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Do Subjective and Objective Resilience Measures Assess Unique Aspects and what is their Relationship to Adolescent Well-being?

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Abstract

Measurement of resilience is important within schools to support student mental health and well-being. Resilience is defined as the healthy integration, adaptation and positive functioning over time in response to the experience of adversity and challenge. This study explored the relationship between a subjective and objective measure of resilience and the respective predictability of psychophysical well-being measures. A sample of 282 Year 10 students completed a subjective resilience measure (Connor-Davidson Resilience Scale) and psychological measures of well-being. A subset of 76 students completed an objective measure of resilience (Heart Rate Variability). Correlational analyses revealed no significant relationship between

the two measures and don't support the use of one measure as a proxy for the other. Hierarchical regression analyses illustrated the significant predictive quality of the subjective measure to psychophysical well-being measures. The strongest relationships were reported with EPOCH sub-scales Optimism (r=.68), Happiness (r=.64) and Perseverance (r=.59). No significant relationships were found between the objective resilience measure and well-being measures. With objective resilience showing no relationship to subjective resilience and well-being, it is possible that HRV instead measures the capacity for resilience, rather than resilience. This study highlights the importance of defining resilience and the implications for measurement in adolescent students.

Keywords: psychology, schools, adolescence, resilience, heart rate variability, well-being

Do Subjective and Objective Resilience Measures Assess Unique Aspects and what is their Relationship to Adolescent Well-being?

The adolescent years can be difficult to navigate and adolescents may need professional support to manage their health and well-being (Patton et al., 2016; Sawyer et al., 2012). Research shows adolescents experience higher rates of mental ill-health, notably anxiety and depression, compared with other stages of life, yet only 19 to 34% seek professional help (Gulliver et al., 2010; World Health Organisation, 2011). Identifying personal attributes in adolescents that can enhance well-being and also be self-managed is therefore becoming increasingly important. Resilience is one such attribute that is important for the development and well-being of adolescents as it enables them to not only cope but thrive in the face of adversity or setback (Rickard et al., 2016; Wang et al., 2010).

Defining Resilience

There are two key aspects to resilience. The first is that an individual has experienced adversity and the second is that there is an observable positive outcome or increased level of functioning, sometimes referred to as wellbeing, in response to the challenge (Shean, 2015). The feature common to all resilience definitions is positive adaptation to adversity, challenge or setbacks; underscoring resilience as a dynamic process (McEwen & Gianaros, 2010; Shastri, 2013; Walsh, 2003). When personal growth occurs in response to adverse events, individuals move closer to reaching their full potential and can evolve beyond their perceived level of skill (Reivich & Shatte, 2002). Over time the definition of resilience has shifted to a positive focus on competence and adaptive behaviour. This shift aligns with the World Health Organisation's (WHO) shift in the definition of mental health as a state of positive well-being, with mental health no longer viewed as the absence of mental disorder (WHO, 2011).

Palomar and Victorio-Estrada's (2014) study of 1,093 adolescents with an average age 14.92 (± 1.29) years, report that a person's ability to overcome adversity increases their level of subjective well-being, their level of 'positive health' as reflected in energy levels, and the capacity to recuperate. Richardson and colleagues (1990) spoke to the dynamic union of factors resulting in the biopsychospiritual balance ("homeostasis"), which is the adaptation of body, mind (emotion and thoughts), and spirit (goals/ aims) to current life circumstances. This view is further supported by Hansen (2014) who states resilience is an integrated system requiring the alignment of several factors that contribute to well-being; the body (exercise, sleep and nutrition), the heart (positive emotions, emotion regulation and impulse

control), the mind (optimism, agility and disputation of thinking traps) and the spirit (sense of purpose and motivation).

Despite some differences in definitions of resilience (Rutter, 2013; Ungar, 2013) most definitions are based on a sequence of several constructs:

Adversity→ Coping Strategies → Resilience → Well-being

As such resilience is defined for the current study, as the healthy integration, adaptation and positive functioning over time in response to the experience of adversity and challenge.

The literature on children's resilience over the past 50 years has resulted in widespread acceptance that both psychological and neurophysiological factors need to be studied to accurately measure the construct of resilience (Cicchetti & Blender, 2006; Masten, 2007; Obradovic, 2012) and determine the effectiveness of programs designed to build skill and sustain capability (Rickard & Vella-Brodrick, 2014). However, researchers studying resilience often use only one measure of resilience: self-assessment. The use of a single measure limits the understanding of resilience to one facet of the construct – the cognitive assessment of one's own ability to respond to challenge. This raises the question of whether the use of a subjective tool is sufficient to accurately measure resilience. This question will be explored in the following section.

Subjective Measures of Resilience

Subjective assessments of resilience measure participants' perceptions of their ability to deal with challenges and their ability to adapt and respond to future risks (i.e. psychological resilience) (Jones, 2019). These include self-assessed standardized questionnaires such as the Connor-Davidson Resilience Scale (CD-RISC), the Resilience Scale for Adults and the Brief Resilience Scale (Windle et al., 2011). The

popularity of these tools, particularly in school settings with young people, can be attributed to the low administration cost, the speed of completion, reliability of measurement and the strong predictions of mental health and well-being they provide (Connelly & Ones, 2010; Duckworth & Yeager, 2015).

Studies which utilise these tools have shown that resilience is a learnable skill with low scores on a resilience scale associated with higher levels of mental illness. Resilience has been found to correlate with well-being by buffering against negative threats and assisting in the maintenance of physical and psychological health (Bajaj & Pande, 2016; Khanlou & Wray, 2014; Souri & Hasanirad, 2011). However, the use of such tools is not without criticism. Methodological reviews note the complexity of resilience has resulted in numerous approaches to measurement, this in turn has led to conceptual and theoretical inconsistencies (Windle et al., 2011).

Currently, a comprehensive framework does not exist to support subjectively studying an individual or environment that is constantly changing. This raises the question of which responses to events sit within normal bounds of adaptation and when the skill of resilience is required. The specific factors that are selected to indicate resilience outcomes influence the answer to this question. Within the current research there are two frequently used indicators of positive outcomes. The first is the absence of psychopathology, such as depression and anxiety, which co-occur with numerous risk factors including low socio-economic status, high rates of mental ill-health and difficult family relationships (Shean, 2015). The second is measurable levels of competence as demonstrated by higher academic results and social skills. Whilst widely utilised, there is difficulty in applying these indicators to unequivocally determine if an individual is resilient. This is best illustrated in Shean's (2015) example which questions whether or not an individual can be classified as resilient

because they have strong academic performance and are socially well adjusted, yet are diagnosed with depression.

When determining resilience, further variation in measurement becomes apparent when the timeliness of events is considered. Some studies report on individuals who have recently faced adversity and are in the stages of processing and coping, others report on individuals who have experienced a stressful event some time before and have the time and resources to respond positively to it. These inconsistencies in measurement result in discrepancies when reporting, as the same group of people may be considered resilient in one study but non-resilient in another. The consequence of this is a limitation in the ability to compare studies (Shean, 2015).

Determining the suitability of self-reporting measures requires consideration of factors that may affect the validity of the tool. Questionnaires on resilience and well-being can be compromised due to the truthfulness and accuracy of subjective responses. The situations or behaviours which are questioned may be difficult to recall or the participant may have a sensitivity towards the subject matter such that responses are subject to bias. Cognitive bias impacts the validity of results due to inaccuracies in the interpretation of the question and the ability to recall memory or information (Brener et al., 2003). Situational bias, particularly within an adolescent sample, may result in a higher propensity of answers being misleading or untruthful in order to meet perceived social desirability standards. This is often driven by an adolescent's need to provide others with a favourable impression of themselves or to achieve recognition and status for inappropriate behaviour (Brener et al., 2003). The application of the CD-RISC in the study of adolescents and more broadly in studies across different cultures, gender, age groups, and clinical and non-clinical

populations, means it is the most commonly operationalised definition of resilience within the literature and hence, provides the good rationale for its use in the current study. Objective measures of resilience are also available and may offer an alternative or complementary option for assessment with young people.

Objective Measures of Resilience

Objective measures of resilience occur via an external mechanism, differing from subjective measures which utilise participants' assessment of their own level of resilience (Jones, 2019). Objective assessment tools provide an immediate and direct measurement of physiological properties (biomarkers) thought to represent an individual's overall resilience (Kim et al., 2018). The literature highlights the existence of a number of biomarkers associated with resilience such as cortisol and DHEA (dehydroepiandrosterone), hormones released from the adrenal cortex in response to a stressor (physical and psychological); DHEA and DHEA-S (dehydroepiandrosterone sulphate), released during periods of challenge and found to moderate the impact of stress; oxytocin, a hormone produced by the hypothalamus and released by the pituitary gland shown to improve social interaction and reduce anxiety and stress; Testosterone, found to drop with psychological stress; cytokines and interferons are inflammatory markers that influence the release of cortisol; and HRV (Walker et al., 2017). The use of these objective measures occurs predominately in studies of military service personnel experiencing PTSD. While, the findings show promise for using strong biomarkers in predicting resilience however, many studies report inconclusive results.

The choice of any measure needs to consider the relative ease of data collection. HRV testing is a non-invasive measurement of the interactions between the brain, the heart and other systems within the body and is more cost effective than

other assessment tools, such as salivary, hair or blood cortisol collection, which requires lab analysis (Sinan, 2019). With these considerations in mind, HRV was selected as the objective measure for this study.

HRV is defined as 'the temporal variation between sequences of consecutive heartbeats' (Karim et al., 2011). This beat to beat change in heart rate is also known as coherence, a state of balance or homeostasis (Hansen, 2015). Leher and Gevirtz (2014), explore the impact of HRV training on the effect of homeostasis in the baroreceptor (a reflex influencing blood vessel expansion and contraction and thus link blood pressure, heart rate and vascular tone) and the associated outcomes for a range of disorders and performance enhancement. Despite not providing a definition of resilience, the review found that higher and more complex heart rate oscillations are an indication of both physical and emotional resilience. The premise that resilience, as discussed earlier, is a dynamic process that involves positive and functional adaptation in response to adversity leads researchers to propose that HRV may underlie different levels of resilience, offering insight into the brain-body pathways for resilience and adaptation (Carnevali et al., 2018). Conversely, low HRV within individuals was associated with poorer physical and emotional function and is a predictor of future health concerns such as disease and death (Sharma & Gedeon, 2012; Thayer et al., 2012).

HRV is often used to assess the balance or coherence of the sympathetic and parasympathetic systems on the autonomic nervous system. The sympathetic system controls the flight or fight reactions in response to perceived stress resulting in increased heart rate or a decrease in the interval between heartbeats. The parasympathetic system controls the body's 'rest and digest' responses and is associated with recovery, resulting in decreased heart rate or an increase in heartbeat

intervals. HRV is captured across various frequencies including ultra-low frequencies (ULF), which have a cycle length greater than 6 hours; very low frequencies (VLF), which have a cycle length greater than 25 seconds; low frequencies (LF), which have a cycle greater than 6 seconds; and high frequencies (HF), which have a cycle length between 2.5 and 6 seconds. It is this last frequency that is linked to the respiratory system (Karim et al., 2011). The higher frequencies are reflective of the parasympathetic inputs and the lower frequencies are a combination of the parasympathetic and sympathetic inputs. It is only the parasympathetic system that can cause changes to the beat to beat timing of the heart (Thayer et al., 2012).

Large variations in heart rate are indicative of a stress response and have therefore, been considered an appropriate measure of stress resilience. Stress is defined as an individual's physical and psychological response to perceived threat, and occurs when the demands of a situation are greater than the perceived resources an individual has to deal with the situation (O'Dowd et al., 2018). When assessing situations, the short-term and long-term adaptive response is for an individual to assume any uncertainty as a possible threat. HRV is suggestive of an individual's conscious and unconscious perceptions to threat or safety (Thayer et al., 2012). HRV testing can measure acute stress by tracking the frequency and force of heart contractions. When an individual experiences chronic stress, there is a resulting effect of a heavier heart mass enabling a better response to stress (Sharma & Gedeon, 2012).

In response to a perceived threat there is an increase in epinephrine (adrenalin), which is released by the medulla of the adrenal gland, with the level of epinephrine positively correlated to negative emotions. Negative emotions result in physiological responses such as an increased heart rate and respiratory rate, vasoconstriction and vasodilation, muscle constriction and stimulation of

glycogenolysis. This increases both blood glucose and fatty acids and also stimulates the adrenal cortex to release cortisol, which often occurs in response to stress. These processes are part of a complex neural structure that regulate not only physiology but also cognition, perception and behaviour. They enable the body to integrate signals from within and outside the body in order to respond to a situation. Thayer et al. (2012) stated that HRV acts as an index to reflect the adaptation of the individual to change as this system oscillates between a range of states with a degree of flexibility. A system in balance will see high variations in HRV as it adapts to the many changes in input, as an optimal level of HRV is associated with good physical health, the ability to self-regulate and resilience. When there is little to no variability, the system is considered dysfunctional, locked in a pattern of negative behaviour and not reflective of the change in inputs (Thayer et al., 2010). Thus, HRV may provide a psychophysical marker for wellbeing, mental and physical health (Kemp et al., 2017).

The use of an objective measure like HRV addresses many of the criticisms that impact the validity of subjective measures (e.g. interpretation, social benefit, desirability and culture), due to physiological processes being predominately involuntary (Carnevali et al., 2018; Diener, 2000). However, the use of HRV is not without criticism. The majority of HRV research has been conducted in clinical populations, removed from real life situations, which makes the generalising of findings to non-clinical cohorts unjustified. Consideration must be given to the susceptibility of HRV testing to variations in measurement, particularly with retesting days and months post first assessment (Cipryan, 2016). Variations include factors such as age (adolescents have a greater range of beat to beat variation than older participants), gender, state of alertness, obesity, fitness levels (participants who regularly exercise have associated lower heart rate and higher HRV), smoking and

drinking status (participants who smoke or drink regularly show higher heart rate and lower HRV) (Hammoud et al., 2018; Sharma & Gedeon, 2012). Other additional factors specific to testing include the position of the participant (sitting upright or lying), rate of respiration and the pacing of breathing. Thus, it is deemed critically important to select appropriate norms for testing, namely time and frequency domains (Shaffer & Ginsberg, 2017).

Studies with non-clinical populations have predominately focused on subjective well-being. Studies report that well-being is underpinned neurologically, with higher levels of HRV associated with emotional regulation (Appelhans & Luecken, 2006; Beauchaine & Thayer, 2015), motivation for social engagement (Kemp et al., 2012), improved executive functioning, namely working memory and attention control (Hansen et al., 2003; Shaffer & Grinsberg, 2017), high levels of resilience (Hidebtandt et al., 2016) and lower levels of stress (Rickard & Vella-Brodrick, 2014).

Adolescent Resilience and Physical Health

The World Health Organisation has recognised the key dimensions of general health and well-being as being physical, psychological and social well-being and functioning as per the multi-dimensional Health-Related Quality of Life (HRQoL) construct (Bottolfs, et al., 2020). There is limited research available examining HRQoL among young people. A Norwegian study of 611 Year 8 students reported that resilience was a positive predictor of HRQoL (β 0.18 to 0.27), providing a protective factor against the risk of disease and enabling positive outcomes for adolescents (Bottolfs, et al., 2020). An earlier study of 1,100 Norwegian adolescents reported moderately strong relationships between resilience and physical health,

where higher scores of resilience factors were associated with structured, well-organised and frequent physical activity (Moljord et al., 2014).

The relationship of mental health and resilience is influenced by physical health. When physically active the result is higher levels of resilience and lower levels of mental ill health (Wells et al., 2012; Wermelinger et al., 2018), providing a buffer against stress, stress related disorders and chronic disease. Good physical health can also decrease an individual's reaction to stress as they have lower levels of inflammation and physiological and metabolic reactivity. The impact of this dampening effect has been recognised on the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system, resulting in higher rates of resilience. Physical health also leads to psychological benefits such as decreased emotional reactivity, depression and anxiety whilst increasing positive mood and cognitive function, in particular learning and memory (Silverman & Deuster, 2014).

In terms of positive mental health in adolescents, this was found to peak when the average duration of sleep ranged from 8.75-9 hours per school night. Alarmingly however, the Sleep Health Foundation (2011) noted that sleep is less regular for adolescents than at other points in life, with research highlighting that Australian adolescents fail to achieve sufficient sleep across the school week (Short et al., 2013). From the age of 11 years (Grade 6) to 18 years (Year 12) there is a loss of 90 minutes sleep for each school night (Tarokh et al., 2016), as such adolescents are receiving 1 to 3 hours less per night sleep than the recommended range of 8-10 hours for this cohort (National Sleep Foundation, 2016). The impact of these sleep difficulties is reflected in poorer daytime performance and functioning. Insufficient sleep quality and duration which is defined as less than 7 hours of sleep, reduces levels of

resilience and increases the risk of developing anxiety or depression (Williams et al., 2018).

As highlighted, research has predominately focused on determining the risk factors for disease and the adverse result on well-being outcomes, particularly as they relate to adolescent mental ill-health (Seligman & Csikszentmihalyi, 2000). However, the focus has shifted with research studies demonstrating that well-being includes optimism, motivation and character traits which enable the development of positive emotions (happiness), engagement, relationships, meaning and accomplishment or PERMA that results in human thriving (Seligman, 2011).

Resilience and Psychological Well-being

Determining resilience as a pathway to well-being is well supported by research (Bajaj & Pande, 2016; Nurius et al., 2015; Souri & Hasanirad, 2011). With higher levels of resilience, individuals are better able to navigate difficulties and problems, which in turn influences levels of autonomy, control and creativity, contributing to subjective well-being (Palomar-Lever & Victorio-Estrada, 2013; Weinberg & Tomyn, 2016).

Studies have found that resilience is also negatively correlated to depressive symptomology (Pereira e al., 2016). Fredrickson and Joiner (2002) stated via the Broaden and Build theory that negative emotions narrow the options for one's thinking and behaviours particularly in response to negative events, whilst the opposite is true if one has positive emotions. The effect of positive emotions is a resultant upward spiralling to improved emotional well-being. Souri and Hasanirad (2011), in their study of 414 medical students, stated that resilience was a predictor of well-being, noting optimism as a mediator in the relationship. Bajaj and Pande (2016) in their study of 327 undergraduate students, which used structural equation

modelling, reported that resilient individuals were able to maintain both psychological and physical health and were shielded against the negative impacts of adverse events. They concluded that resilience was an important source of subjective well-being and life satisfaction. Thus, any work aimed at building resilience in adolescents must focus on protective factors for adolescents. Assets for resilience in adolescents include social skills for relating to peers, academic skills, extracurricular activities and a self-determination to engage in health promoting behaviours (Stevenson & Zimmerman, 2005).

Resilience Measurement in Schools

Previous literature has revealed the need for a multidimensional approach to measuring resilience, yet highlighted inconsistencies in how resilience is defined and measured. This is no less prevalent within the school context. Subjective resilience measurement tools are numerous and often adapted to a particular cohort or study, for example: Resilience Scale for Children and Adolescents (Prince-Embury, 2008) and Academic Resilience Scale (Martin & Marsh, 2006). Objective measures of resilience within the school context appear to be non-existent based on the literature review conducted. The use of an objective measure may present an opportunity to accurately (less prone to subjective bias) and quickly monitor programs designed to build resilience using a standardised biological predictor (Walker et al., 2017). Thus, clarity of definition and mode of measurement is imperative to ensure the best learning, resilience and well-being outcomes for students.

The aim of the current study is to address this gap in the literature by exploring the relationship between a subjective (CD-RISC) and an objective (HRV) measure of resilience in an adolescent sample. The use of both measures extends previous research by providing a more comprehensive view of the validity of

resilience measurement tools. Subsequently, this study looks to determine which tool is a better predictor of well-being among students, using both psychological and physical health measures.

Thus, the study seeks to answer the following questions: Are the two measures of resilience positively correlated and as such be a suitable proxy for each other? Which resilience measure, subjective or objective, explains the greatest variance in well-being?

Method

Two measures were used to quantify the levels of resilience in an adolescent sample. HRV was examined by the student researcher within the school environment and a self-report questionnaire was completed online by the participants within the same testing period.

Participants

The participants of this study were 282 Australian Year 10 students (M=117, F=165) from two Victorian state high schools. These schools were part of a larger sample consisting of independent and state schools, selected to participate in a school-based evaluation of adolescent well-being. Consideration was given to the selection of the state high schools to ensure the student participants had similar socioeconomic demographics. The schools reside in an urban environment, located 23km and 75km respectively from Melbourne's CBD and report similar school distributions as per the Index of Community Socio-Educational Advantage (ICSEA). In this study the ICSEA values for the schools were within the range of 985 to 1040 ($ICSEA_{median}$: 1000; $ICSEA_{SD}$: 100). The predominant student culture, as represented by country of birth, was Australian (School 1: 82%; School 2: 88%). Country of birth does not necessarily signify that students were Caucasian. The multicultural profile of Victoria is diverse

and whilst students are born in Australia this does not reflect a student's ethnicity, for example, African-Australian, Chinese-Australian and Indian-Australian.

The family unit profile for the participants was reflective of the national data with 64% of students living in a nuclear family unit (living with both biological parents); 20% living in a single parent household; 15% living with a single parent who also had a partner living in the same household; and 1% living in a household without either parent present. In comparison, the 2016 Australian Census (ABS, 2016) of 6 million families reported single parent families with a dependent child was 15.85% of all Australian families (81.8% headed by females). Stepfamilies (a child residing in a family unit that is not of both parents) constitutes 6.3% of families, de facto marriages totalled 10.4% and 11.4% recorded as divorced or separated. Living with others (no parent-child relationship) was 2%.

The full student cohort at both schools were required to participate in a well-being program as part of their school curriculum. From the entire sample, 76 students completed both the HRV testing and online assessments (65.4% female, *M*age = 15.31, *SD*=.52). The number of students participating in HRV was adversely affected by the requirement for students to 'opt in' to participate in HRV measurement and to provide additional consent from a parent or guardian, resulting in a lower number of students completing this element of the testing. The school curriculum for student participants included sport and physical education (PE) timetabled weekly for the full year cohort. However, specific information was not collected on students who were exempt from participation in school based physical activity nor was information collected for sporting activities undertaken in a social / community context. As noted previously, modifiable lifestyle factors such as physical activity, smoking and drinking, along with other factors including medication and stimulants, may impact

HRV results (Kim et al., 2018). Students were not required to provide details of smoking, drinking, medication or stimulant usage, details of sexual activity nor delinquent behaviour. The students involved in the study were from a general population, rather than a clinical population and therefore, mental and physical ill health would be expected to represent a similar proportion to that found in a general population. The consideration of these risk behaviours in typical and atypical students by Dong and Ding (2012) noted that the majority of adolescent's transition into adulthood without serious complication.

Measures

Connor-Davidson Resilience Scale

Participants completed the self-assessment measure of resilience as part of a battery of tests. Building on the theory of homeostasis, Connor and Davidson (2003) developed the CD-RISC incorporating questions to address control, commitment, change viewed as challenge, clear goals/aims, adaptability to change, social problem solving, humour, responsibility of response to an event, strengthening of capability post event, secure/stable affection bonds, and previous experience of success and achievement.

The scale comprised 10 items (example question: "I am able to adapt when change occurs"), scored using a 5-point Likert scale ranging from *not true at all* (1) to *true nearly all the time* (5), with higher scores reflecting higher levels of resilience. The tool has reported strong internal consistency with a Cronbach's alpha coefficient of 0.93 (Jokar, 2007).

Studies and meta-analysis of 19 subjective resilience tools (including Resilience Scale for Adults, Brief Resilience Scale, Adolescent Resilience Scale, California Healthy Kids Survey, Child and Youth Measure and Youth Resiliency:

Assessing Developmental Strengths) reported the CD-RISC had the strongest psychometric properties, with the clinical criteria for interpreting results (Madewell & Ponce-Garcia, 2016; Windle et al., 2011). This measure has a proven ability to capture variations after resilience programs (Davidson et al., 2005). The tool has broad applications in research studies that use clinical and general populations with a variety of age ranges, racial groups and mix of genders (Baek et al., 2010; Vaishnavi et al., 2007; Wang et al., 2010; Yu & Zhang, 2007). In particular, the tool has a demonstrated ability to capture changes in response to resilience building strategies (Weinberg & Tomyn, 2016).

Heart Rate Variability

Each participant was scheduled to complete the HRV assessment by a well-being or administrative staff member from their respective schools and was taken to the testing area at their allocated time. Testing sessions ran at 15-minute intervals between 8.45 am and 3.30 pm across the school day. Upon arrival, participants were provided with a brief outline of the procedure and verbal consent was obtained. Prior to testing, written consent was obtained by the student and their parent(s) or guardian. Participants who arrived late or at a time outside their scheduled appointment were seated in pairs or alone in a neutral, low stimulus waiting room and instructed to sit in silence (to facilitate a resting autonomic cardiac state), before being called individually for testing.

Participants were provided with a diagram and verbal instructions to self-administer disposable electrodes to the torso, placing them 1cm below each clavicle and on the lower ribcage (Bernston et al., 2007). A respiration strap was positioned firmly around the lower abdomen to capture the influence of respiration on heart rate, namely respiratory sinus arrhythmia (RSA) (Magagnin et al., 2010). Both were

checked by the researcher to ensure the strap was smooth and untangled. Electrodes were then connected, and both produced a recognisable beat pattern. To determine HRV and RSA at baseline, the electrocardiography (ECG) and respiration data were recorded by the researcher using a monitoring software package (NeXus-10, Mind Media, 2004-2006) to record the stability of participants' breathing throughout the testing period. For each participant, five minutes of continuous recording at a digitisation rate of 1000 Hz was obtained. This is the recommended best-practice method for recording short-term HRV (Quintana et al., 2016; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Short term recordings capture measures of resting-state HRV (tonic HRV). These recordings are thought to represent the summation of multiple psychological moments providing a strong marker for future health (Kemp et al., 2017).

Researchers have found participants record 9-24 breaths per minute, equating to a breathing frequency of 0.15 to 0.4 Hz or high frequency (HF) (Lehrer & Gevirtz, 2014). Throughout HRV data recording, participants observed a neutral breathing pacer program (Pranayama Universal Breathing) set at 9 breaths per minute to assist participants to regulate breathing. Experimental control of respiration is a recommended method to encourage respiration rates to remain constant and are captured within the high-frequency HRV band (Bernston et al., 1997). However, given evidence that unsuccessful attempts to regulate breathing can be a source of distress for individuals during RSA testing and nullify any potential benefit of respiratory control (Wilhelm et al., 2004), participants were provided with the instruction to "try out the breathing pacer, but if you find it uncomfortable or too difficult, just breathe at your own slow, regular pace. It is most important that you just

relax". During recording, ECG and respiration data were monitored by the researcher on a second computer screen which was concealed from the participant to reduce the possibility of confounding effects such as increased sympathetic arousal, distraction, or interruption of respiration or heart rate via biofeedback processes.

Resting HRV was evaluated using a spectral analysis of the high frequency component of the power spectrum (HF%, 0.15 – 0.40 Hz). Another alternative (yet short-term) time-frequency measure of HRV was recorded; the root mean square of successive differences (RMSSD) in R-R intervals. Values were expressed as the natural logarithm (Ln) of the original scores to enable a more normal distribution (Schaffer & Ginsberg, 2017). RMSSD is the preferred index of measurement due to its higher reliability compared to other frequency domain indices, particularly when using a single HRV measurement. Reliability of Ln RMSSD in 10 consecutive 5-minute trials reported an average typical error of 0.20 (90% CL: 0.18; 0.22) and a coefficient of variation of 9.9% (8.8; 11.3) in healthy young participants. Importantly, the typical error as a result of biological variation was deemed trivial, having no significant impact on HRV reliability (Cipryan, 2016). Silvetti et al. (2001) further support the use of RMSSD in their review of HRV in healthy children and adolescents. The assessment of HRV using RMSSD minimised the impact of other factors with no significant difference between male and female participants across the four age groups covering the range of 1-20 years. Whilst there were significant increases in RMSSD for the age ranges 1-5 years and 6-10 years, there was no significant increase for the age groups 11-15 years and 16-20 years. However, RMSSD was significantly related to body mass index (BMI).

Four consecutive minutes of HF-HRV recording was selected from the 5-minute recording period as a measure of baseline HF-HRV, with the first and final 30

seconds of the original recording removed to optimise relaxation, allow for breathing regulation, and to exclude setting-related disturbances such as the experimenter preparing or finalising the recording session.

Data was then pre-processed and manually edited for abnormal beats and artifacts (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Measurement artifacts were identified by applying a criterion threshold based on the distribution of an individual's heart rate and interbeat interval (IBI). A variance of 20% or greater of the previous beat-to-beat interval was treated as artifact and removed from analysis (Bernston et al., 2007; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Respiration was recorded to detect the stability of participants' breathing throughout the HRV recoding period. The raw data was checked, and all participants' respiration was found to be eligible. Calculations of time indices (the amount of HRV recorded during testing) and frequency domain values (amount of signal energy across four frequency bands), were undertaken with BioTrace statistical software (Shaffer & Ginsberg, 2017). Focusing on the peak frequency of the high frequency band of 0.15-0.40 Hz the values for RMSSD, HF, HF% and calculations of respiration data (mean, standard deviation) were derived for this study.

Psychological Well-being

Participants completed a multidimensional self-assessment of adolescent well-being, the EPOCH (Kern et al., 2016), as part of a battery of tests. This measure is an extension of Seligman's (2011) PERMA theory which measures five characteristics which enable flourishing in adulthood, namely: positive emotions, engagement, positive relationships with others, sense of meaning, and accomplishment. The

EPOCH measure was developed specifically for adolescents and has been tested across 10 samples and with 4,480 adolescents (aged 10-18 years) from Australia and the United States (Kern et al., 2016), and as such it is a relevant measure for this study. EPOCH consists of 25 questions with 5 items for each of the following subscales; Engagement (α=.78; example question: "When I do an activity, I enjoy it so much that I lose track of time"); Perseverance (α=.81; example question: "Once I make a plan to get something done, I stick to it*")*; Optimism (α=.86; example question: "I believe that I can do just about anything I set my mind to"); Connectedness (α=.88; example question: "There are people in my life who really care about me"); and Happiness (α=.90; example question: "I love life"). Questions are rated on a 5-point Likert scale from *almost never* (1) to *almost always* (5). Each subscale is averaged and reported as a profile across the domains with higher scores reflecting higher levels of well-being.

Positive Health

Students were asked a series of demographic questions relating to overall well-being. The questions customised for this study were based on the World Health Organisation (WHO) health questionnaire from 2011 and were selected as single items that provided a quantifiable result and minimised the burden on the participants who were already committed to answering a large battery of tests. The questions selected included:

- Physical health: "In general, I would say my physical health is excellent". Rated on a 6-point Likert scale from *not at all* (1) to *all of the time* (6).
- Sleep Quality (reverse scored): "How satisfied are you with your sleep quality?" Rated on a 7-point Likert scale from *extremely dissatisfied* (1) to *extremely satisfied* (7)

- Sleep Duration: “In the past month, on average how many hours sleep do you have each night?” Participants were asked to select the number from 1-15.
- Energy Levels: “Do you have enough energy to allow you to carry out your daily activities?” AND “Do you feel energised when you wake up in the morning?’ Both questions ranked on a 7-point Likert scale with students asked to respond to each question with *hardly ever* (1) to *almost daily* (7).

Procedure

Ethics approval for the study was obtained from the University of Melbourne Human Ethics Committee, as part of a broader research project. Written consent to participate in testing was obtained from both the participating student and their parent or legal guardian prior to commencement of testing. Testing was undertaken in two parts. The entire Year 10 student cohort for the two participating schools completed the online assessment as part of their well-being classes within the school curriculum. Well-being classes were separated into two categories; the customised positive education program ‘Learning to Flourish’ and the ‘well-being as usual program’. Testing was conducted by the classroom teacher and with the assistance of University of Melbourne researchers at three different time points. HRV testing was completed within a two-week period of the online assessments with specific consent for this testing required. This testing was conducted by the student researcher. HRV data was then checked for outliers via examination of frequency histograms. The data set was then log transformed to approximate a normal distribution for linear regression (Ellis et al., 2008).

Data Analysis

HRV monitoring and feedback was recorded using NeXus-10 BioTrace software (Mind Media, 2004-2006). Data was manually edited for abnormal beats and artifacts,

including spikes (electrode movement) and skips in heart beats. This is critical as even a single artifact may render the HRV data unreliable (Kaufmann et al., 2011). The defined criteria for artifact rejection was:

- IBIs that differ by more than 25% from the previous IBI, replacing it with interpolated data using (IBI[n]=(IBI[n-1]+IBI)/2)
- IBI values greater than the upper limit of 1500ms
- IBI values less than the lower limit of 500ms

The remaining four minutes of HRV data was then processed in full, HRV values in the high-frequency band (0.15-0.40 Hz) were extracted and the time domain measure of HRV was calculated using RMSSD (root mean square of successive differences). HF-HRV and RMSSD values were log transformed to better approximate a normal distribution and meet assumptions of linear regression (Ellis et al., 2008).

The Connor-Davidson RISC-10 as previously noted was scored on a 5-point scale (score range 1-5). These scores were re-coded for the item score range to be 0-4 as originally developed by Campbell-Sills and Stein (2007). This is to reflect the large number of studies that have used this range and to enable comparison to the findings of such studies. HRV and self-report data were entered into SPSS for all statistical analyses (version 26, IBM Chicago, IL, USA).

A series of Pearson bivariate correlations were conducted to determine the relationship between CD-RISC 10 and HRV (HF-HRV and RMSSD) well-being measures (EPOCH and physical health). A series of hierarchical multiple regression analyses were also conducted to determine the predictive strength of the resilience measures to each of the well-being measures. Step 1 included the covariates of gender

and age. Step 2 included the subjective and objective measures of resilience. All analyses performed were two-tailed and analysed at a significance level of $p < .05$.

Results

To investigate the relationship between objective and subjective measures of resilience a series of Pearson bivariate correlations were performed. Descriptive statistics for HRV, CD-RISC, well-being and demographic characteristics are presented below:

_____

Insert Table 1 about here

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Using the re-coded scores, the mean score for the CD-RISC 10 was 24.67 (*SD* 7.87). This score aligns with those reported in studies using similar student samples. The range of means reported were 24.8 to 27.2 (*SD* 5.8 to 6.8) (Campbell-Sills & Stein, 2007; DiFabio & Sakloske, 2014). The frequency-domain measure of HRV, HF-HRV, reported a mean of 7.64 (*SD* 1.06). The time domain measure of HRV, RMSSD, reported a mean of 4.08 (*SD* 0.52). These indices were calculated using the same methodology as Constantin et al. (2017), whose study included 25 parents of children aged between 7 and 12 years and reported HF-HRV with a mean of 6.02 (*SD* 0.84) and RMSSD with a mean of 6.72 (*SD* 0.86).

The subjective measure of well-being, EPOCH, reported the following: Engagement (*M* = 3.31, *SD* = .84); Perseverance (*M* = 3.21, *SD* = .89*)*; Optimism (*M* = 3.31, *SD* = 1.00); Connectedness (*M* = 3.81, *SD* = .97); and Happiness (*M* = 3.60, *SD* = 1.00). Comparatively, an Australian Grammar School student sample of 746 (Age *M* = 14.22, *SD* = 1.96) reported the following: Engagement (*M* = 3.20, *SD* = .73); Perseverance (*M* = 3.40, *SD* = .82*)*; Optimism (*M* = 3.26, *SD* = .85);

Connectedness (*M* = 4.18, *SD* = .84); and Happiness (*M* = 3.98, *SD* = .94) (Kern et al., 2016). Physical well-being, as measured by hours of sleep, reported a mean of 7.39 (*SD* 2.15). This result aligns to the National Sleep Foundation 2016 report of adolescents averaging 7.02 to 7.36 hours sleep per night.

The results of Pearson's bivariate correlations showed that there was no significant relationship between the subjective measure of resilience and the objective measure of resilience (HF-HRV: $r = -.00$, $p > .05$) (RMSSD: $r = -.08$, $p > .05$). Significant positive relationships were found between CD-RISC 10 and the EPOCH subscale Optimism ($r = .68$, $p < .01$), EPOCH subscale Happiness ($r = .64$, $p < .01$) and the EPOCH subscale Perseverance ($r = .59$, $p < .01$). The weakest relationship exists for CD-RISC 10 and the physical health measure Hours of Sleep (HoS) ($r = .13$, $p < .05$).

Correspondingly, no bivariate correlation between HRV and any measure of well-being was significant. A correlation matrix of HRV, CD-RISC 10 and well-being is presented in Table 2. When interpreting this table, it is important to note the students involved in HRV totalled 76 as opposed to 282 students for all other measures.

Insert Table 2 about here

Preliminary data analyses were conducted to ensure all assumptions of hierarchical multiple regression were not violated (Tabachnick & Fidell, 2007). Controlling for age and gender, multiple hierarchical regression analyses revealed that CD-RISC 10 was the most important predictor of psychological well-being (measured by EPOCH) which uniquely explained variation in the following: Engagement (42%),

Perseverance (37%), Optimism (37%), Connectedness (50%), and Happiness (50%). Effects sizes were large as measured by semi-partial correlations squared (sr^2). HRV did not significantly predict psychological well-being. A summary of the full hierarchical regression models is presented in Table 3.

Insert Table 3 about here

Controlling for age and gender, multiple hierarchical regression analyses revealed that CD-RISC 10 was the most significant predictor of physical well-being which uniquely explained variation in the following: Quality of Sleep (20%), Energy for Daily Activities (27%), Wake feeling Energised (20%). Effects sizes were large as measured by semi-partial correlations squared (*sr*2). CD-RISC 10 did not significantly predict Hours of Sleep. HRV did not significantly predict physical well-being. A summary of the full hierarchical regression models is presented in Table 4.

Insert Table 4 about here

Discussion

The first question of this study was to examine the relationship between subjective and objective measures of resilience in a general adolescent sample. In the current study CD-RISC 10 and HRV, both considered measures of resilience (Leher & Gevirtz, 2014; Madewell & Ponce-Garcia, 2016; Windle et al., 2011), were not found to have a relationship and as such are not considered a suitable proxy for each other.

The results for this cohort using the subjective measure of resilience aligned with the findings from the body of literature as highlighted in the following studies: The mean score range for undergraduate students (n=1,622) in the study by Campbell-Sills and Stein (2007) was 27.21 (SD 5.84); DiFabio and Sakloske's (2014) study of 164 high school students reported a mean of 24.8 (6.2); Markovitz and colleagues 2014 study (as cited in Davidson, 2018) of Dutch students (n=254) calculated a mean of 25.7 (SD 6.8); and the study by Lim et al. (2011) of 190 adolescents (ranging from 12-16 years) from Singapore had a mean score of 27.9. Scores vary according to country and are generally lower for students than the general population where scores range from 29.0 (*SD* 0.1) to 33.5 (*SD* 6.2) (Davidson, 2018). This lends further support to the meta-analysis conducted by Gheshlagh et al. (2017), reporting that resilience and mental health were lower in students than in other populations. The importance of measuring and developing resilience and promoting mental health for adolescents is further highlighted when considering the expectation that anxiety and depression will be the most common diseases by 2030, with one in five people in the world suffering from a mental disorder (Gheshlagh et al., 2017).

The results from the objective measure were more difficult to interpret. The majority of the literature suggests that a higher HRV score is associated with a higher level of resilience, yet; there is no definitive scale to determine low, medium or high scores. This is reflective of the inconsistency of many studies to follow the protocol of the Task Force Standards on HRV (established in 1996) and the 2015 New Joint Position Statement on the advances in HRV (Bobskowski, et al., 2017). In addition, studies on the relationship of HRV as an indicator of resilience and well-being are still relatively low in number, with small numbers of adult participants.

The HRV measures of HF-HRV and RMSSD, as used in this study, have been associated with a global measure of subjective health (Jarczok et al., 2015). However, studies using HRV to assess indices of well-being have also failed to reach significance, raising questions as to the suitability of HRV to be applied beyond cardiac autonomic function (Sloan et al., 2017).

The inconsistency of results across the body of literature may in fact lie in the very constructs being measured. HRV directly captures changes in intervals between heart beats, changes in intervals reflective of the stress an individual may feel at a point in time. Thus, it could be postulated that HRV may be more accurately measuring the ability to cope (the application of cognitive and behavioural strategies enabling an individual to deal with a stressful situation) and reflects the capacity for developing resilience. Whereas, the subjective measure of resilience captures an individual's cognitive assessment of their ability to align heart (emotions), mind (thinking) and spirits (goals) informed by the successful adaptation and growth from previous challenges and setbacks. The terms coping and resilience are often used interchangeably and whilst they are related, they remain distinct (Campbell-Sills et al., 2006; Meneghel et al., 2019).

Resilience is an extension of coping where there is an adaptation to adverse events that in turn provides higher levels of coping and/or inoculation to stress. The study conducted by O'Dowd et al. (2018) of physicians noted that many of the professionals interviewed defined resilience as coping. Many of the strategies utilised to deal with stressors (long shifts, high workloads and poor sleep) are coping behaviours to protect against burnout and stress and not resilience practices. This is clearly evident in one participant's quote, "resilience, I suppose, is your ability to deal with setbacks and bumps in the road without falling apart". This definition does not

encompass the state of thriving, with the study noting that only 6% of participants recognised resilience as the use of strategies to develop and adapt to challenges, to thrive in spite of difficulty. Additionally, only 32% of participants noted that resilience encompassed the ability to maintain good mental health, well-being and happiness. This distinction of the role of coping and the subsequent development of resilience may explain why many of the studies that do find a relationship between HRV and resilience report small to very small levels of significance. Just because HRV is viewed as a biological marker of stress, it does not automatically translate to a marker of resilience as defined within this study. The psychophysiological pathways between stress, adaptation (cardiovascular response) and health remain unclear despite the large number of studies that link stress, psychological and social functioning to health and well-being (Hughes et al., 2018). Thus, there does not seem to be any clarity of how these pathways relate to resilience. In defining resilience as the adaptation and growth of body, mind and spirit in response to current life circumstances (Connor & Davidson, 2003), the results of this study highlight the potential benefit of an objective measurement (HRV) to complement the use of subjective assessment (CD-RISC 10) but the two tools should not be used interchangeably.

Given the small body of literature, consideration must be given to the differences in cohorts, age, gender and various measures of HRV used within studies. In terms of cohorts, a large proportion of HRV research has focused on clinical populations including sufferers of congenital heart defects and disease, Attention Deficit Hyperactivity Disorder (ADHD) and Type 1 diabetes. Few studies have been undertaken on general populations and fewer still on general adolescent samples.

The second question of this study was to determine which of the two measures explained the greatest variance in well-being. The subjective measure significantly predicated numerous measures of well-being, which included EPOCH (Engagement, Perseverance, Optimism, Connectedness and Happiness) and self-assessments of positive health, after controlling for age and gender, with large effect size. Thus, higher scores of resilience would be indicative of higher levels of well-being. The objective measures (HF-HRV and RMSSD) were not significantly correlated and did not predict any measure of well-being.

CD-RISC reported the largest unique contribution to well-being. The strongest of all measures was optimism. It is expected that individuals who have a high level of resilience will have correspondingly high levels of optimism, as positive expectations about the future buffer against feelings of distress when faced with adversity. Optimism enables individuals to actively persist and move forward from events, more so than individuals who are pessimistic about the future (Tusaie et al., 2007). The negativity bias results in individuals feeling fearful, isolated and pessimistic (MacConville & Rae, 2012; Seligman, 2011). The ability to reframe from pessimistic thinking to a more adaptive positive thinking style is an important aspect in the development of resilience given the human brain's negative default position.

Happiness also demonstrated a strong relationship with resilience. Everly and Brown (2009) hypothesised that an individual's ability to have low or high resilience may be related to either being happy or regretful. The broaden and build theory suggests that resilience and the impact on positive emotions increased life satisfaction (Cohn et al., 2009). In short, being resilient promotes happiness.

It is interesting to note that optimism and happiness had a stronger relationship to resilience than perseverance. When asked to define resilience, the majority of

individuals think of grit, determination and perseverance before optimism and happiness. Kern et al. (2016) reported that grit, whilst mostly associated with Perseverance, was also associated with Optimism and Engagement. In addition, physical activity was more strongly related to Perseverance, Optimism and Happiness than the other EPOCH subscales. This was also supported in this study with EDA and WFE showing the strongest relationships with Perseverance, Optimism and Happiness.

Of the physical health measures considered in this study, the weakest relationship was found between subjective resilience and sleep, namely the quality of sleep and sleep duration. As discussed earlier this is reflective of the low levels of sleep duration and quality experienced by adolescents. Unfortunately, the strength of self-assessment for resilience does not translate to accuracy of self-assessment for sleep. The majority of sleep research has been conducted using self-report measures, with some measures consisting of a single question. Objective measurement is conducted through a sleep laboratory with sleep monitored through a polysomnography. Whilst cost effective, self-report measures are not well calibrated with sleep duration and on average are over-reported by 31 minutes compared to an objective measure of sleep. Therefore, the use of self-reported sleep may overestimate the measurement of physical health and any associations with other constructs including resilience (Arora et al., 2013; Lauderdale et al., 2008).

Consideration must also be given to the possibility that the variation between the objective and subjective measures may lie in the self-report questionnaire responses which may have been influenced by the participant's desire for social approval and conformity to social conventions (Crown & Marlowe, 1960). This is a common bias that impacts self-assessment. Given the propensity of adolescents to

seek acceptance, it is possible that responses may be pre-empted to fit a socially desirable view of what is accurate and avoid responses that truly reflect themselves (McElhaney et al., 2008; Oleson et al., 2000; Schriber & Guyer, 2016). The implication of this would be that the comparison of self-assessment levels of resilience to self-assessment levels of well-being could be influenced by the same bias. The use of an objective measure would negate this bias and hence may result in the discrepancy between two measures of the same construct.

Differences between the subjective and objective measures may also exist due to cognitive capacity of the participants who may or may not have a full understanding of the meaning of the questions being asked of them. Previous studies have highlighted that young people who report low levels of emotion regulation (ER) are not in tune with how they are truly feeling and therefore cannot answer the self-report resilience questions with understanding (Duckworth & Yeager, 2015). The benefit of an objective measure of resilience is that it removes the need for understanding and insight.

Limitations

Several limitations of this study should be noted. This is a single study and as such is unable to provide conclusive findings. The study may be limited by several factors; the sample consisted largely of Australian born, English speaking adolescents, with no allowance for racial differences (Faulkner et al., 2003); a small sample size for HRV data collection; and environmental and personal factors that may influence HRV in a real-world study. Environmental factors may include variation in the time of assessment (time slots were allocated across the school day), location of testing (dependent on room availability), disruption due to school bells signifying change in lessons, recess, lunch and end of school, movement in corridors between

lessons, and access to the testing space by other students. Personal factors may include variation in student movement during testing, body mass index, possible caffeine, nicotine, and/or medication use by students (Quintana & Heathers, 2014). These limitations restrict the generalisability of the present findings. Replication of the study in other contexts, with multiple data points and larger samples is necessary. It is important to acknowledge that few studies have been conducted to examine this relationship. Hence, this study can promote further, better quality studies in this much needed field.

Implications for Schools

The construct of resilience has increasingly been a topic of interest within education settings, as schools are recognised as an ideal place to promote positive outcomes for students beyond academic achievement. Thus, the measurement of resilience is necessary to determine current levels of functioning and to inform program development to support mental health and well-being for students. The suitability of any measure is subject to the question being investigated. Given the varied terms and definitions of resilience (e.g. stress resilience, emotional resilience, developmental resilience, academic resilience) within the body of literature, clarity of what is being measured is critical. The current study highlights the need for careful selection of measurement tools for examining resilience. Validated self-report measures, such as the CD-RISC10, provide robust data to ascertain resilience levels and are statistically significant in the ability to predict associated levels of well-being.

In the pursuit of improved adolescent resilience there has been increased attention to and measurement of physiological responses, such as sleep duration. Whilst, the current study did not find a relationship between the subjective and objective measure of resilience, the use of HRV to measure the impact of stress and

the effectiveness of coping may provide a wholistic view for student performance. However, there is need for caution in the use of this measure. The increased interest of HRV has resulted in a number of apps and wearable devices offered in the market. The result of this is a mode of measurement that is portable, affordable and able to be utilised in large numbers (e.g. a class). Whilst these devices are similar, they are not the same as clinical measurement, often relying on a single data point (pulse) that is captured on the wrist. The accuracy of these devices is still being debated and caution is recommended for the following reasons: devices are not formally validated against an ECG, standard metrics for reporting are not available with results often calculated using a proprietary metric, no access to raw data and no regulatory body assessing the reliability and validity of these devices exists (Quintana et al., 2016).

Conclusion

In summary, the current study provides clear support for the use of a subjective measure of resilience to determine the current levels of adolescent resilience and provide a strong predictive marker of psychological well-being. The use of HRV to predict psychological well-being was not supported. In addition, the study findings highlight that the subjective and objective measure of resilience have a marked difference in the definition of the construct being investigated, with the CD-RISC measuring resilience as the positive adaptation and growth after adversity and HRV thought to be measuring stress resilience or coping. Given this finding, it is possible that HRV does not measure resilience but the capacity for resilience. The use of HRV to measure capacity for resilience needs further exploration as such information that can provide depth and insight and depth into a wholistic view of resilience, in particular the psychophysical responses to stress. Future studies should

explore further the relationship between subjective and objective measures of resilience using a more representative sample of adolescents.

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Table 1: *Descriptive Properties for Demographic Characteristics, Resilience and Well-being Measures*

Measures	M	SD	Actual Data Range
Age (years)	15.32	.52	14-17
EPOCH-E	3.31	0.84	1-5
EPOCH-P	3.21	0.89	1-5
EPOCH-O	3.31	1.00	1-5
EPOCH-C	3.81	0.97	1-5
EPOCH-H	3.60	1.00	1-5
QoS	4.24	1.69	1-7
HoS	7.39	2.15	2-13
EDA	4.67	1.77	1-7
WFE	3.34	1.85	1-7
CD-RISC 10	24.67	7.87	8-40
HF-HRV	7.64	1.06	5.51-10.15
RMSSD	4.08	0.52	2.40-4.81

Note. N = 282, HRV participants *N* = 76. CD-RISC 10 = Connor Davidson Resilience Scale; HF-HRV = log transformed high frequency heart rate variability; RMSSD= log transformed root square of successive differences; EPOCH-E = EPOCH emotion subscale; EPOCH-P = EPOCH perseverance subscale; EPOCH-O = EPOCH optimism subscale; EPOCH-C = EPOCH connectedness subscale; EPOCH-H = EPOCH happiness subscale; QoS = Quality of sleep; HoS = Hours of Sleep; EDA = Energy for daily activities; WFE = Wake feeling energised.

Table 2: *Correlations matrix for resilience and well-being measures*

Measures	1	2	3	4	5	6	7	8	9	10	11	12
1. EPOCH-E	-											
2. EPOCH-P	.78**	-										
3. EPOCH-O	.76**	.79**	-									
4. EPOCH-C	.63**	.61**	.69**	-								
5. EPOCH-H	.69**	.69**	.83**	.71**	-							
6. QoS	.25**	.31**	.34**	.17**	.33**	-						
7. HoS	.10	.15**	.13*	.02	.17**	.55**	-					
8. EDA	.42**	.49**	.52**	.35**	.47**	.51**	.29**	-				
9. WFE	.34**	.60**	.48**	.24**	.38**	.54**	.33**	.63**	-			
10. CD-RISC	.56**	.59**	.68**	.54**	.64**	.27**	.13*	.52**	.36**	-		
11. HF-HRV	.07	.11	.07	.07	.05	-.11	.02	-.07	-.05	.00	-	
12. RMSSD	.06	.07	.03	.03	.01	-.14	.06	-.09	-.07	-.08	.89**	-

Note. CD-RISC = Connor Davidson Resilience Scale; HF-HRV = log transformed high frequency heart rate variability; RMSSD= log transformed root square of

successive differences; EPOCH-E = EPOCH emotion subscale; EPOCH-P = EPOCH perseverance subscale; EPOCH-O = EPOCH optimism subscale; EPOCH-C = EPOCH connectedness subscale; EPOCH-H = EPOCH happiness subscale; EDA = Energy for daily activities; WFE = Wake feeling energised. * $p<.05$, ** $p<.01$

Table 3: *Hierarchical Multiple Regression Models Examining Subjective and Objective Resilience with respect to Adolescent Psychological Well-Being (EPOCH dimensions)*

Hierarchical regression step	EPOCH Engagement	*B*	*b*	*t*	*p*	95% CI for Lower	95% CI for Upper
Model 1	Gender	-.29	-.17	-1.42	.16	-.70	.12
	Age	.08	.05	.43	.67	-.29	.46
R^2 = .03 (p = .28)							
F = 1.28 (p = .28)							
Model 2	CD-RISC	.07	.67	7.27	**< .001**	.05	.09
	HF-HRV	-.06	-.08	-.39	.70	-.37	.25
	RMSSD	.25	.16	.79	.43	-.39	.91
R^2 change = .42 (p < .001)							
F = 11.67 (p < .001)							
Average VIF = 1.09							
Hierarchical regression step	EPOCH Perseverance	*B*	*b*	*t*	*p*	95% CI for Lower	95% CI for Upper
Model 1	Gender	-.04	-.02	-.16	.88	-.51	.44
	Age	.26	.14	1.22	.23	-.17	.70
R^2 = .02 (p = .44)							
F = .83 (p = .44)							
Model 2	CD-RISC	.07	.63	6.58	**< .001**	.05	.09
	HF-HRV	-.03	-.04	-.18	.86	-.40	.33
	RMSSD	.35	.19	.91	.37	-.42	1.12
R^2 change = .39 (p < .001)							
F = 9.70 (p < .001)							
Average VIF = 1.09							
Hierarchical regression step	EPOCH Optimism	*B*	*b*	*t*	*p*	95% CI for Lower	95% CI for Upper
Model 1	Gender	-.32	-.15	-1.27	.21	-.51	.44
	Age	.16	.08	.68	.50	-.17	.70
R^2 = .03 (p = .29)							
F = 1.27 (p = .29)							
Model 2	CD-RISC	.10	.80	10.50	**< .001**	.08	.12
	HF-HRV	-.07	-.07	-.45	.66	-.38	.24
	RMSSD	.30	.15	.92	.36	-.35	.96
R^2 change = .60 (p < .001)							

***F* = 23.76 (*p* < .001)**
Average VIF = 1.09

Note. Significant relationships are presented in bold font.

Table 3 (continued)

Hierarchical Multiple Regression Models Examining Subjective and Objective Resilience with respect to Adolescent Psychological Well-Being (EPOCH dimensions)

Hierarchical	EPOCH					95% CI	
regression step	Connectedness	*B*	*b*	*t*	*p*	Lower	Upper
Model 1	Gender	.38	.21	1.78	.08	-.04	.80
	Age	-.04	-.02	-.21	.84	-.43	.34
R^2 = .05 (*p* = .18)							
F = 1.76 (*p* = .18)							
Model 2	CD-RISC	.08	.72	8.46	**< .001**	.06	.09
	HF-HRV	-.06	-.07	-.40	.70	-.35	.24
	RMSSD	.22	.13	.70	.48	-.40	.84

R^2 change = .49 (*p* < .001)
***F* = 15.93 (*p* < .001)**
Average VIF = 1.09

Hierarchical	EPOCH					95% CI	
regression step	Happiness	*B*	*b*	*t*	*p*	Lower	Upper
Model 1	Gender	-.18	-.08	-.71	.48	-.69	.30
	Age	.08	.04	.35	.73	-.39	.55
R^2 = .01 (*p* = .69)							
F = .38 (*p* = .69)							
Model 2	CD-RISC	.09	.73	8.37	**< .001**	.07	.11
	HF-HRV	-.24	-.03	-.13	.90	-.38	.34
	RMSSD	.13	.07	.35	.73	-.63	.89

R^2 change = .50 (*p* < .001)
***F* = 14.61 (*p* < .001)**
Average VIF = 1.09

Note. Significant relationships are presented in bold font. CD-RISC = Connor Davidson Resilience Scale; HF-HRV = log transformed high frequency heart rate variability; RMSSD= log transformed root square of successive differences.

Table 4: *Hierarchical Multiple Regression Models Examining Subjective and Objective Resilience with respect to Adolescent Physical Well-Being*

Hierarchical regression step	Quality of Sleep	*B*	*b*	*t*	*p*	95% CI Lower	95% CI Upper
Model 1	Gender	-.81	-.23	-1.96	.05	-1.64	.01
	Age	.08	.02	.20	.84	-.68	.83
R^2 = .06 (p = .13)							
F = 2.11 (p = .13)							
Model 2	CD-RISC	.10	.47	4.44	**< .001**	.05	.14
	HF-HRV	-.05	-.03	-.14	.89	-.77	.67
	RMSSD	-.41	-.12	-.54	.59	-1.92	1.10
R^2 change = .23 (p < .001)							
F = 5.56 (p < .001)							
Average VIF = 1.09							
Hierarchical regression step	Hours of Sleep	*B*	*b*	*t*	*p*	95% CI Lower	95% CI Upper
Model 1	Gender	-.68	-.18	-1.55	.13	-1.55	.20
	Age	.33	.10	.82	.41	-.47	1.13
R^2 = .05 (p = .16)							
F = 1.87 (p = .16)							
Model 2	CD-RISC	.04	.19	1.61	.11	-.01	.09
	HF-HRV	-.33	-.20	-.78	.44	-1.18	.52
	RMSSD	.95	.28	1.06	.29	-.84	2.75
R^2 change = .05 (p = .34)							
F = 1.44 (p = .22)							
Average VIF = 1.09							

Note. Significant relationships are presented in bold font.

Table 4 (continued)

Hierarchical Multiple Regression Models Examining Subjective and Objective Resilience with respect to Adolescent Physical Well-Being

Hierarchical regression step	EDA	*B*	*b*	*t*	*p*	95% CI Lower	95% CI Upper
Model 1	Gender	-.23	-.06	-.53	.60	-1.10	.64
	Age	.15	.05	.39	.70	-.64	.95
R^2 = .01 (p = .77)							
F = .27 (p = .77)							
Model 2	CD-RISC	.11	.54	5.10	**< .001**	.07	.16
	HF-HRV	-.19	-.12	-.52	.61	-.93	.55
	RMSSD	.10	.03	.13	.90	-1.45	1.65
R^2 change = .28 (p < .001)							
F = 5.51 (p < .001)							
Average VIF = 1.09							
Hierarchical regression step	WFE	*B*	*b*	*t*	*p*	95% CI Lower	95% CI Upper
Model 1	Gender	-.32	-.08	-.69	.49	-1.23	.60
	Age	.14	.04	.34	.74	-.70	.98
R^2 = .01 (p = .70)							
F = .36 (p = .70)							
Model 2	CD-RISC	.10	.46	4.20	**< .001**	.05	.15
	HF-HRV	-.11	-.06	-.27	.79	-.92	.70
	RMSSD	-.01	.00	-.01	1.00	-1.72	1.71
R^2 change = .21 (p < .01)							
F = 3.82 (p < .01)							
Average VIF = 1.09							

Note. Significant relationships are presented in bold font. CD-RISC = Connor Davidson Resilience Scale; HF-HRV = log transformed high frequency heart rate variability; RMSSD= log transformed root square of successive differences EDA = Energy for Daily Activities, WFE= Wake Feeling Energised.