adversities and individual-level resilience resources. Participants also received a five dollar shopping voucher as compensation for their time completing the survey.

Measures

Adversity exposure

Similar to Study 1, participants' exposure to adversity was assessed using an adapted version of Seery, Holman, *et al.* (2010) and Seery, Leo, *et al.* (2010) measure. The measure differed slightly from the first study, in that 21, as opposed to 15, items were selected from the original measure (see the online Supporting Information). The items again reflected the eight broad categories of: own illness or injury, loved ones illness or injury, violence, bereavement, social/environmental stress, relationship stress, threat or harassment, and others death or injury. Participants indicated for each item whether they had experienced the adversity (0 = no, 1 = yes). A composite score was created for each category of adversity to indicate whether the category had been experienced or not.

Resilience resources

The measures for the individual-level resources again captured the four broad resilience resources encapsulated by the concept of psychological capital, namely hope, efficacy, resilience, and optimism (Luthans *et al.*, 2007). With the exception of self-efficacy, the measures were identical to tools used in Study 1. Test scores in this study demonstrated good reliability evidence: BRS ($\alpha = .86$), LOT-R ($\alpha = .81$), and hope ($\alpha = .90$).

Self-efficacy. An adapted measure based upon Bell and Kozlowski's (2002) tool was utilized to assess participant's self-efficacy in relation to lifetime adversity. The measure consisted of four items (e.g., 'I am convinced that I can handle the demands in my life') that were assessed on a 7-point scale anchored by 1 *strongly disagree* and 7 *strongly agree*. Scores on the scale have demonstrated good levels of internal consistency evidence (α = .82) in past research (Lindberg, Wincent, & Örtqvist, 2013). Internal reliability evidence was excellent in the present study (α = .95).

Data analysis

We used the same analyses as reported in Study 1.

Results

Descriptive statistics

The proportions of the sample who experienced each lifetime adversity category and differences in psychosocial factors means are presented in Table 1. Bereavement was the most commonly reported adversity (85.9%) followed by loved one's illness/injury (55.9%). Males were more likely to have experienced illness/injury (p = .019) and other death/injury (p = .000) and less likely to have experienced loved one's illness/injury (p = .000) and social/environmental stress (p = .010) than females. Sex differences were also observed in outcome variables, with males reporting higher levels of bounce-back resilience (p < .001), hope (p = .000) and self-efficacy (p = .000).

Class identification

Model fit statistics of all models tested are detailed in Table 2. The CAIC, BIC, and ABIC all suggested a 3-class solution, whereas the BLRT supported additional classes until the 6-class solution. The entropy level was generally high, which would suggest a preference for

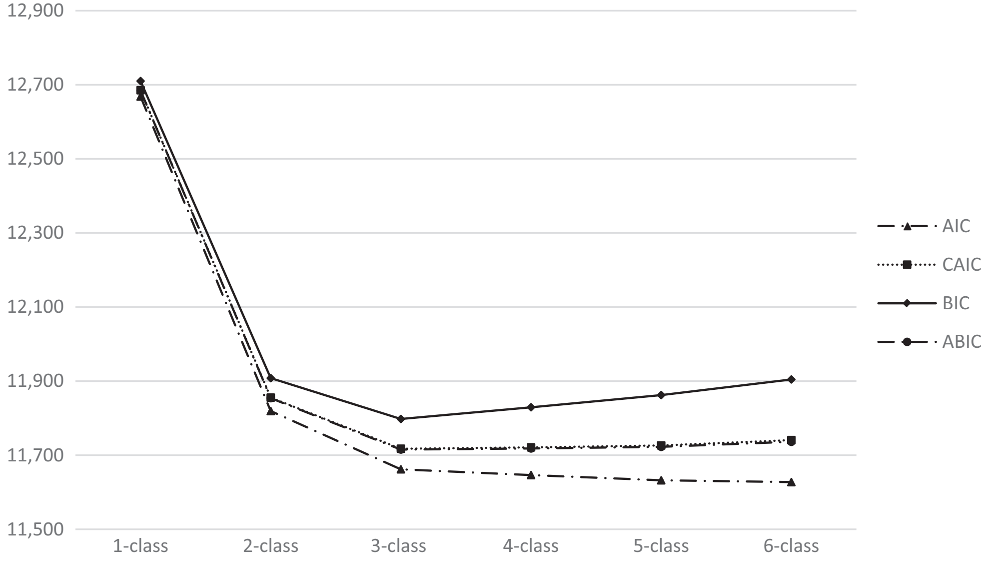

Figure 4. Elbow plot of the information criteria for latent class models in Study 2. *Note.* ABIC = adjusted BIC; AIC = Akaike's information criteria; BIC = Bayesian information criteria; CAIC = consistent AIC.

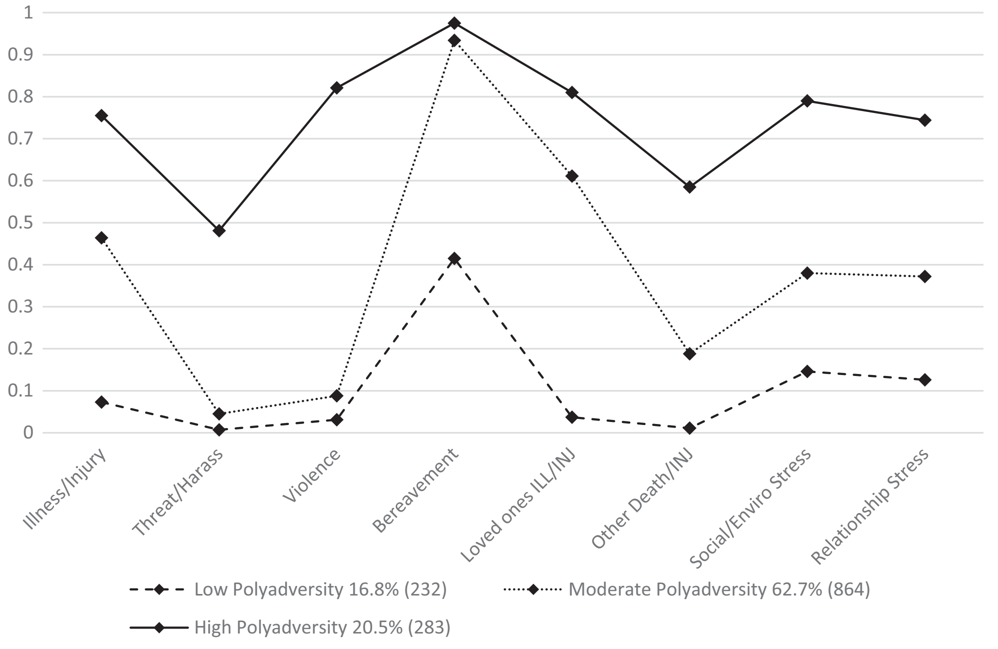

Figure 5. Category probability plot for the three LTA classes in Study 2. *Note.* Enviro = environmental; Harass = harassment; ILL = illness; INJ = injury.

the CAIC and BIC over the ABIC and BLRT. An examination of the elbow plot shows a flattening of the slope at the 3-class model (see Figure 4). In the light of these results, the 3-class solution was retained for further examination.

Three distinct classes can be seen in the estimated probability plot for an individual having experienced the examined lifetime adversity categories (see Figure 5). The first class can be seen along the bottom of the plot, denoted by the dashed line; participants in this class had the lowest probabilities of experiencing all lifetime adversity categories, with the exception of bereavement (.42). This class accounted for 16.8% of the sample and was labelled *Low Polyadversity*. The second class, denoted by the solid line, accounted for 20.5% of the sample. This class had the highest probabilities of experiencing all lifetime adversity categories (.66–1), with the exception of threat/harassment (.48) and other death/injury (.59). This class was labelled *High Polyadversity*. The final class, identified by the dotted line, can be seen to have category probabilities that fall between those of the other two classes. They experienced low probabilities in three categories (threat/harassment, violence, and other death/injury), moderate probabilities in four (illness/injury, loved one's illness/injury, social/environmental stress, and relationship stress), and a high probability of bereavement (.93). This class was labelled *Moderate Polyadversity* and contained 62.7% of the sample.

Covariates

A number of demographic differences were found between classes in terms of the observed covariates. Males were more likely to be in the *Low Polyadversity* class than the *Moderate Polyadversity* class (.55, SE = .24, p = .02). Individuals within the *Low*

Polyadversity class were younger than those participants in both the *Moderate Polyadversity* (.08, $SE = .01$, $p < .001$) and *High Polyadversity* (.06, $SE = .01$, $p < .001$) classes. Finally, individuals in the *High Polyadversity* class were significantly younger than those people in the *Moderate Polyadversity* ($-.02$, $SE = .01$, $p < .01$) class.

Outcomes

The results for the psychosocial variables show a number of differences between classes (see Table 4); standardized scores for each psychosocial variable across the three classes are depicted in Figure 6. Individuals in the *Low Polyadversity* class reported lower levels of resilience and optimism than people in the *Moderate Polyadversity* Class. The *Low Polyadversity* class also reported higher levels of all outcome variables than individuals in the *High Polyadversity* class. Participants in the *High Polyadversity* class reported lower levels of all psychosocial variables than individuals in the *Moderate Polyadversity* class.

Discussion

The current study utilized a person-centred approach to examine subpopulations of adversity exposure in two samples. We further examined differences between adversity class memberships and individual-level resilience resources. H1 was supported, such that we observed in both samples a class characterized by a relatively high likelihood of experiencing most or all of the assessed adversities (high polyadversity). H2 was also supported with a class identified in both samples characterized by a lower likelihood of experiencing most or all of the assessed adversities (low polyadversity). H3 was partially supported, such that in Study 1 we identified a class characterized by a high likelihood of experiencing a specific trauma (vicarious adversity), yet in Study 2 the third class was characterized by moderate experiences of adversities (moderate

Table 4. Means and mean-level class difference of outcome variables in Study 2

Reference class	Mean	Low polyad	Mod polyad	High polyad
Low polyad				
BRS	4.41 (0.09)		5.05*	7.20**
HOPE	2.95 (0.05)		.40	8.80**
LOT	3.20 (0.06)		4.31*	6.33*
GSE	5.13 (0.10)		1.98	5.93*
Mod polyad				
BRS	4.66 (0.06)			22.58***
HOPE	2.98 (0.02)			16.22***
LOT	3.36 (0.04)			20.01***
GSE	5.29 (0.05)			15.28***
High polyad		Overall test		
BRS	4.05 (0.10)	22.67***		
HOPE	2.75 (0.05)	16.81***		
LOT	2.98 (0.07)	20.09***		
GSE	4.77 (0.11)	15.28***		

Notes. BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LOT = Life Orientation Test; Polyad = polyadversity.
*$p < .05$; **$p < .01$; ***$p < .001$; standard deviations are reported in brackets.

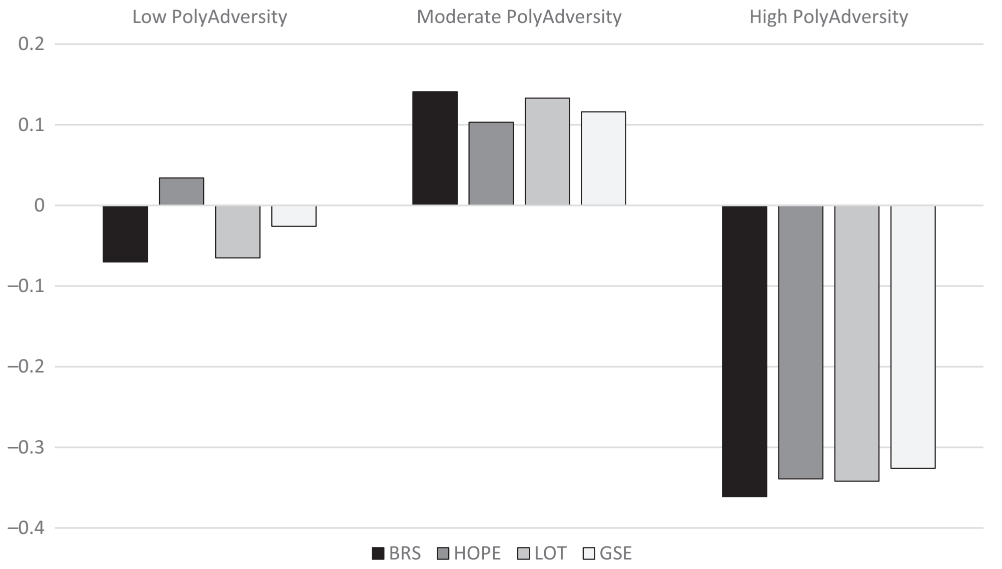

Figure 6. Standardized outcome variable scores across profiles in Study 2. *Note.* BRS = Brief Resilience Scale; GSE = General Self-Efficacy; LOT = Life Orientation Test.

polyadversity). H4 was also partially supported, such that in Study 2 the moderate polyadversity class was associated with higher levels of all resources than the high adversity class and higher levels in two of the four resources (optimism and resilience) than the low-adversity class. However, these differences in reported individual-level resilience resources were largely absent from the student sample in Study 1, with the exception of optimism.

Although past work has examined how certain adversities can affect individual-level resilience resources (e.g., Kivimäki *et al.*, 2005), there has been little research on how the experience of multiple adversities might contribute to an individual's resilience capacity. The question is of interest for both substantive (e.g., qualitative differences in adversity experiences) and practical (e.g., interventions, and health care) reasons. The latent classes we observed within the present study were largely in line with our hypotheses, such that we revealed three distinct classes that best represented polyadversity profiles. The review informing our hypotheses found seven of the nine reviewed studies reported a 'high-trauma class' and all nine reported a 'low-trauma class' (Contractor *et al.*, 2018). Classes with a similar interpretation were observed in the current study across the student and community samples. Although the two samples revealed both high and low polyadversity classes with similar numbers within each, the proportional distribution of classes differed between studies. Specifically, in the student sample the high and low polyadversity classes were comprised of the same proportion of participants (41.3%), whereas in the community sample classes the proportion of members was roughly half (low = 16.8%; high = 20.5%). Contractor *et al.* (2018) found in their review that the classes characterized by high levels of adversity were the smallest. It should be noted that within the review, the studies mainly focused on interpersonal adversities (8 of 9). It has also been found that when categorizing participants by total number of adversities experienced (e.g., zero, low, high), the high category contained more participants than the zero- and low-adversity categories (Seery, Holman, *et al.*, 2010; Seery, Leo, *et al.*, 2010)). A key methodological difference with past work is that we considered a broad array of lifetime adversities, many of which were absent from previous research on adversity exposure. This extension was informed by recommendations for researchers to take into consideration adversities beyond the narrow focus of interpersonal adversities (Contractor *et al.*, 2018). This widening of scope may account for the observed differences in the proportions of those who reported higher levels of polyadversity.

Differences between latent classes of adversity exposure in terms of individual-level resilience resources were mixed. Briefly, the findings of Study 2 were consistent with our expectations, such that members of the moderate polyadversity class reported the highest levels of all resources across the three classes. These differences were statistically significant for all four resilience resources when comparing the moderate class with the high polyadversity class, yet only for bounce-back resilience and optimism when comparing against the low polyadversity class. Conceptually, the findings are consistent with the view that a moderate amount of adversity is optimal, over high and no adversity, to allow for toughening or the opportunity for individual's to develop and/or refine resilience resources (Dienstbier, 1992; Höltge *et al.*, 2018). Speculatively, this opportunity may occur via systematic self-reflection strengthening resilience (Crane *et al.*, 2019). Empirically, the findings are consistent with previous work which has identified a U-shaped association between lifetime adversity and indicators of positive functioning or an inverted U-shaped association with markers of negative functioning (e.g., Höltge *et al.*, 2018; Kondrak & Seery, 2015; Seery, Holman, *et al.*, 2010; Seery, Leo, *et al.*, 2010); Seery *et al.*, 2013). These series of studies consistently found that exposure to some adversity was associated with adaptive (higher/lower) levels of a variety of psychological well-being outcomes (e.g., life satisfaction, global distress, post-traumatic stress) than a history of no/ low or high levels of adversity. Furthermore, exposure to some adversity was associated with being less negatively affected by recent adversity, consistent with the development of resilience (Seery, Holman, *et al.*, 2010; Seery, Leo, *et al.*, 2010)).

Our findings add another layer to previous work by suggesting that exposure to a moderate amount of adversity builds resilience through providing the opportunity to develop these individual-level resources. In turn, research has supported the adaptive nature of these resilience resources, such that people who report higher levels fare better psychologically and physiologically in terms of perceived stress (Lines *et al.*, In Press; Riolli, Savicki, & Richards, 2012), well-being (Avey, Reichard, Luthans, & Mhatre, 2011), body mass index, and blood cholesterol concentration (Luthans, Youssef, Sweetman, & Harms, 2013). Interestingly, members of the high polyadversity class also had significantly lower levels of all resources that those in the low polyadversity class. This suggests that exposure to a fewer adversities may enable an individual to develop these adaptive resources to a lesser extent than a moderate amount of adversity, though exposure to high amounts is highly detrimental to the perceived availability of resources. In a recent review, members of high polytraumatization classes demonstrated the worst health outcomes when compared to those in other classes (e.g., greater likelihood of post-traumatic stress disorder, anxiety, depression, alcohol and drug use, and self-harm; Contractor *et al.*, 2018). These deleterious effects may be a result of the sensitizing role of stressors or adversities, in that exposure to an adversity may sensitize an individual to a lower level adversity in the future (Stroud, Davila, Hammen, & Vrshek-Schallhorn, 2011). This sensitization may lead to maladaptive responses being triggered, undermining resilience (e.g., rumination, self-doubt) in response to lesser adverse events which in turn develops into one's natural response to an adversity (Crane *et al.*, 2019). In the light of the frequently observed beneficial effects of a moderate amount of exposure to adversity, research exploring this sensitization hypothesis should also look at both positive and negative effects.

Differences in individual-level resilience resources between the three classes among the student sample were mixed. Of all the comparisons, only one difference was statistically significant, whereby individuals in the vicarious adversity class reported lower levels of optimism than people in the low polyadversity class. One key difference between the two classes is in the category of loved one's illness/injury, with all members of the vicarious class and none in the low polyadversity having experienced this type of adversity. Kivimäki *et al.* (2005) examined changes in optimism and pessimism following death or severe illness of a loved one and found that pessimism rose by 10% following the onset of an illness of a loved one, though fell by 4% with the absence of such an adversity. This past work provides a useful backdrop upon which to interpret the finding in the current study, as we used a cumulative score for optimism based on the support for the summative unidimensional approach within the literature (Carver & Scheier, 2018). This observation can be seen as important as higher levels of optimism are associated with protective benefits following both severe and mild adverse events (e.g., Chang & Sanna, 2003; Kivimäki *et al.*, 2005). Therefore, it may be beneficial in future research to examine whether interventions aiming to increase optimism (e.g., Blackwell *et al.*, 2013) help individuals via these adaptive benefits following bereavement, or illness/injury of a loved one.

The main difference between the two samples in this study was the nature of the third class. Both classes were characterized by a relatively high ($\geq$0.6) likelihood of experiencing the adversities of bereavement and loved one's illness/injury. However, the community sample in Study 2 had a moderate probability of having experienced an illness/injury, social/environmental stressor, and relationship stressor alongside the two vicarious adversities, whereas the student sample evidenced a low probability of all other adversities. Within both samples, the shapes of the probability plots are similar for this third class, though they differed on the proportion of members with only 17.3% in the first sample, compared to 62.7% in the second sample. Interestingly, in Contractor *et al.*'s (2018) review none of the papers reported a moderate class, though all reported at least one specific trauma class with proportions ranging from 3.6% to 62.6% (mean = 22.1%). The nature of this third class makes comparison between the two classes complex as they are substantively different; that is, one is characterized by endorsement of specific adversities whereas the other is characterized by an overall moderate degree of exposure. The observed differences may have emerged due to the nature of the samples within the two studies, with the first consisting of students (M_{age} = 22.09) and the second an older community sample (M_{age} = 52.77). One might think that with a higher age the older participants have had more time to experience adversities than their younger counterparts, though the adversities faced by younger people may have occurred in more recent memory and are thus more easily recalled (Seery & Quinton, 2016). Indeed, when age has been controlled for as a covariate in past research, it has no effect on outcomes across student and community samples (e.g., Seery, Holman, *et al.*, 2010; Seery, Leo, *et al.*, 2010); Seery *et al.*, 2013). A second possible reason for the findings is that within younger samples of individuals, the categories of bereavement and loved one's illness/injury may be more pertinent. In their study of 68,894 individuals, Benjet *et al.* (2016) found that younger (18–34 years) participants were more likely than older (65+ years) people to report having experienced, among others, unexpected death of a loved one. Finally, adversities that are important for this age group may have been missing from the checklist used in the current study and past work, or were not entirely obvious to participants (e.g., peer bullying).

Strengths and limitations

Key strengths of this study include the person-centred approach to examining adversity exposure, differential effects of adversity experiences and resilience resources, and tests of the study hypotheses in two independent samples. Nevertheless, the current study is not without limitation. Our focus on four individual-level resilience resources may be seen as narrow and therefore requires expansion within future research (e.g., social resources). Furthermore, the assessment of adversity exposure was characterized by a dichotomous yes/no response and therefore excluded an indication as to when the adversity occurred in their developmental pathway. Future research may look to consider the breadth (i.e., number of different adversities) and the depth (i.e., the frequency, intensity, and duration) of adversities experienced. Despite our efforts to examine the robustness of the findings across two samples, the extent to which the nature of the tripartite typology of lifetime adversity exposure generalizes remain uncertain, particularly with respect to the third class where we observed important differences between the university study and community samples and the minimal demographic information collected from our two samples. The cross-sectional nature of the study means that we cannot speak confidently to causality and can only infer such relations from theory (e.g., toughness). Finally, the data were collected via self-report and as such may be affected by self-report biases.

Conclusion

The current study provides initial evidence of how exposure to lifetime adversities group together in two samples, and how class membership is associated with individual-level resilience resources. Across two independent samples – one a group of university students and the other a largely representative community sample – we revealed support for a tripartite representation of individual's experiences of multiple lifetime adversities. A low polyadversity and high polyadversity profile were evident among both samples, with the third class characterized by either two core vicarious adversities (students) or moderate levels across several adversities (community sample). Mixed support was found for our hypotheses regarding differences in individual-level resilience resources between classes; the adaptive nature of a moderate amount of adversity experiences was supported in the community sample but not the students. Our findings regarding the adaptive nature of adversity in the community sample are consistent with literature in other areas. For example, within the context of competitive sport, adversity has been found to distinguish between the super-elite (won at least one gold plus another gold or silver at a major championship) and elite (received athlete personal awards but not medalled at a major championship) athletes, particularly when coupled with a positive sport-related event (Hardy *et al.*, 2017). Broadly, our findings underscore the importance of person-centred approaches to advancing our understanding on the nature of adversity experiences, their interplay, and their associations with resilience resources.

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Supporting Information

The following supporting information may be found in the online edition of the article:

Table S1. Model fit statistics for all latent profile models tested
Figure S1. Elbow plot of the information criteria for latent profile models in Sample 1.
Figure S2. Category probability plot for 2 classes in Sample 1.
Figure S3. Category probability plot for 3 classes in Sample 1.
Figure S4. Category probability plot for 4 classes in Sample 1.
Figure S5. Category probability plot for 5 classes in Sample 1.
Figure S6. Category probability plot for 6 classes in Sample 1.
Figure S7. Category probability plot for 7 classes in Sample 1.
Figure S8. Elbow plot of the information criteria for latent profile models in Sample 2.
Figure S9. Category probability plot for 2 classes in Sample 2.
Figure S10. Category probability plot for 3 classes in Sample 2.
Figure S11. Category probability plot for 4 classes in Sample 2.
Figure S12. Category probability plot for 5 classes in Sample 2.
Figure S13. Category probability plot for 6 classes in Sample 2.
Figure S14. Category probability plot for 7 classes in Sample 2.

Appendix B: Published Article

Published Article

Lines, R. L. J., Ducker, K. J., Ntoumanis, N., Thøgersen-Ntoumani, C., Fletcher, D., McGarry, S., & Gucciardi, D. F. (in press). Stress, physical activity, and resilience resources: Tests of direct and moderation effects in young adults. *Sport, Exercise, and Performance Psychology*. Doi: 10.1037/spy0000152

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Stress, Physical Activity, and Resilience Resources: Tests of Direct and Moderation Effects in Young Adults

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Stress is an important consideration for understanding why individuals take part in limited or no physical activity (PA). The effects of stress on PA do not hold for everyone, so examinations of possible moderators that protect individuals from the harmful effects of stress are required. Aligned with a resilience framework, individual resources (e.g., hope and self-efficacy) may buffer the maladaptive effects of stress, such that people who have access to these resources in greater quantity may be more "resilient" to the deleterious effects of stress on PA. This study was designed to test this expectation. In total, 140 Australian undergraduate students (70.7% female, M_{age} = 21.68 ± 4.88) completed a multisection survey and provided a sample for hair cortisol concentration analysis using immunoassays. Main effects demonstrated primarily small and nonsignificant associations between perceived stress and hair cortisol concentration with different intensities of PA. Similar findings were observed between individual-level resilience resources and PA intensities, with the exception of hope (i.e., positive association with vigorous PA and negative association with sitting), self-efficacy (i.e., positive association with vigorous PA), and resilience (i.e., positive association with walking). Although certain individual-level resilience resources were perceived as beneficial for PA and sedentary time, the moderating role of resilience resources was not supported by the findings. The direct and moderating effects between stress, PA, and resilience resources require further testing using longitudinal designs in which stressful periods occur naturally (e.g., exams for students) or are experimentally manipulated.

Keywords: hair cortisol, psychological capital, hope, self-efficacy, optimism

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Stress is a common part of everyday life, with most people at some point exposed to events that may affect their mental or physical health (Cooper & Quick, 2017). Stressors range from everyday hassles (e.g., financial worries) to life-changing events (e.g., death of a loved one).

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Within the stress literature (Blascovich, 2008; Lazarus & Folkman, 1984), stress is said to occur when individuals perceive events or situations in their environment as taxing or exceeding their available resources. Broadly speaking, resources are concepts that "either are centrally valued in their own right (e.g., self-esteem, close attachments, health, and inner peace) or act as a means to obtain centrally valued ends (e.g., money, social support, and credit)" (Hobfoll, 2002, p. 307). When individuals perceive that their resources exceed the perceived demands of a stressor, stress is appraised as a challenge, yet when demands outweigh resources stress is evaluated as a threat (Blascovich, 2008). Following an appraisal of threat, stress typically leads to physiological and/or psychological responses that can be maladaptive for one's functioning (Chrousos, 2009). The deleterious health outcomes of stress are well established and encompass both psychological (e.g., depression, generalized anxiety disorder, and posttraumatic stress disorder) and physiological consequences (e.g., cardiovascular disease, obesity, and Type 2 diabetes; Thoits, 2010).

When examining the physiological responses to stress, one of the most widely studied markers is associated with the activation of the hypothalamic-pituitary-adrenal (HPA) axis, namely, the release of cortisol in response to the perceived threat or challenge. The HPA is highly responsive to stimulation from external stressors with acute levels of reactivity allowing for beneficial adaptive responses, namely "fight or flight" (Gidlow, Randall, Gillman, Smith, & Jones, 2016). However, dysregulation in secretion over longer periods and/or high levels of repeated reactivity are maladaptive and represent a serious issue for both psychological and psychological health (Short et al., 2016; Stalder et al., 2017). Therefore, measures of HPA activity and its secretion of steroid hormones, particularly cortisol, have become important physiological markers of stress (Fischer et al., 2017).

Cortisol levels have traditionally been determined from salivary, blood, and/or urine samples (Stalder & Kirschbaum, 2012). Although well established within the literature, a single assessment of these methods provides only a snapshot of acute circulating cortisol levels at the time of sampling (saliva and plasma), or in the case of urine cortisol secretion a 24-hr period (Dettenborn, Tietze, Kirschbaum, & Stalder, 2012; Gerber, Jonsdottir, et al., 2013; Stalder & Kirschbaum, 2012). This temporal dimension represents a problem when attempting to assess cortisol levels over longer periods because HPA activity is highly variable (Stalder et al., 2017). Furthermore, the aforementioned methods are affected by a number of factors including circadian rhythmicity, transient levels of stress at the time of sampling, and factors that take place before sampling such as smoking, alcohol, physical activity (PA), and food consumption (Gerber, Kalak, et al., 2013; Stalder & Kirschbaum, 2012; Stalder et al., 2017). Thus, although these methods have utility for capturing acute reactivity of the HPA, their use in measuring long-term or chronic activity is limited (Stalder et al., 2017).

The analysis of hair cortisol concentration (HCC) can attenuate the methodological limitations of traditional methods (Gerber, Jonsdottir et al., 2013; Short et al., 2016; Stalder & Kirschbaum, 2012). As human hair grows ~1 cm per month (Wennig, 2000), HCC provides a reliable retrospective measure of cumulative secretion for up to 6 months (Kirschbaum, Tietze, Skoluda, & Dettenborn, 2009). Research has linked HCC to conditions that are known to alter HPA functioning, such as Cushing's syndrome (Chrousos, 2009; Gidlow, Randall, Gillman, Silk, & Jones, 2016). There is also strong evidence of the overall validity of HCC (Short et al., 2016; Stalder & Kirschbaum, 2012), including good test–retest reliability and high levels of intraindividual stability (Stalder et al., 2017). For these reasons, HCC has been used increasingly over the past decade to examine the effects of chronic stress on a broad range of health-related outcomes (Stalder et al., 2017), including PA (Gerber, Jonsdottir, et al., 2013) and sedentary behavior (Teychenne, Olstad, Turner, Costigan, & Ball, 2018).

The beneficial effects of PA on a wide range of positive health outcomes, both psychological and physical, are well established within the literature (Stults-Kolehmainen & Sinha, 2014). Despite the wealth of information on its numerous benefits, many individuals do not partake in regular or sufficient levels of PA to confer health benefits (Hallal et al., 2012). It is also important to consider sedentary time (i.e., seated or reclined posture with low energy expenditure; Tremblay et al., 2017) alongside PA because high levels of "sitting time" can coexist with an active lifestyle (Healy et al., 2008) and have deleterious effects on health (Ekelund et al., 2018). Stress is one of the major considerations when it comes to understanding why people engage in little PA or perform none at all (Burg et al., 2017), with research typically examining the salubrious effects of PA on stress (Wipfli, Rethorst, & Landers, 2008). However, a systematic review of 168 studies examining the association between stress and PA and sedentary behaviors (Stults-Kolehmainen & Sinha, 2014) found that a majority of the reviewed studies (72.8%) identified a negative association between stress and PA, suggesting that there may be an inverse association with stress negatively affecting one's PA. In the case of prospective studies ($n = 55$), 76.4% found stress to predict lower levels of PA and exercise or higher levels of sedentary behavior. Thus, the stressors people face may act as a barrier to healthy behaviors (e.g., PA) and perpetuate unhealthy choices (e.g., sedentary activities; Burg et al., 2017). Based upon the recent review, the effects of stress on PA do not appear to be universal, and therefore further examination of possible moderators that may protect an individual from the deleterious effects of stress is required (Stults-Kolehmainen & Sinha, 2014). This explanation is in line with a resilience framework in which resources are said to buffer the maladaptive effects of stress and adversity on human functioning (Luthar, Cicchetti, & Becker, 2000; Masten, 2011). Thus, there is a need to examine resilience resources that may buffer the effects of stress on PA.

Over the past 2 decades, there has been a surge of research on psychological resilience (Bonanno, Romero, & Klein, 2015). Although debate remains regarding a universally accepted definition of resilience (Fletcher & Sarkar, 2013), we ascribe to the perspective which suggests that resilience encapsulates one's capacity to sustain or regain relatively stable, healthy levels of psychological and physical functioning despite exposure to significant stressors or adversities (Luthar et al., 2000; Masten, 2011; Windle, 2011). Central to this process of recovery or adjustment are protective factors that encompass personal (e.g., optimism), community (e.g., social support), and societal (e.g., health services) resources (Masten, 2011; Windle, 2011). A recent conceptual and methodological review of resilience measures (Pangallo, Zibarras, Lewis, & Flaxman, 2015) informed our choice of resilience resources in the current study. The higher order concept of psychological capital (Luthans, Youssef, & Avolio, 2007) is composed of measures of hope, self-efficacy, resilience (bounce back), and optimism, and received the highest psychometric rating among 17 resilience measures. In addition, these individual-level resilience resources are modifiable and, therefore, can be targeted via interventions (e.g., self-efficacy, Sheeran et al., 2016; optimism, Littman-Ovadia & Nir, 2014). Within the context of a stress framework, it is likely that some people may have access to these resources in greater quantity and/or quality and therefore be more "resilient" to the deleterious effects of stress. However, the supposition that these resources may interact with stress and PA has not yet been examined with respect to the effects of stress on PA. Conducting research on this issue could shed light on which resources may help individuals to better cope with the demands of life and retain PA levels during stressful periods.

In summary, the objective of this study was to examine the associations between perceived and objective measures of stress, individual-level resilience resources, and their interaction in predicting different intensities of self-reported PA and sedentary behavior. Aligned with a resilience perspective (Luthar et al., 2000; Masten, 2011), we expected resilience resources to buffer the effects of stress on PA, such that the negative association between stress and PA would be attenuated for individuals with higher levels of these resources. We focus on university students for two key reasons. First, tertiary studies can be a highly stressful period (Dixon & Kurpius, 2008), where students face numerous stressors across personal (e.g., relationship difficulties), academic (e.g., coursework demands), and occupational (e.g., career aspirations) contexts (Hurst, Baranik, & Daniel, 2013). The stressful nature of this developmental period is reflected in prevalence statistics reported in national surveys (e.g., 64.2% of university students report their academic experiences to be very or extremely stressful; Headspace National Youth Mental Health Foundation, 2016). Second, during stressful periods, it is important that students remain active, as 40%–50% of students are physically inactive and spend up to 8 hr a day completing sedentary activities such as studying and watching TV (Deliens, Deforche, De Bourdeaudhuij, & Clarys, 2015).

Method

Participants

Given the unavailability of existing work to inform expectations regarding a true effect size, we sought a compromise between financial resources (for hair cortisol analysis) and the smallest effect size of interest to determine how much data to collect. Power analysis using G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that 121 participants would be required to detect a small-to-moderate increase in variance explained by the addition of the two interaction terms to the regression equation (eight total predictors, two tested predictors, 80% power, $f^2 = .12$, $\alpha = .01$). A convenience sample of 140 adults (70.7% female) aged 18–49 years (mean $\pm$ SD = 21.68 $\pm$ 4.88) was recruited from two universities in Australia. Eligibility criteria included being an undergraduate student, willingness to provide a hair sample, and sufficient hair length (2 cm) on the posterior vertex region of the head. Participants were excluded from the analyses if they had an existing medical condition or musculoskeletal injury preventing them taking part in regular PA (n = 5), resulting in a final sample of 135 participants (71.1% female) aged 18–49 years (mean $\pm$ SD = 21.71 $\pm$ 4.94).

Procedure

This study was approved by the Human Research Ethics Committee at the lead author's institution. Participants were recruited to the study by two methods: (a) online via a research participation pool, via which students enrolled in health science degrees can elect to participate in research in return for course credit or gift vouchers ($10 iTunes voucher); and (b) face-to-face via researcher-delivered invitations provided at the start of lectures within courses where students learn about the importance of PA (e.g., exercise science and physiotherapy). Students who expressed an interest in the study attended a 30-min laboratory session where they provided informed consent, completed a multisection survey[1] online via Qualtrics (Qualtrics LLC, Utah, USA), and provided a sample of hair. The hair sample was cut as close as possible to the scalp and taken from the posterior vertex region, as previously described (Sauvé, Koren, Walsh, Tokmakejian, & Van Uum, 2007). Hair samples were cut to ~1.5 cm (minimum ~ 30–50 mg), wrapped in aluminum foil with an elastic band closest to the root end, and stored at room temperature before being sent to a specialist laboratory for analysis (Stratech Scientific APAC, Sydney, Australia).

Measures

Demographics. Participants self-reported the following demographic information: age, sex (female = 0, male = 1), existing musculoskeletal injury, height, and weight.

Perceived stress. The 10-item version of the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) was used to assess to the degree to which situations in an individual's life over the past month were perceived as stressful (e.g., "In the last month, how often have you felt confident in your ability to handle your personal problems?"). Items were assessed on a 5-point scale from 0 (*never*) to 4 (*very often*). Past work with student samples has provided reliability and validity evidence of test scores obtained with the PSS (Shapiro, Brown, Thoresen, & Plante, 2011).

Physical activity. Participants self-reported their PA over the past 7 days using the seven-item short form of the International Physical Activity Questionnaire (IPAQ; Booth, 2000). Six items assess the frequency (days per week) and duration (hours and minutes) of PA intensities (vigorous, moderate, and walking), with two items per intensity (e.g., "On how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling? How much time did you usually spend doing vigorous physical activities on one of those days?"). One question is also included as an indicator of sedentary behavior ("During

[1] Participants also completed measures of lifetime adversity, academic stressors, social support, proactive goal regulation, and mental toughness. These variables will be the focus of separate publications; any overlap will be acknowledged appropriately.

the last 7 days, how much time did you usually spend sitting on a weekday?"). Using guidelines for data processing, the total number of minutes of each PA intensity was calculated following recommendations from the IPAQ website (www.ipaq.ki.se). In the current study, the three PA intensities were analyzed as minutes per week and the sitting time as a daily average. In line with data-processing guidelines (www.ipaq.ki.se), participants who answered "do not know" for an intensity were omitted from analyses for that intensity. The IPAQ is one of the most widely used PA questionnaires, and meta-analytic data of 21 studies including 152 effect sizes spanning five PA categories have provided reliability and validity evidence of IPAQ scores (Kim, Park, & Kang, 2013).

Resilience resources. Participants completed established measures of the components which comprise the higher order construct of psychological capital (Luthans et al., 2007), including hope, generalized self-efficacy, resilience, optimism, as well as a measure of adaptability. All scales were measured on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Adult Hope Scale. The Adult Hope Scale (Snyder et al., 1991) measures an individual's hope toward goals and consists of 12 items, including four fillers. Two factors are measured, each with four items. The Pathway items reflect people's perceptions of their capability to overcome goal-related barriers to achieve their goals (e.g., "I can think of many ways to get out of a jam"), whereas the Agency subscale captures motivation and goal-directed energy to utilize pathways to pursue goals (e.g., "I energetically pursue my goals"). In this study, the filler items were omitted to reduce participant burden. In the current study, the two subscale scores were combined to create a total hope score, with a higher score reflecting greater hope. The full-scale scores, including filler items, have demonstrated reliability evidence for use within student samples (Feldman & Kubota, 2015).

General Self-Efficacy Scale. The General Self-Efficacy Scale (GSE; Chen, Gully, & Eden, 2001) is an eight-item, unidimensional measure of an individual's belief in their ability to perform in a variety of differing situations (e.g., "I believe I can succeed at most any endeavor to which I set my mind"). Scores on the GSE are summative with larger scores indicating higher levels self-efficacy. Test scores on the GSE have demonstrated good internal consistency (α between .86 and .90) and test–retest reliability evidence (r = .62 to .66; Chen et al., 2001) in a student sample.

Life Orientation Test—Revised. The 10-item Life Orientation Test—Revised (LOT-R; Scheier, Carver, & Bridges, 1994) is a measure of Optimism (e.g., "In uncertain times, I usually expect the best") and Pessimism (e.g., "I hardly ever expect things to go my way"), with each dimension assessed using three items (the remaining four are fillers and were omitted in this study). We created a composite score by combining the Optimism and Pessimism items (first reversed scored), with higher scores reflecting greater optimism. This cumulative scoring method has been commonly utilized in previous research (Atienza, Stephens, & Townsend, 2004; Feldman & Kubota, 2015; Hinz et al., 2017). Scores on the full Life Orientation Test—Revised, including filler items, have demonstrated good internal consistency within a student sample (α between .7 and .8; Scheier et al., 1994) and test–retest reliability evidence (.58–.79; Atienza et al., 2004) in a female sample (M_{age} = 43.7).

Brief Resilience Scale. The Brief Resilience Scale (BRS; Smith et al., 2008) measures an individual's perception of their ability to bounce back from stress. The scale consists of six items with three positively worded (e.g., "I usually come through difficult times with little trouble) and three negatively worded (e.g., "I have a hard time making it through stressful events") statements. The three negatively worded items were reverse scored to give a total resilience score, with a higher score reflecting increased levels of resilience. The Brief Resilience Scale scores have demonstrated good internal consistency (α between .8 and .91) and test–retest reliability evidence (r = .69 after 1 month and r = .62 after 3 months; Smith et al., 2008) across samples consisting of students and cardiac rehabilitation patients.

Adaptability Scale. This nine-item tool (Martin, Nejad, Colmar, & Liem, 2012) is a measure of psycho-behavioral adjustment in response to novelty and/or uncertainty (e.g., "I am able to revise the way I think about a new situation to help me through it"). A higher score on the scale indicates a greater level of adaptability. Validity and reliability evidence of the scale scores has been demonstrated in cross-sectional and longitudinal studies, within high school and university student samples (Martin et al., 2012; Martin, Nejad, Colmar, & Liem, 2013).

Hair cortisol. For preparation and cleaning, hair was cut to 1.5 cm from the root end to represent cortisol secretion over a period of at least the previous month, due to the variability of the hair growth rate (Wennig, 2000). Cortisol extraction followed the widely published enzyme-linked immunosorbent assay (ELISA) method (Davenport, Tiefenbacher, Lutz, Novak, & Meyer, 2006). Samples were first treated with isopropanol and then methanol, and allowed to dry for 5 days. In preparation for analysis, the hair was weighed for extraction and mechanically crushed. Methanol was used for extraction for 24 hr with sonication, with the tubes subsequently dried to remove all methanol before the samples were reconstituted in PBS for analysis. Cortisol was then analyzed in duplicate using a commercially available ELISA immunoassay (Salimetrics, USA) according to the manufacturer's instructions (intraassay variability = 5.4%, interassay variability = 6%).

Statistical Analyses

Descriptive statistics were calculated using SPSS, Version 24 (SPSS Inc., Chicago, IL, USA). Linear regression was employed to examine the primary research questions. With regard to moderation effects, variables were grand mean centered prior to interaction terms being computed between each of the resilience resources and both subjective and objective measures of stress. Five potential individual-level resilience resources were tested (resilience, hope, optimism, self-efficacy, and adaptability) for each of four PA intensities (vigorous, moderate, walking, and sitting). Each moderator variable was examined separately against each of the PA intensities. The analysis was completed in a sequential stepwise fashion to examine the effects of the covariates (age, sex, and BMI) alone (Step 1) and with the inclusion of direct effects of the stress variables and resilience resources (Step 2), followed by the addition of the interaction terms (Step 3).[2] We planned to probe significant interactions using a simple slopes analysis (Aiken & West, 1991). HCC's were log transformed so as to approximate a normal distribution, which is common in research utilizing hair cortisol (Gerber, Jonsdottir, et al., 2013; Gidlow, Randall, Gillman, Silk, et al., 2016; Staufenbiel, Penninx, de Rijke, van den Akker, & van Rossum, 2015).[3] Due to the nature of the analysis and concerns relating to Type I errors, we adopted a conservative level of statistical significance at $p < .01$ to minimize the chances of a possible Type I error while not choosing a level which was so stringent so as to risk the chance of a Type II error. The moderation analyses were performed with Mplus 8 (Muthén & Muthén, 2017) using a robust maximum likelihood estimator.

Results

Descriptive Statistics and Bivariate Correlations

Subscale-level statistics including means, standard deviations, internal reliability estimates, and bivariate correlations are presented in Table 1. Briefly, individual-level resilience resources demonstrated significant moderate-to-strong correlations with each other ($.43 < r < .80$), significant moderate-to-strong negative correlations with subjective stress ($-.47 < r < -.61$), weak negative correlations with objective stress ($-.06 < r < -.17$), and weak-to-moderate correlations with PA ($.21 < r < .32$). The different intensities of PA demonstrated weak-to-moderate correlations with each other ($-.21 < r < .32$), a single significant weak negative correlation was observed between subjective stress and vigorous PA ($r = -.23$), and weak correlations were demonstrated between objective stress ($-.16 < r < .03$) and the different intensities of PA.

Vigorous Physical Activity

Full details of the results for vigorous physical activity (VPA) are presented in Table 2; we focus here on statistically significant effects at Step 3 of the analysis. Sex was positively associated with

[2] A model was ran including all moderators simultaneously; this information is provided as a online supplementary file (Tables 1–4) due to being underpowered to detect a meaningful effect: 20 total predictors, 10 tested predictors (i.e., interaction terms), 80% power, $f^2 = .12$, $\alpha = .01$, would require 198 participants.

[3] Analyses were also run with non-transformed PA data see online supplementary materials for comparisons (Tables 6–9).

Table 1
Descriptive Statistics, Internal Reliability Estimates, and Bivariate Correlations Among Study Variables

Variables	Descriptive statistics					Correlations													
	N	*M*	*SD*	Skew	Kurtosis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	135	21.71	4.94	3.02	10.89	—													
2. Gender	135	—	—	—	—	−.06	—												
3. BMI[a]	135	22.75	3.03	0.52	−0.12	.20*	.09	—											
4. Perceived stress[b]	135	1.89	0.64	0.20	0.10	−.16	−.22*	−.02	(.88)										
5. Hair cortisol[c]	135	0.49	0.28	0.24	1.60	.08	−.34**	.17	.12	—									
6. Vigorous PA[d]	132	155.04	186.71	1.78	3.42	−.12	.35**	.04	−.23**	−.16	—								
7. Moderate PA[e]	130	142.27	208.14	2.72	8.62	.05	.33**	.03	−.14	−.15	.32**	—							
8. Walking[f]	111	264.82	271.81	1.86	3.62	−.15	.25*	.06	.07	−.14	.09	.11	—						
9. Sitting[g]	127	376.54	191.00	0.86	0.52	.16	−.14	−.03	.08	.03	−.21*	−.17	.00	—					
10. Resilience[h]	135	4.41	1.33	−0.44	−0.32	.16	.33**	.05	−.61**	−.17*	.28**	.22*	.16	.02	(.89)				
11. Hope[h]	135	5.01	0.96	−0.82	1.79	.09	.12	.04	−.55**	−.06	.32**	.16	−.00	−.21*	.59**	(.87)			
12. Optimism[h]	135	4.60	1.04	−0.35	−0.29	.14	.08	.01	−.50**	−.11	.14	.01	.02	−.08	.43**	.60**	(.78)		
13. Self-efficacy[h]	135	5.10	1.01	−1.22	2.69	.08	.16	.05	−.47**	−.08	.29**	.11	−.06	−.11	.61**	.80**	.58**	(.93)	
14. Adaptability[h]	135	4.80	1.01	−0.84	1.35	.14	.29**	−.02	−.47**	−.15	.26**	.14	.10	−.17	.64**	.74**	.51**	.74**	(.92)

Note. BMI = body mass index; PA = physical activity.
[a] BMI scores in kg/m^2. [b] Range = 0–4. [c] Hair cortisol concentrations in $pg \cdot mg^{-1}$ log transformed. [d] Vigorous physical activity minutes per week. [e] Moderate physical activity minutes per week. [f] Walking minutes per week. [g] Sitting minutes per day. [h] Range = 1–7.
* Correlation is significant at the .05 level (two-tailed). ** Correlation is significant at the .01 level (two-tailed).

Table 2
Vigorous Physical Activity Three-Step Regression Analyses

Variables	Step 1 Observations: 132 β	95% CI	*p*	Step 2 β	95% CI	*p*	Step 3 β	95% CI	*p*
Age	−.105	[−.212, .003]	.056	**−.157**	**[−.275, −.040]**	**.009**	**−.163**	**[−.287, −.040]**	**.009**
Sex	**.338**	**[.182, .495]**	**.000**	**.243**	**[.064, .422]**	**.008**	**.241**	**[.058, .425]**	**.010**
BMI	.033	[−.114, .180]	.661	.063	[−.084, .211]	.401	.055	[−.089, .199]	.457
PSS				−.085	[−.252, .082]	.320	−.082	[−.250, .086]	.338
HCC				−.036	[−.247, .174]	.736	−.037	[−.237, .164]	.721
BRS				.175	[−.023, .372]	.083	.193	[−.011, .396]	.063
PSS × BRS							−.077	[−.210, .056]	.258
HCC × BRS							.007	[−.151, .165]	.931
R^2		.132			.181			.186	
Age	−.105	[−.212, .003]	.056	−.136	[−.247, −.024]	.017	−.113	[−.233, .008]	.068
Sex	**.338**	**[.182, .495]**	**.000**	**.281**	**[.116, .446]**	**.001**	**.287**	**[.123, .452]**	**.001**
BMI	.033	[−.114, .180]	.661	.040	[−.107, .187]	.590	.020	[−.122, .163]	.780
PSS				−.028	[−.193, .137]	.741	−.016	[−.180, .148]	.852
HCC				−.039	[−.250, .171]	.714	−.048	[−.251, .156]	.645
HOP				**.272**	**[.105, .438]**	**.001**	**.340**	**[.147, .532]**	**.001**
PSS × HOP							−.105	[−.252, .041]	.159
HCC × HOP							−.128	[−.279, .023]	.097
R^2		.132			.214			.243	
Age	−.105	[−.212, .003]	.056	−.140	[−.266, −.015]	.029	−.139	[−.268, −.010]	.035
Sex	**.338**	**[.182, .495]**	**.000**	**.284**	**[.108, .461]**	**.002**	**.291**	**[.114, .468]**	**.001**
BMI	.033	[−.114, .180]	.661	.046	[−.096, .188]	.523	.037	[−.107, .181]	.615
PSS				−.153	[−.309, .004]	.056	−.156	[−.309, −.002]	.047
HCC				−.036	[−.256, .183]	.746	−.038	[−.258, .182]	.738
LOT				.053	[−.115, .220]	.538	.048	[−.115, .212]	.562
PSS × LOT							−.020	[−.147, .106]	.753
HCC × LOT							−.049	[−.240, .141]	.613
R^2		.132			.165			.168	
Age	−.105	[−.212, .003]	.056	−.138	[−.249, −.026]	.015	−.130	[−.248, −.012]	.030
Sex	**.338**	**[.182, .495]**	**.000**	**.270**	**[.099, .442]**	**.002**	**.252**	**[.080, .424]**	**.004**
BMI	.033	[−.114, .180]	.661	.040	[−.105, .184]	.590	.033	[−.112, .178]	.658
PSS				−.081	[−.244, .082]	.332	−.085	[−.249, .079]	.311
HCC				−.037	[−.248, .174]	.731	−.049	[−.244, .147]	.627
GSE				**.210**	**[.073, .347]**	**.003**	**.275**	**[.106, .445]**	**.001**
PSS × GSE							−.125	[−.299, .050]	.163
HCC × GSE							−.178	[−.339, −.018]	.030
R^2		.132			.197			.247	
Age	−.105	[−.212, .003]	.056	−.153	[−.276, −.031]	.014	−.151	[−.284, −.017]	.027
Sex	**.338**	**[.182, .495]**	**.000**	**.250**	**[.075, .426]**	**.005**	**.240**	**[.062, .419]**	**.008**
BMI	.033	[−.114, .180]	.661	.056	[−.086, .198]	.439	.056	[−.087, .199]	.441
PSS				−.119	[−.282, .045]	.156	−.112	[−.277, .053]	.183
HCC				−.036	[−.250, .178]	.742	−.031	[−.238, .177]	.772
ADA				.148	[−.007, .303]	.061	.175	[−.019, .368]	.076
PSS × ADA							−.017	[−.140, .107]	.790
HCC × ADA							−.098	[−.273, .077]	.274
R^2		.132			.179			.189	

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT = Life Orientation Test; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

VPA across all models for each resilience resource, such that males reported higher levels of VPA. Conversely, age was negatively associated with VPA within the model for which bounce back resilience (BRS) was the individual-level resilience resource tested. In terms of resilience resources, hope and general self-efficacy evidenced moderate positive associations with VPA. There were no significant interaction effects for VPA.

Moderate Physical Activity

Full details of the results for moderate physical activity (MPA) are presented in Table 3. Sex was positively associated across all models for each resilience resource, such that males took part in higher levels of MPA. There were no other significant main or interaction effects for MPA.

Walking

Full details of the results for walking can be seen in Table 4. Age was negatively associated with walking in Steps 2 and 3 of the BRS model. Within this model, BRS also demonstrated a moderate positive association with walking in Steps 2 and 3. There were no significant interaction effects for walking.

Sitting

Full details of the results for sitting are presented in Table 5. Age demonstrated a positive association with sitting time within Step 2 of the models, including hope, optimism, and adaptability. There were no other significant main or interaction effects for sitting.

Discussion

In the current study, we examined the moderating effects of individual-level resilience resources on the association between stress and PA among a sample of adults. Aligned with a stress-buffering hypothesis, we expected individual-level resilience resources (self-efficacy, hope, optimism, bounce-back resilience, and adaptability) to moderate the effects of perceived and physiological stress on self-reported PA, such that individuals with higher levels of these resources would be less affected by the deleterious effects of stress and, therefore, report higher levels of PA. Direct effects, bivariate correlations and regression coefficients indicated primarily small and nonsignificant negative associations between subjective and objective indices of stress and the different intensities of PA. The associations between individual-level resilience resources and PA intensities were mixed, though largely consistent across the bivariate correlations and regression coefficients in terms of magnitude and sign. Specifically, there were mainly significant small-to-moderate positive associations between individual-level resilience resources with VPA; small, nonsignificant positive associations with MPA and walking; and small, nonsignificant negative associations with sitting. Our predictions regarding the moderating effect of individual-level resilience resources were unsupported.

The small and primarily nonsignificant associations between perceived and physiological stress and PA have also been demonstrated in past research (Gidlow, Randall, Gillman, Silk, et al., 2016; Stalder et al., 2017). When examining the bivariate correlations, although they were primarily small and nonsignificant, the direction of the effects observed were mostly consistent with Stults-Kolehmainen and Sinha's (2014) review in that the majority of studies found a negative association, with higher levels of stress associated with lower levels of PA. Of the cross-sectional studies reviewed, 67% reported a negative association, with correlations within the small-to-moderate range (−0.28 to −0.42). In the current study, we sought to gain a more nuanced understanding of this association by examining different intensities of PA. We found a negative association for VPA and MPA, though not for walking, which may suggest that the association strengthens as PA intensity increases. Further support comes from the finding of a salient negative association between perceived stress and VPA, which approached reported levels in the review paper. This finding suggests that the association between stress and PA is more important at the vigorous end of the PA spectrum, something that may have been hitherto overlooked due to amalgamated assessments of PA. Therefore, an interesting avenue for future research may be to explore the nature of the different intensities of PA that may be driving these associations with perceived stress.

Objectively measured stress displayed a similar trend to perceived stress, whereby higher

Table 3
Moderate Physical Activity Three-Step Regression Analyses

Variables	Step 1 Observations: 130 β	95% CI	*p*	Step 2 β	95% CI	*p*	Step 3 β	95% CI	*p*
Age	.069	[−.174, .313]	.577	.049	[−.187, .284]	.684	.045	[−.173, .264]	.685
Sex	**.339**	**[.190, .488]**	**.000**	**.288**	**[.113, .462]**	**.001**	**.291**	**[.113, .469]**	**.001**
BMI	−.019	[−.166, .129]	.805	.005	[−.141, .150]	.952	.003	[−.141, .147]	.969
PSS				−.001	[−.208, .207]	.996	.000	[−.205, .205]	1.000
HCC				−.036	[−.231, .160]	.722	−.041	[−.229, .147]	.667
BRS				.105	[−.080, .291]	.265	.102	[−.087, .291]	.292
PSS × BRS							−.001	[−.121, .120]	.989
HCC × BRS							.037	[−.157, .231]	.709
R^2		.116			.127			.128	
Age	.069	[−.174, .313]	.577	.063	[−.172, .298]	.599	.063	[−.154, .279]	.571
Sex	**.339**	**[.190, .488]**	**.000**	**.317**	**[.153, .480]**	**.000**	**.316**	**[.154, .477]**	**.000**
BMI	−.019	[−.166, .129]	.805	−.018	[−.171, .135]	.819	−.023	[−.174, .129]	.769
PSS				.022	[−.163, .207]	.815	.030	[−.155, .214]	.753
HCC				−.035	[−.231, .161]	.729	−.041	[−.234, .153]	.680
HOP				.137	[−.031, .305]	.111	.181	[−.017, .378]	.073
PSS × HOP							−.092	[−.262, .079]	.292
HCC × HOP							−.007	[−.192, .178]	.941
R^2		.116			.133			.140	
Age	.069	[−.174, .313]	.577	.066	[−.187, .319]	.607	.062	[−.182, .305]	.618
Sex	**.339**	**[.190, .488]**	**.000**	**.302**	**[.137, .467]**	**.000**	**.301**	**[.136, .467]**	**.000**
BMI	−.019	[−.166, .129]	.805	−.002	[−.150, .146]	.976	.006	[−.142, .154]	.939
PSS				−.099	[−.289, .091]	.309	−.085	[−.280, .110]	.394
HCC				−.047	[−.242, .149]	.640	−.048	[−.240, .145]	.626
LOT				−.079	[−.259, .101]	.391	−.066	[−.244, .111]	.463
PSS × LOT							−.042	[−.195, .110]	.585
HCC × LOT							.071	[−.124, .266]	.475
R^2		.116			.125			.130	
Age	.069	[−.174, .313]	.577	.061	[−.190, .311]	.635	.062	[−.195, .318]	.636
Sex	**.339**	**[.190, .488]**	**.000**	**.310**	**[.144, .476]**	**.000**	**.300**	**[.129, .472]**	**.001**
BMI	−.019	[−.166, .129]	.805	−.009	[−.162, .143]	.904	−.009	[−.163, .144]	.904
PSS				−.039	[−.205, .127]	.645	−.042	[−.214, .129]	.629
HCC				−.037	[−.232, .158]	.710	−.043	[−.238, .152]	.666
GSE				.038	[−.097, .173]	.582	.068	[−.091, .228]	.402
PSS × GSE							−.060	[−.219, .100]	.463
HCC × GSE							−.054	[−.238, .130]	.566
R^2		.116			.121			.128	
Age	.069	[−.174, .313]	.577	.059	[−.188, .306]	.639	.059	[−.183, .300]	.634
Sex	**.339**	**[.190, .488]**	**.000**	**.308**	**[.137, .479]**	**.000**	**.308**	**[.131, .485]**	**.001**
BMI	−.019	[−.166, .129]	.805	−.006	[−.155, .142]	.936	−.006	[−.156, .143]	.936
PSS				−.051	[−.223, .122]	.566	−.051	[−.223, .121]	.564
HCC				−.037	[−.233, .158]	.708	−.037	[−.231, .156]	.705
ADA				.015	[−.123, .153]	.834	.015	[−.157, .187]	.866
PSS × ADA							−.001	[−.128, .126]	.983
HCC × ADA							.003	[−.185, .191]	.974
R^2		.116			.120			.120	

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT = Life Orientation Test; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Table 4
Walking Activity Three-Step Regression Analyses

Variables	Step 1 Observations: 111			Step 2			Step 3		
	β	95% CI	*p*	β	95% CI	*p*	β	95% CI	*p*
Age	−.133	[−.243, −.023]	.018	**−.148**	**[−.259, −.038]**	**.008**	**−.147**	**[−.255, .038]**	**.008**
Sex	.226	[.022, .429]	.030	.146	[−.056, .348]	.157	.138	[−.070, .346]	.193
BMI	.068	[−.080, .216]	.366	.096	[−.056, .249]	.216	.108	[−.045, .260]	.166
PSS				.253	[.015, .491]	.037	.256	[.019, .494]	.034
HCC				−.084	[−.222, .054]	.232	−.088	[−.229, .054]	.226
BRS				**.282**	**[.084, .481]**	**.005**	**.266**	**[.075,, .456]**	**.006**
PSS × BRS							.099	[−.078, .275]	.272
HCC × BRS							−.028	[−.157, .100]	.665
R^2		.079			.137			.146	
Age	−.133	[−.243, −.023]	.018	−.116	[−.222, −.010]	.032	−.116	[−.220, −.012]	.030
Sex	.226	[.022, .429]	.030	.211	[.001, .421]	.049	.210	[−.002, .423]	.052
BMI	.068	[−.080, .216]	.366	.076	[−.081, .234]	.343	.079	[−.080, .238]	.328
PSS				.100	[−.115, .316]	.361	.097	[−.117, .311]	.374
HCC				−.084	[−.224, .055]	.234	.084	[−.223, .055]	.237
HOP				.015	[−.183, .213]	.884	−.010	[−.224, .204]	.925
PSS × HOP							.056	[−.128, .239]	.553
HCC × HOP							−.010	[−.151, .132]	.893
R^2		.079			.092			.094	
Age	−.133	[−.243, −.023]	.018	−.122	[−.227, −.016]	.024	−.115	[−.219, −.011]	.031
Sex	.226	[.022, .429]	.030	.218	[.007, .429]	.043	.237	[.015, .460]	.037
BMI	.068	[−.080, .216]	.366	.077	[.080, .234]	.335	.060	[−.092, .212]	.441
PSS				.136	[−.085, .356]	.228	.138	[−.093, .368]	.242
HCC				−.074	[−.214, .065]	.296	−.084	[−.234, .065]	.269
LOT				.090	[−.144, .324]	.449	.086	[−.146, .318]	.470
PSS × LOT							−.079	[−.309, .151]	.501
HCC × LOT							−.063	[−.238, .112]	.479
R^2		.079			.098			.110	
Age	−.133	[−.243, −.023]	.018	−.116	[−.224, −.008]	.035	−.114	[−.226, −.001]	.047
Sex	.226	[.022, .429]	.030	.217	[.006, .429]	.044	.226	[.012, .440]	.039
BMI	.068	[−.080, .216]	.366	.083	[−.072, .237]	.295	.078	[−.081, .236]	.336
PSS				.061	[−.133, .254]	.540	.065	[−.131, .261]	.513
HCC				−.087	[−.227, .054	.226	−.080	[−.222, .062]	.269
GSE				−.069	[−.267, .129]	.494	−.051	[−.264, .163]	.642
PSS × GSE							−.028	[−.257, .201]	.812
HCC × GSE							.080	[−.072, .231]	.303
R^2		.079			.095			.101	
Age	−.133	[−.243, −.023]	.018	−.127	[−.240, −.013]	.028	−.124	[−.241, −.008]	.036
Sex	.226	[.022, .429]	.030	.184	[−.043, .412]	.113	.196	[−.037, .430]	.100
BMI	.068	[−.080, .216]	.366	.080	[−.081, .240]	.330	.076	[−.086, .239]	.356
PSS				.139	[−.078, .355]	.209	.131	[−.085, .347]	.234
HCC				−.082	[−.219, .055]	.241	−.086	[−.225, .054]	.229
ADA				.109	[−.078, .296]	.252	.080	[−.118, .278]	.428
PSS × ADA							.045	[−.088, .178]	.508
HCC × ADA							.073	[−.043, .189]	.215
R^2		.079			.100			.109	

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT = Life Orientation Test; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

Table 5
Sitting Time Three-Step Regression Analyses

Variables	Step 1 Observations: 127 β	95% CI	*p*	Step 2 β	95% CI	*p*	Step 3 β	95% CI	*p*
Age	.164	[.031, .297]	.015	.166	[.025, .307]	.021	.160	[.011, .308]	.035
Sex	−.124	[−.304, .057]	.180	−.143	[−.342, .056]	.160	−.135	[−.332, .063]	.181
BMI	−.053	[−.210, .104]	.506	−.040	[−.199, .119]	.619	−.035	[−.190, .120]	.658
PSS				.163	[−.105, .430]	.233	.161	[−.104, .426]	.233
HCC				−.026	[−.161, .109]	.706	−.042	[−.190, .105]	.575
BRS				.134	[−.128, .395]	.316	.112	[−.156, .380]	.411
PSS × BRS							.053	[−.095, .200]	.485
HCC × BRS							.088	[−.089, .264]	.329
R^2		.045			.063			.074	
Age	.164	[.031, .297]	.015	**.181**	**[.049, .313]**	**.007**	.172	[.036, .308]	.013
Sex	−.124	[−.304, .057]	.180	−.106	[−.291, .079]	.262	−.107	[−.290, .076]	.251
BMI	−.053	[−.210, .104]	.506	−.045	[−.200, .110]	.569	−.041	[−.199, .116]	.608
PSS				−.032	[−.248, .184]	.772	−.032	[−.255, .192]	.781
HCC				−.029	[−.163, .104]	.666	−.028	[−.163, .107]	.685
HOP				−.223	[−.404, −.043]	.015	−.226	[−.446, −.006]	.044
PSS × HOP							−.009	[−.176, .158]	.913
HCC × HOP							.042	[−.091, .175]	.533
R^2		.045			.088			.089	
Age	.164	[.031, .297]	.015	**.187**	**[.045, .328**	**.010**	.182	[.037, .326]	.014
Sex	−.124	[−.304, .057]	.180	−.115	[−.303, .073]	.231	−.109	[−.295, .078]	.253
BMI	−.053	[−.210, .104]	.506	−.053	[−.213, .107]	.516	−.055	[−.218, .109]	.511
PSS				.057	[−.138, .252]	.566	.087	[−.120, .294]	.412
HCC				−.034	[−.167, .098]	.611	−.036	[−.169, .097]	.598
LOT				−.070	[−.235, .095]	.407	−.050	[−.218, .118]	.559
PSS × LOT							−.104	[−.261, .053]	.193
HCC × LOT							.071	[−.078, .220]	.348
R^2		.045			.057			.068	
Age	.164	[.031, .297]	.015	.182	[.041, .323]	.011	.178	[.033, .324]	.016
Sex	−.124	[−.304, .057]	.180	−.107	[−.296, .082]	.267	−.104	[−.291, .084]	.278
BMI	−.053	[−.210, .104]	.506	−.051	[−.212, .109]	.532	−.052	[−.211, .107]	.520
PSS				.053	[−.161, .267]	.628	.063	[−.151, .277]	.564
HCC				−.030	[−.161, .102]	.657	−.025	[−.162, .112]	.722
GSE				−.083	[−.295, .128]	.441	−.060	[−.307, .187]	.634
PSS × GSE							−.051	[−.236, .133]	.586
HCC × GSE							.111	[−.054, .276]	.186
R^2		.045			.058			.071	
Age	.164	[.031, .297]	.015	**.199**	**[.057, .341]**	**.006**	.180	[.034, .327]	.016
Sex	−.124	[−.304, .057]	.180	−.075	[−.261, .111]	.428	−.073	[−.261, .115]	.446
BMI	−.053	[−.210, .104]	.506	−.066	[−.227, .096]	.426	−.066	[−.224, .092]	.414
PSS				.024	[−.181, .228]	.822	.024	[−.181, .229]	.819
HCC				−.036	[−.165, .093]	.588	−.033	[−.160, .094]	.608
ADA				−.166	[−.365, .032]	.101	−.137	[−.376, .102]	.261
PSS × ADA							−.102	[−.314, .109]	.343
HCC × ADA							.095	[−.044, .234]	.179
R^2		.045			.073			.086	

Note. CI = confidence interval; BMI = body mass index; PSS = Perceived Stress Scale; HCC = hair cortisol concentration; BRS = Brief Resilience Scale; HOP = Hope Scale; LOT = Life Orientation Test; GSE = General Self-Efficacy; ADA = Adaptability. Boldface indicates significance ($p < .01$).

levels of HCC demonstrated small and nonsignificant associations with lower levels of PA. Previous research exploring this association is limited. For example, within Stults-Kolehmainen and Sinha's review, although there were studies recruiting objectively stressed populations (e.g., caregivers), only three utilized an objective measure of stress. Similar small and nonsignificant associations have also been reported in past cross-sectional research utilizing HCC (Stalder et al., 2013; Steptoe, Easterlin, & Kirschbaum, 2017), as well as cross-sectional research specifically utilizing the IPAQ as a measure of PA (Gidlow, Randall, Gillman, Silk, et al., 2016; Staufenbiel et al., 2015). The small and nonsignificant correlations with HCC extended to all self-report measures, with the exception of the BRS. Inconsistencies have often been observed in the findings between self-reported and physiological measures, adding to a growing body of literature advocating a "lack of psychoendocrine covariance" (Staufenbiel, Penninx, Spijker, Elzinga, & van Rossum, 2013, p. 1230). Specifically, with regard to perceived stress and HCC, small associations have been observed frequently (Gidlow, Randall, Gillman, Silk, et al., 2016; Gidlow, Randall, Gillman, Smith, et al., 2016) and confirmed in meta-analytic syntheses (Stalder et al., 2017; Staufenbiel et al., 2013). One explanation for these findings is the temporal component of the assessments. Many studies have looked at hair lengths of 2–3 cm, representing ~2–3 months of secretion, against self-reported stress (PSS) which assesses perceived stress over the previous month. We considered this temporal dimension of the assessment protocol so that perceived stress and HCC overlapped; however, consistent with past work, we revealed a small and nonsignificant association. A second explanation relates to the context in which studies have been conducted; that is, participants typically have been assessed during periods of relatively low stress levels, thereby stress could have had minimal effects on longer term cortisol secretion (Stalder et al., 2017). Future research can address this methodological limitation by assessing participants longitudinally during naturally occurring or experimentally induced stressful periods (e.g., examination periods).

The direct effects between the individual-level resilience resources and PA intensities were mixed. Examination of the bivariate correlations shows that the effects were generally positive in nature, suggesting higher levels of resilience resources are associated with higher levels of PA. These findings are in line with past research which has shown higher levels of these personal resources to be linked to higher levels of PA (e.g., hope, Gustafsson, Podlog, & Davis, 2017; self-efficacy, Lewis, Williams, Frayeh, & Marcus, 2016; optimism, Huffman et al., 2016; and resilience, Gerber, Jonsdottir, Lindwall, & Ahlborg, 2014). This observation was especially evident for VPA which demonstrated significant small-to-moderate associations with all resources, with the exception of optimism. However, this trend did not extend to sitting for which we observed a negative association. Intuitively, individuals with higher levels of resources who are taking part in more PA may in turn be spending less time sitting. It is possible that having higher levels of these resources may allow individuals to gain the benefits of PA and negate the deleterious effects of too much sedentary time. Although these findings suggest that higher levels of perceived resources are associated with greater levels of different PA intensities, the cross-sectional nature of this study precludes us from ruling out the alternative explanation that higher levels of PA are associated with increased perceptions of available resilience resources. Longitudinal studies are needed to establish the importance of the perceived availability of these resources, which could inform resource-focused interventions that help individuals maintain PA levels during stressful periods.

Within the regression analyses, three of the examined individual-level resilience resources were found to share salient associations with PA. First, when looking at VPA, the resources of hope and self-efficacy were found to have salient positive weak-to-moderate associations. A possible mechanism by which hope demonstrated this positive association with VPA is via its two interactive components: pathway and agency. For example, individuals who have higher levels of hope may have an increased awareness of the various routes to be physically active (pathway), and the motivation to use these routes (agency). The finding that self-efficacy was also related positively with VPA is interesting as a central tenet of hope theory is that those who have higher levels of hope are instilled with an increased feeling of self-efficacy (Snyder, 2002), and therefore could reflect a byproduct of their enhanced awareness of pathways to achieve their PA goals. Hope theory (Snyder, 2002) also suggests that hope is linked to one's motivation toward a goal; thus, the observed association between higher levels of hope and increased VPA can be seen to be in line with motivation toward a goal of being physically active. Furthermore, the negative association between hope and sitting time approached significance, and less time sitting could also be seen to be in line with a goal of being more physically active. Second, one's ability to bounce back from stress, as measured by the BRS, was found to share a significant positive weak-to-moderate association with walking activities. Research utilizing the BRS has demonstrated that groups of individuals who display resilience are more physically active than those who had low levels of resilience (Gerber et al., 2014). Specifically, in relation to light PA (e.g., walking and light gardening), those who engaged in light PA had reduced odds of being classed as highly burdened or stressed, that is, lower levels in the BRS. Bearing in mind the cross-sectional nature of these data, these findings suggest that individuals who are well resourced to bounce back from adversity are better equipped to engage in higher amounts of walking activity. Research exploring this association between resilience and PA has mainly been focused at higher intensities of PA (Thogersen-Ntoumani, Black, Lindwall, Whittaker, & Balanos, 2017); thus, further work is needed to disentangle the association at all intensities of PA. Together, these findings are important, as moderate-to-vigorous PA is the most important form of activity for individuals to improve their fitness, and gain its related health benefits (Garber et al., 2011), and sedentary behavior (sitting time) has consistently been shown to be associated with numerous deleterious outcomes (Australian National Preventive Health Agency, 2014). Therefore, the findings that these individual-level resilience resources are related to increased levels of PA are important and may offer a fruitful line of further enquiry.

When examining the moderation effects of individual-level resilience resources, our hypothesis that these resources would moderate the association between stress and PA was unsupported. There are several possible explanations for the nonsignificant moderation effects observed in the current study. First, our selection of individual-level resilience resources may have been insensitive to the primary outcomes; future research should consider resilience sources that are contextually tailored to the outcomes of interest (e.g., exercise self-efficacy). Second, the degree to which individual-level resilience resources attenuate the effects of stress on PA may be small, yet practically meaningful, in which case the current study was likely underpowered to detect such an effect. Third, against the backdrop of the transactional perspective of stress (Lazarus & Folkman, 1984), our focus on secondary appraisals (i.e., perceptions of one's available resources to deal with stressors) in the absence of primary appraisals (i.e., interpretation of the stressor as a threat or challenge to personal functioning) could be considered a simplistic view of association between stress and PA. For example, individual-level resilience resources might moderate the effect of one's interpretations of the stressors, rather than the degree to which stress has been experienced. Finally, the cross-sectional nature of this study means that we captured a static snapshot of the associations between stress, PA, and individual-level resilience resources; the interactive effects among these variables may be dynamic in nature and, therefore, cannot be captured using a cross-sectional design. Despite its potential significance, previous research exploring possible moderators of the stress−PA association is limited. In a recent study examining the possible bidirectional association between stress and PA, moderation effects were also examined, including the resource of optimism; similar to the current study, no moderation effects were observed (Burg et al., 2017). The current study utilized a cross-sectional design, whereas Burg et al. (2017) utilized only baseline measures of possible moderators; thus, future research may benefit from longitudinal designs with repeated assessments of participant's dispositional levels of individual-level resilience resources.

Strengths and Limitations

Notable strengths of this study were the assessment of stress via perceived and physiological indices, decomposition of PA into its different intensities rather than a global score, and consideration of stress-buffering individual-level resilience resources. Nevertheless, four limitations should be considered when interpreting our findings. First, the findings are based on a sample of university students (predominantly female) who engaged in relatively high levels of PA; therefore, caution should be taken if generalizing to other populations, particularly as the bias in the sample (e.g., wide age range and incentives) may have decreased the likelihood of finding significant associations. For example, the higher percentage of females was likely due to our eligibility criterion of sufficient hair length (2 cm) on the posterior vertex region of the head. Relatedly, the largely healthy nature of our sample means that we observed relatively low levels of perceived stress, which affects longer term cortisol secretion (Stalder et al., 2017). When compared with past investigations of HCC in student samples, for example, cortisol levels in the current study (3.91 ± 3.52 pg/mg) were considerably lower than values in past research (e.g., 19.9 ± 33.5 pg/mg, Karlén, Ludvigsson, Frostell, Theodorsson, & Faresjö, 2011). Nevertheless, levels were similar to previous studies utilizing the same (ELISA) analysis within the same laboratory (3.51 ± 3.11 pg/mg, Simmons et al., 2016). Furthermore, liquid chromatography-mass spectrometry is seen as the gold standard in cortisol-extraction techniques (Gerber, Jonsdottir, et al., 2013), and in a sample of healthy adults, levels of HCC were roughly equivalent (median = 3.18, range = 2.16–5.58 pg/mg; Staufenbiel et al., 2015). Second, as there was a small amount of missing data on the dependent variables, some of the analyses were insufficiently powered to detect the smallest effect size of interest in this study. Third, we excluded an assessment of stress appraisals, which may have mediated our findings, as they have been found to predict salivary cortisol levels in research in the physical domain (Quested et al., 2011). Relatedly, we are unable rule out the potential effects of possible depressive symptoms or time availability to partake in PA outside of university demands because we did not collect this information (e.g., number of hours of un/paid work). Finally, the reliance on the IPAQ as a self-report assessment of PA levels. The IPAQ measures an individual's perceptions of the amount of PA they take part in at different intensity levels, and these perceptions of PA intensities (e.g., moderate and vigorous) may vary greatly between individuals. Perhaps most salient, people tend to overreport their activity levels on the IPAQ when compared with an objective measure of PA (e.g., accelerometer; Rääsk et al., 2017); thus, future research may benefit from utilizing objective measures of PA.

Conclusion

There are theoretical reasons (e.g., buffering hypothesis) and empirical evidence (Gerber et al., 2014) to support the prediction that resilience resources buffer the effects of stress on PA. However, the results of this study are contrary to these expectations in that we found nonsignificant interaction associations between self-reported individual-level resilience resources and stress (self-reported and assessed via HCC) on PA intensities. Nevertheless, we did find that certain resources correlate with more PA time and less sitting time. These associations were observed in relation to VPA, which is an important intensity at which to exercise to attain to gain improvements in fitness, and its related health benefits. We also found that all resilience resources were negatively associated with perceived stress, and in the case of the BRS with HCC, again adding support to the importance of these resources. In light of the significant burden stress has on mental and physical health globally, it is important that strategies, such as resilience resource development programs, are explored which may help mitigate this burden for individuals. However, additional research is required to disentangle the dynamic associations between individual-level resilience resources and PA intensities before definitive recommendations can be made regarding the nature of such interventions.

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Profiles of Adversity and Resilience Resources: A Latent Class Analysis of Two Samples.

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Appendix E: Ethical Approval

Ethical Approval for Studies One and Two

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Perth Western Australia 6845

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Web research.curtin.edu.au

27-May-2016

Name: Daniel Gucciardi
Department/School: School of Physiotherapy and Exercise Science
Email: D.Gucciardi@curtin.edu.au

Dear Daniel Gucciardi

RE: Ethics approval
Approval number: HRE2016-0017

Thank you for submitting your application to the Human Research Ethics Office for the project **Stress, physical activity and resilience resources: Tests of cross-sectional associations**.

Your application was reviewed through the Curtin University low risk ethics review process.

The review outcome is: **Approved**.

Your proposal meets the requirements described in National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007)*.

Approval is granted for a period of one year from to . Continuation of approval will be granted on an annual basis following submission of an annual report.

Personnel authorised to work on this project:

Name	Role
Gucciardi, Daniel	CI
Lines, Robin	Student
Ducker, Kagan KJ	Supervisor
Ntoumanis, Nikos	Supervisor
Thogersen-Ntoumani, Eva	Supervisor

Standard conditions of approval

1. Research must be conducted according to the approved proposal
2. Report in a timely manner anything that might warrant review of ethical approval of the project including:

  - proposed changes to the approved proposal or conduct of the study
  - unanticipated problems that might affect continued ethical acceptability of the project
  - major deviations from the approved proposal and/or regulatory guidelines
  - serious adverse events

3. Amendments to the proposal must be approved by the Human Research Ethics Office before they are implemented (except where an amendment is undertaken to eliminate an immediate risk to participants)
4. An annual progress report must be submitted to the Human Research Ethics Office on or before the anniversary of approval and a completion report submitted on completion of the project
5. Personnel working on this project must be adequately qualified by education, training and experience for their role, or supervised
6. Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, that bears on this project
7. Changes to personnel working on this project must be reported to the Human Research Ethics Office
8. Data and primary materials must be retained and stored in accordance with the Western Australian University Sector Disposal Authority (WAUSDA) and the Curtin University Research Data and Primary Materials policy
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Yours sincerely

Dr Catherine Gangell
Manager, Research Integrity

Appendix F: Ethical Approval

Ethical Approval for Study Three

Curtin University

Office of Research and Development

GPO Box U1987
Perth Western Australia 6845

Telephone +61 8 9266 7863
Facsimile +61 8 9266 3793
Web research.curtin.edu.au

20-Dec-2016

Name: Daniel Gucciardi
Department/School: School of Physiotherapy and Exercise Science
Email: D.Gucciardi@curtin.edu.au

Dear Daniel Gucciardi

RE: Ethics approval
Approval number: HRE2016-0512

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Personnel authorised to work on this project:

Name	Role
Gucciardi, Daniel	CI
Ducker, Kagan	Supervisor
Fletcher, David	Supervisor
Lines, Robin	Student
Ntoumanis, Nikos	Supervisor
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