

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

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### **Abstract**

Stress is an important consideration for understanding why individuals take part in limited or no physical activity. The negative effects of stress on physical activity do not hold for everyone, so examinations of possible resilience resources that might protect individuals from the harmful effects of stress are required. Accordingly, we conducted a measurement-burst study with 53 university students over a six-month period to examine the dynamics among stress, physical activity, sedentary behaviour, and resilience resources. Participants completed three bursts of six days, with each burst separated by an 8-week gap. Expectations regarding the moderating effects of resilience resources were unsupported. Daily reports of academic and general stress were positively associated with sedentary behaviour, and negatively associated with light and moderate intensity physical activity. Hair cortisol concentration significantly moderated the association between academic stress and sedentary behaviour, such that in bursts where cortisol was lower the daily positive association between stress and sedentary behaviour was weaker. The finding that academic and general stress are dynamically associated with lower levels of light and moderate intensity physical activity and higher levels of sedentary behaviour is an important extension to previous research, which has relied mainly on cross-sectional designs and self-report methods. Future research might examine resilience resources that are specific to the outcomes of interest rather than rely on generic resources.

**Keywords:** measurement burst; psychological capital; hair cortisol; multilevel modelling

## **1. 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 therefore 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 et al., 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, we aimed to examine the associations between stress, physical activity (PA), and sedentary behaviour (SB) across naturalistically different periods of stress, using physiological and self-report indices.

Examination periods are commonly reported as stressful experiences by university students (Murphy et al., 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 represent naturalistically

stressful periods 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 non-examination period (e.g., Oaten and Cheng, 2005; Steptoe et al., 1996). In addition to increases in perceived stress, past research has also documented elevated levels of stress during examination periods via biological markers such as salivary cortisol (e.g., Murphy et al., 2010; Weekes et al., 2006).

Evidence suggests that examination periods are associated with increased activity in the hypothalamic-pituitary-adrenal (HPA) axis, which in turn results in an increase in cortisol release (e.g., Lacey et al. 2000; Lucini et al., 2002; Weekes et al., 2006). Nevertheless, there are inconsistencies in such findings, with either no change or a decrease in cortisol secretion also being reported (Weekes et al., 2006). These studies utilised saliva and blood serum as measures of cortisol, which provide snapshots of acute cortisol levels at the time of sampling (Dettenborn et al., 2012). These 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, 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 et al., 2009). The utility of HCC as a measure of chronic stress accumulation is well 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 examine the associations between chronic stress and several health-related behaviours such as PA (e.g., Gerber et al., 2013a) and SB (e.g., Teychenne et al., 2018).

The benefits of PA for 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). The 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. In one report, for example, only 22% of adults meet PA guidelines, with 36% of adults reporting no leisure time activity at all (Piercy & Troiano, 2018). Among student populations, meta-analytical evidence reports that between 40% and 50% of college students were physically inactive (according to the American College of Sports Medicine's PA guidelines; Keating et al., 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 et al., 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 and physical inactivity to identify possible intervention targets to promote a more active lifestyle for students (Deliens et al., 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 et al., 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 biological measures of stress (e.g., salivary cortisol), though stress was assessed via biological markers only in 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, medical students) and in naturalistically varying periods of elevated stress (e.g., examination periods vs a baseline control time point). Collectively, these findings suggest 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 et al., 2003) have demonstrated that transient acute stress has a negative effect on PA. Although 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 span 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. Idiographic methods via which individuals are assessed repeatedly and intensively over long periods are an exciting approach for disentangling the temporal dynamics between stress and PA and SB. For example, in a 12-month observational study of 79 healthy adults who completed daily reports of stress and provided device-based assessment of PA via Fitbits, Burg et al. (2017) revealed negative associations between exercise and stress which can be uni- or bi-directional depending on the person.

Measurement burst design studies (Nesselroade, 1991) offer an alternative yet complementary perspective 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 within 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 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 associations between stress, PA, and SB are 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 et al., 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, 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., 2020). 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; these associations were predominantly small and non-significant for the other PA intensities. The hypothesised buffering effect of resilience resources on the association between stress – both self-reported and biological – 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 association between stress, 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-based measured PA and SB and stress (both perceived and biological), and the 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 when they reported higher levels of stress. We also anticipated that higher levels of stress (both perceived and biological) 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 association between stress, 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 together with device-based assessments of 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.

## **2. Methods**

### **2.1. Participants**

This study was approved by [name blinded for peer review] University's Human Research Ethics Committee. University students from a major Australian university 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. In total, 52 participants completed at least 1 burst; 75% (n=39) completed all three bursts, 15.4% (n=8) completed two bursts, and 9.6% (n=5) completed one burst only. The participants were aged 18 – 38 years ( $21.94 \pm 4.57$ ), and 78.8% (n=41) of the sample was female. Of the sample, 50% (n=26) were born in Australia, 71.2% (n=37) spoke 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 ( $10.29 \pm 8.73$  hrs), and 53.8% (n=28) of participants took part in unpaid or voluntary work ( $2.52 \pm 3.47$  hrs). The current sample size was determined by a combination of heuristics (e.g., typical sample sizes from similar previous designs) and resource constraints (i.e., availability of devices to assess physical activity, restricted time for doctoral research, and research funds available for hair cortisol concentration analyses), constraints which are common within psychological research (Lakens; 2021).

## **2.2. Measures**

### ***2.2.1. Start of Burst Measures***

**2.2.1.1. Perceived stress.** The 10-item Perceived Stress Scale (PSS; Cohen et al., 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 et al., 2011). In the current

sample, internal reliability evidence was sound (burst 1  $\alpha = .88$ ; burst 2  $\alpha = .88$ ; and burst 3  $\alpha = .86$ ).

**2.2.1.2. Resilience resources.** Our choice of resilience resources was informed by a conceptual and methodological review of 17 measures of resilience (Pangallo et al., 2015). The Psychological Capital Questionnaire (PSYCAP; Luthans et al., 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 items were measured on a 7-point scale ranging between 1 *strongly disagree* and 7 *strongly agree*.

**2.2.1.2.1. 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  $\alpha = .84$ ).

**2.2.1.2.2. Optimism.** The Life Orientation Questionnaire – Revised (LOT-R) (Scheier et al., 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 et al., 2004). Internal reliability evidence in the current study was sound (burst 1  $\alpha = .75$ ; burst 2  $\alpha = .75$ ; and burst 3  $\alpha = .87$ ).

**2.2.1.2.3. General self-efficacy.** The General Self-Efficacy Scale (GSE) (Chen et al., 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 of 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  $\alpha = .92$ ).

**2.2.1.2.4. 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 setbacks 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 ( $\alpha = .81 - .91$ ) 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  $\alpha = .84$ ; burst 2  $\alpha = .88$ ; and burst 3  $\alpha = .89$ ).

## **2.2.2. Daily Diary Measures**

**2.2.2.1. Academic Stressors.** We developed an 18 item scale to assess the frequency of academic stressors. Drawing from a review of 40 papers (Hurst et al., 2012), stressors were generated according to 7 themes: relationships, resources, expectations, academics,

environment, diversity, and other (e.g., “Inadequate academic support from teaching staff”). Participants indicated whether they had experienced stressors each day using a binary response (0 = *no* and 1 = *yes*; e.g., “Thinking about your day today, please indicate whether you experienced academic or coursework demands”). A composite score was created by summing the total number of different academic stressors experienced, with a possible range between 0 and 18.

**2.2.2.2. Perceived Stress.** The 4-item Perceived Stress Scale (PSS-4; Cohen & Williamson, 1988) was used to measure an individual’s general perceived stress. We adapted the item stem to capture daily perceptions of stress (e.g., “Today, how often have you felt confident about your ability to handle your personal problems?”). 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  $\alpha = .69$ ; burst 2  $\alpha = .71$ ; and burst 3  $\alpha = .72$ ).

### **2.2.3. 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 GENEActive 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 et al., 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.

**2.2.3.1. Data processing.** The accelerometers were set up and the data were downloaded using the GENEActiv software version 3.1, with raw .csv files converted into .bin files for data processing. Data were analysed using the R package GGIR version 3.3.3 (<https://cran.r-project.org/web/packages/GGIR/>). 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 ( $1 g = 9.81 \text{ m}\cdot\text{s}^{-2}$ ;  $1 \text{ mg} = 0.00981 \text{ m}\cdot\text{s}^{-2}$ ). The summary measures used in the current study are time spent (in minutes) in the following physical activity intensities: sedentary ( $<50 \text{ mg}$ ), light ( $50 - 100 \text{ mg}$ ), moderate ( $100 - 400 \text{ mg}$ ), and vigorous ( $>400 \text{ mg}$ ), as utilised in past research (e.g., Hildebrand et al., 2014). Non-wear time was removed using a previously validated algorithm (see van Hees et al., 2013), with valid days including over 16 hours of wear time. Accelerometer data were confined to 6 full days and nights (4 weekdays and 2 weekend days), starting at waking time on the day after the devices were collected. 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.

#### ***2.2.4. 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  $< 3 \text{ cm}$ , 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 et al., 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).

### **2.3. Procedures**

The study consisted of three bursts of six 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 our 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 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 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).

#### **2.4. Statistical Analysis**

Due to the nested nature of the data we used multilevel modelling in *Mplus* 8 (Muthén & Muthén, 2017) to (i) analyse the associations between stress (academic and perceived) and each of the PA intensities and SB, 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, Body Mass Index (BMI), work, and voluntary/unpaid work) were grand mean 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 (grand mean 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.

### 3. Results

#### 3.1. Descriptive Statistics

The descriptive statistics for the sample are presented by burst in Tables 1 – 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 SB (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 SB ( $-.20 < r < -.37$ ). Both day level measures of stress demonstrated significant weak to moderate positive 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 ( $.26 < r < .47$ ).

#### 3.2. Empty Means Models

The decomposition of variance of study variables across the three levels of analysis is presented in Table 4. With the exception of academic stress, the day-level (level 1) demonstrated the most variation (between 51.1% and 73.8% of total variance). Variation at the between person-level (level 3) was smaller than that of the between day-level (ranging between 20.5% and 45.1%). Variance across bursts was 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%).

### **3.3. Academic Stress**

#### ***3.3.1. Covariates***

Results of the multilevel analyses with academic stress as the predictor of PA and SB are detailed in Supplementary Tables 1-4. An inverse association was observed between BMI and SB in the models for hope, optimism, and HCC, such that individuals with a higher BMI reported 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 physical activity 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.

#### ***3.3.2. Direct Effects***

The day-level effect of academic stress was positive and significant for SB across all models, indicating that the time spent in sedentary activities 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 each of the 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.

### ***3.3.3. 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.

## **3.4. General Stress**

### ***3.4.1. Covariates***

Results of the multilevel analyses with general stress as the predictor of PA and SB are detailed in Supplementary Tables 5 - 8. As in models including academic stressors as the primary predictor, work was significantly inversely associated with SB, such that individuals who spent more time working spent less time in sedentary activities. Conversely, work hours were positively associated with light and moderate PA minutes, with people spending more time in these activity intensities the longer they more hours they worked. 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.

### ***3.4.2. Direct Effects***

Results showed a significant positive day-level effect of general stress on SB 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 was 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.

### ***3.4.3. 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. Discussion**

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-reports and cross-sectional designs to explore this association. The aim of 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 associations between physiological and psychological stress at the beginning of bursts and PA and SB and anticipated negative associations. In addition, we tested the possible buffering effects of burst level individual resilience resources on the associations between daily stress and PA and SB. 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 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 et al., 2009; Ortega-Montiel et al., 2015). The association has also been observed 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 et al., 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 SB. In cases where individuals have higher levels of perceived stress, sedentary activities 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. Previous research has typically found stress to have a deleterious effect on PA levels, with the majority utilising 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 (Burg et al., 2017). The negative associations between stress and 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 is associated with over reporting (Rääsk et al., 2017). Therefore, the use of device-based measures of PA intensities in the current study adds support to the negative association between stress and PA. As the effects of stress appear detrimental to PA participation, interventions aimed at stress reduction appear warranted to mitigate the deleterious downstream effects of stress (e.g., depression, anxiety) and increase PA levels. Furthermore, as academic stressors were found to have stronger associations with physical activity 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 association between stress, PA, and SB will be reduced for those individuals who report higher levels of resilience resources. We found none of the psychosocial resilience resources moderated the associations between stress, 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 (Burg 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 SB, it may be important to draw upon the transactional theory of stress (Lazarus & Folkman, 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. 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 et al., 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 et al., 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 biological and self-reported – as moderators of the effects of daily stress. HCC was identified as a salient moderator variable for SB only, such that in bursts where lower levels of cortisol were present, the daily positive association between academic stress and 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 et al., 2009), whereas others reported positive (Nabi et al., 2016) associations with SB (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 there are similarities between vigorous PA and psychological stress with regard to HCC (Gerber et al., 2017). For example, in a sample of university students ( $M_{\text{age}} = 21.2 \pm 1.87$ ), 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 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 are an indication that less PA took place, consequently more time might have been spent in SBs. 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* biological indices, and utilisation of a device-based measure of PA and SB 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 are other strengths of the design. Despite these strengths, several limitations must be considered when interpreting the findings, in addition 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 variables in the actual exam week would offer 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 et al., 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. 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 et al., 2011; Rocke et al., 2009), we were likely underpowered to detect moderation effects. Power simulations would be required to provide further clarification on this matter. Despite the small sample for such tests, the availability of this data in the long run is expected to be valuable for future meta-analytical work in this area (Maxwell & Kelley, 2011). Furthermore, research investigating the dynamic temporal associations between stress and PA and SB is limited, therefore the findings from this paper provide a deeper understanding into the size of these associations. Readers should interpret the p-values with caution and instead focus on the effects sizes and confidence intervals surrounding these effects considering the range of effects that remain plausible which may help to inform future research.

## **5. 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 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 SBs, thereby protecting them from associated deleterious outcomes (e.g., cardiovascular disease and obesity).

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Stress, Physical Activity, and Resilience  
Table 1

*Descriptive Statistics for Burst 1*

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

*Note.* *N* = 48; a = BMI scores in kg·m<sup>2</sup>; b = Measured in hours; c = Hair cortisol concentrations in pg·mg<sup>-1</sup>; d = Range 1 – 5; e = Range 1 – 7; f = Daily Academic Stress; g = Daily Perceived Stress, Range 0 – 5; h = scores in min·day<sup>-1</sup>; \* = Correlation is significant at the 0.05 level (2-tailed); \*\* = Correlation is significant at the 0.01 level (2-tailed).

Stress, Physical Activity, and Resilience

Table 2

*Descriptive Statistics for Burst 2*

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

Note. N = 48; a = BMI scores in kg·m<sup>2</sup>; b = Measured in hours; c = Hair cortisol concentrations in pg·mg<sup>-1</sup>; d = Range 1 – 5; e = Range 1 – 7; f = Daily Academic Stress; g = Daily Perceived Stress, Range 0 – 5; h = scores in min·day<sup>-1</sup>; \* = Correlation is significant at the 0.05 level (2-tailed); \*\* = Correlation is significant at the 0.01 level (2-tailed).

Stress, Physical Activity, and Resilience

Table 3

*Descriptive Statistics for Burst 3*

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

Note. N = 43; a = BMI scores in kg·m<sup>2</sup>; b = Measured in hours; c = Hair cortisol concentrations in pg·mg<sup>-1</sup>; d = Range 1 – 5; e = Range 1 – 7; f = Daily Academic Stress; g = Daily Perceived Stress, Range 0 – 5; h = scores in min·day<sup>-1</sup>; \* = Correlation is significant at the 0.05 level (2-tailed); \*\* = Correlation is significant at the 0.01 level (2-tailed).

## Stress, Physical Activity, and Resilience

Table 4

*Variance decomposition in empty three-level models.*

	Physical Activity				Stress	
	Sedentary	Light	Moderate	Vigorous	Academic	General
Level 3	3552.626	640.653	1249.934	20.857	3.186	0.212
(Across People)	(41.3%)	(33.4%)	(45.1%)	(20.5%)	(48.9%)	(34.3%)
Level 2	245.733	46.248	104.562	5.823	0.771	0.028
(Across Bursts)	(2.9%)	(2.4%)	(3.8%)	(5.7%)	(11.8%)	(4.5%)
Level 1	4801.218	1228.848	1415.010	74.965	2.562	0.378
(Across Days)	(55.8%)	(64.1%)	(51.1%)	(73.8%)	(39.3%)	(61.2%)

*Note.* Proportion of total variance in brackets.

**SUPPLEMENTARY MATERIAL**

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

Stress, Physical Activity, and Resilience  
 Supplementary Table 1. *Results of 3-level model for sedentary behaviour and academic stress.*

	BRS	HOPE	LOT	GSE	HCC	PSS
<b>Within Level –</b>						
<b>Day</b>						
<i>SB RV</i>	4584.689 (617.584)***	4564.789 (622.069)***	4566.467 (621.557)***	4584.786 (625.578)***	4549.997 (604.850)***	4581.896 (624.487)***
<b>Between Level – Burst</b>						
<i>Slope1 R-ON L2_Res</i>	5.108 (5.370)	2.539 (5.263)	2.583 (5.159)	0.864 (4.861)	0.147 (0.625)	-3.465 (4.100)
<i>Burst</i>	6.959 (5.420)	6.997 (3.976)	7.273 (3.914)	6.943 (3.732)	6.709 (3.719)	6.764 (3.652)
<i>AS &amp; Slope1 COR</i>	-63.798 (161.576)	-85.390 (117.782)	-87.791 (107.058)	-88.763 (107.039)	-34.040 (68.421)	-87.514 (98.562)
<i>Mean L2_Res</i>	0.000 (0.142)	0.000 (0.112)	0.000 (0.152)	0.000 (0.115)	-0.002 (0.635)	0.000 (0.079)
<i>Variance L2_Res</i>	1.195 (0.191)***	0.719 (0.136)***	1.211 (0.196)***	0.755 (0.270)**	30.362 (21.496)	0.434 (0.054)***
<i>SB RV</i>	192.262 (270.335)	207.526 (258.945)	215.871 (261.666)	215.095 (255.366)	234.073 (209.614)	249.810 (260.756)
<i>Slope1 RV</i>	24.235 (81.553)	43.054 (77.168)	39.608 (74.652)	39.230 (77.156)	35.923 (83.461)	34.365 (56.139)
<b>Between Level –</b>						
<b>Person</b>						
<i>Slope1 R-ON L3_Res</i>	-1.769 (6.334)	-0.290 (6.182)	0.124 (5.447)	-0.237 (4.922)	0.249 (0.599)	0.000 (5.184)
<i>Slope2 R-ON L3_Res</i>	-5.638 (4.579)	-2.886 (4.150)	-0.718 (3.249)	-1.540 (2.883)	-1.447 (0.428)**	2.596 (5.382)
<i>AGE</i>	2.358 (2.510)	1.913 (2.190)	1.718 (2.110)	1.716 (2.078)	1.979 (2.093)	1.652 (2.059)
<i>SEX</i>	-5.776 (21.367)	-5.247 (18.033)	-5.726 (18.711)	-4.007 (18.224)	-4.925 (18.405)	-7.275 (19.703)
<i>BMI</i>	-4.611 (2.528)	-4.746 (2.394)*	-4.954 (2.395)*	-4.655 (2.427)	-4.595 (2.229)*	-4.784 (2.477)
<i>WRK</i>	-3.477 (0.929)***	-3.150 (0.903)***	-3.073 (0.915)**	-3.192 (0.908)***	-3.285 (0.894)***	-3.290 (0.968)**
<i>VOL</i>	-1.139 (2.590)	-1.018 (2.805)	-0.826 (2.702)	-0.951 (2.6450)	-1.198 (2.286)	-0.103 (2.775)
<i>Slope1 &amp; Slope2 COR</i>	-1.038 (181.438)	-5.685 (76.302)	-5.633 (50.641)	-5.293 (44.554)	-0.679 (33.978)	-0.905 (16.057)
<i>Slope1 &amp; SB COR</i>	-132.496 (177.017)	-173.876 (119.867)	-160.609 (117.988)	-167.895 (115.761)	-179.797 (129.169)	-62.037 (121.721)
<i>Slope1 COR</i>	17.800 (157.343)	79.412 (103.815)	84.021 (91.3980)	75.230 (94.921)	7.802 (106.522)	34.491 (110.112)
<i>Mean L3_Res</i>	0.000 (0.135)	0.000 (0.110)	0.000 (0.139)	0.000 (0.117)	0.000 (0.558)	0.000 (0.079)
<i>SB Intercept</i>	1199.621 (8.049)***	1201.147 (7.970)***	1201.254 (8.011)***	1201.407 (7.797)***	1201.066 (7.617)***	1201.344 (7.767)***
<i>Slope1 Intercept</i>	4.108 (1.980)*	3.801 (1.802)*	4.116 (1.790)*	3.587 (1.823)*	3.495 (1.719)*	3.912 (1.634)*
<i>Slope2 Intercept</i>	-0.893 (5.540)	-0.495 (3.289)	-0.255 (3.173)	-0.520 (3.121)	-0.077 (3.366)	-0.933 (2.801)
<i>Variance L3_Res</i>	0.944 (0.187)***	0.624 (0.128)***	1.010 (0.175)***	0.713 (0.271)**	16.170 (10.907)	0.324 (0.061)***
<i>SB RV</i>	2375.099 (905.665)**	2451.942 (707.020)**	2416.117 (587.061)***	2411.961 (574.832)***	2194.665 (457.757)***	2364.526 (494.092)***
<i>Slope1 RV</i>	7.494 (126.817)	12.482 (83.697)	10.801 (95.515)	11.838 (83.752)	14.833 ( 89.036)	1.628 (6.349)
<i>Slope2 RV</i>	0.584 (307.790)	3.154 (147.709)	3.531 (102.196)	2.934 (92.441)	0.326 (27.246)	0.970 (50.761)

*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; Res = Resilience Resource; \* =  $p < .05$ ; \*\* =  $p < .01$ ; \*\*\* =  $p < .001$ .

Stress, Physical Activity, and Resilience

Supplementary Table 2. Results of 3-level model for light intensity activity and academic stress.

	BRS	HOPE	LOT	GSE	HCC	PSS
<b>Within Level –</b>						
<b>Day</b>						
<i>PA RV</i>	1126.894 (153.998)***	1118.485 (144.535)***	1118.805 (149.108)***	1121.538 (145.747)***	1119.915 (142.400)***	1117.970 (155.080)***
<b>Between Level – Burst</b>						
<i>Slope1 R-ON L2_Res</i>	-2.978 (2.832)	-2.151 (2.825)	-3.012 (2.666)	-1.086 (3.160)	-0.141 (0.619)	3.631 (6.496)
<i>Burst</i>	-3.245 (1.925)	-3.301 (1.947)	-3.466 (1.820)	-3.272 (2.188)	-3.242 (1.929)	-3.274 (1.869)
<i>AS &amp; Slope1 COR</i>	-28.584 (31.034)	-35.403 (33.951)	-35.440 (52.912)	-35.834 (35.218)	-27.073 (34.491)	-36.972 (44.523)
<i>Mean L2_Res</i>	0.000 (0.142)	0.000 (0.112)	0.000 (0.152)	0.000 (0.115)	-0.008 (0.650)	0.000 (0.079)
<i>Variance L2_Res</i>	1.195 (0.191)***	0.719 (0.136)***	1.211 (0.196)***	0.755 (0.270)**	30.366 (21.517)	0.434 (0.054)***
<i>PA RV</i>	42.528 (59.297)	49.314 (63.421)	51.999 (88.834)	50.173 (63.034)	46.442 (56.538)	52.968 (104.843)
<i>Slope1 RV</i>	20.275 (19.296)	26.727 (25.986)	24.825 (22.676)	26.93 (28.577)	25.653 (28.119)	26.797 (47.170)
<b>Between Level –</b>						
<b>Person</b>						
<i>Slope1 R-ON L3_Res</i>	0.925 (2.810)	0.608 (3.291)	1.528 (2.579)	0.472 (3.279)	-0.026 (0.710)	-2.521 (13.620)
<i>Slope2 R-ON L3_Res</i>	3.010 (1.549)	2.263 (1.353)	1.953 (2.003)	2.168 (1.303)	0.505 (0.440)	-1.178 (5.434)
<i>AGE</i>	-0.409 (1.050)	-0.120 (1.006)	-0.109 (1.159)	0.058 (1.006)	-0.061 (1.026)	0.039 (1.027)
<i>SEX</i>	-8.083 (7.335)	-7.989 (7.402)	-7.370 (7.296)	-8.978 (7.542)	-7.648 (8.087)	-9.164 (10.292)
<i>BMI</i>	1.762 (1.088)	1.780 (1.052)	1.827 (1.476)	1.591 (1.064)	1.719 (1.451)	1.806 (1.939)
<i>WRK</i>	1.710 (0.459)***	1.543 (0.446)**	1.548 (0.443)***	1.599 (0.461)**	1.536 (0.536)*	1.527 (0.582)**
<i>VOL</i>	-0.447 (1.291)	-0.517 (0.909)	-0.515 (2.199)	-0.432 (0.846)	-0.445 (1.310)	-0.564 (2.212)
<i>Slope1 &amp; Slope2 COR</i>	0.388 (24.947)	-0.010 (10.959)	0.103 (63.227)	0.174 (14.996)	0.423 (35.399)	-0.073 (27.333)
<i>Slope1 &amp; PA COR</i>	-10.920 (39.204)	-21.256 (31.610)	-18.700 (97.950)	-20.780 (41.680)	-19.609 (56.390)	-19.286 (176.354)
<i>Slope1 COR</i>	-14.626 (33.089)	-0.244 (22.457)	-2.549 (57.116)	-3.891 (20.889)	-9.373 (68.121)	1.284 (64.032)
<i>Mean L3_Res</i>	0.000 (0.135)	0.000 (0.110)	0.000 (0.139)	0.000 (0.117)	0.000 (0.558)	0.000 (0.079)
<i>PA Intercept</i>	126.245 (3.610)***	125.767 (3.595)***	126.385 (3.808)***	125.887 (3.668)***	125.429 (3.766)***	125.278 (3.661)***
<i>Slope1 Intercept</i>	-2.074 (0.868)*	-1.930 (0.888)*	-2.068 (0.968)*	-1.821 (0.884)**	-1.765 (0.998)	-1.902 (1.451)
<i>Slope2 Intercept</i>	1.046 (1.500)	0.754 (1.314)	0.690 (1.907)	0.778 (1.452)	0.401 (1.187)	0.704 (1.547)
<i>Variance L3_Res</i>	0.944 (0.187)***	0.624 (0.128)***	1.010 (0.175)***	0.713 (0.271)**	16.170 (10.907)	0.324 (0.061)***
<i>PA RV</i>	403.524 (138.245)**	419.915 (119.375)***	412.674 (165.578)*	408.645 (128.452)**	414.431 (212.638)	417.785 (207.077)*
<i>Slope1 RV</i>	0.336 (33.281)	1.141 (47.656)	0.885 (51.824)	1.128 (61.229)	1.011 (63.402)	0.943 (160.977)
<i>Slope2 RV</i>	0.800 (18.929)	0.287 (9.707)	0.279 (44.352)	0.358 (15.303)	0.600 (59.270)	0.483 (73.938)

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; Res = Resilience Resource; \* = p < .05; \*\* = p < .01; \*\*\* = p < .001.



## Stress, Physical Activity, and Resilience

Supplementary Table 3. Results of 3-level model for moderate intensity activity and academic stress.

	BRS	HOPE	LOT	GSE	HCC	PSS
<b>Within Level –</b>						
<b>Day</b>						
<i>PA RV</i>	1354.271 (202.249)***	1356.016 (203.884)***	1355.197 (202.617)***	1358.641 (204.717)***	1353.982 (203.628)***	1357.991 (204.539)***
<b>Between Level – Burst</b>						
<i>Slope1 R-ON L2_Res</i>	-2.557 (2.080)	-1.210 (2.461)	-0.620 (2.758)	0.416 (2.299)	0.138 (0.559)	1.455 (2.167)
<i>Burst</i>	-3.379 (2.478)	-3.537 (2.570)	-3.659 (2.745)	-3.510 (2.581)	-3.292 (4.390)	-3.451 (2.670)
<i>AS &amp; Slope1 COR</i>	-6.824 (25.237)	-9.638 (24.120)	-11.737 (26.973)	-10.841 (25.184)	-1.520 (50.994)	-11.216 (26.643)
<i>Mean L2_Res</i>	0.000 (0.142)	0.000 (0.112)	0.000 (0.152)	0.000 (0.115)	-0.001 (0.635)	0.000 (0.079)
<i>Variance L2_Res</i>	1.195 (0.191)***	0.719 (0.136)***	1.211 (0.196)***	0.755 (0.270)**	30.362 (21.499)	0.434 (0.054)***
<i>PA RV</i>	82.540 (82.098)	84.861 (81.421)	82.366 (83.624)	86.161 (81.289)	92.902 (146.836)	86.218 (81.939)
<i>Slope1 RV</i>	1.410 (16.323)	2.605 (13.614)	2.712 (15.196)	2.776 (14.104)	1.844 (34.806)	2.611 (15.720)
<b>Between Level –</b>						
<b>Person</b>						
<i>Slope1 R-ON L3_Res</i>	1.065 (2.156)	-0.061 (2.694)	-0.877 (2.897)	-0.821 (2.336)	-0.407 (0.492)	-0.221 (3.081)
<i>Slope2 R-ON L3_Res</i>	3.320 (2.030)	1.488 (2.068)	-0.184 (2.017)	0.244 (1.931)	0.815 (1.083)	-1.509 (3.491)
<i>AGE</i>	-2.162 (1.164)	-1.939 (1.246)	-1.789 (1.326)	-1.884 (1.277)	-1.929 (3.005)	-1.823 (1.309)
<i>SEX</i>	9.065 (10.357)	8.597 (10.607)	8.614 (10.706)	7.962 (10.623)	8.122 (10.214)	7.632 (10.854)
<i>BMI</i>	2.357 (1.416)	2.529 (1.356)	2.681 (1.397)	2.563 (1.348)	2.422 (2.017)	2.489 (1.439)
<i>WRK</i>	1.825 (0.462)***	1.626 (0.462)***	1.550 (0.475)**	1.640 (0.475)**	1.738 (0.496)***	1.636 (0.477)***
<i>VOL</i>	1.562 (1.452)	1.449 (1.535)	1.283 (1.461)	1.307 (1.496)	1.497 (3.914)	1.349 (1.458)
<i>Slope1 &amp; Slope2 COR</i>	-1.033 (17.959)	-3.338 (23.477)	-3.516 (29.200)	-3.603 (28.115)	-1.576 (179.223)	-2.681 (33.017)
<i>Slope1 &amp; PA COR</i>	-63.148 (37.324)	-75.160 (36.781)*	-72.068 (37.909)	-74.527 (36.256)*	-74.869 (49.487)	-69.388 (39.052)
<i>Slope1 COR</i>	13.347 (45.688)	39.135 (43.827)	42.790 (61.300)	42.351 (50.442)	16.070 (458.064)	33.656 (71.699)
<i>Mean L3_Res</i>	0.000 (0.135)	0.000 (0.110)	0.000 (0.139)	0.000 (0.117)	0.000 (0.558)	0.000 (0.079)
<i>PA Intercept</i>	108.288 (4.664)***	107.351 (4.637)***	106.950 (4.779)***	106.998 (4.655)***	107.337 (4.688)***	107.299 (4.655)***
<i>Slope1 Intercept</i>	-2.070 (0.965)*	-2.017 (1.050)	-2.144 (1.071)*	-1.823 (1.038)	-1.736 (2.633)	-1.871 (0.991)
<i>Slope2 Intercept</i>	0.324 (2.286)	-0.059 (3.120)	-0.245 (2.831)	-0.103 (3.085)	-0.260 (4.469)	-0.010 (3.118)
<i>Variance L3_Res</i>	0.944 (0.187)***	0.624 (0.128)***	1.010 (0.175)***	0.713 (0.271)**	16.170 (10.907)	0.324 (0.061)***
<i>PA RV</i>	873.053 (205.924)***	908.726 (219.631)***	902.550 (195.360)***	898.995 (208.364)***	787.859 (623.817)	900.791 (202.334)***
<i>Slope1 RV</i>	4.670 (16.268)	6.437 (11.931)	5.917 (12.766)	6.358 (13.105)	7.232 (65.508)	5.529 (15.223)
<i>Slope2 RV</i>	0.623 (18.500)	2.270 (20.677)	2.583 (29.987)	2.566 (24.205)	0.545 (145.036)	1.854 (32.060)

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; Res = Resilience Resource; \* =  $p < .05$ ; \*\* =  $p < .01$ ; \*\*\* =  $p < .001$ .

Stress, Physical Activity, and Resilience

Supplementary Table 4. *Results of 3-level model for vigorous intensity activity and academic stress.*

	BRS	HOPE	LOT	GSE	HCC <sup>#</sup>	PSS
<b>Within Level –</b>						
<b>Day</b>						
<i>PA RV</i>	73.855 (26.748)**	73.700 (26.610)**	73.500 (27.566)**	73.871 (26.389)**		73.807 (27.201)**
<b>Between Level – Burst</b>						
<i>Slope1 R-ON L2_Res</i>	0.259 (0.382)	0.612 (0.859)	0.351 (0.552)	0.134 (0.687)		-0.314 (0.477)
<i>Burst</i>	-0.256 (0.668)	-0.286 (0.654)	-0.304 (0.841)	-0.276 (0.701)		-0.297 (0.756)
<i>AS &amp; Slope1 COR</i>	0.093 (4.420)	0.038 (3.597)	0.075 (5.068)	0.114 (4.506)		0.082 (5.354)
<i>Mean L2_Res</i>	0.000 (0.142)	0.000 (0.112)	0.000 (0.152)	0.000 (0.115)		0.000 (0.079)
<i>Variance L2_Res</i>	1.195 (0.191)***	0.719 (0.136)***	1.211 (0.196)***	0.755 (0.270)**		0.434 (0.054)***
<i>PA RV</i>	0.278 (4.181)	0.116 (5.674)	0.233 (4.777)	0.332 (5.586)		0.256 (4.770)
<i>Slope1 RV</i>	0.035 (2.327)	0.015 (3.502)	0.029 (1.435)	0.044 (4.256)		0.034 (2.417)
<b>Between Level –</b>						
<b>Person</b>						
<i>Slope1 R-ON L3_Res</i>	-0.116 (0.360)	-0.233 (0.951)	-0.092 (0.626)	0.071 (0.780)		-0.164 (0.534)
<i>Slope2 R-ON L3_Res</i>	-0.095 (0.302)	-0.623 (0.557)	-0.590 (0.456)	-0.433 (0.571)		0.311 (0.517)
<i>AGE</i>	-0.041 (0.237)	0.013 (0.265)	-0.011 (0.260)	-0.050 (0.235)		-0.058 (0.211)
<i>SEX</i>	3.908 (2.172)	3.757 (2.685)	3.276 (3.056)	3.910 (2.757)		3.944 (2.117)
<i>BMI</i>	0.387 (0.209)	0.398 (0.201)*	0.399 (0.317)	0.410 (0.244)		0.392 (0.294)
<i>WRK</i>	0.009 (0.062)	0.006 (0.058)	0.002 (0.075)	0.004 (0.062)		0.016 (0.061)
<i>VOL</i>	-0.121 (0.212)	-0.108 (0.212)	-0.221 (0.253)	-0.137 (0.215)		-0.189 (0.273)
<i>Slope1 &amp; Slope2 COR</i>	0.268 (2.466)	-0.237 (2.224)	0.036 (2.758)	-0.184 (2.873)		0.031 (2.448)
<i>Slope1 &amp; PA COR</i>	1.002 (1.459)	1.015 (1.545)	1.251 (1.818)	0.961 (1.796)		1.102 (2.035)
<i>Slope1 COR</i>	0.306 (2.965)	-0.401 (2.339)	0.522 (2.953)	-0.072 (2.799)		0.656 (2.440)
<i>Mean L3_Res</i>	0.000 (0.135)	0.000 (0.110)	0.000 (0.139)	0.000 (0.117)		0.000 (0.079)
<i>PA Intercept</i>	5.959 (0.871)***	5.878 (1.062)***	5.674 (1.107)***	5.864 (1.078)***		5.916 (0.886)***
<i>Slope1 Intercept</i>	0.1424 (0.189)	0.176 (0.244)	0.145 (0.243)	0.138 (0.178)		0.123 (0.170)
<i>Slope2 Intercept</i>	-0.158 (0.383)	-0.233 (0.415)	-0.261 (0.441)	-0.201 (0.405)		-0.224 (0.387)
<i>Variance L3_Res</i>	0.944 (0.187)***	0.624 (0.128)***	1.010 (0.175)***	0.713 (0.271)**		0.324 (0.061)***
<i>PA RV</i>	10.916 (7.265)	10.608 (6.638)	15.814 (9.283)	11.558 (5.891)*		15.606 (11.343)
<i>Slope1 RV</i>	0.149 (2.921)	0.141 (1.926)	0.100 (3.225)	0.120 (2.594)		0.081 (3.501)
<i>Slope2 RV</i>	1.028 (2.179)	0.921 (1.552)	0.064 (2.109)	0.812 (2.180)		0.142 (1.643)

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; Res = Resilience Resource; <sup>#</sup> Model estimation did not terminate normally due to an error in computation; \* = p < .05; \*\* = p < .01; \*\*\* = p < .001.

Stress, Physical Activity, and Resilience  
 Supplementary Table 5. *Results of 3-level model for sedentary behaviour and general stress.*

	BRS	HOPE	LOT	GSE	HCC	PSS
<b>Within Level –</b>						
<b>Day</b>						
<i>SB RV</i>	4699.166 (642.805)***	4676.953 (637.473)***	4701.992 (645.083)***	4706.066 (644.044)***	4712.594 (688.273)***	4704.407 (645.431)***
<b>Between Level – Burst</b>						
<i>Slope1 R-ON L2_Res</i>	1.627 (10.168)	5.701 (11.356)	1.088 (11.222)	1.735 (16.676)	-0.949 (0.983)	-0.951 (13.732)
<i>Burst</i>	7.520 (4.094)	7.447 (4.165)	7.467 (4.033)	7.144 (4.286)	9.776 (4.661)*	7.542 (4.225)
<i>GS &amp; Slope1 COR</i>	-40.195 (250.217)	-38.477 (240.912)	-40.504 (243.803)	-34.252 (248.514)	-55.002 (246.215)	-43.851 (231.811)
<i>Mean L2_Res</i>	0.000 (0.142)	0.000 (0.112)	0.000 (0.152)	0.000 (0.115)	-0.043 (0.637)	0.000 (0.079)
<i>Variance L2_Res</i>	1.195 (0.191)***	0.719 (0.136)***	1.211 (0.196)***	0.755 (0.270)**	30.491 (21.610)	0.434 (0.054)***
<i>SB RV</i>	219.321 (247.747)	218.607 (258.752)	217.653 (245.562)	212.528 (257.719)	195.575 (461.832)	219.706 (250.759)
<i>Slope1 RV</i>	8.264 (272.174)	7.578 (263.244)	8.448 (262.134)	6.441 (241.173)	18.601 (163.649)	9.682 (264.722)
<b>Between Level –</b>						
<b>Person</b>						
<i>Slope1 R-ON L3_Res</i>	1.688 (9.682)	4.640 (12.591)	1.220 (12.084)	0.980 (15.937)	0.024 (1.554)	2.907 (17.761)
<i>Slope2 R-ON L3_Res</i>	-1.314 (7.700)	-6.067 (10.395)	-1.617 (6.620)	-5.060 (9.111)	-0.503 (10.771)	-3.335 (25.134)
<i>AGE</i>	1.848 (2.341)	1.828 (2.457)	1.794 (2.353)	1.715 (2.446)	1.832 (2.801)	1.902 (2.351)
<i>SEX</i>	-9.930 (17.668)	-10.373 (17.845)	-9.272 (17.349)	-9.302 (17.712)	-9.147 (18.351)	-9.106 (17.379)
<i>BMI</i>	-4.635 (2.599)	-4.603 (2.718)	-4.630 (2.519)	-4.531 (2.638)	-4.753 (2.840)	-4.751 (2.729)
<i>WRK</i>	-3.501 (1.047)**	-3.449 (1.174)**	-3.489 (1.095)**	-3.437 (1.105)**	-3.509 (1.309)**	-3.553 (1.053)**
<i>VOL</i>	0.139 (2.352)	0.152 (2.374)	0.131 (2.366)	0.155 (2.353)	0.233 (2.442)	0.275 (2.355)
<i>Slope1 &amp; Slope2 COR</i>	-9.272 (863.250)	-3.356 (1170.483)	-3.187 (738.944)	-1.812 (981.206)	2.350 (1079.427)	-1.843 (1048.989)
<i>Slope1 &amp; SB COR</i>	63.709 (382.863)	23.468 (365.984)	24.476 (341.031)	15.350 (383.878)	-19.972 (471.482)	15.764 (513.281)
<i>Slope1 COR</i>	-347.066 (1025.786)	-345.384 (1041.545)	-315.780 (1000.078)	-290.123 (1058.901)	-270.327 (1839.834)	-288.405 (1530.398)
<i>Mean L3_Res</i>	0.000 (0.135)	0.000 (0.110)	0.000 (0.139)	0.000 (0.117)	0.000 (0.558)	0.000 (0.079)
<i>SB Intercept</i>	1200.830 (8.057)***	1200.185 (8.121)***	1200.811 (8.079)***	1200.519 (8.502)***	1199.115 (11.311)***	1201.748 (9.355)***
<i>Slope1 Intercept</i>	8.346 (3.849)*	7.526 (4.250)	8.633 (3.613)*	8.549 (3.491)*	8.867 (3.583)*	9.103 (3.931)**
<i>Slope2 Intercept</i>	8.061 (11.868)	8.085 (13.465)	7.792 (11.693)	6.891 (14.001)	6.391 (10.429)	8.058 (12.002)
<i>Variance L3_Res</i>	0.944 (0.187)***	0.624 (0.128)***	1.010 (0.175)***	0.713 (0.271)**	16.170 (10.907)	0.324 (0.061)***
<i>SB RV</i>	2372.351 (597.461)***	2372.826 (613.788)***	2372.594 (607.766)***	2364.210 (667.487)***	2355.623 (1230.084)	2346.655 (689.582)**
<i>Slope1 RV</i>	2.193 (486.870)	0.648 (756.443)	0.808 (411.409)	0.672 (521.398)	0.796 (450.556)	0.677 (546.825)
<i>Slope2 RV</i>	51.455 (477.031)	50.966 (433.426)	42.724 (446.091)	36.331 (486.618)	31.813 (1858.566)	36.140 (698.082)

*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 general stress and SB; L2 = Level 2; L3 = Level 3; GS = General Stress; Res = Resilience Resource; \* =  $p < .05$ ; \*\* =  $p < .01$ ; \*\*\* =  $p < .001$ .

Stress, Physical Activity, and Resilience

Supplementary Table 6. Results of 3-level model for light intensity activity and general stress.

	BRS	HOPE	LOT #	GSE	HCC	PSS
<b>Within Level –</b>						
<b>Day</b>						
<i>PA RV</i>	1190.044 (158.154)***	1190.400 (158.915)***		1193.776 (159.212)***	1195.389 (172.620)***	1190.030 (158.103)***
<b>Between Level – Burst</b>						
<i>Slope1 R-ON L2_Res</i>	-3.309 (5.568)	-6.488 (5.327)		-3.330 (8.600)	0.866 (0.874)	4.578 (7.274)
<i>Burst</i>	-3.608 (2.074)	-3.378 (2.024)		-3.366 (2.081)	-3.739 (2.332)	-3.578 (2.080)
<i>GS &amp; Slope1 COR</i>	-27.362 (64.508)	-18.185 (56.810)		-22.695 (70.244)	-22.686 (109.872)	-30.146 (74.339)
<i>Mean L2_Res</i>	0.000 (0.142)	0.000 (0.112)		0.000 (0.115)	-0.030 (0.601)	0.000 (0.079)
<i>Variance L2_Res</i>	1.195 (0.191)***	0.719 (0.136)***		0.755 (0.270)**	30.419 (21.615)	0.434 (0.054)***
<i>PA RV</i>	41.676 (64.806)	40.230 (63.221)		39.189 (65.017)	34.860 (113.980)	42.008 (69.050)
<i>Slope1 RV</i>	20.715 (133.560)	10.38 (110.157)		16.089 (126.329)	18.163 (77.841)	24.596 (145.690)
<b>Between Level –</b>						
<b>Person</b>						
<i>Slope1 R-ON L3_Res</i>	2.134 (5.099)	1.989 (5.687)		1.354 (8.346)	-0.642 (0.921)	-5.867 (7.912)
<i>Slope2 R-ON L3_Res</i>	1.221 (4.073)	1.958 (2.837)		1.412 (2.050)	0.071 (4.452)	3.082 (11.958)
<i>AGE</i>	-0.193 (1.220)	-0.134 (1.302)		-0.107 (1.305)	-0.031 (1.533)	-0.208 (1.322)
<i>SEX</i>	-4.496 (6.713)	-4.51 (6.441)		-4.363 (6.857)	-4.330 (8.666)	-4.198 (7.128)
<i>BMI</i>	2.006 (1.276)	1.957 (1.135)		1.928 (1.193)	1.982 (1.3140)	2.054 (1.327)
<i>WRK</i>	1.643 (0.455)***	1.592 (0.493)**		1.590 (0.487)**	1.573 (0.569)**	1.644 (0.449)***
<i>VOL</i>	-0.869 (0.813)	-0.866 (0.838)		-0.823 (0.817)	-0.853 (0.820)	-0.906 (0.793)
<i>Slope1 &amp; Slope2 COR</i>	-19.248 (185.463)	-16.614 (135.707)		-16.619 (148.908)	-4.945 (155.712)	-15.654 (183.304)
<i>Slope1 &amp; PA COR</i>	84.003 (152.677)	74.451 (130.018)		77.485 (150.953)	63.877 (198.495)	76.293 (207.372)
<i>Slope1 COR</i>	-90.828 (360.453)	-89.268 (351.157)		-86.447 (360.897)	-31.387 (357.0800)	-80.872 (506.568)
<i>Mean L3_Res</i>	0.000 (0.135)	0.000 (0.110)		0.000 (0.117)	0.000 (0.558)	0.000 (0.079)
<i>SB Intercept</i>	125.176 (3.538)***	125.728 (3.513)***		125.670 (3.550)***	125.653 (4.863)***	124.969 (4.212)***
<i>Slope1 Intercept</i>	-3.800 (2.234)	-3.243 (2.224)		-3.588 (2.173)	-3.894 (2.146)	-4.095 (2.354)
<i>Slope2 Intercept</i>	-4.366 (4.520)	-3.708 (4.411)		-3.697 (4.615)	-1.609 (5.339)	-4.482 (4.456)
<i>Variance L3_Res</i>	0.944 (0.187)***	0.624 (0.128)***		0.713 (0.271)**	16.170 (10.907)	0.324 (0.061)***
<i>PA RV</i>	393.923 (96.842)***	395.928 (100.727)***		395.409 (100.770)***	398.681 (221.826)	387.099 (96.472)***
<i>Slope1 RV</i>	18.709 (166.909)	14.835 (111.105)		16.647 (137.278)	12.133 (131.789)	16.386 (167.442)
<i>Slope2 RV</i>	21.374 (412.706)	20.618 (398.996)		19.437 (416.709)	3.323 (544.637)	17.385 (612.314)

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 general stress and PA; L2 = Level 2; L3 = Level 3; GS = General Stress; Res = Resilience Resource; # Model estimation did not terminate normally due to an error in computation; \* = p < .05; \*\* = p < .01; \*\*\* = p < .001.

Stress, Physical Activity, and Resilience

Supplementary Table 7. Results of 3-level model for moderate intensity activity and general stress.

	BRS	HOPE	LOT	GSE	HCC	PSS
<b>Within Level –</b>						
<b>Day</b>						
<i>PA RV</i>	1375.530 (194.472)***	1369.884 (192.473)***	1374.652 (195.006)***	1376.926 (195.562)***	1374.040 (187.615)***	1375.579 (201.822)***
<b>Between Level – Burst</b>						
<i>Slope1 R-ON L2_Res</i>	-0.482 (5.231)	-4.785 (5.984)	-0.747 (5.583)	-0.593 (7.742)	0.146 (1.079)	0.027 (7.279)
<i>Burst</i>	-3.922 (2.537)	-3.887 (2.532)	-3.999 (2.480)	-3.660 (2.530)	-5.056 (3.338)	-4.033 (3.763)
<i>GS &amp; Slope1 COR</i>	-21.591 (89.118)	-22.179 (95.414)	-23.170 (89.741)	-19.957 (83.857)	-11.966 (43.121)	-24.175 (97.619)
<i>Mean L2_Res</i>	0.000 (0.142)	0.000 (0.112)	0.000 (0.152)	0.000 (0.115)	-0.006 (0.654)	0.000 (0.079)
<i>Variance L2_Res</i>	1.195 (0.191)***	0.719 (0.136)***	1.211 (0.196)***	0.755 (0.270)**	30.365 (21.487)	0.434 (0.054)***
<i>PA RV</i>	82.661 (76.366)	81.267 (80.265)	83.454 (76.219)	80.646 (77.424)	82.635 (87.641)	84.697 (93.961)
<i>Slope1 RV</i>	6.289 (90.808)	6.554 (88.283)	7.062 (89.712)	5.618 (84.713)	17.273 (39.085)	7.554 (126.523)
<b>Between Level – Person</b>						
<i>Slope1 R-ON L3_Res</i>	-0.796 (6.224)	0.073 (6.391)	-0.832 (5.890)	0.495 (7.662)	0.099 (1.227)	-1.545 (16.567)
<i>Slope2 R-ON L3_Res</i>	1.906 (4.221)	4.058 (7.109)	0.930 (4.552)	3.563 (6.067)	0.699 (3.822)	3.709 (22.927)
<i>AGE</i>	-1.657 (1.315)	-1.676 (1.479)	-1.666 (1.292)	-1.596 (1.305)	-1.720 (1.372)	-1.787 (1.242)
<i>SEX</i>	9.651 (9.515)	10.332 (9.754)	9.016 (9.137)	9.042 (9.349)	9.342 (9.338)	8.788 (13.417)
<i>BMI</i>	2.377 (1.298)	2.359 (1.324)	2.413 (1.276)	2.315 (1.325)	2.447 (1.359)	2.479 (1.583)
<i>WRK</i>	1.885 (0.690)**	1.865 (0.799)*	1.897 (0.710)**	1.848 (0.691)**	1.921 (0.745)*	1.965 (0.906)*
<i>VOL</i>	0.903 (1.564)	0.915 (1.536)	0.882 (1.516)	0.856 (1.526)	0.875 (1.726)	0.763 (2.252)
<i>Slope1 &amp; Slope2 COR</i>	7.382 (424.265)	8.716 (528.468)	8.938 (374.837)	7.728 (492.530)	11.018 (366.978)	7.812 (1008.620)
<i>Slope1 &amp; PA COR</i>	-39.455 (172.702)	-47.725 (178.818)	-51.610 (147.179)	-51.430 (153.288)	-63.127 (121.052)	-52.000 (379.606)
<i>Slope1 COR</i>	-162.712 (335.385)	-158.564 (360.271)	-150.221 (323.874)	-130.245 (317.666)	-148.837 (485.788)	-127.841 (849.994)
<i>Mean L3_Res</i>	0.000 (0.135)	0.000 (0.110)	0.000 (0.139)	0.000 (0.117)	0.000 (0.558)	0.000 (0.079)
<i>SB Intercept</i>	108.119 (5.009)***	108.261 (4.804)***	107.874 (4.821)***	108.033 (5.124)***	108.680 (5.042)***	106.997 (9.427)***
<i>Slope1 Intercept</i>	-4.287 (2.217)	-3.831 (2.525)	-4.251 (1.897)*	-4.585 (1.915)*	-4.607 (2.073)*	-4.606 (2.442)
<i>Slope2 Intercept</i>	-6.492 (6.768)	-6.740 (8.217)	-6.669 (7.007)	-5.667 (8.477)	-5.774 (7.072)	-6.617 (7.286)
<i>Variance L3_Res</i>	0.944 (0.187)***	0.624 (0.128)***	1.010 (0.175)***	0.713 (0.271)**	16.170 (10.907)	0.324 (0.061)***
<i>PA RV</i>	872.041 (270.423)***	870.961 (291.866)**	869.935 (266.390)**	868.587 (308.500)**	853.572 (345.473)*	857.380 (590.282)
<i>Slope1 RV</i>	2.076 (224.936)	2.832 (307.200)	3.365 (201.476)	3.367 (236.332)	5.016 (201.304)	3.474 (497.299)
<i>Slope2 RV</i>	30.989 (152.202)	29.484 (104.668)	26.560 (122.919)	20.192 (122.435)	26.675 (279.202)	19.690 (299.275)

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 general stress and PA; L2 = Level 2; L3 = Level 3; GS = General Stress; Res = Resilience Resource; \* = p < .05; \*\* = p < .01; \*\*\* = p < .001.

Stress, Physical Activity, and Resilience

Supplementary Table 8. *Results of 3-level model for vigorous intensity activity and general stress.*

	BRS	HOPE	LOT	GSE	HCC	PSS
<b>Within Level –</b>						
<b>Day</b>						
<i>PA RV</i>	74.092 (25.784)**	73.847 (25.877)**	74.238 (26.022)**	74.158 (25.752)**	74.128 (24.131)**	74.173 (25.807)**
<b>Between Level – Burst</b>						
<i>Slope1 R-ON L2_Res</i>	-0.162 (1.164)	1.149 (2.780)	0.375 (0.950)	-0.191 (1.663)	-0.021 (0.314)	0.090 (1.016)
<i>Burst</i>	-0.345 (0.454)	-0.388 (0.460)	-0.358 (0.451)	-0.368 (0.452)	-0.394 (0.595)	-0.330 (0.449)
<i>GS &amp; Slope1 COR</i>	-0.045 ( 7.175)	-0.021 (7.514)	-0.039 (6.373)	-0.048 (8.667)	-0.023 (0.509)	-0.051 (7.675)
<i>Mean L2_Res</i>	0.000 (0.142)	0.000 (0.112)	0.000 (0.152)	0.000 (0.115)	-0.003 (0.655)	0.000 (0.079)
<i>Variance L2_Res</i>	1.195 (0.191)***	0.719 (0.136)***	1.211 (0.196)***	0.755 (0.270)**	30.363 (21.504)	0.434 (0.054)***
<i>PA RV</i>	0.092 (6.264)	0.044 (6.254)	0.072 (5.838)	0.093 (6.604)	1.201 (0.754)	0.098 (6.633)
<i>Slope1 RV</i>	0.081 (24.544)	0.034 (46.471)	0.068 (18.759)	0.083 (30.740)	0.049 (0.778)	0.093 (24.515)
<b>Between Level –</b>						
<b>Person</b>						
<i>Slope1 R-ON L3_Res</i>	-0.651 (1.319)	-2.224 (3.487)	-0.680 (0.995)	-0.744 (1.697)	0.096 (0.295)	0.576 (1.639)
<i>Slope2 R-ON L3_Res</i>	0.321 (1.632)	-0.338 (2.299)	-0.463 (0.920)	-0.141 (1.020)	0.707 (2.605)	-0.804 (2.942)
<i>AGE</i>	-0.118 (0.200)	-0.136 (0.220)	-0.146 (0.213)	-0.135 (0.213)	-0.132 (0.410)	-0.105 (0.252)
<i>SEX</i>	4.122 (4.403)	3.768 (8.235)	3.824 (4.432)	3.813 (4.614)	2.854 (5.648)	3.909 (3.986)
<i>BMI</i>	0.426 (0.185)*	0.432 (0.223)	0.446 (0.193)*	0.435 (0.192)*	0.467 (0.421)	0.432 (0.184)*
<i>WRK</i>	0.018 (0.052)	0.027 (0.053)	0.030 (0.054)	0.024 (0.053)	0.029 (0.060)	0.010 (0.053)
<i>VOL</i>	-0.182 (0.202)	-0.184 (0.279)	-0.200 (0.216)	-0.181 (0.227)	-0.152 (0.196)	-0.172 (0.199)
<i>Slope1 &amp; Slope2 COR</i>	-0.256 (18.454)	-0.381 (35.909)	-0.437 (17.502)	-0.429 (19.234)	0.053 (24.503)	-0.348 (15.397)
<i>Slope1 &amp; PA COR</i>	-0.911 (5.8700)	-1.412 (6.193)	-1.502 (5.059)	-1.551 (6.378)	-3.127 (5.882)	-1.295 (6.135)
<i>Slope1 COR</i>	4.748 (9.563)	4.542 (17.678)	4.859 (10.565)	4.636 (11.589)	-0.255 (48.833)	4.605 (9.770)
<i>Mean L3_Res</i>	0.000 (0.135)	0.000 (0.110)	0.000 (0.139)	0.000 (0.117)	0.000 (0.558)	0.000 (0.079)
<i>SB Intercept</i>	6.153 (0.968)***	6.043 (1.106)***	5.980 (0.951)***	6.063 (0.879)***	6.155 (1.111)***	6.191 (1.018)***
<i>Slope1 Intercept</i>	-0.343 (0.343)	-0.337 (0.600)	-0.439 (0.467)	-0.311 (0.494)	-0.399 (0.561)	-0.434 (0.387)
<i>Slope2 Intercept</i>	-0.195 (0.958)	-0.327 (1.076)	-0.150 (0.937)	-0.209 (0.991)	0.078 (1.673)	-0.153 (0.880)
<i>Variance L3_Res</i>	0.944 (0.187)***	0.624 (0.128)***	1.010 (0.175)***	0.713 (0.271)**	16.170 (10.907)	0.324 (0.061)***
<i>PA RV</i>	17.065 (6.799)*	16.909 (7.274)*	16.793 (7.032)*	16.922 (6.415)**	13.882 (5.362)*	17.268 (6.806)*
<i>Slope1 RV</i>	0.082 (13.133)	0.130 (17.539)	0.164 (9.109)	0.175 (12.342)	0.727 (6.591)	0.139 (11.368)
<i>Slope2 RV</i>	1.446 (4.392)	1.302 (5.950)	1.510 (2.861)	1.386 (8.221)	0.038 (71.095)	1.352 (7.950)

*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 general stress and PA; L2 = Level 2; L3 = Level 3; GS = General Stress; Res = Resilience Resource; \* =  $p < .05$ ; \*\* =  $p < .01$ ; \*\*\* =  $p < .001$ .