Feeling Stressed Out? Re-Thinking the Conceptualization and Measurement of Stress in Children and Adolescents

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ABSTRACT

Feeling Stressed Out? Re-Thinking the Conceptualization and Measurement of Stress in Children and Adolescents

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Stress is an important determinant of health across the lifespan. Stress is a ubiquitous term that captures several interrelated constructs that are often examined in isolation, including stressor exposure, psychological response, and physiological response to stressors. Existing research with children and adolescents has predominantly focused on stressful life events (particularly event count) as the sole indicator of stressor exposure. Other stressor attributes (i.e., timescales, chronicity, life domains, severity of stressful life events) may be inconsistently measured in existing pediatric measures. There is far less research attention on global subjective stress in children and adolescents, a measure of one's psychological response. Moreover, there is a paucity of research disentangling differences in the conceptualization and measurement of stressful life events and global subjective stress, and how that may decipher their disparate associations with health outcomes. The overarching goal of this research programme was to refine the conceptualization and measurement of stressor exposure and psychological response in children and adolescents.

Three complementary studies were conducted. Study 1, a systematic review, outlined the historical context of major milestones and paradigm shifts in the conceptualization and measurement of stress, and synthesized available pediatric stress measures. Study 1 showed that the majority of measures assess stressor exposure, particularly life events, with few measures examining psychological stress; and, stressor attributes were not comprehensively assessed in these measures (e.g., assessment timeframes chronicity, life domains, severity). Study 2 demonstrated the predictive utility of improving select stressor attributes in the measurement of stressful life events. Yet, even after improving these stressor attributes, global subjective stress still better predicted a range of health outcomes, compared to stressful life events. Study 2 also demonstrated that the stress and health association may be inflated due to mono-informant bias. Using a longitudinal, repeated-measures design, Study 3 suggested that global subjective stress

may be a less dynamic construct than originally conceptualized, and demonstrated stable individual differences in adolescents' global subjective stress.

Overall, the current dissertation programme aimed to harmonize the vast literature on childhood and adolescent stress, and to address select gaps related to the conceptualization and measurement of stressor exposure and psychological response. Research to further dissect the construct of global subjective stress is warranted. This line of inquiry has important implications for the field of stress science.

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CONTRIBUTION OF AUTHORS

For Studies 1-3, Jinshia Ly developed the research questions, conducted the literature review, collected, cleaned, and synthesized data, undertook the statistical analyses, interpreted the results, and wrote and revised manuscripts. As Jinshia's research supervisor, Dr. Jennifer J. McGrath co-developed the research questions, obtained grant funding support from the Canadian Institutes of Health Research, collected research data, coordinated research data management, supervised the statistical analyses and results interpretation, and revised manuscripts.

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LIST OF ABBREVIATIONS

ACE……..Adverse Childhood Experience

APA……American Psychological Association

APES ……Adolescent Perceived Events Scale

ASQ……Adolescent Stress Questionnaire

AUC_{TG}…… Area Under the Curve Total Relative to Ground

BMI……....Body Mass Index

CASE……...Child and Adolescent Survey of Experiences

CBCL……Child Behavior Checklist

CSQ……Child Stress Questionnaire

DBP……Diastolic Blood Pressure

EBA……..Evidence-Based Assessment

HDL……..High Density Lipoprotein

ICC……....Intra-Class Correlation

LDL……....Low Density Lipoprotein

LEC……..Life Events Checklist

LEDS……..Life Events and Difficulties Schedule

LER……Life Events Record

PACE……Psychological Assessment of Childhood Experiences

PSS……Perceived Stress Scale

SBP……...Systolic Blood Pressure

SLES……..Stressful Life Events Schedule

GENERAL INTRODUCTION

The current research programme is comprised of three complementary studies, which together focus on refining the conceptualization and measurement of stress in children and adolescents. In the following background sections of this general introduction, first, definitional issues related to the multidimensional construct of stress are discussed to highlight the complexity of stress measurement. Second, the vast literature on the intersection between stress and health outcomes is succinctly reviewed to provide context for pediatric research. Third, selected pediatric findings on stress are reviewed to highlight existing knowledge gaps relevant to the conceptualization and measurement of stress during childhood and adolescence. Finally, the broad aims of this research programme are presented.

Stress: A Multidimensional Construct

Stress is a ubiquitous term used to refer to a state of threatened homeostasis. In fact, stress encompasses a set of interrelated constructs, including stressor exposure, psychological response, and physiological response to such exposure (Cohen, Kessler, & Gordon, 1995; Epel et al., 2018). Stressor exposure is commonly quantified by measuring exposure to life events (i.e., event count) that are consensually judged as threatening, such as divorce, family death, and job loss, among others (Brown & Harris, 1989; Holmes & Rahe, 1967). Stressor exposure is also sometimes derived by measuring exposure to daily hassles and microstressors, which are minor nuisances and demands common to everyday life (e.g., daily arguments, traffic, losing things; Kanner, Coyne, Schaefer, & Lazarus, 1981). Psychological stress response can be specific or general. Specific psychological response is derived by measuring the level of severity, intensity, threat, or negative impact associated with endorsed stressor exposure. General psychological response (i.e., global subjective stress) taps into an individual's perception of how demanding their life is, and is commonly quantified using the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983). Physiological stress response is derived from reactivity or changes to the autonomic nervous system, sympathetic-adrenal medullary system, and hypothalamus-pituitary-adrenal axis.

Intersection of Stress and Health Outcomes

Adult Health Outcomes. A vast body of research has demonstrated stress is an important determinant of health in adults. Although stress is not predictive of *all* health outcomes, studies have linked stressor exposure, psychological response, and physiological

stress response with a myriad of health conditions that carry substantial burden of morbidity and mortality (Cohen, Janicki-Deverts, & Miller, 2007; Cohen, Gianaros, & Manuck, 2016). In adults, exposure to stressful life events prospectively predicts prodromal symptoms, clinical onset, and subsequent recurrences of clinical depression and anxiety (Cohen et al., 2007; Gotlib & Joormann, 2010; Monroe & Reid, 2009; Williamson et al., 1998). Mounting systematic review and meta-analytic findings from the Adverse Childhood Experiences (ACE) literature have evidenced that exposure to stressful life events in childhood is associated with depression, ischemic heart disease, cancer, hepatitis, lung diseases, and early mortality in adulthood (Chapman et al., 2004; Chartier, Walker, & Naimark, 2010; Felitti et al., 1998; Flaherty et al., 2013; Hanson & Chen, 2010; Lampert et al., 2016; O'Donovan, Neylan, Metzler, & Cohen, 2012; Repetti, Taylor, & Seeman, 2002). A meta-analysis of prospective studies found that adults reporting higher levels of global subjective stress are at 27% increased risk of developing cardiovascular diseases over an average of 13 years (Richardson et al., 2012). Disruptions of autonomic and neuroendocrine functioning have been associated with cardiovascular precursors, including hypertension, obesity, and cholesterol (Bao, Threefoot, Srinivasan, & Berenson, 1995; Steptoe & Kivimäki, 2012). Altogether, there is compelling evidence for the etiological role of stress in health outcomes during adulthood.

Child and Adolescent Health Outcomes. Examining stress among children and adolescents is paramount given the evidence that the etiological role of stressor exposure on health outcomes evolves early during the lifecourse. Considerable research has indicated a cross-sectional association between stressor exposure and adverse health outcomes during childhood and adolescence. These negative health outcomes include internalizing and externalizing behaviours (Grant et al., 2003; Malone et al., 2004), asthma attacks (Oren, Gerald, Stern, Martinez, & Wright, 2017), obesity (De Vriendt, Moreno, & De Henauw, 2009; Garasky, Stewart, Gundersen, Lohman, & Eisenmann, 2009), and poorer parent-/self-rated health (Boynton-Jarrett, Ryan, Berkman, & Wright, 2008). Greater exposure to stressful life events also predicts onset of clinical depression and anxiety in children and adolescents (Allen, Rapee, & Sandberg, 2008; Goodyer, Park, & Herbert, 2001), as well as slower recovery from treatment (Willemen, Koot, Ferdinand, Goossens, & Schuengel, 2008). Altogether, there is a robust association between stressor exposure and health outcomes during childhood and adolescence.

Evidence from available cross-sectional and prospective studies support an association between global subjective stress and adverse health outcomes during childhood and adolescence. Adolescents reporting higher global subjective stress have more depressive symptoms (Lu et al., 2014; Martin, Kazarian, & Breiter, 1995; Williams, Turner-Henson, Davis, & Soistmann, 2017), elevated anxiety symptoms (Lu et al., 2014), larger weight status (Van Jaarsveld, Fidler, Steptoe, Boniface, & Wardle, 2009), and greater asthma severity (Lu et al., 2014). Global subjective stress is less commonly examined in school-aged children, but it has been associated with poorer sleep quality, shorter sleep duration, and disrupted diurnal cortisol (Ly, McGrath, & Gouin, 2015). Together, these findings suggest the relevance of considering global subjective stress in children and adolescents.

Current Dissertation: Focus During Childhood and Adolescence

The current research programme focuses on the measurement and conceptualization of stress during the periods of childhood and adolescence for several methodological reasons. First, studies with children and adolescents examining stress and health has predominantly focused on stressor exposure. Further, these existing studies rely almost exclusively on the measurement of event count as the indicator of stressor exposure. Epel and colleagues' recent Integrated Lifespan Model of Stress and Health proposed consideration of additional attributes in the measurement of stressor exposure, such as *timeframe* (e.g., events in the last year, month, or day), *proximity* (e.g., time lapse between actual exposure and reporting of stressor), *timescale* (e.g., acute versus chronic stressor), *chronicity* (e.g., duration, frequency), *life domain* (e.g., family, health, employment), and *severity* (e.g., objective measure of threat, subjective appraisal of intensity; Epel et al., 2018). These additional stressor attributes are important; for example, more severe life events have been associated with increased risk of asthma attacks in children, and risk is magnified for children who experience multiple chronic stressors (Sandberg et al., 2000). Uncontrollable events or events involving loss in relationships were more prevalent among depressed and anxious children than normal controls (Williamson, Birmaher, Dahl, & Ryan, 2005). Although stressor attributes may add to the prediction of health outcomes, stressor attributes have been inconsistently assessed across measurement tools and across studies in children and adolescents.

Second, extant child and adolescent findings have examined stressor exposure or psychological response in isolation; their relation to one another remains largely unclear. There

is a need to disentangle these two constructs for a more precise lens through which to interpret the literature. In children and adolescents, compared to life events, global subjective stress better predicts dysregulation of diurnal cortisol (Ly et al., 2015), more sleep problems (Ly et al., 2015), and greater depressive symptoms (Martin et al., 1995). These findings raise the question as to why global subjective stress is a better predictor of health outcomes than life events. It remains unclear whether the disparate results are due to differences in the conceptualization and measurement of stressor exposure versus global subjective stress.

Third, a knowledge gap remains related to the broader construct of general psychological response. Recent adult findings suggest that global subjective stress may reflect a stable individual difference. For example, individuals high in trait neuroticism tend to perceive stressful situations as highly threatening with low coping resources, compared to those with lower trait neuroticism (Ebstrup, Eplov, Pisinger, & Jørgensen, 2011; Mroczek & Almeida, 2004). As well, individuals with low general self-efficacy report higher global subjective stress than individuals with high self-efficacy (Chemers, Hu, & Garcia, 2001). Available longitudinal findings suggest that global subjective stress demonstrates moderate to high stability (r=0.63-.90; Almadi, Cathers, Hamdan Mansour, & Chow, 2012; Chaaya, Osman, Naassan, & Mahfoud, 2010; Remor, 2006; Siqueira Reis, Ferreira Hino, & Romélio Rodriguez Añez, 2010; Wongpakaran & Wongpakaran, 2010). One question remains whether stable individual differences in global subjective stress emerge early in the developmental lifecourse. There is a paucity of adolescent research examining global subjective stress with repeated measurements; therefore, it is unknown whether global subjective stress is a stable individual difference in adolescents. Understanding whether global subjective stress is a stable individual difference in adolescence is a meaningful contribution to stress conceptualization.

Aim of the Current Dissertation Programme

The aim of the current dissertation programme was to address some of the gaps in the existing literature on childhood and adolescent stress. Broadly, the current research aimed to refine the conceptualization and measurement of stress during childhood and adolescence. Examining stress during childhood and adolescence is a timely question, as there have been increasing calls for better harmonization of conceptualization and measurement in the field of stress science (Epel et al., 2018). Three complementary studies were conducted: **Study 1** consists of a comprehensive and systematic review of existing stress measures developed or adapted for

use with children and adolescents. Within the historical context of the field, this study outlines the chronology of major milestones and paradigm shifts in the conceptualization and measurement of stress, as well as methodological challenges specific to child and adolescent populations. This study contributes to the child and adolescent literature by synthesizing our understanding of available measures used in existing research. **Study 2** compares the relation of health with stress, assessed via life events and global subjective stress. This study fastidiously dissects key differences in the conceptualization and measurement of life events and global subjective stress that may contribute to the prediction of health outcomes. Additionally, this study considered whether the association between stress and health outcomes vary based on informant source and health outcomes measured. **Study 3** addresses a larger conceptual question regarding global subjective stress. To date, the majority of studies have conceptualized global subjective stress as a dynamic, time-varying construct. In adults, a handful of studies have demonstrated moderate to high stability in global subjective stress over time, alluding to a more stable individual difference conceptualization. Using a longitudinal design, this study is an initial examination of the stability of global subjective stress during adolescence.

STUDY 1:

Evidence-Based Stress Measurement in Children and Adolescents: A Systematic Review

Abstract

Mounting evidence recognizes the enduring contribution of stressor exposure and psychological response on health outcomes across the lifespan. Yet, the conceptualization and measurement of childhood stress are still emerging, and the literature is based predominantly on adult retrospective reports. Accurate assessment of stress during childhood is important. Wide-ranging "stress" measures are used in the pediatric literature, and their evidence base remains largely unexplored. Within the historical context of the field, this paper outlines the chronology of major milestones and paradigm shifts in the conceptualization and measurement of stress. Measures of stressor exposure and psychological response for children and adolescents are comprehensively and systematically reviewed, including an examination of stressor attributes, psychometric properties, and APA evidence-based ratings. Of the 31 pediatric stress measures reviewed, two-thirds (61.3%) assess life events, most are questionnaires (87.1%), and they span a wide age range across childhood and adolescence. Stressor attributes, including severity, timeframe, chronicity (duration, frequency), and life domains, are being increasingly assessed in emerging measures. Test-retest reliability was moderate when time intervals were short between administrations (<1 month); child and parent agreement for life events varied, but improved for specific, time-limited events versus general, ongoing stressors; and, internal consistency was moderate to high; notably, reported psychometric data were limited. Close to half of measures reviewed met APA criteria as being "well-established" (*n*=14; 45.2%), with almost as many "not meeting evidence-based assessment criteria" (*n*=11, 35.5%). Refinements for conceptualization and standardized measurement of stressor exposure and psychological response during childhood and adolescence are recommended.

Evidence-Based Stress Measurement in Children and Adolescents: A Systematic Review

Stressor exposure early in development shapes health trajectories across the lifespan. Children and adolescents exposed to stressors are at greater risk for depression (Williamson et al., 1998, 2003), anxiety (Grant et al., 2003; Grant, Compas, Thurm, McMahon, & Gipson, 2004), obesity (De Vriendt et al., 2009; Garasky et al., 2009), and chronic diseases during adulthood (Kessler, Davis, & Kendler, 1997; Kessler et al., 2010). While there is robust evidence for the adverse effect of stressors on children and adolescents' health, the magnitude of this effect has been small to moderate (Grant et al., 2004). Wide-ranging definitions and measures of stressors have been used in the pediatric literature (c.f., Grant et al., 2004), which may explain disparate results and varied magnitudes of the association.

"Stress" is the ubiquitous term that encompasses related yet distinct constructs (i.e., stressor exposure, psychological and behavioural response, and physiological response. *Stressor exposure* (e.g., life events, early life adversities, hassles, laboratory stressors) can be operationally defined based on specific attributes such as measurement timeframe (e.g., past month, past year, ever) and proximity (e.g., retrospective, time from exposure), as well as stressor timescale (e.g., acute, daily, chronic), duration (e.g., minutes, days, years), severity (e.g., life change unit), or life domain (e.g., family, friendships, health, school, work). Psychological and behavioural response includes stressor appraisal, global subjective stress, and coping. Physiological response refers to the cascade of physiological change or reactivity following stressor exposure, such as autonomic reactivity, cortisol response, and allostatic load. Precise terminology to delineate stress typology and to harmonize stress measurement has been proposed in Epel and colleagues' recent Integrated Lifespan Model of Stress and Health (Epel et al., 2018). Another measurement consideration especially relevant for children and adolescents is the informant source (e.g., child/self, parent, teacher, caretaker). Traditionally, most pediatric studies rely on parental report of their child's stress; while this method makes sense for young children, it becomes increasingly problematic as children age since parents cannot be fully knowledgeable about their child's psychological response or stressor exposures outside the home environment. The question remains whether existing pediatric measures comprehensively assess stressor exposure and psychological response among children and adolescents.

In the following sections, a brief history of stress science is discussed to provide background context for the current review. First, the chronology of major milestones and

paradigm shifts in the conceptualization and measurement of stress across the adult and pediatric literatures are discussed (see Figure 1). Second, available evidence supporting the pertinence of assessing stress exposure early during childhood and adolescence is discussed to provide context for the present systematic review of pediatric measures used to assess stress. (Note that detailed discussion of the physiological stress response system is beyond the scope of the current study; therefore, it is largely omitted from the following background sections and subsequent review.)

Brief History of Stress Conceptualization and Measurement

The evolution of stress science can be explained through key milestones and paradigm shifts in the conceptualization and measurement of stress. Modern stress research can be traced to the foundational work of Hans Selye in the 1930s, who examined the endocrine responses to laboratory stressors in animals. Selye (1936) observed a consistent physiological stress response pattern, including decreased thymus gland size, adrenal gland swelling, and gastric ulcers when animals were exposed to stressors of physical restraint, extreme cold, inescapable electric shock or food deprivation. Selye (1956) coined the term *General Adaptation Syndrome* to describe the alarm, resistance, and exhaustion stages of the physiological stress response. Selye's seminal work was foundational for understanding the pathophysiology of stress in the development of disease and the measurement of stress in humans.

Stressor Exposure: Stressful Life Events

Stressful Life Event Checklists in Adults. In the 1930's, Adolf Meyer advocated the role of stressful life events in the etiology of illness. Meyer recommended physicians use a life chart methodology during medical examinations to document stressful events in patients' lives (Lief, 1948; Meyer, 1951). Meyer's idea led to pioneering research in the 1940s examining stressful life events and its links with health outcomes. Notable longitudinal evidence emerged, including a 20-year prospective study of 3,500 telephone operators who were more susceptible to physical and mental illness during periods of high interpersonal conflicts and tensions than other periods (Hinkle & Wolff, 1958). While Meyer's life chart methodology inspired the first body of research studies linking stress and health outcomes in humans, researchers relied on anecdotal assessment of stressful life events. No systematic method existed to document the occurrence of stressful life events, rendering the comparison of findings across studies difficult.

In the 1950s, Hawkins and colleagues made an initial attempt to systematize Meyer's life chart methodology (Hawkins, Davies, & Holmes, 1957). Informed by a 10-year medical chart

review of tuberculosis patients, Hawkins found that 50% of reported stressful life events clustered into the two years preceding disease onset. These findings led to the creation of the Schedule of Recent Experience, a self-report questionnaire, which listed 43 discrete, stressful life events, including death of spouse, divorce, and employment. One limitation of this measure was the use of a simple frequency count (i.e., event count) of the number of stressful life events endorsed to yield the stress index. Thus, this aggregate method did not differentiate severity of stressors; the occurrence of death of spouse and minor law violation (e.g., traffic tickets) were equated on Hawkins' stress index.

In 1967, a pivotal milestone in stress science occurred when Holmes and Rahe developed the Social Readjustment Rating Scale to standardize and increase the precision of stressful life event measurement. Upon review of 5,000 Navy medical records, Holmes and Rahe identified that stressful life events clustered into one to two years prior to physician visits and hospitalizations (Holmes & Rahe, 1967). They then used a scaling procedure to quantify norms for the severity of these stressful life events. Marriage was arbitrarily selected as the referent stressful life event and assigned a weight of 500 points. A convenience sample of adults estimated the severity and time necessary to adjust to each life event, compared to marriage; life events that were judged to require more adjustment than marriage were assigned proportionately larger weights, and vice-versa. Consensus was reached across adults from different social and ethnic groups. This scaling procedure yielded a *life change unit* for each stressful life event, which represented the amount of adjustment each event required. Life change units assigned to the events endorsed were summed to yield an index of stress (Holmes & Rahe, 1967). Holmes and Rahe's Social Readjustment Rating Scale was a simple, time- and cost-efficient method to quantify stressor exposure in a checklist format. It also introduced the novel conceptualization and measurement of the attribute of *stressor severity*. Although the assigned life change unit for an event was standardized, this was the first attempt to quantify the severity of a stressful life event. Thus, this paradigm shift reflected that the magnitude of change or readjustment elicited by these events that was the basis of experiencing stress (Holmes & Masuda, 1974; Paykel, 1974). Together, the Social Readjustment Rating Scale and its subsequent revisions (added 44 life events, rescaled life change units, renamed Recent Life Change Questionnaire; Rahe, 1975; rescaled life change units; Miller & Rahe, 1997) became the foundation of stressful life event checklists, inspiring the development of the PERI Life Events Scale (Dohrenwend, Askenasy,

Krasnoff, & Dohrenwend, 1978) and the Life Experiences Survey (Sarason, Johnson, & Siegel, 1978) for adults, and the Life Event Record (Coddington, 1972) for children, among several others. Stressful life event checklists continue to be the predominant approach to measuring stressor exposure.

Stressful Life Event Checklists in Children and Adolescents. In the 1960s, researchers focused almost exclusively on traumatic events (e.g., maternal separation) and their role in childhood development and psychopathology. Stemming from the popularity of life event checklists, pediatric researchers recognized the paradigm shift from negative, traumatic events to life events "that were socially acceptable and desirable but required coping, adaptation or readjustment" (Coddington, 1972). Investigators began having parents complete Holmes and Rahe's stressful life event checklist as an overall indicator of household stress and proxy for their children's stress. In 1972, Coddington set out to identify life events that occurred during childhood. Using methodology similar to that of Holmes and Rahe, a convenience sample of pediatricians, teachers, and mental health workers estimated the intensity and length of time necessary for a child's readjustment to age-specific life events; their ratings were used to inform standardized life change units. Birth of a sibling was arbitrarily selected as the referent life event and assigned a life change unit of 500 points. Coddington's Life Event Record established standardized life change units for preschool (30 events), elementary (36 events), junior high (40 events) and senior high school aged youth (42 events; Coddington, 1972). Coddington's measure sparked significant interest in the etiological role of life events in childhood health and disease (c.f., Grant et al., 2003, 2004).

Burgeoning research questioned the conceptualization of life change units and strived to enhance measurement of childhood stressor exposure. While the use of teachers, pediatricians, and health professionals' ratings to develop life change unit norms was deemed suitable for preschoolers and young children, this approach was considered imprecise and possibly inaccurate for older children and adolescents, as it failed to capture their evaluation of life events. Not surprisingly, the use of adults to inform life change units for life events occurring during childhood and adolescence was later challenged by several findings demonstrating lack of agreement between adults and children's ratings of the intensity and length of time for readjustment (Yamamoto, 1979; Yeaworth, York, Hussey, Ingle, & Goodwin, 1980). Consequently, subsequent pediatric stressful life event measures were developed using children

and adolescents' ratings to establish norms for life change units (Johnson & McCutcheon, 1980; Lewis, Siegel, & Lewis, 1984; Yamamoto, 1979; Yeaworth et al., 1980). In the 1980s and early 1990s, researchers compared stressful life events endorsed by parents and children (i.e., self-report); parent-child agreement yielded mixed results, with evidence of low to high concordance (Allen, Rapee, & Sandberg, 2012; Compas, Davis, Forsythe, & Wagner, 1987; Larson & Ham, 1993; Sandberg et al., 1993; Swearingen & Cohen, 1985). Initially, these mixed findings were interpreted to mean that children were unreliable informants of their own stressor exposure. However, Allen and colleagues contended parents may not be fully knowledgeable about how their children experience and perceive stressful events (Allen et al., 2012). Upon closer examination of parent-child agreement, they observed higher concordance for events known by both parent and child (e.g., new family member, failing a grade) and lower concordance for events less readily observable by the parent (e.g., bullying, peer relations; Allen et al., 2012). Thus, pediatric stress measurement using parents and children as complementary informants may more accurately and comprehensive capture children's experience of stress. Moreover, children as young as 8 years old have been found to reliably report stressor exposure (Lin et al., 2007; Ly et al., 2015; Martin et al., 1995; Vacek, Coyle, & Vera, 2010).

Interview-Based Stressful Life Events Measures in Adults. Paralleling the emergence of childhood stressful life event checklists, researchers in the adult literature started challenging the basic assumptions of the checklist approach (Brown, 1974; Kaplan, 1979; Mechanic, 1975; Sarason et al., 1978). First, concerns were raised that the checklist approach did not include a sufficiently representative list of events and that the broad categorization of life events (e.g., "serious illness or death of family member") failed to capture the context in which the life event occurred. Second, the use of standardized life change units inherently assumed that each event carried a ubiquitous level of readjustment across individuals; yet, clinicians recognized that individuals differed in their readjustment to the same life events. Third, adults were asked to indicate whether the event occurred (binary yes/no) during a specified timeframe, typically over the past year. The original rationale for the use of 1-year recall period stemmed from concerns about biased recall; researchers assumed health outcomes manifested within about one year following exposure to a stressful life event (Holmes, 1979). However, evidence for this assumption was limited and methodologically questionable; findings demonstrated adverse effects of stressor exposure on health using an assessment recall window up to 10 years (Kessler

et al., 1997). Adult retrospective report of stressful life events during childhood was associated with higher incidence of physical conditions (heart disease, asthma, diabetes, arthritis, chronic pain, chronic headache) and mental health (depression, anxiety disorders, suicide) during adulthood (Dube et al., 2001; Kessler & Magee, 1994; McLaughlin, Conron, Koenen, & Gilman, 2010), suggesting long-lasting consequences of stressor exposure. Fourth, retrospective checklist methods precluded precise assessment of the dates when the event occurred (i.e., temporal proximity) and the duration of the life event. Together, these criticisms led researchers to reconsider the assessment method for stressful life events and prompted a shift toward an interview approach in the adult literature.

To address limitations of the checklist measurement approach, an interview-based approach to measure stressful life events began to emerge at the end of the 1970's. The two approaches differed in terms of how stress was both conceptualized and measured. The interview-based approach conceptualized that life events threatening the goals, plans, commitments, and social roles of an individual were the basis for experiencing stress, and that severe and chronic events within the individual's life context were the most threatening to physical and mental health (Brown & Harris, 1978; Brown & Harris, 1989). Interview-based methods led to several refinements in the assessment of stressful life events. First, the *duration* of the event was assessed during the interview, which enabled the distinction between acute and chronic stressor exposure that was not previously captured in event checklist measures. Acute events were operationally defined as discrete stressors; chronic events were defined as ongoing negative circumstances (>6 months, e.g., poor work conditions, financial strains; Adrian & Hammen, 1993; Brown & Harris, 1989). While both acute and chronic forms of stressors were linked to various health outcomes, findings from the depression literature had shown that chronic stressors further amplified the relation of acute stressors to greater depressive symptoms (Hammen, 2009). Second, the interview-based approach emphasized "stressfulness" or stressor severity unique to the individual, rather than a standardized life change unit, which was not previously considered in the traditional checklist approach (Brown & Harris, 1989). Third, the classification of stressful events by *life domain* (e.g., family, friendships, work, health, finance) began to emerge in the interview-based approach (Brown & Harris, 1978). Grounded on the principles of event- and diagnostic-specification, interviewers would categorize an event based

on its broad class or life domain and decide whether it was "truly stressful" based on interview information (Brown & Harris, 1989).

One of the earliest and most renowned interviews for assessing stressful life events was Brown and Harris' (1978) Life Events and Difficulties Schedule. A trained interviewer used a semi-structured interview with standardized, qualitative probes to elicit a complete assessment of stressful life events and to obtain detailed, narrative information about their occurrence (i.e., start/end date, duration), characteristics, and contextual information. Collected information was compared to established operational definitions documented in comprehensive manuals containing precedent examples of more than 2,000 stressful life events that were derived from Brown and Harris' program of research conducted over 30 years (Brown & Harris, 1978). For each endorsed event, the interviewer applied a rigorous coding decision hierarchy (i) to determine whether the event met the threshold for "stressful life event", rather than relying on respondent interpretation, (ii) to distinguish acute and chronic timescale exposure, and (iii) to specify the severity of the event. The interviewer then presented the threshold events to a panel of trained raters, who were blind to the respondent's symptom profile, onset of health problems, and presentation during the interview. Panel members compared the similarities and differences of the reported events to the precedent examples in the manual. The final panel rating of an event was subjected to a consensus vote; this process was repeated for each endorsed event. Altogether, it took ~30 hours to complete the entire process (respondent interview, panel discussion, consensus voting) for a single participant! Brown and Harris' rigorous assessment method inspired the development of shorter semi-structured interviews, like the Structured Events Probe and Narrative Rating (Dohrenwend, Raphael, Schwartz, Stueve, & Skodol, 1993) and the Interview for Recent Life Events (Paykel, 1997), but administration still took up to several hours.

The interview-based approach addressed some critiques of the checklist measurement of stressful life events. A few studies directly compared the two approaches. In a sample of hospitalized patients with depression, Katschnig (1986) compared life events in the two years preceding hospital admission using a checklist (Social Readjustment Rating Scale, Holmes & Rahe, 1967) and an interview (Life Events and Difficulties Schedule, Brown & Harris, 1978). Both approaches indicated increased stressful life events prior to hospitalization, especially within the prior six months. However, upon detailed examination, patients reported nearly

double the number of stressful life events when completing checklists, compared to the interviews. Further, the number of reported events across the two measurement methods was only modestly correlated, suggesting a lack of congruence between the two methods. One explanation for these discrepancies is that the interview approach relied on stringent criteria to determine whether a life event met the stress threshold. In fact, studies had demonstrated that up to 63.0% of events endorsed on checklists were deemed to not meet the threshold for stressful life event during interviews (McQuaid et al., 1992; Oei & Zwart, 1986; Zimmerman, Pfohl, & Stangl, 1986); these findings questioned the validity of these "objective" stressfulness threshold definitions. Researchers also contended that individuals were prone to over-reporting trivial events in the checklist approach (McQuaid, Monroe, Roberts, Kupfer, & Frank, 2000). An alternative explanation is that individuals may have been less forthcoming when disclosing stressful events to interviewers.

Interview-Based Stressful Life Events Measures in Children and Adolescents. In the 1980's and 1990's, interview-based approaches were adapted for use with children, adolescents, and parents to address the critiques of checklist measures, which mirrored those raised in the adult literature. Brown and Harris' Life Events and Difficulties Schedule was adapted for use with adolescents (Monck & Dobbs, 1985; Williamson et al., 1998). Williamson and colleagues further revised the interview and developed the Stressful Life Events Schedule, which directly asked children and adolescents whether an event from a list of stressful life events occurred in the preceding year and provided interviewers with specific criteria to evaluate the duration and severity of each endorsed event (Williamson et al., 2003). Williamson's Stressful Life Events Schedule was a significant milestone in the measurement of child and adolescent stressor exposure, as it reduced the administration time from 30 hours to 1 hour for each participant (Williamson et al., 2003).

Stressor Exposure: Daily Hassles and Microstressors.

As the debate surrounding interviews versus checklists continued (Brown & Harris, 1978; Dohrenwend & Dohrenwend, 1974; Dohrenwend et al., 1978), researchers noted the curious finding that the accumulation of stressful life events was weakly correlated with health outcomes (r <.02; 76, Cohen, Tyrrell, & Smith, 1993; Sarason et al., 1978). In contrast to the stressful life events approach, Lazarus and colleagues' recognized the significance of adapting to minor nuisances and pleasures common to everyday life (Lazarus, 1966; Lazarus & Cohen, 1977).

Kanner and colleagues (1981) contended that one's daily transaction with the environment generated the emotional or psychological response to life events. *Daily hassles*, or microstressors, were defined as irritating, frustrating, familiar demands that characterized these everyday transactions with the environment (e.g., arguments, traffic, losing things; Kanner et al., 1981). Daily hassles became an essential conceptual intermediary between life event stressor exposure and psychological response (i.e., affective, emotional).

In 1981, Kanner and colleagues developed the Hassles Scale, a self-report checklist of 117 specific, daily hassles (e.g., customers give you hard time, planning meals, friends too far away, filling out forms, inconsiderate smokers) across multiple domains (e.g., work, family, friends, finance, environment; Kanner et al., 1981). Respondents identified hassles that occurred within the past month and rated the severity of each endorsed hassle on a 3-point scale (earlier versions included a persistence rating, which was found to be redundant with the severity rating). Kanner's Hassles Scale yielded three scores: frequency (sum of hassles endorsed), severity (sum of severity rating), and intensity (severity divided by frequency; i.e., "how strongly or intensely the average hassle was experienced, regardless of the number (frequency) of hassles checked", 76). A prospective study of daily hassles (past month; nine monthly assessments) compared with stressful life events (two assessments: retrospective 2.5 years prior to study start, retrospective 9 months at study end), revealed that hassle intensity was not related to life events pre-study nor during the study; hassle frequency was correlated modestly with life events pre-study (r = .21), but was correlated with life events during the study in women only (r = .36, versus men r = .02, 76). Overall, work by Kanner and colleagues highlighted the importance of transaction between individuals and their environment; however, hassles still captured specific stressors and severity ratings for these stressors.

Stress Response: Subjective Appraisal and Global Subjective Stress.

Lazarus and Folkman (1984) criticized that the assessment of stressor exposure failed to consider individuals' subjective interpretation of stressors. Their work led to a major paradigm shift toward the conceptualization of the *psychological response* or the subjective appraisal of stressors. Instead of assessing the stressor exposure, they advocated the importance of evaluating the transaction between the person and environmental (Lazarus & Folkman, 1984). An emphasis on individuals' perceptions of environmental demands (i.e., global subjective stress) began to emerge in the literature (Cohen, Kamarck, & Mermelstein, 1983). Health risk associated with

stressor exposure was considered dependent on the extent to which individuals *perceived* an event to be stressful. This novel conceptualization had indirectly influenced the measurement of stressful life events; self-report severity ratings were introduced in subsequent modifications of stressful life event checklists (c.f., Cohen et al., 1983).

In 1983, Cohen and colleagues' developed the Perceived Stress Scale (Cohen et al., 1983), which has become the iconic measure of global subjective stress. Based on Lazarus and Folkman's Stress Appraisal Theory (Lazarus, 1966; Lazarus & Folkman, 1984), the appraisal of environmental demands as exceeding one's resources to cope is the basis of experiencing stress (and of relevance to health) and the central assumption underlying this measure. The Perceived Stress Scale assesses the extent to which situations in one's life are appraised as stressful over the past month (1-month measurement timeframe). The original measure, intended for use with high-school educated community samples, consisted of 14 items that tapped into the degree to which individuals found their lives unpredictable, uncontrollable, and overloaded (Cohen et al., 1983). Cohen and Williamson (1988) subsequently shortened the questionnaire to 10 items, which yielded improved psychometric properties than the original 14-item version (Cohen & Williamson, 1988; Cole, 1999; Roberti, Harrington, & Storch, 2006). A 4-item version was also developed for screening purposes, and yielded more moderate psychometric properties (Cohen & Williamson, 1988; Cohen et al., 1983; Warttig, Forshaw, South, & White, 2013). Interestingly, many studies examining the relation between stress and health outcomes observed effect sizes that were almost doubled for global subjective stress derived from the Perceived Stress Scale, compared to measures of stressor exposure (Cohen et al., 1983; Pbert, Doerfler, & DeCosimo, 1992). These findings may be partly attributable to the narrower measurement timeframe interval (30 days) and global life domains (general, non-specific) captured by the Perceived Stress Scale, in contrast to stressful life event measures that commonly assessed exposure in the past year across multiple, specific life domains, and inherently had longer proximity between the stressor exposure and its assessment (e.g., adult retrospective reports of childhood adverse events). Global subjective stress measures, such as the Perceived Stress Scale, may be more sensitive to ongoing life circumstances. The development of the Perceived Stress Scale constituted a major milestone in the measurement of subjective stress in adults, and reinforced Lazarus and Folkman's paradigm shift toward appraisal and the stress response.

Daily Hassles & Global Subjective Stress in Children and Adolescents. In 1987, Kanner and colleagues developed and validated a pediatric version of the Hassles Scale for use with children and adolescents (Kanner, Feldman, Weinberger, & Ford, 1987). Daily hassles were shown to be conceptually distinct from stressful life events; their associations with health outcomes were almost doubled compared to stressful life events (Kanner et al., 1981). Similar to the original adult Perceived Stress Scale, these findings could be accounted for by the shorter assessment timeframe (1-3 months) captured by most daily hassle measures versus stressful life event measures (typically 1 year). The emergence of daily hassle measures informed later modifications of adult and pediatric stressful life events checklists to expand and include common daily hassles (traffic, crowded living, noisy environment). Daily hassle measures capture minor, transient events from multiple domains.

Few studies have considered global subjective stress or stress appraisal among children and adolescents. Only recently has the Perceived Stress Scale been used with children and adolescents. Emerging findings suggest that children and adolescents who endorse greater stress on the Perceived Stress Scale evidence greater depressive symptoms (Martin et al., 1995), poorer sleep (Ly et al., 2015), and more disrupted diurnal cortisol profile (Ly et al., 2015; Rotenberg & McGrath, 2016; Vacek et al., 2010), compared to stressful life events. Similar to adults, these findings may be partly attributable to the shorter timeframe and more general life domains captured by the Perceived Stress Scale, compared to pediatric stressful life event measures. More research is needed to compare the conceptual differences captured by stressful life event measures and the Perceived Stress Scale.

Stress Measurement Background Summary

Over the last decades, notable milestones and paradigm shifts in the conceptualization and measurement of stress have emerged in the literature. While stressful life event checklists continue to be the dominant approach to assess stressor exposure in adults and children, research continues to expand across other measurement approaches. Existing measures are continuously refined and validated with different age groups, and new measures that tap into subjective appraisal have been developed in an effort to better capture individuals' psychological response.

There is an increased recognition of the importance of stress measurement during early childhood and adolescence. Accumulating adult retrospective findings support that early experiences of stress are likely biologically-embedded and alter children's psychobiological

responses to stress. In turn, these early alterations shape health trajectories, placing children at differential risks for later health outcomes that emerge in adulthood. Stress experienced early in development has been associated with heightened cortisol levels and inflammation during childhood and later in adulthood, which have implications for eventual health conditions (Carpenter et al., 2010; Hanson & Chen, 2010; Repetti et al., 2002; Taylor, Way, & Seeman, 2011). Findings from the Adverse Childhood Experiences Study convincingly demonstrate that children exposed to severe forms of stressful life events (e.g., parental death, parental mental illness, living in a violent household) are at greater risk for heart disease, cancer, chronic lung disease, and major depressive disorder in adolescence and adulthood. In fact, risk for adverse health outcomes is increased with greater, cumulative stressor exposure (Chapman et al., 2004; Chartier, Walker, & Naimark, 2010; Felitti et al., 1998; Flaherty et al., 2013; Flaherty et al., 2006). Similar conclusions were established in a systematic review, which showed that children exposed to stressful life events were at greater risk for adverse health outcomes in adulthood (Repetti et al., 2002). Together, these findings demonstrate that stressor exposure early in childhood development can shape health trajectories across the lifespan. Interestingly, most studies in the Adverse Childhood Experience literature are based upon adult retrospective reports of stress. Recent findings have challenged the consistency of adult reporting of childhood stress (Colman et al., 2016). These critiques underscore the need to examine the measurement of stress experiences during childhood and adolescence.

Current State of Stress Measurement in Children and Adolescents

Stressor exposure is most commonly derived from stressful life event measures. Indeed, since the publication of the first pediatric stressful life event measure by Coddington (Coddington, 1972), the number of new stressful life event measures developed for use with children and adolescents has increased exponentially in the literature (Grant et al., 2006). There has been a growing research interest in the associations between stressful life events and various health outcomes in children and adolescents. In the adult literature, the measurement of stressor exposure has expanded to include the assessment of stressor attributes, including timeframe, chronicity (duration, frequency), life domains, and severity. These refinements have been only partly reflected in the conceptualization and measurement of stressors for children and adolescents. The examination of psychological response is still emerging in the child and adolescent literature. Further, the evidence base for pediatric stress measures remains largely

unexplored. Given the central role of early life stress in the etiology of myriad physical and mental health problems, it is imperative to use valid and reliable measures to assess stress experiences among children and adolescents. A previous systematic review elucidated the evidence base and clinical utility of frequently used pediatric stressor exposure measures by researchers and practitioners (Blount et al., 2008). Though findings demonstrated adequate evidence base for measures of stressor exposure (e.g., sensitivity, predictive validity of health outcomes), the narrow review was limited to three measures only, and precluded inclusion of other stressful life event measures commonly used in the literature (Blount et al., 2008). More recently, a narrative review described a convenience sample of pediatric measures of stressor exposure and psychological response, without consideration of their psychometric properties (Vanaelst, De Vriendt, Huybrechts, Rinaldi, & De Henauw, 2012). Therefore, there is a need for a systematic and comprehensive review of tools currently used to assess stress experiences during childhood and adolescence.

Aim of Current Review

The overarching aim of the present study was to provide a comprehensive and systematic review of existing stress measures developed or adapted for use with children and adolescents. The current review is limited to pediatric measures of stressor exposure or psychological response. The primary objective was to compare stressor attributes (e.g., informant, stress intensity, timeframe, duration, frequency, life domains) examined across measures. Additional measure characteristics, such as targeted age range, administration format, and length, were also reviewed to inform their practical use. The secondary objective was to evaluate available psychometric properties of existing pediatric measures. The tertiary and final objective was to systematically evaluate these pediatric measures using criteria developed by the American Psychological Association (APA) Division 54 Evidence-Based Assessment Task Force (Cohen et al., 2006).

Method

Systematic Literature Search Strategy to Identify Pediatric Stress Articles

An electronic database search of Medline, PsychINFO, and Web of Knowledge was conducted for January 1967 to August 2018, using Boolean combinations (AND, OR, *) of specified search terms (see Figure 2). This initial electronic search, which was limited to English language publications and human studies, yielded 548 non-redundant articles. Titles and

abstracts of these 548 articles were then screened and selected for review if any wording suggested stress was assessed in children or adolescents; this yielded 67 articles for full text review. Descendancy and ascendancy approaches were used to identify additional 265 potentially relevant articles. Together, 332 articles were selected for full text review to identify potential pediatric stress measures for the current study.

Pediatric Stress Measure Inclusion and Exclusion Criteria

Measures of stressor exposure (e.g., life events, daily hassles, microstressors) and psychological response (e.g., global subjective stress, subjective appraisal) were considered for the current review**.** Pediatric stress measures were included for review if they: (i) were developed or adapted to measure stress in children or adolescents (age range 5-19 years), (ii) were published in a peer-reviewed journal or book chapter, and (iii) were published in English.

Measures included for review were: stressful life event, daily hassles, and global subjective stress measures. Stressful life event measures assessed various discrete stressful events or experiences, using a checklist or interview format. Daily hassle measures assessed irritating or distressing circumstances on a routine day-to-day basis. Global subjective stress measures assessed global subjective appraisal, or subjective perception of the degree to which participants found their lives stressful, unpredictable, uncontrollable, or overloading.

Among the 332 reviewed articles, 94 non-redundant stress measures met inclusion criteria. Of the 94 identified pediatric measures, measures were excluded if they examined experimental stressors (e.g., lab stressor, stress reactivity; 4 excluded), were single-item questionnaires (7 excluded), examined isolated or singular stressful experiences (e.g., bullying, abuse, academic stress *only*; 22 excluded), were an aggregate of existing stress measures already included for review (13 excluded), or were unpublished (17 excluded). In total, 31 measures were included in the current review.

Curation of Supporting Psychometric Studies

An ascendancy approach based on a forward citation search of the 31 selected stress measures using Web of Science was conducted to identify articles reporting supporting psychometric data. Articles were reviewed if titles or abstracts implied that psychometric properties were examined or reported for the selected stress measure. Supporting psychometric data (e.g., internal consistency, test-retest reliability, inter-rater agreement, convergent validity, construct validity) for stress measures reviewed were extracted from selected articles.

Coding of Stressor and Appraisal Attributes

Coded *stressor attributes* included: informant, timeframe, severity, chronicity (duration, frequency), and life domain. Coded *subjective appraisal attributes* included: informant, chronicity, and stress severity.

Informant. *Informant* was defined as the person(s) who report about the child's stress. Informant was coded as "child", "adolescent", "parent", "teacher", "other", or "no information" in questionnaires. Respondent during interviews was coded using the same informant categories.

Timeframe. *Timeframe* was defined as the specific time period used to recall the occurrence of stress experience and was coded as "past week", "past month", "past year", "lifetime/ever", "other", or "no information".

Chronicity. Duration and frequency, together, reflected the acuteness or chronicity of stressors. *Duration* was defined as the length of the stressor. Duration was coded as "actual duration" or "not assessed" to indicate how duration was assessed in the measure. Actual duration was assessed based on questions, such as, "How long did the [event] last in [years, months, weeks, or days]? What is the date when the [event] started? What is the date when the [event] ended?" *Frequency* was defined as the number of occurrences of stressor exposure. Frequency was coded as "actual frequency count", "rating scale", or "not assessed". Actual frequency count was assessed based on questions such as, "How many times have you experienced [event] within [timeframe]?" and "For each event you endorsed, indicate the number of times it has happened to you within [timeframe]". Rating scale assessed frequency of stressor exposure based on Likert scale or visual analog scale using questions such as, "How often has [event] happened within [timeframe]?" Responses were commonly rated on 3-, 4-, or 5-point Likert scales, with anchors such as "never, almost never, sometimes, fairly often, very often".

Life Domain. *Life domain* was defined as the domain in which the stressor occurred. Life domain was coded as "school", "family", "friends/peers", "romantic relationships", "health/death", "finance", "neighbourhood/housing", "work", "general", and/or "other". Individual items of each measure were reviewed and life domains were coded based on *a priori* categories consistent with life domains previously reported in both adult and pediatric stress literature (Brown & Harris, 1978; Williamson et al., 1998, 2003). Items were coded as "school" (e.g., school attendance, performance, workload), "family" (e.g., parental conflicts, separation, divorce, sibling conflicts), "friends/peers" (e.g., fights with friends/peers, bullying, teasing),

"romantic relationships" (e.g., dating, new relationship, conflicts with partner, sexual intercourse) "health/death" (e.g., serious injury, illness, hospitalization, death of a family member or close friend), "finance" (e.g., parental unemployment, familial financial problems), "neighbourhood/housing" (e.g., moving, living in a crowded space, neighbourhood crime/shooting), "work" (e.g., being fired from work, conflicts with colleagues or employer), "general" (i.e., did not assess stress in any specific domains), and "other" (e.g., unexpected bad news; team tryout).

Severity. *Severity* was defined as the magnitude of distress, threat, undesirability, or severity associated with the stressor exposure, and was coded as "rating scale", "assigned rating", or "not assessed". Rating scale assessed severity based on Likert scale or visual analog scale using questions such as, "How stressful would you rate this event? How undesirable would you rate this event? How threatening would you rate this event?" Responses were commonly rated on 4-, 5-, 10-, or 100-point scales, with anchors such as "not at all, very stressful; none, somewhat, quite a bit, a great deal". Assigned rating included pre-assigned life change units in self-report questionnaires or an investigator assigned rating in interviews to indicate the intensity of endorsed stressors.

Evidence-Based Assessment Criteria and Rating

The evidence-based criteria developed by the APA Division 54 Assessment Task Force (Cohen et al., 2006) were used to evaluate measures of stressor exposure and psychological response in the pediatric literature. Measures were rated as "well-established," "approaching well-established," "promising," or "not meeting criteria" for Evidence-Based Assessment (EBA) tools based on APA criteria, which consider (1) availability and adequacy of reliability and validity data of the measure; (2) availability of the measure and instructions on its use and scoring in a published article or upon request; and, (3) use of the measure by other investigators in published peer-reviewed articles. Table 1 presents criteria for determining EBA ratings.

Data Extraction and Coding for Stress Measures

Data from the systematic literature search to identify stress measures were extracted by a single rater (JL), who screened all titles, abstracts, articles, and coded measures in consultation with a second rater (JM). Next, a random sample of 10% of titles, abstracts, and articles and a random sample of 20% of selected measures were blindly re-coded after a three-month interval, with excellent intra-rater agreement for title, abstract, article, measure selection, and evidence-

based assessment criteria (kappa=0.97). A third independent rater (LW) also coded a random sample of 20% of measures at this time. Raters demonstrated high inter-rater agreement for coding decisions (kappa=0.94). Discrepancies in coding were resolved through discussion to reach consensus.

Results

Overview of Pediatric Stress Measures

Characteristics of the pediatric stress measures are presented in Table 2. Thirty-one measures were identified and included in the present review, which assessed life event (*n*=19, 61.3%), daily hassle (*n*=7, 22.6%), global subjective stress (*n*=2, 6.5%), and a combination of daily hassle and life event (*n*=3, 9.7%). Measures varied widely in length, ranging from 4 items to no limit/open ended. The majority of stress measures were questionnaires (*n*=27; 87.1%) versus interviews (*n*=4; 12.9%); measure length was shorter for stress questionnaires (4 to 210 items; *M*=47.62 items), than interviews (61 items to no limit). Stress measures were designed for use with a large age range of children and adolescents, spanning from ages 5-13 years old (*n*=5), ages 12-20 years old (*n*=13), and ages 5-20 years old (*n*=11).

Stressor Attributes in Measures

Informant. Informant of children's stress was specified in 30 (96.8%) of 31 measures, which included child self-report (*n*=23, 76.7%), parent-report (*n*=2, 6.7%), and both child and parent as informants of children's stressor exposure or psychological response (*n*=6, 20.0%). All interview measures (*n*=4) included both child and parent as informants of children's stress, and yielded high inter-rater agreement for total number of endorsed events (ICC=.81-.95) and moderate inter-rater agreement for specific events (κ=.48). Only two stress questionnaires included both child and parent as informants of children's stress, but inter-rater agreement between children and parents was not reported.

Timeframe. Timeframe was specified in 28 (90.3%) of 31 measures, which included 1-month (*n*=3, 10.7%); 3-month (*n*=2, 7.1%), 6-month (*n*=4, 14.3%), 1-year (*n*=11, 39.3%), lifetime (*n*=1, 4.0%), and other (*n*=6, 21.4%) timeframes. Interviews included a narrower assessment timeframe (ranging from 6 to 18 months) compared to questionnaires (ranging from past week to lifetime). Measures with a 1-year (*r*=.65-.98, ICC=.91-.94, *κ*=.61-.75) and lifetime timeframe (*r*=.82-.91) had moderate to high test-retest reliability compared to other timeframes.

Chronicity. *Duration* of stressor exposure was assessed in 4 (12.9%) of 31 measures, all of which were interviews and only considered actual duration (i.e., start and end date of event). Questionnaires did not consider duration information. No psychometric data specific to stress duration were reported. *Frequency* of stressor exposure or psychological response was assessed in 8 (25.8%) of 31 measures, all of which were questionnaires. Interviews did not consider frequency information. Frequency was derived using rating scale (n=6) and actual count (n=1). No psychometric data specific to stress frequency were reported.

Life domains. The majority of measures examined children's stressor exposure across multiple life domains (n=29, 93.5%). Common life domains included: school (n=25, 86.2%), family (n=27, 93.1%), friends/peers (n=18, 62.1%), health/death (n=21, 72.4%), finance (n=13, 44.8%), and neighbourhood/housing (n=12, 41.4%). Fewer included romantic relationships (n=9, 31.0%), work (n=6, 20.7%), general (n=2, 6.9%), or other life domains (n=5, 17.2%), which were only assessed in measures developed for use with older children and adolescents. Interestingly, constructs derived from factor analyses (Principal Components Analysis, Confirmatory Factor Analysis) were inconsistent and did not overlap with the life domains examined in these measures. Correlations among life domains were reported for one measure (r=38-.67); no other psychometric data for individual life domains were reported.

Severity. Severity was assessed in 23 (74.2%) of 31 measures. Severity was derived from rating scale (n=15; 65.2%), assigned rating (life change units in questionnaires; interviewer-assigned ratings in interviews; n=7, 30.4%), and a combination of rating scale and assigned rating (n=1, 4.3%). There was high interviewer agreement on severity (r=.80; k=.87-.95; ICC=.84-.95); agreement between rating scale and assigned ratings were not reported.

Psychometric Data

Limited psychometric data were reported for the reviewed measures. **Test-retest reliability** and/or stability was reported for more than half of the measures (n=17; 54.8%). Time intervals between test administrations varied considerably across measures (1 day to 2 years). Test-retest reliability was relatively higher for measures with shorter time intervals between test administrations (<20 days; r=.28-.98; κ=.61-.86; ICC=.91-.95), than those with longer time intervals (1 month to 2 years; r=.07-.61). **Inter-rater agreement** was reported for 7 (22.6%) of 31 measures, which examined interviewer agreement (n=3), child-parent agreement (n=3), and adolescent-roommate agreement (n=1). Results showed inter-rater correspondence was high

among interviewers (κ=.87-.95; ICC=.84-.95; r=.80) and adolescent-roommates (κ=.82); however, there was wide variability in child-parent agreement, ranging from low to high inter-rater correspondence (κ=.03-.87; ICC=.81). **Convergent validity** among stress measures was reported for 8 (25.8%) of 31 measures, which showed moderate to high convergence among two stressful life event measures (r=.28-.90; ICC=.64-.80; κ=.77), moderate convergence between daily hassle and global subjective stress measures (r=.65-.67), and low convergence between stressful life event and global subjective stress measures (r=.26). **Internal consistency** was reported for 13 (41.9%) of 31 measures. Of these measures, estimates of internal consistency were in the moderate-to-high range (α=.54-.96), except for 1 stressful life event measure with internal consistency in the low-to-moderate range (α=.16-.59). **Construct validity** was inferred from data reduction methods. Results from factor analyses (Principal Components Analysis, Confirmatory Factor Analysis) were reported for 9 (29.0%) of 31 measures, which yielded 1 to 12 factors (M=5.5 factors; see Life Domains above).

Evidence-Based Assessment Rating

Measures were rated as "well-established," "approaching well-established," "promising," or "not meeting criteria" for evidence-based assessment tools based on APA criteria, which consider reliability and validity findings, availability of scoring instructions, and peer-reviewed published findings by independent investigators. The 31 measures were rated as: well-established (n=14, 45.2%), approaching well-established (n=3, 9.7%), promising (n=3, 9.7%), and not meeting evidence-based assessment criteria (n=11, 35.5%). Among the 14 well-established measures, 10 measures included child/adolescent self-report while 4 measures included multiple sources as informants of children's stressor exposure or psychological response. Few well-established measures considered chronicity; 3 measures considered duration, while 4 measures considered frequency. Well-established measures predominantly used a 1-year timeframe (n=5), though timeframes ranged from 1 week to 18 months.

Discussion

The overarching aim of the present study was to provide a comprehensive and systematic review of existing measures of stressor exposure and psychological response developed or adapted for use with children and adolescents. Three key results emerged from the empirical review of 31 pediatric stress measures: First, stressor attributes were not comprehensively assessed in these measures. Second, results demonstrated a dearth of empirical data supporting

the psychometric properties of these measures. Third, there were almost as many measures "not meeting evidence-based assessment criteria" as those that were "well-established".

The extent to which measures captured four stressor attributes was examined: timeframe, chronicity (duration, frequency), life domains, and severity. Most of the measures included a 1-year timeframe, which is consistent with most adult stress measures (Holmes & Rahe, 1967; Sarason et al., 1978). Rapidly accumulating evidence from the Adverse Childhood Experiences literature has shown exposure to life adversities early in childhood shapes health trajectories, placing children at differential risk for later health outcomes in adulthood (Chapman et al., 2004; Chartier et al., 2010; Felitti et al., 1998; Flaherty et al., 2013; Flaherty et al., 2006). As such, limiting the timeframe to 1 year may be insufficient because stressors that occurred before the specified period are excluded from the assessment, but can still have adverse effects on children's health. However, there remains a need to examine childhood stressor exposure prospectively, given recent findings have challenged the consistency of adult retrospective reports of childhood stressor exposure (Colman et al., 2016). Together, current findings suggest the need to broaden the assessment timeframes to capture both proximal and distal stressors, including multiple time windows within a measure.

Previous research suggests that health risk associated with stressor exposure in part depends on the chronicity (duration, frequency) of stressors (Cohen, Kessler, & Gordon, 1995). Though researchers previously supported the use of interviews to differentiate acute from chronic, ongoing events (Williamson et al., 1998), interviews only considered duration and precluded the assessment of frequency. Thus, interviews captured only one facet of the chronicity attribute of childhood stress. In contrast, questionnaires considered frequency, but precluded stress duration. Current findings suggest the need to more comprehensively assess chronicity of stressful experiences among pediatric measures. Not surprisingly, psychometric data was not reported for the chronicity dimension.

Multiple life domains were captured in nearly all stress measures. Measures that had greater empirical support assessed a more general or wider range of life domains. School, family, friends/peers, health/death, finance, and neighbourhood/housing emerged as the most commonly assessed domains. Fewer measures examined stressful experiences in romantic relationships and work domains. These findings make sense given that most existing measures were developed for use with younger children, who typically do not work or are not romantically involved. Despite

prominent examination of multiple life domains in pediatric stress measures, there was a paucity of supporting psychometric data for this stressor attribute. Dickerson and Kemeny's (2004) meta-analysis of 208 studies investigating the effects of acute experimental stressors on cortisol in adults, showed that uncontrollable and socially threatening stressful experiences produced the most adverse physiological sequelae. The question remains whether life domains encompassing uncontrollable and socially threatening experiences are more salient to health outcomes.

Five types of psychometric data were examined: internal consistency, test-retest reliability and/or stability, inter-rater agreement, convergent validity, and construct validity. Internal consistency for measures was in the low-to-high range. This wide variability across measures was largely driven by low internal consistency reported for stressful life events, rather than daily hassle or global subjective stress measures. Estimates of internal consistency, such as Cronbach's alpha, test the extent to which items tap at an underlying construct. Researchers previously argued that stressful life events measures are not intended to assess a latent construct; as such, internal consistency may not be an adequate statistic to examine consistency of stressful life event measures (Cleary, 1980). On the other hand, researchers often observed that stressful circumstances are multifactorial, and thus, moderate correlations across stress items are expected (Turner, Wheaton, & Lloyd, 1995). For example, parental divorce/separation may require children to relocate into different housing, which may result in loss of friendships, new neighbourhoods, and changing schools. Such chains of related stressors typically cluster within the same time interval, and therefore, would likely increase internal consistency (Cohen et al., 1995; Turner et al., 1995). Nevertheless, internal consistency would be expected to be lower among stressful life event measures, compared to those assessing daily hassles and global subjective stress, which corroborates current findings.

Test-retest reliability for measures was in the low-to-high range. The variability in time intervals between test administrations and recall bias may partly explain heterogeneous test-retest reliability observed. Indeed, measures with shorter recall windows yielded higher reliability than those with longer recall windows. Consistent with adult findings, test-retest reliability was lower for specific stressful events, compared to total stressor exposure sum scores, regardless of administration format (Dohrenwend, 2006; Neugebauer, 1983; Paykel, 1983; Rabkin & Struening, 1976; Steele, Henderson, & Duncan-Jones, 1980; Thoits, 1983). Researchers previously proposed that response discrepancies across different administration

times are attributable to the occurrence of a new stressor during the test interval, or the fact that a stressor is no longer covered within the same recall window (Aldwin, 2007). There was a paucity of studies examining test-retest reliability of global subjective stress in children and adolescents. Among adults, test-retest reliability for global subjective stress measures has ranged from moderate to high (Cohen et al., 1983). Cohen (1983) contends that global subjective stress is likely influenced by stressful life events, daily hassles, and changes in the availability of coping resources, all of which vary over time. Accordingly, it is expected that test-retest reliability for global subjective stress decreases with increasing interval length between test administrations.

Few measures using multiple informants had supporting inter-rater agreement. Estimates of parent-child agreement of children's stressor exposure were in the low-to-high range, with children reporting more stressor exposure than their parents. Similar to previous pediatric research (Sandberg et al., 1993; Williamson et al., 2003), agreement varied depending on stressor type examined. Parent-child agreement was higher for stressors whose occurrence was unambiguous, discrete, and elicited high distress (e.g., family death, relocation), versus those that relied on subjective interpretation of their impact (e.g., academic difficulties, peer relations). Parents may not be fully knowledgeable about how their child perceives or appraises stressors, highlighting the pertinence of using direct child- and adolescent-report stress, especially given the relevance and importance of subjective interpretation. Consistent with this viewpoint, more than half of the measures included children and adolescents as informant of their own stressors and psychological response. This is an important finding, as it suggests that there are strides to move away from simply using adult measures or adults as informants or a proxy of children's stress. However, the use of investigator-assigned stress severity ratings in interviews and selected questionnaires remains problematic, as all stressors are assumed to carry a ubiquitous level of severity for all individuals. This assigned-rating approach to assessing severity fails to account for children's perception of stressors.

Convergent validity was available for limited stress measures. Correlations between stressful life event questionnaires and interviews ranged from moderate to high. Previous findings showed that adults tend to report more stressors in questionnaires than interviews, suggesting that respondents may be less comfortable reporting stressful events to interviewers, or interviewers may apply more stringent criteria to define what constitutes a 'stressful experience' (Kessler & Wethington, 1991; Lewinsohn, Rohde, & Gau, 2003; Miller & Salter, 1984).

Correlations between daily hassle and global subjective stress measures in the current study were higher than those between stressful life event with daily hassle or global subjective stress. Notably, daily hassle and global subjective stress measures were based on shorter timeframes (1 to 3 months), compared to stressful life event measures (6 months to lifetime). Consistent with Cohen's postulation, global subjective stress measures may better capture chronic, general stress from ongoing life circumstances or stress related to stressful events not listed in a life event measure (Cohen et al., 1983).

Construct validity was minimally investigated in existing stress measures. Interestingly, factor analyses results were inconsistent or did not overlap with the life domains examined in stressful life event measures. Researchers previously argued that stressful life events measures are not intended to assess a latent construct; as such, factor analysis may not be an adequate statistic to examine validity of stressful life event measures (Cleary, 1980). Alternative analyses, such as cluster analyses, may be appropriate statistics to examine validity to stressful life events. However, it remains that there is limited data on construct validity.

Overall, supporting psychometric data was limited among existing pediatric measures of stressor exposure and psychological response. The current findings are partially consistent with those observed in previous systematic reviews of convenience samples of fewer pediatric measures, which described limited psychometric properties. Future studies of reliability and validity are needed to establish the psychometric properties for measures of stressor exposure and psychological response used with children and adolescents. Further validation studies may be beneficial to determine how the assessment of stress characteristics can better capture the association between childhood stress and health outcomes, given emerging and mounting research demonstrating the physiological and physical sequelae associated with adverse childhood experiences (Carpenter et al., 2010; Chapman et al., 2004; Chartier et al., 2010; Felitti et al., 1998; Hanson & Chen, 2010; Repetti et al., 2002).

Study Limitations, Future Directions, and Conclusion

Two limitations merit discussion. First, the present study was limited to the review of stressful life event, daily hassle, and global subjective stress measures in children and adolescents. This precluded the examination of other stress constructs (e.g., discrete laboratory stressor exposure, physiological stress response) that are described in a recent conceptual paper by Epel et al. (2018), which aimed to provide a unified model of stress measurement. Second,

evidence-based assessment ratings are determined based upon available data; these evidence-based assessment ratings may be subject to change as new psychometric data become available. Relatedly, evidence-based assessment ratings reflects one way to evaluating stress measures, but does not necessarily reflect whether measures comprehensively assess stressor attributes or their validity.

Current findings have direct implications for ongoing research. First, it is recommended that future researchers more comprehensively assess stressor attributes in measures of stressor exposure. Specifically, there is a need to broaden the timeframes to better capture proximal and distal stressors. Second, there are few measures that comprehensively assess chronicity of stressors, though it could become challenging when stressors are more chronic and do not have distinct onset and end. Third, more research is needed to understand the associations between prominent life domains, especially in relation to various health outcomes in children and adolescents, and to examine the controllability, predictability, and pervasiveness of stressors across these life areas. These recommendations are partly in line with those suggested in previous reviews elucidating the associations between stressor exposure and pediatric health outcomes (Grant et al., 2004, 2006). It is particularly pertinent to understand whether particular stressor attributes better elucidate the pathophysiology of stress. Fourth, there is a relative dearth of measures of global subjective stress. Finally, the development of comprehensive and psychometrically-sound measures is needed to better assess stress attributes, which would lead to better understanding their relation with emerging health trajectories.

Taken together, this systematic review provides an important contribution to the growing literature on stress and health in children and adolescents. Results established that wide-ranging measures of stressor exposure and psychological response are used in the pediatric literature, varying in the assessment of informant, timeframes, severity, chronicity (duration, frequency), and life domains. This knowledge, together with future attempts to refine existing measures, aims to elucidate and strengthen standardization in the conceptualization and measurement of stress during childhood and adolescence.

Table 1

Evidence-Based Assessment Criteria Developed by the American Psychological Association Division 54 Assessment Task Force

Rating	Criteria
Well-established	1. Detailed information indicating **good** reliability and validity published in **at least one** peer-reviewed article 2. Availability of measure and instructions on its use and scoring 3. Measure used by **other independent investigators** in **at least two** peer-reviewed journals
Approaching well-established	1. **Moderate** or **vague** information about reliability and validity published in at least one peer-reviewed article 2. Availability of measure and instructions on its use and scoring 3. Measure used by **same or other independent investigators** in **at least two** peer-reviewed journals
Promising	1. **Moderate** or **vague** information about reliability and validity published in **at least one** peer-reviewed article 2. Availability of measure and instructions on its use and scoring 3. Measure used by **same or other independent investigators** in **one** peer-reviewed journals
Not meeting criteria	• Does not meet one or more evidence-based assessment criteria

Table 2

Review of Stress Measures: Measure Characteristics, Stress Attributes, and Psychometrics

MEASURE	CHARACTERISTICS			SEVERITY	TIME FRAME	CHRONICITY		LIFE DOMAINS									PSYCHOMETRICS				
	AGE (YRS)	LENGTH (#ITEMS)	INFORMANT			DURATION	FREQUENCY	SCHOOL	FAMILY	FRIENDS	DATING	HEALTH	FINANCE	HOUSING	WORK	GENERAL	OTHER	INTERNAL CONSISTENCY	TEST-RETEST RELIABILITY/ STABILITY	INTER-RATER AGREEMENT	CONVERGENT VALIDITY	CONSTRUCT VALIDITY
WELL-ESTABLISHED (*n*=14)																					
Life Event Record – LER[1]	5-19	30-50	Self Parent	Assigned (Life change unit)	1 yr	-	Actual count	✓	✓			✓	✓	✓				-	*r*=.65 (3-mo) *r*=.53-.60 (1-yr) *r*=.49 (2-yr)	-	*r*=.69-.74 (Life Event Interview, event count) *r*=.82-.90 (Life Event Interview, stress severity) *r*=.26 (PSS)	*r*=.98 (Event count-stress severity correlation)
Life Events Checklist – LEC[2]	9-18	46	Self	Rating Scale (4-pt)	1 yr	-	-	✓	✓			✓	✓	✓				-	*r*=.55-.72 (2-wk)	-	ICC=.80 (SLES, event count) ICC=.64 (SLES, stress severity)	*r*=.85 (Event count-stress severity correlation)
Adolescent Life Change Event Scale[3]	13-18	31	Self	Assigned (Life change unit)	1 yr	-	-	✓	✓	✓	✓	✓			✓			α=.55-.66 *r*=.85	*r*=.83 (1-wk) *r*=.95-.98 (19-day)	-	-	CFA (yielded 12 factors)
Perceived Stress Scale – PSS[4]	8-18	4-14	Self	-	1 mo	-	Rating Scale (5-pt)									✓		α=.60-.84	*r*=.85 (2-day – 6-wk)	-	*r*=.26 (Life Event Record)	PCA (yielded 2 factors)
Children's Hassle and Uplift Scale[5]	8-17	50	Self	Rating Scale (3-pt)	1 mo	-	-	✓	✓	✓								α=.54-.85	*r*=.77 (1-day) *r*=.82 (1-mo) *r*=.72 (5-mo)	-	-	-
Daily Life Stressor Scale[6]	7-17	30	Self	Rating Scale (5-pt)	1 wk	-	-	✓	✓	✓		✓						-	*r*=.28-.74 (1-wk)	-	*r*=.65-.67 (PSS) *r*=.43 (Yale Children's Global Stress Index)	-
Urban Hassle Index[7]	10-20	21	Self	-	2 wks	-	Rating Scale (3-pt)						✓	✓				α=.75-.85	-	-	-	PCA (yielded 4 factors)
UCLA Life Stress Interview[8†]	8-18	No limit	Self Parent	Assigned (Interviewer rated, 5-pt)	6 mo	Actual duration	-	✓	✓	✓		✓	✓		✓		✓	α=.67	-	*r*=.80 (Interviewer agreement, stress severity)	-	-
Psychological Assessment of Childhood Experiences – PACE[9†]	8-16	No limit	Self Parent	Rating Scale (4-pt), Assigned (Interviewer rated, 3-pt)	18 mo	Actual duration	-	✓	✓	✓	✓	✓		✓				-	κ=.61-.86 (1-wk)	κ=.87-.95 (Interviewer agreement, stress severity)	*r*=.28-.48 (CASE)	-
Stressful Life Events Schedule – SLES[10†]	8-18	61-77	Self Parent	Assigned (Interviewer rated, 5-pt)	1 yr	Actual duration	-	✓	✓		✓	✓	✓	✓	✓		✓	-	ICC=.91-.94 (9-day; all events) κ=.61-.72 (9-day; specific events)	ICC=.81 (Child-parent; all events) κ=.48 (Child-parent; specific events)	ICC=.80 (LEC, event count) ICC=.64 (LEC, stress severity) κ=.77 (LEDS)	-

	AGE (YRS)	LENGTH (#ITEMS)	INFORMANT		TIMEFRAME	DURATION	FREQUENCY	SCHOOL	FAMILY	FRIENDS	DATING	HEALTH	FINANCE	HOUSING	WORK	GENERAL	OTHER	INTERNAL CONSISTENCY	TEST-RETEST RELIABILITY/ STABILITY	INTER-RATER AGREEMENT	CONVERGENT VALIDITY	OTHER
WELL-ESTABLISHED (n=14)																						
Child/ Adolescent Stress Questionnaire CSQ/ ASQ[11]	13-18	58	Self	Rating Scale (5-pt)	1 yr	-	-	✓	✓	✓	✓		✓					α=.62-.92	*r*=.68-.88 (1-wk)	-	-	PCA (yielded 10 factors)
Adolescents Perceived Events Scale APES [12]	12-20	164-210	Self	Rating Scale (9-pt)	3 mo	-	Rating Scale (9-pt)	✓	✓	✓		✓						-	*r*=.74-.89 (2-wk)	κ=.82 (Adolescent-roommate)	-	Factor analysis (1 factor)
Junior High Life Experience Survey[13]	12-14	39	Self	Rating Scale (7-pt)	6 mo	-	-	✓	✓	✓	✓	✓	✓		✓			-	-	-	-	*r*=.71-.96 (event count-severity correlation)
Adolescent Minor Stress Inventory[14]	13-17	72	Self	Rating Scale (6-pt)	2 wk	-	-	✓	✓	✓			✓				✓	α=.96	-	-	-	PCA (yielded 5 factors)
APPROACHING WELL-ESTABLISHED (n=3)																						
Life Events Questionnaire[15]	13-18	39	Self	Rating Scale (5-pt)	<1 yr >1yr	-	-		✓		✓	✓		✓				α=.16-.59 (Subscale)	-	-	-	-
Life Events and Difficulties Schedule – LEDS[16†]	15-20	No limit	Self	Assigned (Interviewer rated, 4-pt)	1 yr	Actual duration	-	✓			✓	✓	✓	✓	✓		✓	-	Adequate (Statistics not reported)	ICC=.84-.95 (Interviewer agreement; stress severity)	κ=.77 (LEDS)	-
Child and Adolescent Survey of Experiences – CASE[17]	7-17	38	Parent	Rating Scale (6-pt)	1 yr	-	-	✓	✓	✓		✓	✓	✓				-	κ=.75 (1-wk)	-	*r*=.28-.48 (PACE) *r*=.74-.89 (APES) *r*=.69-.72 (LEC)	-
PROMISING (n=3)																						
Chinese Adolescent Life Event Scale[18]	12-18	44	Self	Rating Scale (7-pt)	6 mo	-	-	✓	✓	✓	✓	✓						-	κ=.86 (2-wk)	-	-	-
Urban Adolescent Life Experience Scale[19]	12-18	127	Self	Rating Scale (5-pt)	6 mo	-	Rating Scale (5-pt)	✓	✓	✓		✓	✓					α=.77-.90	*r*=.84 (2-wk)	-	-	-
Major Events Inventory[20]	9-13	8-24	Self	Rating Scale (5-pt)	1wk-1yr	-	-	✓	✓			✓					✓	α=.60	*r*=.53-.84 (2-wk)	-	-	-

	AGE (YRS)	LENGTH (#ITEMS)	INFORMANT		TIMEFRAME	DURATION	FREQUENCY	SCHOOL	FAMILY	FRIENDS	DATING	HEALTH	FINANCE	HOUSING	WORK	GENERAL	OTHER	INTERNAL CONSISTENCY	TEST-RETEST RELIABILITY/ STABILITY	INTER-RATER AGREEMENT	CONVERGENT VALIDITY	OTHER
***NOT MEETING CRITERIA* (*n*=11)**																						
Life Events Questionnaire[21]	7-12	12	Self	-	3 mo	-	-	✓	✓	✓								-	-	Children endorsed more events than parents	-	-
Stressful Life Events[22]	9-13	22	Self	Rating Scale (5-pt)	-	-	-	✓	✓			✓						α=.67	*r*=.61(6-wk)	-	-	-
Children's Life Events Questionnaire[23]	13	32	Parent	Assigned (Life change unit)	0-47 mo	-	-	✓	✓	✓								-	-	-	-	-
Life Events and Coping Inventory[24]	11-14	125	Self	Rating Scale (9-pt)	1 yr	-	-	✓	✓	✓	✓	✓	✓		✓			-	*r*=.07-.56 (11-wk)	-	-	-
Life Events Questionnaire Adolescents[25]	14-19	67	Self Parent	-	1 yr	-	-	✓	✓	✓		✓	✓	✓				-	-	*κ*=-.03-87 (Child-mother, specific events)	-	*r*=.38-.67 (Subscale inter-correlation)
Children's Life Events Inventory[26]	5-12	40	-	Assigned (Life change unit)	-	-	-	✓	✓			✓	✓	✓				-	-	-	-	-
Adverse Life Events[27]	-	26	Self	-	1 yr	-	-	✓	✓			✓	✓	✓				-	-	-	-	-
Stressful Life Events Scale[28]	9-11	20	Self	Rating Scale (7-pt)	Lifetime	-	-	✓	✓			✓						-	*r*=.46-.57 (2-mo)	-	-	-
Stress in Children[29]	9-12	21	Self	-	-	-	Rating Scale (4-pt)									✓		α=.86	-	-	-	Factor analysis (yielded 3 factors)
Feeling Bad Scale[30]	-	20	Self	Rating Scale (5-pt)	1 yr	-	Rating Scale (5-pt)		✓	✓				✓				-	-	-	-	Factor analysis (yielded 3 factors)
Brief Daily Hassle Scale[31]	15	14	Self	-	1 mo	-	Rating Scale (5-pt)		✓	✓								α=.82-.88	-	-	-	CFA (yielded 2 factors)

[1] Coddington, 1972; [2] Johnson & McCutcheon, 1980; [3] Yeaworth et al., 1980; [4] Sheldon Cohen et al., 1983; [5] Kanner et al., 1987; [6] Kearney, Drabman, & Beasley, 1993; [7] Miller & Townsend, 2005; [8] Adrian & Hammen, 1993; [9] Sandberg et al., 1993; [10] Williamson et al., 2003; [11] Byrne, Davenport, & Mazanov, 2007; Byrne, Thomas, Burchell, Olive, & Mirabito, 2011; [12] Compas et al., 1987; [13] Swearingen & Cohen, 1985; [14] Ames et al., 2005; [15] Newcomb, Huba, & Bentler, 1981; [16] Monck & Dobbs, 1985; Williamson et al., 1998; [17] Allen & Rapee, 2009; [18] Cheng, 1997; [19] Allison et al., 1999; [20] Elwood, 1987; [21] Bailey & Garralda, 1990; [22] Brown & Cowen, 1988; [23] Deutsch & Erickson, 1989; [24] Dise-Lewis, 1988; [25] Masten, Neemann, & Andenas, 1994; [26] Monaghan, Robinson, & Dodge, 1979; [27] Tiet et al., 1998; [28] Yamamoto, 1979; [29] Osika, Friberg, & Wahrborg, 2007; [30] Lewis et al., 1984; [31] Wright, Creed, & Zimmer-Gembeck, 2010

† Interview measures

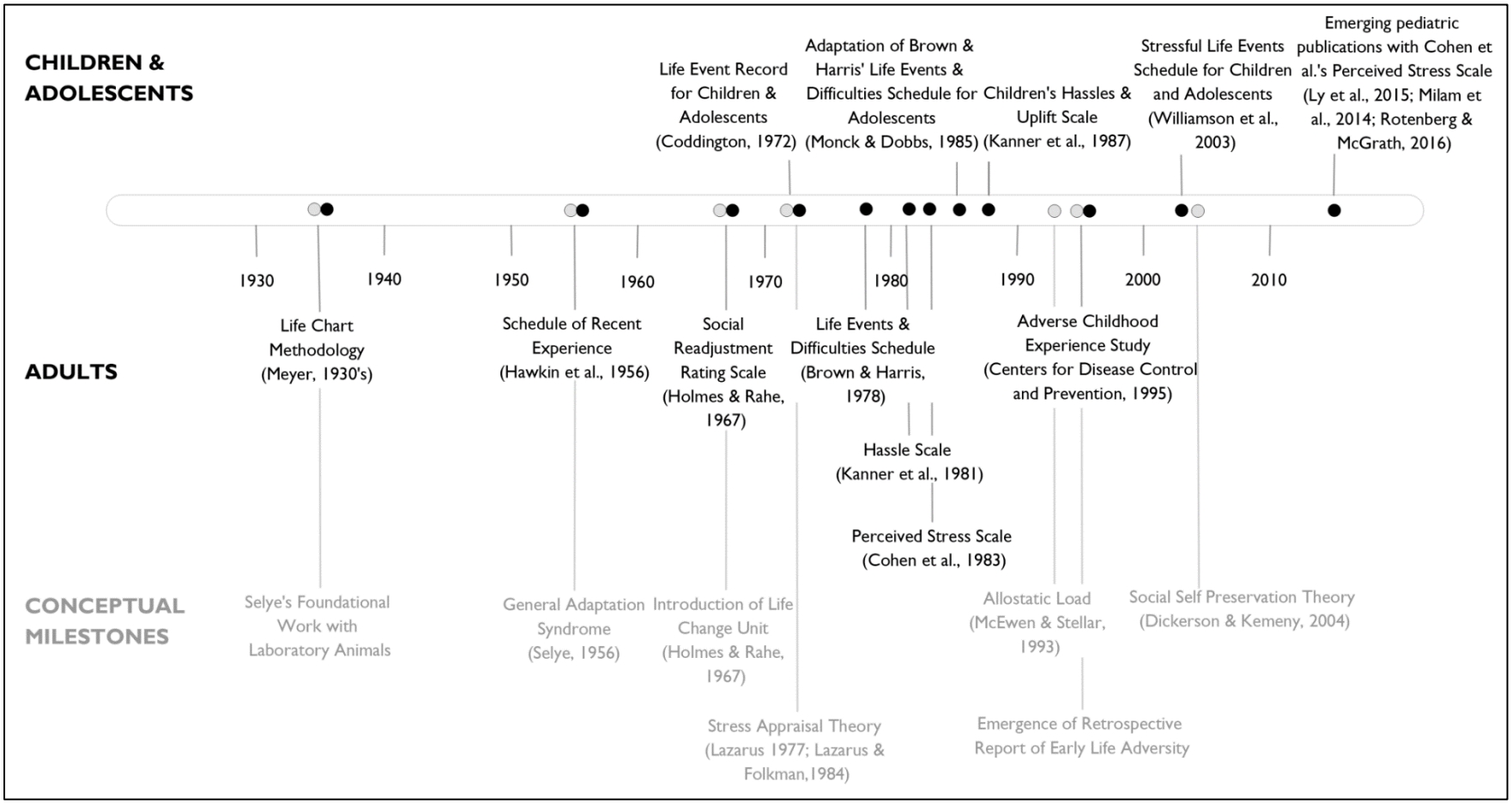

Figure 1. Timeline of chronology of major milestones and paradigm shifts in the conceptualization and measurement of stress across the adult and pediatric literatures

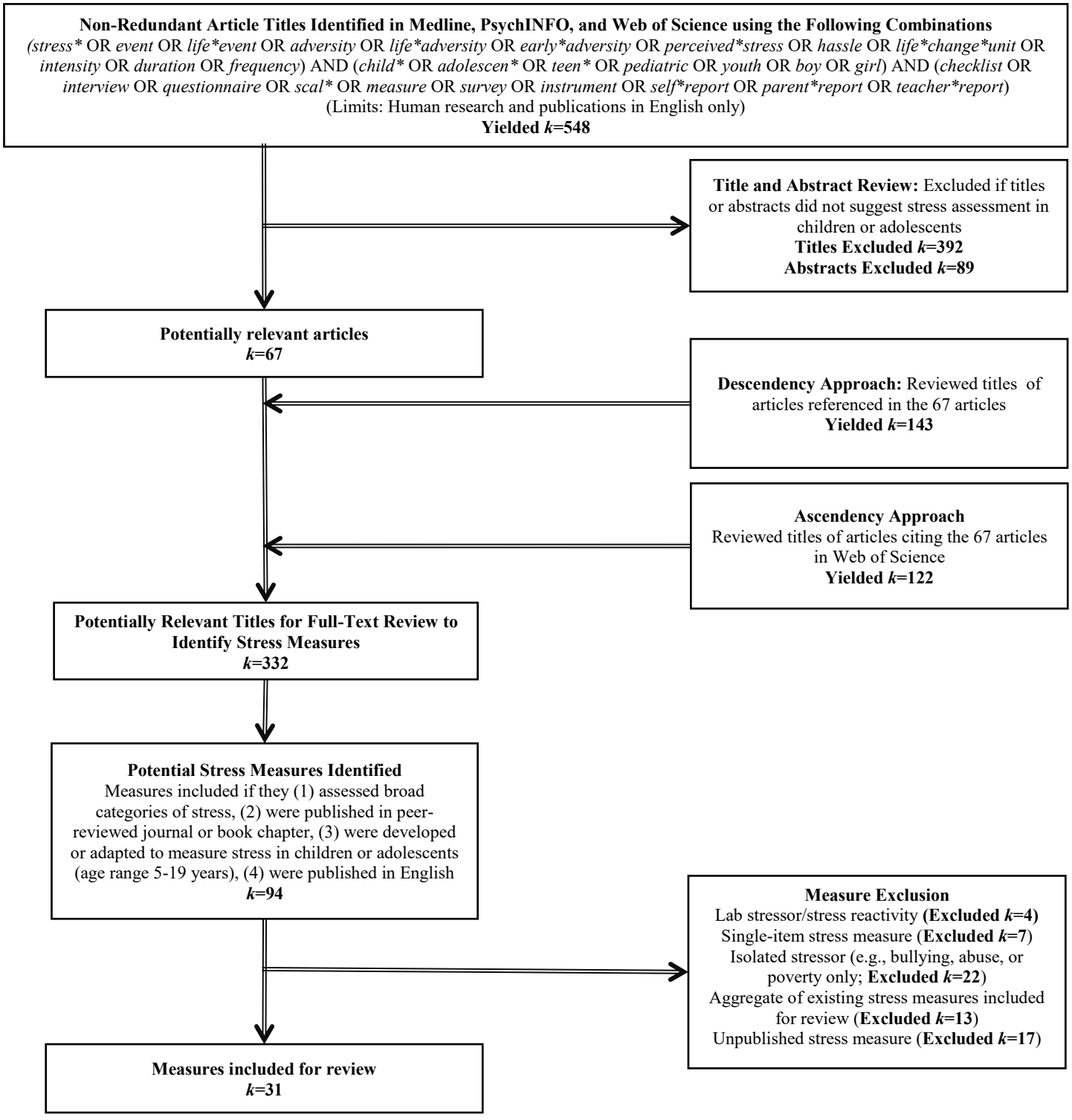

Figure 2. Flow chart for article identification and measure inclusion in review

TRANSITION FROM STUDY 1 TO STUDY 2

Mounting evidence recognizes the enduring contribution of childhood stress in health outcomes across the lifespan. Yet, the conceptualization and measurement of childhood stress are still emerging. Study 1 discussed key conceptual milestones and paradigm shifts that contributed to the evolution of stress science, and addressed methodological challenges specific to child- and adolescent-specific research. Study 1 provided a comprehensive and systematic review of 31 stress measures used with children and adolescents. Results showed that existing measures predominantly focus on the assessment of stressor exposure, particularly stressful life events. Stressor attributes, including severity, timeframe, chronicity (duration, frequency), and life domains, are being increasingly assessed, though inconsistently measured across pediatric measures. Results also showed that close to half of the measures met APA evidence-based assessment criteria, though there is still a dearth of empirical data supporting the psychometric properties of these measures. Study 1 contributes timely knowledge to the literature, as there have been increasing calls for better harmonization of conceptualization and measurement in the field of stress science. Study 1 provides a practical reference guide for available measures of stressor exposure and psychological response used with children and adolescents.

Psychological response or global subjective stress were less common basis of stress measures in children and adolescents, as discovered in Study 1. In the background sections of the General Introduction, I discussed other research evidence that supports an association between global subjective stress and adverse health outcomes during childhood and adolescence. You may recall that children and adolescents who report higher global subjective stress experience greater emotional (e.g., depressive symptoms, anxiety symptoms; Lu et al., 2014; Martin et al., 1995; Williams et al., 2017) and physical health outcomes (e.g., greater asthma severity, larger weight status; Lu et al., 2014; Van Jaarsveld et al., 2009). These findings suggest that it is of relevance to consider global subjective stress in children and adolescents.

Interestingly, available findings suggest that global subjective stress better predicts health outcomes, compared to life events. In adults, global subjective stress better predicts overall physical health and depressive symptoms, compared to life events (global subjective stress: r=0.67-0.76; life events: r=0.18-0.29; Cohen et al., 1983; Pbert et al., 1992). Similar results are observed in children and adolescents. In fact, findings from our own prior work showed that global subjective stress better predicts dysregulation of diurnal cortisol (global

subjective stress: *r*=.10-.21 *versus* life events: *r*=.12-.14; Ly et al., 2015), and more sleep problems (global subjective stress: *r*=.19-.50 *versus* life events: *r*=.11-.28; Ly et al., 2015), compared to life events. Other researchers have observed parallel findings with depressive symptoms (global subjective stress: *r*=0.45-0.58 *versus* life events *r*=0.32-0.25; Martin et al., 1995). These findings were intriguing, and raise the question as to why global subjective stress is a better predictor of health outcomes than life events.

We questioned whether the disparate results were due to conceptual and measurement differences. For example, life events capture the construct of stressor exposure whereas global subjective stress captures the construct of psychological response. In some life event measures, event severity is assessed to quantify psychological response, but event severity captures psychological response that is more specific than global subjective stress. Study 2 addressed plausible conceptual and measurement differences underlying global subjective stress and life events, and tested whether these differences would elucidate the disparate results linking health outcomes with global subjective stress and life events. Specifically, four differences were considered: conceptualization, specificity, proximity, and timeframe.

STUDY 2:

Stressor Exposure versus Psychological Response: Disentangling Conceptualization and Measurement Differences and their Associations with Child and Adolescent Health Outcomes

Abstract

Existing findings show that global subjective stress better predicts health outcomes compared to stressful life events in both adults and youth. The present study examines key differences in the conceptualization and measurement of global subjective stress and stressful life events that may contribute to their disparate associations with health outcomes in children and adolescents. The present study also examines whether the association between stress and health outcomes varied based on informant source and health outcomes measured. Participants included children and adolescents aged 9-17 years (N=192, M_{age}=12.74 years, 56.0% boys). Participants reported their global subjective stress, endorsed stressful life events they were exposed to in the past year and in their lifetime (i.e., event count), and provided three severity ratings for each endorsed event (retrospective, maximum, current event severity). Measures of health outcomes included internalizing and externalizing symptoms, sleep, metabolic factors, and cortisol. Results based on regression analyses showed that event severity ratings (i.e., psychological response) better predicted health outcomes than event count alone (i.e., stressor exposure). Current event severity (i.e., past 30 days) better predicted health outcomes, compared to retrospective or maximum event severity ratings. However, global subjective stress still better predicted health outcomes than current event severity. The association between stress and health outcomes was stronger when a single informant was used to derive both predictor and outcome variables, or when emotional health outcomes were examined. Findings suggest that one's general psychological response to stress, derived from global subjective stress, has a stronger predictive value than stressor exposure or specific psychological response; however, researchers need to carefully consider informant source and health outcomes measured. Implications for conceptualization and recommendation for more precise stress measurement were discussed.

Stressor Exposure versus Psychological Response: Disentangling Conceptualization and Measurement Differences and their Associations with Child and Adolescent Health Outcomes

Exposure to stressful life events early in the developmental lifecourse shapes individual vulnerability for later health outcomes. Accumulating systematic reviews and meta-analyses from the Adverse Childhood Experience (ACE) literature demonstrate a clear pattern evidencing the long-term health consequences of childhood life events. For instance, adults who report experiences of abuse, neglect, and/or family mental illness prior to age 18 years are at 1.5 to 4 times higher risk of developing adult depression and anxiety (Danese et al., 2009; Lindert et al., 2014), sleep disorders (Kajeepeta, Gelaye, Jackson, & Williams, 2015), metabolic syndrome (Danese et al., 2009; Huang et al., 2015), cardiovascular diseases (Su, Jimenez, Roberts, & Loucks, 2015), and cancer (Holman et al., 2016). Importantly, there is a dose-response relation, in that individuals who report one adverse childhood event are at 1.89 times higher risk of illness versus individuals who report four or more events are at up to 12.0 times higher risk (Flaherty et al., 2006; Newbury et al., 2018). Together, evidence from the ACE literature supports the Cumulative Risk Model, which posits that greater cumulation of stressor exposure is associated with worse health outcomes in a dose-response manner (Felitti et al., 1998). Evidence is also consistent with Epel et al.'s (2018) Integrative Lifespan Model of Stress and Health, which emphasizes individuals' *lifetime* stressor exposure in the study of health. The Integrative Lifespan Model of Stress and Health also distinguishes stressor exposure from individuals' psychophysiological response to such exposure, and articulates the importance of considering stressor timescales (e.g., acute, daily, chronic), stressor attributes (e.g., stressor severity, duration, frequency, life domain), and contextual factors (e.g., socioeconomic status, cultural context, genetic predispositions) for more precise stress measurement (Epel et al., 2018).

Despite generally robust findings, the ACE literature is almost exclusively based on adult retrospective report of childhood stressful life events. Recent research, however, has challenged the repeatability of adult retrospective report of ACEs. Findings from population-based studies have demonstrated only 61.0% stability over a 12-year period (Colman et al., 2016), and even lower stability (50.0%) over a 3-year period (Fergusson, Horwood, & Woodward, 2000) in the retrospective report of childhood abuse, parental separation/divorce, and parental substance abuse. Longitudinal studies following respondents from childhood through adulthood have also

demonstrated low agreements (k=.13-.31) between prospectively recorded ACEs during childhood and later retrospectively reported ACEs during adulthood (Naicker, Norris, Mabaso, & Richter, 2017; Newbury et al., 2018; Patten et al., 2015; Reuben et al., 2016). Taken together, there is a need to examine early stressful life events during childhood and adolescence.

The ACE literature generally focuses on traumatic events that threaten the physical and/or psychological safety of the individual or close others, such as physical/sexual abuse and household violence (Epel et al., 2018). However, many events commonly captured in ACE measures overlap with items in life events measures, which are time-limited, episodic, and less severe in nature (e.g., family death, family illness, parental separation/divorce, parental unemployment; Dube, Williamson, Thompson, Felitti, & Anda, 2004; Kessler et al., 1997). Moreover, many life event measures include the assessment of traumatic events, such as sexual/physical abuse, witnessing a crime, household violence, family suicide, among others (e.g., Coddington, 1972; Compas et al., 1987; Masten et al., 1994; Williamson et al., 2003). Even though traumatic events are conceptualized as a severe form of life events (Epel et al., 2018), such distinction is often not clearly delineated or reflected in existing measures. Life events are commonly measured by asking respondents to endorse events they have experienced within a specific assessment timeframe (typically in the past year), and to rate the severity associated with each endorsed event (Cohen et al., 1995). Cumulative stressor exposure is quantified by tallying the number of endorsed events (i.e., event count) or summing severity ratings for endorsed events (i.e., event severity).

Despite robust findings linking stressor exposure with health outcomes, findings consistently show that individuals' global subjective stress better predicts health outcomes compared to life events. Global subjective stress is event-independent, and refers to one's global perception of how demanding their daily life is in the past month (Cohen et al., 1983). In adults, global subjective stress better predicts physical health and depressive symptoms, compared to life events (global subjective stress: r=0.67-0.76; life events: r=0.18-0.29; Cohen et al., 1983; Pbert et al., 1992). Similarly, in children and adolescents, global subjective stress also better predicts dysregulation of diurnal cortisol (global subjective stress: r=.10-.21 *versus* life events: r=.12-.14; Ly et al., 2015), more sleep problems (global subjective stress: r=.19-.50 *versus* life events: r=.11-.28; Ly et al., 2015) and greater depressive symptoms, compared to life events (global subjective stress: r=.45-.58 *versus* life events: r=.21-.25; Martin et al., 1995). These

findings raise the question as to why global subjective stress is a better predictor of health outcomes than life events.

Differences in the conceptualization and measurement of life events and global subjective stress may account for the disparate results. Four differences will be considered: conceptualization, specificity, proximity, and timeframe. First, life events and global subjective stress reflect distinct conceptualizations. Prominent stress theories, like Cognitive Appraisal Theory (Lazarus & Folkman, 1984), Integrative Lifespan Model of Stress and Health (Epel et al., 2018), and Stage Change Model (Cohen et al., 2016), have distinguished two separate, yet interrelated concepts: *stressor exposure* and *psychological response*. Stressor exposure refers to identifiable stimuli or situations deemed demanding, undesirable, or threatening in one's life (Brown & Harris, 1989; Cohen et al., 1995; Epel et al., 2018; Holmes & Rahe, 1967; Paykel, 1997). Psychological response refers to one's subjective perception, appraisal, and/or emotional response, which can be general or specific to a stressor (Cohen et al., 1983; Epel et al., 2018; Lazarus & Folkman, 1984). Extant research suggests that stressor exposure alone is not sufficient to predict health outcomes (Kanner et al., 1981; Koolhaas et al., 2011; Williamson et al., 2005, 2003). Findings show that, while overall individuals who are exposed to life events are at higher risk for health problems, only 50% of individuals develop health outcomes (Cohen et al., 1998). Instead, researchers posit that the effects of stressor exposure on health depends on one's psychological response (Cohen et al., 2016; Epel et al., 2018; Lazarus & Folkman, 1984). Hence, global subjective stress, which captures psychological response, may be a better predictor of health outcomes than life events.

Second, although some life event measures include the assessment of psychological response (i.e., event severity; Paykel, 1997; Williamson et al., 2003), life events and global subjective stress measures differ in terms of *specificity* in the assessment of psychological response. Severity ratings in life event measures reflect one's *response to specific stressors* while global subjective stress captures *general response* (Epel et al., 2018). Studies have showed that psychological response to specific stressors, quantified as the summed severity ratings of stressor exposure, enhances the prediction of health outcomes, compared to examining number of stressor exposure alone (i.e., event count). However, the effect size increase is modest (average *r* increase of .04; Cohen et al., 1995; Sarason et al., 1978). Further, global subjective stress still better predicts health outcomes, compared to psychological response to specific stressors (Cohen

et al., 1983; Ly et al., 2015). In their early work, Cohen et al. (Cohen et al., 1983) argued that measuring psychological response specific to stressors is problematic, as early findings showed that individuals often misattribute the stressor source of their response (Gochman, 1979; Keating, 1979). Further, Cohen et al. (1983) further argued that health risk is likely conferred via individuals' global perception of how demanding their life is, and not just by their psychological response to specific stressors.

Third, life events and global subjective stress measures differ in terms of *proximity* of assessment. In life event measures, individuals are typically asked to retrospectively recall the occurrence (yes/no) of an event, and to retrospectively rate each endorsed life event for its severity at the time they experienced it. Measuring one's psychological response to stressor exposure retrospectively is problematic, as it assumes that individuals can reliably recall their response at the time. It also assumes that individuals' evaluation of an event is static. Individuals engage in an ongoing process of evaluation and re-evaluation, wherein individuals' psychological response to an event is calibrated relative to other stressor exposure in their lives (Epel et al., 2018; Lazarus, 1966; Lazarus & Folkman, 1984). As such, individuals can initially evaluate an event as severe but may later re-evaluate it as benign, or vice versa. There is a need to examine whether individuals' *current psychological response* (i.e., event severity in past month) would enhance the prediction of health outcomes, compared to *retrospective psychological response* to specific stressors (i.e., retrospective recall of event severity). Moreover, there is a need to examine whether *current psychological response* to specific stressors would yield similar results as global subjective stress in predicting health outcomes.

Fourth, disparate results may be attributable to the narrow assessment timeframe commonly used in life event measures. Respondents are typically asked to endorse life events they have experienced in the past year; thus, measures only capture psychological response to *recent stressor exposure* (c.f., Vanaelst et al., 2012). The use of a 1-year timeframe is largely influenced by early stress research with adults, which assumed the effects of stressor exposure manifest approximately one year following the onset of a life event (Holmes, 1979; Holmes & Rahe, 1967). However, abundant evidence from the ACE literature has challenged this original assumption and suggests the importance of considering *lifetime stressor exposure* (e.g., Felitti et al., 1998; Kessler et al., 2010). To date, minimal studies have directly compared the use of different assessment timeframes in the prediction of health outcomes. Findings from two studies

showed that life events in the past year better predicted depressive symptoms and diurnal cortisol, compared to life events in the past 3 months (Martin et al., 1995). These findings suggests that there is incremental utility to expanding the assessment timeframe. However, it remains to be tested whether capturing psychological response to *lifetime* versus *recent* stressor exposure would enhance the prediction of health outcomes. Importantly, it remains to be tested whether *current* psychological response to *lifetime* stressor exposure would yield similar results as global subjective stress in predicting health outcomes.

Taken together, four plausible conceptual and measurement differences may elucidate the stronger association between global subjective stress and health outcomes, compared to life events. In addition to these disparate results, questions remain whether the relation of stressor exposure and psychological response with health depend on "how" and "which" health outcomes are measured. Prominent stress theories, like the Integrated Lifespan Model of Stress and Health (Epel et al., 2018) and Stage Change Model (Cohen et al., 2016), do not address the relevance of informant source in the association between stress and health. Interestingly, existing findings show that life events and health outcomes are often stronger when a single informant is used to derive both predictor and outcome variables, suggesting that the associations may be inflated due to *mono-informant bias*. For example, associations have been stronger for self-rated (r=.18-.40) than researcher-measured health outcomes (r=.07-.08; Reuben et al., 2016). Informant source becomes a particularly important issue in child and adolescent research, where parents are often used as the informant for their child's stressor exposure, psychological response, and health outcomes (Allen & Rapee, 2009; Coddington, 1972; Yamamoto, 1979). Relatedly, self-reported stress (stressor exposure and global subjective stress) usually more strongly predicts emotional and mental health outcomes (r=.40), compared to researcher-measured physical health outcomes (r=.07-.23; Reuben et al., 2016). The weaker associations between stress and physical health outcomes may be attributable to psychometric differences (e.g., measurement error), but may also be due to the stronger affective component captured in psychological response measures (e.g., global subjective stress; Epel et al., 2018). Together, findings suggest that informant source and types of health outcomes influence the association between stress and health outcomes.

The goal of the present study is two-fold. First, we tested whether conceptual and measurement differences would elucidate the disparate results linking health outcomes with global subjective stress and life events. Specifically, we hypothesized that (1) psychological

response would better predict health outcomes than stressor exposure alone; (2) general psychological response would better predict health outcomes than psychological response to specific stressors; and (3) current psychological response to lifetime stressor exposure would better predict health outcomes than retrospective psychological response. Second, we tested whether the association between stress and health outcomes would differ depending on informant source as well as types of health outcomes. Specifically, we hypothesized that the association between stress and health outcomes would be higher (1) when a single informant is used for both stress and health outcomes, and (2) when examining emotional versus physical health outcomes.

Method

Participants

Participants included children and adolescents (*N*=192; 9-17 years) who participated in the larger Healthy Heart Project (Concordia University, Montreal, Quebec) between October 2014 and August 2017. The Healthy Heart Project is an ongoing research study examining early cardiovascular disease precursors. Youth (the term "youth" will be used for parsimony to capture children and adolescents) were recruited using flyers, postcards, and bookmarks distributed throughout the local community, and in schools approved by the English Montreal School Board. The project was approved by the Concordia University Research Ethics Committee (#10000088).

Measures

Stressor Exposure and Psychological Response to Stressors – Youth Informant.

Youth completed the Stressful Life Events Schedule adapted for questionnaire use to address the present study's research question (Williamson et al., 2003). This adapted measure is comprised of 33-item stressful events across 8 life domains, including: school (e.g., failed a grade, changed schools), family (e.g., parental separation, new family member), peers (e.g., bullying, falling-out), romantic relationships (e.g., break up, new romantic relationship), health (e.g., severe illness, injury), finance (e.g., family financial problem, parental unemployment), work (e.g., fired from job, difficulties at work), and neighbourhood/housing (e.g., home burglary, fire). Youth were instructed to endorse stressful life events they have experienced in their lifetime and in the past year. Youth provided 3 severity ratings for each endorsed event on an 11-point Likert scale (0 *not at all* to 10 *very stressful*) for when the event happened (i.e., retrospective), when the event was at its worst (i.e., maximum), and in the past month (i.e., current). An 11-point Likert scale was used, as it has been shown to increase reliability, validity, and sensitivity in self-report

measures (Leung, 2011; Preston & Colman, 2000). Two event count sum scores, with possible ranges of 0-33, were derived to capture lifetime and recent stressor exposure by tallying the number endorsed events: (1) **lifetime events** (defined as lifetime exposure to events) and (2) **recent events** (defined as exposure to events in the past year). Three event severity sum scores, with possible ranges of 0-330, were derived for psychological response to stressors by weighing endorsed events by their respective severity ratings: (1) **retrospective event severity**, (2) **maximum event severity**, and (3) **current event severity** (i.e., past month). These sum scores are used to capture youth's different severity ratings based on the time lapse from initial stressor exposure to the present moment.

Stressor Exposure – Parent Informant. Parents completed the Social Readjustment Rating Scale (Holmes & Rahe, 1967), and were instructed to endorse stressful events they have experienced in the past year. Events overlapping with youth-report stressful events included parental separation/divorce, parental unemployment, and family death, among others. Sum score of items were used as an indicator of **parent-report recent events** (defined as exposure to events in the past year).

General Psychological Response. Youth completed the Perceived Stress Scale (PSS) to derive their global subjective stress. The PSS is a 10-item self-report questionnaire assessing the extent to which individuals find their lives unpredictable, uncontrollable, and overloaded within the past month (Cohen et al., 1983). Youth rated items on a 5-point Likert scale (0 *never* to 4 *very often*). Sum score ranged from 0-40, with higher scores indicating higher levels of **global subjective stress**. The PSS has previously demonstrated good psychometric properties with children and adolescents (α=0.81; Ly et al., 2015). This measure has been used in youth as young as 8 years of age (Ly et al., 2015; Martin et al., 1995; Rotenberg & McGrath, 2016). In the current sample, internal consistency was high (α=0.84).

Participant-Rated Emotional/Behavioural Health Outcomes. Youth and their parents completed the Child Behavior Checklist (CBCL), a standardized screening questionnaire for youth's emotional and behavioural problems. Respondents rated 118 statements on a 3-point Likert scale (0 *not true*, 1 *somewhat or sometimes true*, 2 *very true or often true*). Items were summed to yield a raw score for the "internalizing problems", "externalizing problems", "anxious/depressed", and "withdrawn/depressed" subscales. Subscale raw scores were then

transformed into sex- and age-standardized t-scores (Achenbach, 1991); t-scores above 63 are considered within clinical range.

Participant-Rated Physical Health Outcomes. The quality subscale of the Pittsburgh Sleep Quality Index (PSQI) was used to derive **subjective sleep quality** (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Youth answered the item "Overall, I would rate my sleep as __" on a 10-point Likert scale (1 *very bad* to 10 *very good*). The PSQI has good internal consistency (α=0.81-0.83; Buysse et al., 1989; Grandner, Patel, Gehrman, Perlis, & Pack, 2010). The PSQI and its subscales were designed and validated for adults, and they have been used with children and adolescents (Ly et al., 2015; Tan, 2004).

Researcher-Measured Physical Health Outcomes. Youth's objective sleep was quantified using actigraphy (Actiwatch 2, Philips Respironics, PA, USA), a wrist-worn piezo-electric accelerometer, with microprocessors to detect movements. Youth wore the actigraphy on their non-dominant wrist for up to two weeks (*M*=9.17 days, *SD*=4.12). Actigraphy data was scored using Philips Actiware 6.0.1 by two independent raters, who coded start- and end-time of the rest interval with excellent reliability (i.e., time spent in bed; ICC_{start}=0.99; ICC_{end}=0.93). Mean **sleep onset latency** across recording nights was used for analyses.

Youth's anthropometric measures were taken by trained research assistants while youth were dressed in light clothing. Two weight status measures were derived: **body mass index (kg/m^2)** and **waist circumference**. Weight (kg) was measured with a bioelectrical impedance scale (Tanita Body Composition Analyzer BF-350, Tanita Corp, IL, USA). Height (m) was measured using a standard stadiometer at maximal breath with shoes off. Age-and sex-specific BMI Z-scores were determined using the growth charts published by the U.S. Centers for Disease Control and Prevention (Ogden, Flegal, Carroll, & Johnson, 2002). With a standard measuring tape, waist circumference (cm) was measured at the narrowest part of the body, midway between the lowest rib cage and the iliac crest.

After overnight fasting (12 hrs), youth's blood samples were collected by a registered nurse. Immediately after collection, blood samples were centrifuged at 3300 rpm for 15 min, and sent in dry ice for analyses (Gamma-Dynacare Medical Laboratories). **Fasting serum triglyceride**, **total cholesterol**, and **high-density lipoprotein (HDL) cholesterol** were determined using enzymatic colorimetric tests on Roche/Hitachi MODULAR P/D analyzers

(Roche Diagnostics, Laval, Canada); **low-density lipoprotein (LDL) cholesterol** was calculated based on the Friedewald equation (Friedewald, Levy, & Fredrickson, 1972).

After acclimatization and a 5-minute resting period, youth's **systolic blood pressure (SBP)** and **diastolic blood pressure (DBP)** readings were recorded from their non-dominant arm with an appropriate sized cuff using an auscultatory IBS-SD700A sphygmomanometer (Industrial & Bio-medical Sensors Corp, MA, USA). While seated, four measurements were recorded at 3 min intervals. The mean of four readings was used for analyses.

Youth collected six saliva samples each day over four consecutive weekdays at awakening ($awake_0$), 30min post-awakening ($awake_{+30}$), 45min post-awakening ($awake_{+45}$), pre-lunch, pre-dinner, and bedtime. Saliva samples were collected using the Salivette sampling device (Salimetrics Inc, CA, USA). Samples were returned during the second visit and stored in sub-zero freezers in the lab until they were packaged in dry ice and shipped to the University of Trier, Germany for assay. Samples were assayed using a competitive solid phase time-resolved fluorescence immunoassay with fluorometric end point detection (DELFIA; Dressendörfer, Kirschbaum, Rohde, Stahl, & Strasburger, 1992). The intra-assay coefficients of variation ranged from 4.08-14.40%. Aggregate index for **total cortisol level secreted throughout the day (AUC_{TG})** was calculated for each day of sampling (Rotenberg, McGrath, Roy-Gagnon, & Tu, 2012), and the mean of the four aggregate index was used for analyses. Total cortisol concentration (AUC_{TG}) was used for statistical analyses, as previous work has established that total cortisol is most robustly associated with stressful experiences (Ly et al., 2015).

Covariates. Information about youth's **age**, **sex,** and **puberty**, as well as **parental education level** and **household income** was obtained. Youth reported their pubertal status (adrenarche) using sex-appropriate schematic drawings of pubic hair growth corresponding to Tanner Stages I to V of pubertal development (Golding, Pembrey, & Jones, 2001; Marshall & Tanner, 1969, 1970). Pubertal illustrations have previously demonstrated good validity and reliability (Dorn, Susman, Nottelmann, Inoff-Germain, & Chrousos, 1990; Morris & Udry, 1980).

Procedure

Participants and their parents were scheduled for two visits to the laboratory, two weeks apart. Informed consent and youth assent were obtained. During the first visit, participants completed questionnaires, anthropometric measurements, and blood pressure readings; they

received instructions to use the Actiwatch to collect sleep data and Salivette sampling device to collect saliva samples. During the second visit, participants returned the Actiwatch and saliva samples, and completed blood draws. Participants received monetary compensation for their time.

Data Analyses Plan

Data were inspected for normality, linearity, and outliers to ensure assumptions of analyses were met. Descriptive data (means, standard deviations, skewness, kurtosis) were reviewed for all variables. Missing cortisol values (6.55%) were imputed using multiple imputation (Enders, 2010; McKnight, McKnight, Sidani, & Figueredo, 2007). Little's MCAR test indicated that missing single saliva samples were missing completely at random ($\chi 2$ [1232] = 1282.88, $p > .05$). Imputation of missing cortisol values was informed by data from the larger dataset (e.g., subsequent cortisol samples, time of sampling, awake time, sex, age, puberty); missing values were imputed 50 times with re-sampling technique in SPSS 23.0. Analyses were performed with both the original and imputed datasets. Findings did not vary; therefore, results based on the imputed dataset are presented for parsimony.

All analyses were conducted in SPSS 23.0. Pearson correlations were conducted to examine the bivariate correlations amongst stress variables. Linear regression analyses were conducted, with stress predicting health outcomes. Five targeted comparisons were performed. (1) To test that psychological response would better predict health outcomes than stressor exposure alone, event severity (retrospective, maximum, current event severity) and global subjective stress were compared to event count (lifetime, recent events) to predict health outcomes. (2) To test that general psychological response would better predict health than psychological response to specific stressor, global subjective stress was compared to event severity (retrospective, maximum, current event severity) to predict health outcomes. (3) To test that current psychological response to lifetime stressor exposure would better predict health than retrospective psychological response, current event severity was compared to retrospective event severity to predict health outcomes. (4) To test the mono-informant bias hypothesis, youth- and parent-report stressor exposure were compared to predict youth- and parent-report health outcomes. We examined the strength of association of event count, event severity, and global subjective stress in predicting participant-rated versus researcher-measured health outcomes. (5) To test that the stress and health association depends on health outcome measured, we examined

the strength of association of event count, event severity, and global subjective stress in predicting emotional/behavioural versus physical health outcomes. All analyses controlled for covariates known to influence health outcome variables (e.g., age, sex, adrenarche, parental education, household income, time of awakening).

Results

Descriptive Statistics

The sample consisted of 192 youth, aged 12.74 years (SD=2.08, range=9-17 years). The sample was predominantly Caucasian (63.0%), and about half of the sample were boys (56.0%). The sample included youth across the full range of pubertal stages (10.9% Tanner I, 16.1% Tanner II, 15.6% Tanner III, 27.6% Tanner IV, 19.8% Tanner V). Most parents completed a university degree (32.3%), and annual household income averaged $104,199CAD (median=$95,000CAD, range=$5,000-210,000CAD).

Descriptive statistics for stressor exposure and psychological response are presented in Table 1. On average, youth endorsed minimal stressor exposure, with few lifetime events (*M*=6.11, *SD*=3.99) and even fewer recent events (*M*=2.56, *SD*=2.90). Similarly, parents reported that their children were minimally exposed to life events in the past year (*M*=5.88, *SD*=4.05). Youth's current event severity (i.e., past month; *M*=11.19, *SD*=16.78) was lower than their retrospective event severity (*M*=27.07, *SD*=24.13), which in turn was lower than their maximum event severity (*M*=32.25, *SD*=27.40). Youth reported low global subjective stress (*M*=13.74, *SD*=6.71) based on previously published ranges (Cohen & Williamson, 1988; Cohen et al., 1983). Compared to boys, girls endorsed more lifetime and recent events, and rated events as more severe. Compared to boys, girls also reported higher global subjective stress. Sex difference was not observed in parent-report stressor exposure.

Descriptive statistics for health outcomes are presented in Table 2. Descriptive statistics indicated that youth- and parent-report CBCL scores were within normal limits (<63.0 t-score; <85th percentile). On average, youth reported good sleep quality (*M*=7.08, *SD*=1.77), and took 16 minutes to fall asleep (*M*=16.20 min *SD*=15.86). On average, youth's weight status (M_{BMI}=53.35th percentile, *SD*=29.96; M_{waist}=70.61cm, *SD*=10.19), triglyceride (M_{TRI}=0.82 mmol/L, *SD*=0.34), cholesterol (M_{TC}=3.90 mmol/L, *SD*=0.67), lipoprotein levels (M_{HDL}=1.49 mmol/L, *SD*=0.36; M_{LDL}=2.03 mmol/L, *SD*=0.55), and blood pressure (M_{SBP}=1.99.93 mmHg, *SD*=12.33; M_{DBP}=59.21 mmHg, *SD*=9.46) were within normal limits. On average, youth's

diurnal cortisol (M_{MAX}=13.68 nmol/L, *SD*=3.14; M_{AUCtg}=46.63, *SD*=19.95) were lower than those reported in previous publications with Healthy Heart participants recruited during earlier dates (i.e., before October 2014; M_{MAX}=18.04 nmol/L, *SD*=7.93; M_{AUCtg}=67.87, *SD*=34.05; Ly et al., 2015; Rotenberg & McGrath, 2016; Rotenberg et al., 2012).

Main Hypothesis Testing

Hypothesis 1: Stressor Exposure versus Psychological Response. Overall, psychological response (derived from retrospective, maximum, and current event severity, global subjective stress) better predicted health outcomes than stressor exposure (derived from lifetime and recent events; psychological response: β_{avg}=0.16 *vs* stressor exposure: β_{avg}=0.08). Standardized beta coefficients are averaged to facilitate comparisons (see all values in Table 4).

Hypothesis 2: Specific versus General Psychological Response. Regression analyses revealed that, overall, general psychological response (i.e., global subjective stress) better predicted health outcomes, compared to specific psychological response, derived from retrospective and current event severity (general: β_{avg}=0.24 *vs* specific: β_{avg}=0.14).

Hypothesis 3: Retrospective versus Current Severity Rating. Preliminarily, correlation analyses revealed that event severity ratings were highly correlated amongst each other (*r*=0.74-0.98), indicating that individuals who reported high current event severity also reported high maximum and high retrospective event severity. Correlation analyses also revealed current event severity (i.e., past month) was more correlated with global subjective stress (*r*=0.47), compared to retrospective (*r*=0.42) and maximum event severity (*r*=0.43). Regression results showed that, on average, current severity ratings best predicted health outcomes, compared to maximum or retrospective severity ratings (current: β_{avg}=0.16 *vs* maximum: β_{avg}=0.13 *vs* retrospective event severity: β_{avg}=0.12). Interestingly, global subjective stress still better predicted health outcomes compared to current event severity (global subjective stress: β_{avg}=0.24 *vs* current event severity: β_{avg}=0.16).

Hypothesis 4: Mono-Informant Bias. To test mono-informant bias, results for the association between stressor exposure and health were compared between youth versus parents as informant of recent events and emotional health outcomes. On average, youth-report recent events predicted youth-report emotional health outcomes (β_{avg}=0.19), but did not predict parent-report emotional health outcomes (β_{avg}=0.01). Similarly, on average, parent-report recent events

predicted parent-report emotional health outcomes (β_{avg}=0.13), but did not predict youth-report emotional health outcomes (β_{avg}=0.01).

To further test mono-informant bias, the association between stress and health was compared between participant-reported versus researcher-measured health outcomes. Overall, youth-report stress better predicted participant-reported than researcher-measured health outcomes (reported health outcomes: β_{avg}=0.23 *vs* measured health outcomes: β_{avg}=0.06)

Hypothesis 5: Emotional versus Physical Health Outcomes. Overall, stressor exposure, event severity, and global subjective stress better predicted emotional than physical health outcomes. This pattern was observed for event count (emotional: β_{avg}=0.14 *vs* physical: β_{avg}=0.05), event severity ratings (emotional: β_{avg}=0.25 *vs* physical: β_{avg}=0.06), and global subjective stress (emotional: β_{avg}=0.43 *versus* physical: β_{avg}=0.10).

Discussion

Extant research consistently has shown that individuals' global subjective stress better predicts health outcomes compared to life events. No studies to date have considered whether conceptualization and measurement differences between life events and global subjective stress may account for why these results are disparate. Past findings also suggest informant source and types of health outcomes may be relevant. Five key hypotheses were tested in the present study.

First, our hypothesis that psychological response would better predict health outcomes than stressor exposure was supported. The strength of the relation of health outcomes with psychological response was double that of stressor exposure. Additionally, these findings showed that psychological response to specific stressors better predict health outcomes compared to stressor exposure. Our findings extend existing research, which previously showed life events do not carry ubiquitous levels of severity (Koolhaas et al., 2011; Williamson et al., 2003). Our findings also support existing theories, which posit that one's psychological response to stressors is of greater relevance to health than stressor exposure, and that stressor exposure alone is not sufficient to predict health outcomes (Cohen et al., 2016; Epel et al., 2018; Lazarus & Folkman, 1984)). This finding in part supports why global subjective stress, which captures psychological response, may better predict health outcomes than life events, which typically only captures stressor exposure.

Second, the hypothesis that general psychological response derived from global subjective would better predict health outcomes than psychological response to specific stressors

derived from event severity ratings was supported. The strength of the relation of health outcomes with global subjective stress was almost double that of event severity ratings. Additionally, global subjective stress was only moderately correlated with current event severity. This implies that global subjective stress and event severity ratings in life event measures provide unique, non-overlapping information. Current findings extend Cohen et al.'s (1983) early work that one's global stress appraisal is more strongly predictive of health outcomes, compared to stressor-specific psychological response.

Third, current event severity (i.e., past month) better predicted health outcomes compared to retrospective event severity (i.e., retrospective recall of severity). Multiple event severity ratings, including retrospective, maximum, and current event severity, were used to capture youth's psychological response at different timepoints elapsed since the initial stressor exposure. The present findings suggest that there is incremental utility to examining current event severity in the prediction of health outcomes, compared to using retrospective event severity only. Youth rated lower current event severity than retrospective event severity, suggesting that individuals' psychological response to specific stressors decay over time. This finding is largely consistent with existing theories, which posits that individuals' psychological response to stressor exposure can change over time (Cohen et al., 2016; Epel et al., 2018; Lazarus & Folkman, 1984).

The present study showed that there were high correlations amongst event severity ratings. This finding was intriguing, as it suggested that youth who endorsed high current event severity also reported high maximum and retrospective event severity. Two plausible reasons may account for the strong correlations. Youth who have initially rated the events as severe continue to rate them as severe. Alternatively, individuals who currently rate the events as severe are biased to provide more severe ratings for maximum and retrospective event severity; in other words, one's current state may alter retrospective appraisal of a stressor. A longitudinal design directly comparing prospective and retrospective report of stressor exposure is required to examine these possibilities. Existing longitudinal studies have compared prospectively and retrospectively-reported stressor exposure, and demonstrated low agreements (k=.13-.31; Naicker et al., 2017; Newbury et al., 2018; Patten et al., 2015; Reuben et al., 2016). Albeit these low agreements, both prospective and retrospective stressor exposure have been associated with health outcomes, and stronger associations have been observed for retrospective stressor exposure (retrospective: r=.13-40 *versus* prospective: r=.11-.23; Reuben et al., 2016). These

findings suggest that events that individuals *currently* report matter most to health. Importantly, stronger associations are observed when retrospective stressor exposure and health outcomes are concurrently measured.

Fourth, the hypothesis that mono-informant bias drives the association between stress and health was supported. We examined whether informant source influences the association between stressor exposure and health outcomes. Findings showed that youth-report stressor exposure predicted all youth-report emotional/behavioural health outcomes, but inconsistently predicted parent-report emotional/behavioural health outcomes. Similarly, parent-report stressor exposure predicted greater parent-report emotional health outcomes, but did not predict youth-report emotional health outcomes. We also established that stressor exposure and psychological response better predicted participant-rated health outcomes than researcher-measured health outcomes. This pattern of results was intriguing, and suggests the associations between stress and subjective health outcomes lie "in the eyes of the beholder". That is, individuals who report more stress are likely to report more health problems. These findings corroborate research in the adult literature that have established stronger associations when self-report measures were used for both predictor and health outcomes (Naicker et al., 2017; Reuben et al., 2016). This pattern has important implications for pediatric research, which often uses parents as the sole informant of children's health. There is need to examine both participant-rated and researcher-measured health outcomes in stress and health research.

Fifth, the hypothesis that stress would better predict emotional health outcomes compared to physical health outcomes was supported. Specifically, the association of emotional health outcomes with event count, event severity ratings, and global subjective stress were more than double that of physical health outcomes. Our findings support existing research, which shows that stressor exposure most strongly predict emotional and mental health outcomes (r=.40), compared to physical and physiological health outcomes (r=.07-.23; Reuben et al., 2016). The stronger association between stress and emotional health outcomes may be attributable to mood-congruent memory bias. Colman et al. (2016) have shown that negative mood state is associated with greater reports of stressor exposure. Thus, it is not surprising global subjective stress, which captures an affective component, most strongly predicted emotional health outcomes. Future studies should examine whether individuals' mood state influence the association between stress and emotional health outcomes.

The lack of association between event count, event severity, and global subjective stress with blood pressure and diurnal cortisol was unanticipated. In fact, these findings are inconsistent with our own prior work, which established significant associations (e.g., Ly et al., 2015; Rotenberg & McGrath, 2016). Two possible explanations may account for the lack of findings. First, the disparate results may be attributable to participants coming from families with higher socioeconomic status compared to participants in previous studies (household income ~$105,000 in current sample; household income ~67,000 in Ly et al., 2015; Rotenberg & McGrath, 2016). Second, the lack of association may be attributable to the fact that the current sample endorsed fewer stressful events (average 6.11 out of possible 33 events) and low global subjective stress. Youth may not have accumulated sufficient "wear-and-tear" on their physiological system, and it may take longer for certain physiological health outcomes to emerge. The silver lining of these findings is that there is still time to offset this health trajectory.

Study Limitations, Future Directions, and Conclusions

There were several methodological limitations in the present study that merit discussion. First, children and adolescents from the current sample came from relatively high socioeconomic status family compared to previous studies (household income ~$105,000 in current sample; household income ~67,000 in Ly et al., 2015), which limits generalizability to only more affluent youth. Second, children and adolescents in the current sample endorsed fewer life events and reported minimal global subjective stress compared to those reported in previous child and adolescent studies (e.g., Ly et al., 2015). This may have a ceiling effect on the association between stress and health outcomes, and may explain the lack of association between stress and many physical health outcomes. Third, the present study was based on cross-sectional, retrospective data, which does not allow conclusions to be drawn about cause and effect. Future research should compare the relation between stressful life events and health outcomes longitudinally, with a focus on retrospective versus prospective measures of stressor exposure in the prediction of health outcomes during childhood and adolescence.

Despite these limitations, the present study was amongst the first to address conceptualization and measurement issues that may account for the disparate results linking health with global subjective stress and life events. As well, the present study also showed that informant source and types of health outcomes influence the magnitude of the association between stress and health. The present study has important implications for future research. First,

future studies should consider assessment of event severity when measuring individuals' exposure to life events, with focus on current (i.e., past month) as opposed to retrospective event severity ratings. Second, future studies should examine global subjective stress to enhance the prediction of health outcomes. Finally, future studies should carefully consider informant source in the measurement of stressor exposure, global subjective stress, and health outcomes.

Table 1

Means and Standard Deviations of Youth- and Parent-Report Stress

	Total (*N*=192)		Boys (*n*=109)		Girls (*n*=83)		
	M	*SD*	*M*	*SD*	*M*	*SD*	*t*
Event Count							
Lifetime Events (0-33)	6.111	3.996	5.482	3.708	6.938	4.226	**2.535***
Recent Events (0-33)	2.557	2.901	2.027	2.205	3.253	3.513	**2.516***
Event Severity							
Retrospective Event Severity (0-330)	27.069	24.127	22.068	19.315	33.637	28.064	**3.380***
Maximum Event Severity (0-330)	32.246	27.398	25.784	20.904	40.732	32.320	**3.880***
Current Event Severity (0-330)	11.185	16.779	8.633	11.986	14.537	21.131	**2.447***
Global Subjective Stress (0-40)	13.738	6.710	12.823	6.371	14.940	6.988	**2.187***
Parent-Report Recent Events	5.875	4.052	5.617	3.910	6.201	4.236	0.865

*$p<.05$

Table 2

Means and Standard Deviations of Emotional and Physical Health Outcomes

		Total (*N*=192)		Boys (*n*=109)		Girls (*n*=83)		
		M	*SD*	*M*	*SD*	*M*	*SD*	*t*
Participant-Rated Health Outcomes	Youth-Report CBCL T-Scores							
	Total Problems	51.208	9.387	51.620	7.870	50.642	11.180	0.647
	Internalizing Problems	53.223	10.116	53.391	8.949	52.985	11.638	0.247
	Externalizing Problems	48.658	8.614	49.000	8.135	48.182	9.283	0.588
	Anxious/Depressed	56.151	7.100	56.044	6.735	56.299	7.622	0.223
	Anxious/Withdrawn	55.195	6.488	54.902	5.304	55.597	7.855	0.666
	Parent-Report CBCL T-Scores							
	Total Problems	49.769	11.221	50.188	10.804	49.238	11.795	0.501
	Internalizing Problems	52.287	10.704	53.025	10.755	51.349	10.650	0.929
	Externalizing Problems	48.650	9.863	48.750	9.645	48.524	10.210	0.136
	Anxious/Depressed	55.091	6.728	55.563	7.053	54.492	6.296	0.944
	Anxious/Withdrawn	55.385	6.724	56.250	7.341	54.286	5.718	**1.750†**
	Sleep							
	Subjective Sleep Quality (0-10)	7.08	1.772	7.06	1.715	7.11	1.855	-0.206
Researcher-Measured Health Outcomes	Sleep Latency (min)	16.202	16.858	18.969	18.007	12.489	11.504	**2.800***
	Weight Status							
	Body Mass Index (Z Score)	0.143	1.024	0.151	1.046	0.133	1.001	0.124
	Waist Circumference (cm)	70.613	10.193	71.361	10.948	69.639	9.091	1.159
	Metabolic Factors							
	Triglyceride (nmol/L)	0.816	0.336	0.799	0.319	0.842	0.361	0.794
	Total Cholesterol (nmol/L)	3.895	0.673	3.839	0.726	3.974	0.584	1.252
	HDL (nmol/L)	1.492	0.361	1.467	0.369	1.526	0.348	0.998
	LDL (nmol/L)	2.032	0.553	2.008	0.579	2.065	0.516	0.643
	Blood Pressure							
	SBP (mmHg)	99.926	12.327	102.056	12.157	97.180	12.068	**2.751***
	DBP (mmHg)	59.210	9.463	58.771	9.651	59.776	9.243	0.725
	Cortisol							
	Maximum Sample (nmol/L)	13.679	3.138	13.168	5.776	14.329	4.591	1.374
	AUC_{TG}	46.627	19.945	43.827	20.540	50.186	18.705	**2.015***

Table 3

Zero-Order Correlations between Stress Measures

	1	2	3	4	5	6
Stressor Exposure						
1. Lifetime Events	-					
2. Recent Events	0.690*	-				
Specific Psychological Response						
3. Retrospective Severity	0.836*	0.530*	-			
4. Maximum Severity	0.846*	0.539*	0.975*	-		
5. Current Severity	0.558*	0.326*	0.766*	0.737*	-	
6. Global Subjective Stress	0.316*	0.153*	0.415*	0.431*	0.467*	-
7. Parent-Report Recent Events	0.089	-0.029	0.061	0.062	-0.031	0.089

*$p<.05$

Table 4

Univariate Regression Models Predicting Health Outcomes Adjusted for Covariates

Emotion/Behaviour Outcomes	Youth-Report CBCL								Parent-Report CBCL							
	Internalizing Problems		Externalizing Problems		Anxious/ Depressed		Withdrawn/ Depressed		Internalizing Problems		Externalizing Problems		Anxious/ Depressed		Withdrawn/ Depressed	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Stressor Exposure																
Lifetime Events	**0.226**	**2.845***	**0.395**	**5.284***	**0.214**	**2.711***	0.152	1.888†	0.109	1.256	0.132	1.492	0.078	0.872	0.058	0.644
Recent Events	**0.134**	**1.671†**	**0.355**	**4.664***	**0.173**	**2.169***	0.091	1.148	0.001	0.008	-0.010	-0.115	0.007	0.080	-0.028	-0.313
Specific Psyc Response																
Retrospective Severity	**0.318**	**4.112***	**0.430**	**4.709***	**0.315**	**4.085***	**0.249**	**3.161***	**0.181**	**2.127***	0.120	1.362	**0.184**	**2.103***	0.133	1.504
Maximum Severity	**0.332**	**4.313***	**0.366**	**4.832***	**0.327**	**4.268***	**0.269**	**3.414***	**0.179**	**2.079***	0.112	1.255	**0.182**	**2.055***	0.108	1.204
Current Severity	**0.400**	**5.343***	**0.276**	**3.528***	**0.348**	**4.571***	**0.356**	**4.768***	**0.226**	**2.735***	**0.147**	**1.712†**	**0.286**	**3.419***	**0.225**	**2.641***
Global Subjective Stress	**0.579**	**8.684***	**0.361**	**4.743***	**0.572**	**8.590***	**0.400**	**5.572***	**0.451**	**6.022***	**0.269**	**3.238***	**0.457**	**5.912***	**0.399**	**5.010***
Parent-Report Events	-0.131	-1.397	0.054	0.594	-0.074	-0.794	-0.128	-1.472	**0.133**	**1.691†**	**0.160**	**1.994***	**0.146**	**1.807†**	0.099	1.215

Physical Outcomes	Subjective Sleep Quality		Objective Sleep Latency		BMI Z-Score		Waist Circumference	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Stressor Exposure								
Lifetime Events	-0.117	-1.550	-0.076	-0.984	0.062	0.806	0.036	0.498
Recent Events	0.003	0.045	0.033	0.426	-0.005	-0.066	0.023	0.318
Specific Psyc Response								
Retrospective Severity	-0.119	-1.569	0.004	0.046	-0.024	-0.310	-0.043	-0.590
Maximum Severity	**-0.154**	**-2.024***	-0.002	-0.025	-0.019	-0.249	-0.040	-0.548
Current Severity	**-0.158**	**-2.135***	**0.164**	**2.176***	-0.038	-0.502	-0.041	-0.571
Global Subj Stress	**-0.324**	**-4.642***	0.036	0.480	**0.155**	**2.100***	**0.149**	**2.132***
Parent-Report Events	-0.007	-0.079	-0.029	-0.348	**0.143**	**1.767†**	**0.171**	**2.254***

Physical Outcomes	Metabolic Factors								Blood Pressure				Diurnal Cortisol			
	Triglyceride		Total Cholesterol		HDL		LDL		SBP		DBP		Maximum Cortisol		AUC_{TG}	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Stressor Exposure																
Lifetime Events	0.140	1.459	0.036	0.373	**-0.162**	**-1.709†**	0.104	1.067	0.017	0.232	-0.022	-0.270	-0.004	-0.45	-0.035	-0.422
Recent Events	0.021	0.217	-0.088	-0.937	-0.068	-0.732	0.043	0.726	-0.007	-0.101	-0.131	-1.603	0.008	0.094	-0.056	-0.681
Specific Psyc Response																
Retrospective Severity	0.154	1.627	-0.046	-0.480	**-0.159**	**-1.700†**	0.001	0.013	-0.013	-0.183	-0.036	-0.433	-0.036	-0.415	-0.006	-0.068
Maximum Severity	**0.189**	**1.973†**	-0.040	-0.418	**-0.186**	**-1.966***	0.015	0.152	0.008	0.110	-0.020	-0.240	-0.013	-0.148	0.007	0.083
Current Severity	**0.172**	**1.828†**	-0.057	-0.600	-0.075	-0.799	0.068	0.704	-0.071	-0.992	0.000	0.006	0.015	0.170	0.042	0.508
Global Subj Stress	**0.185**	**1.991***	0.061	0.654	-0.125	-1.350	0.101	1.065	-0.032	-0.443	0.015	0.182	-0.007	-0.082	0.035	0.423
Parent-Report Events	0.165	-1.030	0.054	0.524	-0.126	-1.251	0.098	0.924	0.101	1.362	0.017	0.195	-0.094	-0.986	-0.04	-1.022

Note. All analyses controlled for age, sex, adrenarche, parental education, household income. Analyses predicting metabolic factors additionally controlled for sleep duration. Analyses predicting Maximum Cortisol and AUC_{TG} additionally controlled for BMI-Zscore, sleep duration, time of awakening. Bold values indicate significance: †p<.10 *p<.05.
Results for participant-rated health outcomes are highlighted in gray in table.

TRANSITION FROM STUDY 2 TO STUDY 3

Existing research showed that global subjective stress and life events are disparately associated with health outcomes in children and adults. Thus, given the pediatric stress measurement issues identified in Study 1, we sought to craft nuanced comparisons to isolate unique, specific explanations that may account for these disparate results. The primary goal of Study 2 was to examine whether conceptual and measurement differences would elucidate the associations between global subjective stress and life events with health outcomes. We established three main findings related to this objective. First, psychological response better predicted health than stressor exposure alone. Second, general psychological response better predicted health than specific psychological response. Third, current psychological response better predicted health than retrospective psychological response to specific stressors. The secondary goal of Study 2 was to examine whether the association between stress and health outcomes differed depending on informant source for stressor exposure and types of health outcomes examined. We established two main findings related to this objective. First, we established that mono-informant bias largely drives the association between stress and health; youth-report stressor exposure predicted youth-report health outcomes, but inconsistently predicted parent-report health outcomes, and vice-versa. Second, we established that stressor exposure and global subjective stress more strongly predicted emotional health outcomes than physical health outcomes.

An interesting pattern of results emerged in Study 2. Global subjective stress yielded larger effect sizes compared to life events, regardless of how life events were measured (i.e., event count or event severity ratings). In fact, results from Study 2 are consistent with our own previous work, which showed that global subjective stress better predict sleep and diurnal cortisol, compared to stressful life events (Ly et al., 2015). These findings alluded to the idea that global subjective stress alone, in the absence of stressor exposure, may be sufficient to contribute to health outcomes.

Cohen et al. (1983) contended that global subjective stress is dynamic and sensitive to ongoing changes in individuals' life circumstances. Given this responsive, transient conceptualization, researchers previously posited that global subjective stress at a single point in time should not reliably predict long term health consequences (Epel et al., 2018). Interestingly, a meta-analysis of prospective studies with adults found that higher global subjective stress was

associated with a 27% increased risk in cardiovascular disease over 13 years (Richardson et al., 2012). This raises the question of the stability of global subjective stress, and whether individuals who consistently report high global subjective stress are at greater risk of health outcomes. Several adult studies have established moderate to high stability in global subjective stress (*r* and ICC=0.65-0.90), suggesting that global subjective stress may be less dynamic than originally conceptualized (Almadi et al., 2012; Chaaya et al., 2010; Remor, 2006; Siqueira Reis et al., 2010; Wood, Maltby, Gillett, Linley, & Joseph, 2008).

At present, there is a paucity of adolescent research examining global subjective stress longitudinally using repeated-measures designs. Examining the stability of global subjective stress in adolescents is important because stress experienced early in the developmental lifecourse shapes health trajectories (Hertzman, 1999). Thus, the overarching goal is to examine the stability of global subjective stress during adolescence and to consider whether it is a stable individual difference in a sample of adolescents followed longitudinally.

STUDY 3:

Individual Differences in Global Subjective Stress in a Longitudinal Sample of Adolescents

Abstract

Global subjective stress was originally conceptualized as a dynamic construct, reflective of one's subjective stress appraisal. Adult findings suggest greater stability in reported global subjective stress. The goal of the present study was to examine whether stable individual differences in global subjective stress exist in adolescents. Adolescents (*N*=382) recruited at 7th grade in secondary school participated across eight data collection cycles over 4 years. Global subjective stress and covariates, including sex, subjective social status, household chaos, and life events were measured. Overall, a moderate 47.0% stability in global subjective stress was observed across eight data collection cycles. Sex differences in stability of global subjective stress were observed, with adolescent girls exhibiting higher baseline and greater increase in global subjective stress over time than adolescent boys. Among all covariates, household chaos accounted for the most variance in global subjective stress over time. Specifically, rate of change in global subjective stress depended on adolescents' household chaos over time. Adolescents who reported increasing levels of household chaos over time showed the fastest rate of increase in global subjective stress over time; adolescents with consistently high household chaos showed decrease in global subjective stress over time. Taken together, current findings provide preliminary support for moderate stability in global subjective stress among adolescents, with nuanced fluctuations sensitive to recent stressor exposure. Implications for future research to further dissect the construct of global subjective stress are discussed.

Individual Differences in Global Subjective Stress in a Longitudinal Sample of Adolescents

Mounting evidence consistently links global subjective stress with health outcomes during adolescence. Cross-sectionally and prospectively, there is a robust association between global subjective stress and adverse health such that adolescents reporting higher global subjective stress have more depressive symptoms (r=0.48-0.76; Lu et al., 2014; Martin et al., 1995; Williams et al., 2017), elevated anxiety symptoms (r=0.44-0.53; Lu et al., 2014), larger weight status (r=0.15-0.18; Van Jaarsveld et al., 2009), and greater asthma severity (r=0.17; Lu et al., 2014). Global subjective stress is thought to link with adolescents' health both indirectly and directly (Moeini et al., 2008). Indirectly, global subjective stress likely exerts its influence via increased health-risk behaviours. For instance, higher global subjective stress has been associated with smoking initiation and maintenance (Byrne et al., 2007), unhealthy dietary choices (e.g., more frequent consumption of sweets, fatty food, fast food; Austin, Smith, & Patterson, 2009; Cartwright et al., 2003; Mikolajczyk, El Ansari, & Maxwell, 2009), and unhealthy sleep habits and sleep curtailment (Ly et al., 2015; Mousseau, Lund, Liang, Spencer, & Walsh, 2016). Directly, global subjective stress has been associated with disruptions to regulatory systems, like neuroendocrine functioning (Ly et al., 2015; Milam, Slaughter, Verma, & McConnell, 2014; Rotenberg & McGrath, 2016), autonomic nervous system functioning (Rotenberg & McGrath, 2016), and inflammatory response/immune functioning (Cohen et al., 2007; Sexton et al., 2017). Despite evidence for the implication of global subjective stress on health, researchers have criticized the lack of thoroughness in conceptualization and measurement of global subjective stress (Epel et al., 2018). Therefore, the present paper examines the dynamic nature and psychometric stability of global subjective stress to meaningfully contribute to stress science research.

Global subjective stress (also known as global perceived stress in the literature) refers to individuals' general perception of how demanding their life is, and captures one's global psychological response rather than exposure to specific stressors (Cohen & Williamson, 1988; Cohen et al., 1983; Epel et al., 2018). Cohen et al. (1983) initially conceptualized global subjective stress as a dynamic construct sensitive to ongoing changes in individuals' life circumstances, such as recent stressor exposure and changes in coping resources. The contention that global subjective stress is a dynamic construct was supported by Cohen et al.'s early work that demonstrated global subjective stress measured two days apart yielded a higher correlation

(*r*=.85) than six weeks apart (*r*=.55; Cohen et al., 1983). Therefore, they concluded that one's global subjective stress would not be stable, but rather would fluctuate in response to changes in individuals' life circumstances.

Curiously, recent findings suggest that global subjective stress may reflect a stable individual difference, and that it is less dynamic than originally posited. In other words, while there may be dynamic variation in one's global subjective stress, within-individual variation is markedly less than between-person variation. Individuals high in trait neuroticism tend to perceive stressful situations as highly threatening with low coping resources, resulting in higher global subjective stress (Ebstrup et al., 2011; Mroczek & Almeida, 2004). Individuals low in general self-efficacy (i.e., global and stable sense of personal competence to deal effectively with demands across wide ranging domains of functioning; Schwarzer & Jerusalem, 1995) report higher global subjective stress compared to individuals with higher self-efficacy (Chemers et al., 2001; Pintrich & De Groot, 1990). Importantly, Federenko and colleagues examined the heritability of global subjective stress in a comparative twin study, and showed heritability as high as 45.0% (Federenko et al., 2006). These findings imply there may be more stable individual differences in global subjective stress.

Limited research has considered the stability of individual differences in global subjective stress over time. Available adult studies typically examine test-retest reliability of global subjective stress at two timepoints; stability of global subjective stress can still be inferred from these studies because the same statistics are used to derive stability and test-retest reliability (e.g., ICC, Intra-Class Correlation; *r*, Pearson correlation; DeVellis, 2006). Several studies have established high stability in global subjective stress 1 to 4 weeks apart (ICC=0.72-0.90; Almadi et al., 2012; Chaaya et al., 2010; Remor, 2006; Siqueira Reis et al., 2010; Wongpakaran & Wongpakaran, 2010). Wood et al. (2008) demonstrated moderate stability when the timespan was extended to three months (*r*=0.65-0.68). Further, the stability of global subjective stress remains similar even when the timespan is extended to 12 months (*r*=0.63; Cacioppo, Hawkley, & Thisted, 2010) and 24 months apart (*r*=0.67; Barbosa-Leiker et al., 2013). Overall, existing findings provide evidence of stable individual differences in global subjective stress among adults, despite nuanced fluctuations in the dynamic response to more proximal experiences over the past month.

The question remains whether stable individual differences in global subjective stress emerge early in the developmental lifecourse. Among adolescents, there is a paucity of research examining global subjective stress with repeated measurements. In one longitudinal study, adolescents' global subjective stress was examined at two timepoints, 12 months apart (Lorenzo-Blanco & Unger, 2015). Adolescents' global subjective stress was moderately correlated across the two timepoints (r=.41; Lorenzo-Blanco & Unger, 2015). Meaningful conclusions cannot be drawn from these findings due to measurement constraints as an abbreviated version of the Perceived Stress Scale (4-item vs 10-item) was administered at the second timepoint to derive global subjective stress (Lorenzo-Blanco & Unger, 2015). The 4-item version of the Perceived Stress Scale was initially developed for screening purposes, and has demonstrated lower internal consistency than the 10-item version of the measure (Lee, 2012). Therefore, it remains unclear whether global subjective stress is a stable individual difference during adolescence.

In adult studies, time-invariant and time-varying covariates, such as sex, subjective social status, and stressor exposure have been associated with global subjective stress. For instance, sex differences in global subjective stress have been well-established, with female respondents reporting significantly higher global subjective stress compared to their male counterparts (Andreou et al., 2011; Hewitt, Flett, & Mosher, 1992; Lesage, Berjot, & Deschamps, 2012; Leung, Lam, & Chan, 2010; Remor, 2006). Higher subjective social status, has also been associated with lower global subjective stress in adults (Watson, Logan, & Tomar, 2008). Greater stressor exposure, measured by number of life events in the past year, has been associated with higher global subjective stress (Cohen et al., 1998; Ly et al., 2015). Problematically, existing findings are limited to the cross-sectional association between the covariates and global subjective stress. There is a paucity of longitudinal studies considering how these covariates contribute to the variability in global subjective stress over time.

Additionally, global subjective stress has been associated with cortisol, a marker of physiological stress response. Predominant approaches to measure physiological stress response are derived from salivary, plasma, or urine cortisol. Cortisol is secreted in a pulsatile manner; thus, single samples only provide cortisol concentration levels at one static point in time (Stalder & Kirschbaum, 2012). Despite this pharmacokinetic limitation, researchers have used repeated sampling of saliva, plasma, or urine as a proxy for longer term cortisol secretion, by aggregating cortisol samples collected over 24 hrs across multiple days (Stalder & Kirschbaum, 2012).

However, this methodology becomes increasingly difficult to apply in larger scale studies, and may not be the most valid approach to examining cortisol secretion. Recently, the measurement of cortisol in hair has emerged as a promising stress biomarker (Gow, Thomson, Rieder, Van Uum, & Koren, 2010; Russell, Koren, Rieder, & Van Uum, 2012; Stalder & Kirschbaum, 2012). Hair has a fairly predictable growth rate of 1cm/month. The most proximal 1cm hair segment to the scalp has been used to estimate cortisol secreted over the last month (Wennig, 2000). Cortisol in hair is not released in a pulsatile fashion, and hair cortisol concentrations show a high level of intra-individual stability in the absence of severe life events, such as divorce or family death (Karlén, Ludvigsson, Frostell, Theodorsson, & Faresjö, 2011; Stalder & Kirschbaum, 2012). That is, cortisol detected in hair at a given assessment timepoint is largely determined by long-term, systemic influences rather than transient, daily fluctuations (Stalder & Kirschbaum, 2012). Thus, it is plausible that hair cortisol would covary with one's global subjective stress, if global subjective stress also reflects greater stability.

To date, the association between hair cortisol and global subjective stress has only been examined in adults, and findings have been mixed. Specifically, studies have established moderate associations (r=0.24-0.47; Kalra, Einarson, Karaskov, Van Uum, & Koren, 2007; Van Uum et al., 2008), weak associations (r=0.06-0.11; Karlén et al., 2011; Wells et al., 2014), and no associations between global subjective stress and hair cortisol (Dowlati et al., 2010; O'Brien, Tronick, & Moore, 2013). These mixed findings may be due to sample characteristics. For example, the association between hair cortisol and global subjective stress is stronger among clinical populations (Kalra et al., 2007; Van Uum et al., 2008), but weaker among the general population (Wells et al., 2014). The association between hair cortisol and global subjective stress is stronger in female-only studies (Kalra et al., 2007). It remains to be tested whether hair cortisol is associated with global subjective stress in adolescents, and whether hair cortisol contributes to the variability of global subjective stress over time.

Taken together, adult findings suggest that global subjective stress may be a moderately stable individual difference, even though it was initially conceptualized as a dynamic construct sensitive to ongoing changes in individuals' life circumstances. It remains unclear whether global subjective stress is a stable individual difference among adolescents. This is a timely question to address given increasing calls for improvement in stress measurement and conceptualization (Epel et al., 2018). Moreover, examining individual differences in global

subjective stress among adolescents is particularly opportune given that stress in adolescence shapes disease trajectories later in life (Hertzman, 1999). The first objective was to examine whether global subjective stress is stable individual difference in a longitudinal sample of adolescents. The second objective was to examine whether time-invariant and time-varying covariates, such as sex, subjective social status, stressor exposure, and hair cortisol may account for variability in global subjective stress over time.

Method

Participants

Adolescents were recruited as part of a larger longitudinal cohort study (AdoQuest II) designed to examine smoking initiation among never-smoking adolescents. The sampling procedure was designed to be representative of the general adolescent population. Adolescents were recruited from 7th grade classrooms in French-speaking secondary schools, approved by the local school board, within the greater Montreal area in Quebec. The project was approved by the Concordia University Research Ethics Committee (#1000116).

Procedure

School principals and teachers were contacted to obtain their agreement to collect data during class time for the first cycle. Informed consent and assent were provided by parents and adolescents, respectively. During the school visit, adolescents completed self-report questionnaires, while trained research assistants collected a hair sample from each adolescent. For adolescents who agreed to take part in subsequent data collection cycles, study materials were mailed to adolescents' homes, including standardized instructions to complete self-report questionnaires and collect the hair sample at home (see details below). AdoQuest II used a staggered recruitment procedure, with the first data collection cycle launched in 2011 and the last cycle in 2015. The second data collection cycle occurred ~1 year after the first collection cycle; remaining collection cycles occurred at ~4 month intervals. Adolescents were given the opportunity to participate in up to a total of eight cycles; they were permitted to skip any given cycle without penalty. Adolescents received financial compensation for their participation ($25 gift card per cycle).

Measures

Global Subjective Stress. Adolescents completed the Perceived Stress Scale (PSS) at each data collection cycle. The PSS is a 10-item self-report questionnaire that measures

individuals' global perception of how demanding their daily life is over the past month (Cohen et al., 1983). Specifically, it assesses individuals' perceived level of uncontrollability, unpredictability, and overload in their daily life. Participants rated items on a five-point Likert scale (0 *never* to 4 *very often*). Items were summed to derive a total score for global subjective stress (negative items reverse coded), with higher scores indicating higher levels of global subjective stress. The French version of the Perceived Stress Scale was used for the current sample. The French version has been previously validated, and demonstrated good internal consistency among adults (α=0.73-0.81; Lesage et al., 2012). In the current sample, the Perceived Stress Scale demonstrated high internal consistency across all cycles (α=0.75-0.92).

Covariates

Hair Cortisol. At the school visit, trained research assistants using fine-tipped surgical scissors collected a sample of hair strands of ~.25 in/1cm in diameter (approximate size of a pencil eraser) cut closely to the scalp from the vertex posterior region of the head. Hair collected from the vertex posterior region has been shown to have the lowest coefficient of variation (Sauvé, Koren, Walsh, Tokmakejian, & Van Uum, 2007). Upon receipt at the laboratory, participants' hair strands were stored in a small manila envelope in a dark, dry room at room temperature (68-74°F) until couriered for assay. For subsequent collection cycles, written instructions were provided to adolescents to remind them how to collect hair strand samples with the help of a family member. Research shows that adolescents can reliably collect hair samples at home, and that hair samples can be mailed to the laboratory via regular post without affecting cortisol measurement (Ouellet-Morin et al., 2016).

Hair samples were assayed for cortisol at the Centre for Studies on Human Stress, Montreal, QC. Cortisol concentrations were obtained for the first centimeter hair segment most proximal to the scalp, providing a retrospective index of cortisol secretion over the past month. Protocols for washing of hair strands and steroid extraction, described in previous published studies, were used (Davenport, Tiefenbacher, Lutz, Novak, & Meyer, 2006; Kirschbaum, Tietze, Skoluda, & Dettenborn, 2009). Hair cortisol levels were determined in duplicate using a commercially available luminescence immunoassay with detection range .005-4 ug/dl. Intra-assay coefficients of variation were 6.54%.

Subjective Social Status. Adolescents completed the Subjective Social Status Scale (also known as the MacArthur Scale of Subjective Social Status) at each data collection cycle to

derive their **subjective social status**. The Subjective Social Status Scale is a validated, adolescent-specific measure that captures adolescents' sense of their social standing relative to others (Goodman et al., 2001). On a 10-rung ladder, adolescents rated their social status relative to peers in their school in terms of grades and popularity.

Stressor Exposure. Two measures were used to assess adolescents' stressor exposure. Adolescents completed the Chaos, Hubbub And Order Scale (CHAOS) at each data collection cycle. The CHAOS is a 15-item self-report questionnaire measuring the extent of **household chaos** (Matheny et al., 1995). Items assess the extent to which the daily home atmosphere is characterized by lack of routine, disorganization, and noise. Participants rated each item on a five-point Likert scale (0 *definitely false* to 4 *definitely true*). Items were summed for a total household chaos score (negative items reverse coded), with higher scores representing more stressful, disorganized, and noisy household environments. Adolescents also completed an adapted version of the Stressful Life Events Schedule at their last data collection cycle to assess their exposure to **life events** (Williamson et al., 2003). This adapted measure is comprised of 36 life events. Adolescents were instructed to endorse life events they have experienced in their lifetime, in the past year, and in the past month. Three sum scores, with possible ranges of 0-33 by tallying the number endorsed events: (1) **events lifetime**, (2) **events past year**, and (3) **events past month**.

Statistical Analyses Plan

Adolescents who completed at least two data collection cycles were included in the present study. Of the 549 participants who took part in the first data collection cycle (i.e., school visit), 382 participants took part in at least one subsequent data collection cycle (i.e., mailed to home). Missing data were due to the use of a staggered recruitment procedure, which permitted adolescents to skip any given cycle without penalty. Preliminary analyses revealed there were no differences in terms of sample characteristics, initial hair cortisol, or initial global subjective stress between adolescents who completed and those who did not complete any subsequent data collection cycles. Missing cycle data were addressed using multiple imputation in SPSS 23.0 (Enders, 2010; McKnight et al., 2007). Multiple imputation procedures were informed by data in the AdoQuest II Study (e.g., data collection cycle, sex, age, subjective social status, hair cortisol, household chaos, life events, and global subjective stress); missing values were imputed 25 times with re-sampling technique. Analyses were performed with both the original and imputed

datasets. Effect sizes were larger for the non-imputed data. More conservative results based on imputed dataset are presented for parsimony. All analyses were conducted using SPSS 23.0.

For the first objective, classical measurement theory was used to examine the stability of global subjective stress. Specifically, intra-class correlation (ICC) analyses were used to evaluate the stability of global subjective stress across cycles. The use of ICC is more statistically appropriate than Pearson *r*, as ICC accounts for absolute consistency (DeVellis, 2006; Kroll, 1962; Ludbrook, 2002). The ICC coefficient was calculated using the two-way mixed effect model described by Shrout & Fleiss (1979). The ICC represents the ratio of between-subject variability (σ^2_{bs}) to total variability (i.e., between-subject variability plus within-subject variability σ^2_{ws}; ICC= $\sigma^2_{bs}/[\sigma^2_{bs}+ \sigma^2_{ws}]$). An ICC ranges from 0 to 1, with larger values meaning higher stability.

For the second objective, multilevel modelling was used to test whether time-invariant and time-varying covariates may account for variability in global subjective stress over time. Within-individual change in global subjective stress was modeled as a function of time measured in months to account for the non-equidistant time intervals between data collection cycles. Growth models were centered to time 1, and a total of seven models were estimated. In Model 1, an unconditional means model was estimated for global subjective stress and the intra-class correlation (ICC) was calculated as $\sigma^2_{intercept} / [\sigma^2_{intercept} + \sigma^2 \varepsilon]$. As indicated above, the ICC reflects the proportion of variance in global subjective stress accounted for by between-individual clustering (Peugh, 2010; Singer & Willet, 2003). In Model 2, an unconditional growth model was estimated to examine the extent of variability that exists in global subjective stress over time (i.e., rate of change in global subjective stress).

In Models 3 and 4, time-invariant covariates (sex, events lifetime) were added to the growth model singularly to estimate the contribution of each covariate in the rate of change in global subjective stress. Events lifetime were included in the model as a time-invariant covariate, as they were measured in the last collection cycle only. In Models 3 and 4, the main effect of time-invariant covariates was estimated to reflect the average difference in initial global subjective stress (at Time 1) associated with one unit increase in the covariate. The time-invariant covariate by time interaction effect was estimated to reflect the average difference in the rate of change in global subjective stress associated with one unit increase in the covariate.

In Models 5-7, time-varying covariates (subjective social status, hair cortisol, household chaos) were added to the growth model singularly to estimate the contribution of each covariate in the rate of change in global subjective stress. The main effect of the time-varying covariate was estimated to reflect the average difference over time in global subjective stress associated with one unit increase in the covariate. The time-varying covariate by time interaction effect was estimated to reflect the different contribution of the covariate in the rate of change in global subjective stress (i.e., the rate of change in global subjective stress across different change trajectories in the time-varying covariate).

For Models 3-7, pseudo-R^2 was calculated as (σ^2_{TIME} in Model 2 - σ^2_{TIME} in subsequent model) / σ^2_{TIME} in Model 2. The interpretation of pseudo-R^2 is analogous to that of ΔR^2, with higher values representing greater proportion of variance in changes in global subjective stress over time that is accounted for by the additional covariates in the model.

Results

At initial assessment (Cycle 1), participants included adolescents recruited at 7th grade (M_{age} = 12.98 years, SD_{age} = 0.85). About half of the sample were females (58.1%), and the majority of the sample were White/Caucasians (66.0%). On average, adolescents rated 7 on a 10-rung ladder for subjective socioeconomic status (M =7.06, SD=1.54). On average, adolescents' hair cortisol levels were 16 pg/mg (M=16.58; SD=8.65), which are comparable to values reported in a previous publication with adolescents (Vanaelst, Huybrechts, et al., 2012). Adolescents endorsed low to moderate household chaos (M=33.63, SD=6.06), and minimal life events in their lifetime (M=7.43, SD=4.19), in the past year (M=3.22, SD=2.42), and in the past month (M=3.10, SD=2.16). Adolescents reported low to moderate global subjective stress (M=13.13, SD=6.31), with girls (M=13.76, SD=6.78) reporting higher global subjective stress than boys (M=12.25, SD=5.49). Means and standard deviations for adolescents' age, subjective social status, hair cortisol, household chaos, events, and global subjective stress across data collection cycles are presented in Table 1.

The cross-sectional relation between relevant covariates and global subjective stress were examined. Across all cycles, adolescents who rated higher subjective social status reported lower global subjective stress (r=-0.27- -0.20, p<.001). Adolescents with higher hair cortisol reported higher global subjective stress (r=0.15-0.32, p<.001). Adolescents who reported higher household chaos (r=0.49-0.71, p<.001), and more life events in their lifetime (r=0.22-0.36,

p<.001), past year (r=0.19-0.32, p<.001), and past month (r=0.27-0.46, p<.001) also reported higher global subjective stress. Notably, events past month were most strongly correlated with global subjective stress measured at Cycle 8 (r=0.46, p<.001) versus global subjective stress measured at all earlier cycles (r=0.27-0.40). As well, global subjective stress at Cycle 8 was better correlated with events past month (r=0.46, p<.001) than events lifetime (r=0.22-0.36, p<.001) or past year (r=0.19-0.32, p<.001). Correlation results by cycle are presented in Table 2.

For the first objective, ICCs were conducted to examine the stability of global subjective stress over time. Overall, global subjective stress was moderately stable across all eight data collection cycles (ICC=0.47, p<.001). Global subjective stress was most stable when examined between more proximal or adjacent data collection cycles (~4 months apart; ICCs=0.50-0.65, p<.001). Global subjective stress was least stable when examined between more distal data collection cycles, specifically between the first and remaining data collection cycles (~12 months apart; ICCs=0.27-0.50, p<.001). Stability results based on ICCs are presented in Table 2.

For the second objective, multilevel modelling was used to test the effects of time-invariant and time-varying covariates in the variability in global subjective stress over time (see Table 3). Identical to stability results based on ICCs, Model 1 (i.e., unconditional means model) indicated substantial between-individual variability in global subjective stress, with the ICC estimated at 0.47. Model 2 (i.e., unconditional growth model) demonstrated a significant linear increase in global subjective stress over time (b=.044, p<.001), indicating that on average, global subjective stress tended to increase over time.

Models 3 and 4 examined the contribution of time-invariant covariates on the rate of change in global subjective stress. Model 3 revealed a significant main effect of sex, indicating that on average, girls reported 2.57 points more than boys in global subjective stress at Time 1 (b=2.574, p<.001). Model 3 also showed a significant sex by time interaction effect (b=0.057, p<.001). Figure 1 depicts this interaction effect, and shows that girls had a greater increase in global subjective stress over time while boys had a lower and more stable global subjective stress trajectory. Model 3 accounted for 3.7% of the variability in global subjective stress over time (Pseudo-R^2=.037). Model 4 showed a significant main effect for events lifetime (b=0.436, p<.001), but there was no significant events lifetime by time interaction effect (b=0.001, p=.64). These results suggest that greater events in adolescents' lifetime were associated with higher global subjective stress at Time 1, but were not associated with the rate of change in global

subjective stress. Models 4 accounted for minimal variability in global subjective stress over time (Pseudo-R^2=.000).

Models 5-7 examined the contribution of time-varying covariates on the rate of change in global subjective stress. Model 5 showed a significant main effect of subjective social status (b=-0.875, p<.001), indicating that on average global subjective stress over time was higher when subjective social status was lower. There was an average increase of 0.88 points in global subjective stress associated with one point decrease in subjective social status. However, there was no significant subjective social status by time interaction effect (b=0.003, p=.61), suggesting that changes in subjective social status did not contribute to the rate of change in global subjective stress. Model 5 accounted for 3.3% of the variability in global subjective stress over time (Pseudo-R^2=.033).

Model 6 showed a significant main effect of hair cortisol (b=0.139, p<.001), indicating that on average global subjective stress over time was higher among adolescents with higher hair cortisol. There was an average increase of 0.14 points in global subjective stress over time associated with 1pg/mg increase in hair cortisol. However, there was no significant hair cortisol by time interaction effect (b=0.003, p=.77), suggesting that changes in hair cortisol did not predict the rate of change in global subjective stress. Model 6 accounted for 14.2% of the variability in global subjective stress over time (Pseudo-R^2=.142), which was mainly driven by the fixed effects of hair cortisol.

Model 7 revealed a significant main effect of household chaos (b=0.452, p<.001), suggesting that global subjective stress was higher among adolescents with higher household chaos. There was an average increase of 0.45 points in global subjective stress over time associated with one point increase in household chaos. Model 7 also revealed a significant household chaos by time interaction effect (b=-0.003, p<.001), suggesting that the rate of change in global subjective stress was different across adolescents with different household chaos trajectories. To facilitate the interpretation of this interaction effect, groups based on cluster analyses were derived to demonstrate the changes in global subjective stress for adolescents with different trajectories of household chaos. Figure 2 visually depicts this interaction effect. Adolescents with consistently low and moderate household chaos had similar increases in global subjective stress over time. Adolescents with increasing levels household chaos over time had the greatest increase in global subjective stress over time. Unexpectedly, adolescents with

consistently high household chaos showed decreases in global subjective stress over time. Model 7 accounted for 60.0% of the variability in global subjective stress over time (Pseudo-R^2=.600).

Discussion

Global subjective stress was originally conceptualized as a dynamic construct, reflective of transient changes in stress appraisal. Emerging adult longitudinal studies suggest that global subjective stress is a psychological stress response that has moderate to high stability observed, and may reflect a stable individual difference. Increasing adolescent research has considered global subjective stress, but there is a paucity of prospective studies examining global subjective stress with repeated measurements. The overarching goal of the present study was to examine the stability of global subjective stress during adolescence. The first objective of the study was to examine whether global subjective stress is stable in a longitudinal sample of adolescents followed over eight timepoints. The second objective of the study was to examine whether time-invariant covariates (sex, life events) and time-varying covariates (subjective social status, hair cortisol, household chaos) accounted for variability in global subjective stress over time.

Overall, the present study established five main findings. First, global subjective stress was moderately stable, with 47.0% stability across eight data collection cycles; global subjective stress was more stable when assessed across more proximal than distal timepoints. Second, adolescent girls had higher global subjective stress at baseline and showed greater increase in global subjective stress over time compared to boys. Third, lower subjective social status and higher hair cortisol were associated with elevated global subjective stress; however, changes in subjective social status or hair cortisol were not associated with variability in global subjective stress over time. Fourth, events lifetime were not associated with increase in global subjective stress over time. Cross-sectionally, events past month was more correlated with global subjective stress, compared to events lifetime and past year. Importantly, events past month was most correlated with global subjective stress measured at the last collection cycle, compared to its relation with global subjective stress measured at earlier cycles. Finally, variability in global subjective stress over time depended on adolescents' household chaos trajectories. Specifically, adolescents with increasing levels of household chaos over time showed the greatest increase in global subjective stress over time. Interestingly, adolescents with consistently high household chaos showed decrease in global subjective stress over time.

Current results supported previous adult and adolescent studies that have suggested a conceptualization of global subjective stress reflecting greater stability. The current study extends adult findings that showed moderate to high stability for global subjective stress over time (Almadi et al., 2012; Chaaya et al., 2010; Remor, 2006; Siqueira Reis et al., 2010; Wongpakaran & Wongpakaran, 2010; Wood et al., 2008). The observed moderate stability of global subjective stress over shorter assessment timespans was consistent with previously reported adult studies that have examined global subjective stress 6 weeks apart (Cohen et al., 1983) and 3 months apart (Wood et al., 2008). The observed stability of global subjective stress lowered over longer assessment timespans, which was consistent with a previous adolescent study that observed moderate stability over 12 months (Lorenzo-Blanco & Unger, 2015). However, adult studies suggest even higher stability during adulthood over extended periods of time, including moderate to high stability of global subjective stress examined 12 to 24 months apart (Barbosa-Leiker et al., 2013; Cacioppo et al., 2010). These findings suggest that individual differences in global subjective stress may emerge early in the development and become increasingly stable during adulthood. It is plausible that global subjective stress increases throughout adolescence as observed in the present study, and becomes more stable as adolescents transition into adulthood. A longitudinal study following adolescents through adulthood is needed to examine the trajectory of global subjective stress across the lifespan.

The present study was amongst the first to examine the contribution of covariates on global subjective stress over time. Current findings were consistent with previous cross-sectional studies, which showed that female respondents report higher global subjective stress compared to males (Andreou et al., 2011; Hewitt et al., 1992; Lesage et al., 2012; Leung et al., 2010; Remor, 2006). Importantly, current findings showed that adolescent girls have greater increases in global subjective stress over time compared to boys, whose trajectory remained relatively lower and more stable. These findings extend past experimental studies, which showed that female participants have stronger psychological response following an experimental stressor tasks (more distress, fear, irritability, confusion), compared to their male counterparts (Kelly, Tyrka, Anderson, Price, & Carpenter, 2008). The sex difference in global subjective stress trajectory observed in the present study has important implications, suggesting that stability of psychological stress response is different for boys versus girls, and this difference emerges early. Previous studies demonstrated sex disparities in health outcomes, with females being at greater

risk for adverse health outcomes than males (e.g., cardiovascular diseases, depression, self-rated health; Boerma, Hosseinpoor, Verdes, & Chatterji, 2016; Ladwig, Marten-Mittag, Formanek, & Dammann, 2000; Van de Velde, Bracke, & Levecque, 2010). Further research is required to elucidate potential associations between early sex differences in the stability of global subjective stress and sex disparities in health outcomes.

Subjective social status and hair cortisol were associated with initial global subjective stress level, but did not contribute to *changes* in global subjective over time. Current findings replicate previous cross-sectional adult studies, which demonstrated an association between lower subjective social status and greater global subjective stress (Watson et al., 2008). Small to moderate associations between global subjective stress and hair cortisol were observed. The present findings were consistent with adult studies that observed small to moderate associations between global subjective stress and hair cortisol (Kalra et al., 2007; Van Uum et al., 2008; Wells et al., 2014).

The present study established a cross-sectional association between life events and global subjective stress. This finding is consistent with a number of adult and adolescent studies that have reported a small to moderate correlation between events past month and global subjective stress (r=0.26-0.38; Cohen et al., 1983, 1993; Ly et al., 2015; Martin et al., 1995). The present study established that events past month were most correlated with global subjective stress, compared to events lifetime or events past year. This finding partly supports the dynamic nature of global subjective stress sensitive to recent changes and stressor exposure (Cohen et al., 1983). Alternatively, the strong association may be driven by mono-informant bias, given that life events and global subjective stress were measured concurrently. It is plausible that adolescents who endorsed more events in the past month were more likely to report higher global subjective stress, and vice versa. Interestingly, greater events lifetime did not contribute to the increases in global subjective stress over time. Researchers have posited the potential influence of stressor exposure in global subjective stress over time. For instance, Hobfoll (2011) proposed that frequent and ongoing stressor exposure depletes one's resources more quickly. Thus, individuals who have experienced or are currently experiencing stressors are likely to experience more global subjective stress over time. The lack of association between events lifetime and changes in global subjective stress over time could be due to measurement issues. Life events were measured retrospectively and at one timepoint only, at the last data collection cycle. Further

studies are required to disentangle prospectively-measured versus retrospectively-reported life events and their association with global subjective stress.

A different picture for the relation between stressor exposure and global subjective stress emerged when household chaos was examined. Of all covariates, household chaos accounted for the most variability in changes in global subjective stress over time. Adolescents with higher household chaos reported higher levels of global subjective stress, suggesting that adolescents experience higher global subjective stress when living in home atmospheres characterized by disorganization, noise, and lack of routine. Rate of change in global subjective stress varied for adolescents with different household chaos trajectories. Adolescents who reported low or moderate household chaos over time had similar rate of increase in global subjective stress over time. Interestingly, adolescents who reported increasing levels of household chaos over time showed the fastest rate of increase in global subjective stress over time. As well, adolescents with consistently high household chaos showed decrease in global subjective stress over time. These findings suggest that adolescents' global subjective stress may be sensitive to changes in their environment. However, adolescents may begin to have higher thresholds for global subjective stress, and perhaps even "blunting" of psychological stress response among adolescents who are habituated to chronically chaotic household environments. Given that only a small percentage of adolescents reported increasing levels of household chaos, power issue may limit the generalizability of these findings. Future research with a larger sample size is required to disentangle the contribution of household chaos on global subjective stress.

Study Limitations and Strengths

The present investigation is not without limitations. First, as mentioned above, the examination of life events was limited to the last data collection cycle only. Examining stressful life events in their lifetime and in the past month may help capture the effects of cumulative and more proximal events in the stability of global subjective stress in adolescents. Therefore, there is a need to examine stressful life events prospectively in future studies. Second, considerable variability in global subjective stress over time remain unaccounted for. The unaccounted variability could in part due to statistical reasons, with covariates added to the growth model singularly. Examining the contribution of all covariates simultaneously were not possible due to power issue. The unaccounted variability could also be due to systematic and unsystematic covariates not examined in the present study (e.g., socioeconomic status, coping resources).

Third, measures of current mood-state were not included. Mood-congruency hypothesis posits that negative mood state facilitates the recall of negatively-valenced information (Bower, 1981). For example, Colman and colleagues have shown that negative mood state is associated with greater likelihood of endorsing life events and decreased likelihood of omitting life events (Colman et al., 2016). Given the demonstrated influence of mood state on self-reported stressor exposure, it would be expected that mood state would also influence one's global subjective stress over time. Fourth, the current study did not consider personality traits. Neuroticism and general self-efficacy have been previously associated with global subjective stress (Chemers et al., 2001; Ebstrup et al., 2011; Mroczek & Almeida, 2004; Pintrich & De Groot, 1990). Careful consideration of the role personality traits would be necessary to extend our stability findings toward a trait-like conceptualization of global subjective stress. Fifth, the present study used a staggered recruitment procedure, which allowed adolescents to skip any data collection cycles without penalty. This recruitment procedure helped reduced attrition, but also resulted in numerous missing data across cycles. Multiple imputation procedure was used to help maintain statistical power and reduce bias due to unbalanced data structure. Thus, the pattern of missing data may be attributable to systematic non-participation, and limit the generalizability of current findings.

Despite these limitations, the present study had several strengths. First, the present study included up to eight timepoints, a powerful repeated-measures design that allowed the study of stability of global subjective stress during adolescence. Second, the present study was amongst the first to examine the contribution of covariates in adolescents' stability in global subjective stress. Relatedly, the present study was also amongst the first to examine hair cortisol in an adolescent sample, and its association with global subjective stress. Given the longitudinal design, the present study provided opportunity to examine whether changes in hair cortisol predict changes in global subjective stress over time.

Conclusions, Implications, and Future Directions

The present study established that global subjective stress evidences moderate stability during adolescence. Current findings meaningfully add to current stress conceptualization. The present study suggests that global subjective stress may reflect a stable individual difference, with nuanced fluctuations sensitive to more proximal experiences over the past month. It is plausible that the stability of global subjective stress, or our psychological response to stressors,

emerges early in the developmental lifecourse. Future research should replicate our findings and elucidate how early this stable individual difference begins to emerge. To the best of our knowledge, this is one of the first studies to consider the stability of global subjective stress across adolescence; further longitudinal research with improved measurements and larger sample size is warranted. Current findings have important implications for future researcher, including the need to consider health risks amongst individuals who consistently report higher versus lower global subjective stress over time.

Table 1

Means (Standard Deviations) of Covariates and Global Subjective Stress by Data Collection Cycle

Cycle	Age (years)	Subjective Social Status (1-10)	Hair Cortisol (pg/mg)	Stressor Exposure				Global Subjective Stress[b] (0-40)		
				Household Stress (5-75)	Events Lifetime[a] (0-36)	Events Past Year[a] (0-36)	Events Past Month[a] (0-36)			
								Total (*N*=382)	Girls (*n*=222)	Boys (*n*=160)
1	12.98 (0.85)	7.06 (1.54)	16.58 (8.65)	33.63 (6.06)	-	-	-	13.12 (6.31)	13.76 (6.78)	12.25 (5.49)
2	14.01 (0.99)	6.93 (1.32)	23.38 (6.06)	32.71 (8.06)	-	-	-	14.31 (7.05)	15.81 (7.30)	12.24 (6.14)
3	14.44 (0.96)	6.97 (1.18)	23.85 (5.51)	32.81 (8.33)	-	-	-	14.03 (6.76)	15.41 (6.82)	12.11 (6.18)
4	14.73 (0.98)	6.91 (1.25)	23.84 (7.57)	33.48 (8.54)	-	-	-	14.05 (7.11)	16.00 (7.14)	11.34 (6.12)
5	15.18 (1.10)	6.84 (1.33)	22.90 (7.61)	33.17 (8.50)	-	-	-	14.56 (6.85)	16.64 (7.03)	11.68 (5.42)
6	15.45 (1.06)	6.75 (1.13)	27.52 (6.15)	33.09 (9.07)	-	-	-	14.25 (6.78)	15.97 (6.97)	11.85 (5.70)
7	15.93 (0.97)	6.84 (1.04)	23.63 (4.59)	33.16 (7.05)	-	-	-	15.12 (5.84)	16.91 (5.90)	12.66 (4.77)
8	16.29 (0.96)	6.86 (0.92)	23.46 (4.00)	32.76 (6.47)	7.43 (4.19)	3.22 (2.42)	3.10 (2.16)	14.86 (5.37)	16.84 (5.16)	12.10 (4.36)

[a] Time-invariant covariates measured at cycle 8 only

[b] Significant sex difference at $p<.001$ level in global subjective stress across all 8 cycles

Table 2

Correlation between Covariates and Global Subjective Stress & Stability of Global Subjective Stress

	Correlation between Covariates and Global Subjective Stress (Pearson r[a])						Stability of Global Subjective (Intra-Class Correlation[a, d])							
	Time-Varying Covariates			Time-Invariant Covariates										
Cycle	Subjective Social Status[b]	Hair Cortisol[b]	Household Chaos[b]	Events Lifetime[c]	Events Past Year[c]	Events Past Month[c]	1	2	3	4	5	6	7	8
1	-0.22	0.15	0.71	0.22	0.19	0.27	-							
2	-0.27	0.20	0.49	0.26	0.20	0.32	0.50	-						
3	-0.20	0.32	0.50	0.29	0.23	0.31	0.42	0.58	-					
4	-0.25	0.23	0.55	0.33	0.27	0.36	0.46	0.51	0.62	-				
5	-0.22	0.17	0.58	0.35	0.28	0.40	0.40	0.45	0.52	0.64	-			
6	-0.25	0.21	0.55	0.35	0.32	0.32	0.40	0.46	0.52	0.52	0.61	-		
7	-0.23	0.31	0.62	0.36	0.36	0.40	0.30	0.36	0.38	0.49	0.54	0.50	-	
8	-0.25	0.20	0.59	0.30	0.25	0.46	0.27	0.35	0.41	0.42	0.51	0.44	0.65	-

[a] All correlations and ICCs significant at $p<.001$ level
[b] Time-varying covariates and its relation to global subjective stress at each cycle
[c] Time-invariant covariates measured at cycle 8 only and its relation to global subjective stress at each cycle
[d] *ICC*=0.47 for stability of global subjective stress across all 8 cycles

Table 3

Multilevel Models Estimating the Effects of Time-Invariant and Time-Varying Predictors in Global Subjective Stress Changes Over Time

	MODEL 1 Unconditional Means Model	**MODEL 2** Unconditional Growth Model	**MODEL 3** Sex	**MODEL 4** Events Lifetime	**MODEL 5** Subjective Social Status	**MODEL 6** Hair Cortisol	**MODEL 7** Household Chaos
	UNSTANDARDIZED FIXED EFFECT COEFFICIENTS						
Intercept	14.285***	13.254***	11.745***	10.018***	19.387***	10.443***	1.800*
Time	-	0.044***	0.012	0.034*	0.017	0.033†	0.150***
TIME-INVARIANT COVARIATES							
Sex	-	-	2.574***	-	-	-	-
Sex x Time	-	-	0.057*	-	-	-	-
Events Lifetime	-	-	-	0.436***	-	-	-
Events Lifetime x Time	-	-	-	0.001	-	-	-
TIME-VARIANT COVARIATES							
Subjective Social Status	-	-	-	-	-0.875***	-	-
Subj Social Status x Time	-	-	-	-	0.003	-	-
Hair Cortisol	-	-	-	-	-	0.139***	-
Hair Cortisol x Time	-	-	-	-	-	-0.001	-
Household Chaos	-	-	-	-	-	-	0.452***
Household Chaos x Time	-	-	-	-	-	-	-0.003***
	RANDOM EFFECT VARIANCE COMPONENTS						
Residual (σ^2_{ε})	22.750***	19.759***	19.719***	19.757***	19.354***	19.332***	17.245***
Intercept ($\sigma^2_{intercept}$)	20.312***	30.359***	28.890***	27.001***	28.137***	28.69***	13.866***
Time (σ^2_{time})	-	0.014***	0.013***	0.014***	0.013***	0.012***	0.006***
Pseudo-R^2	-	-	0.037	0.000	0.033	0.142	0.600

† Unstandardized fixed effects significant at $p<.10$ level
* Unstandardized fixed effects significant at $p<.05$ level
*** Unstandardized fixed effects significant at $p<.001$ level

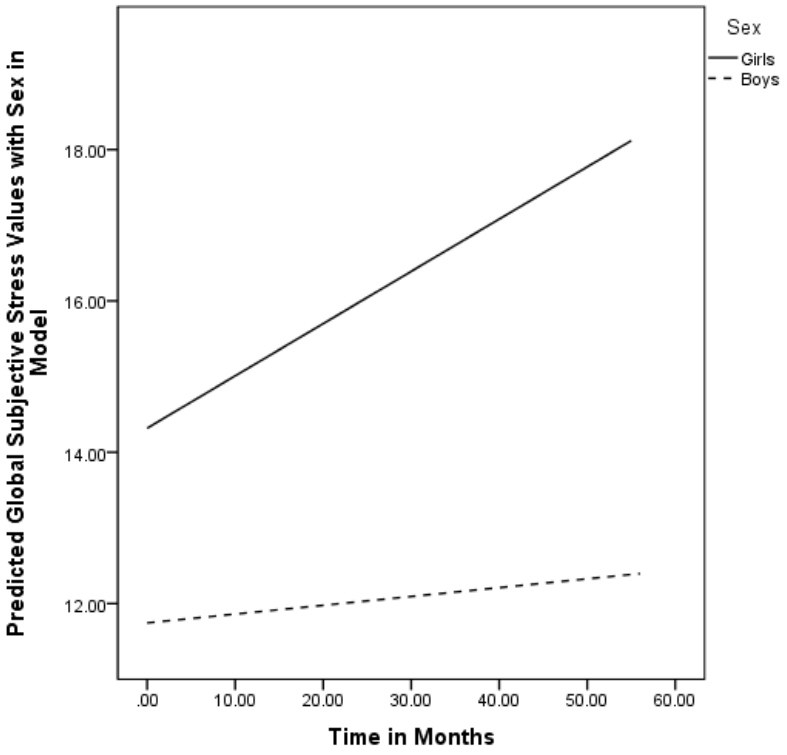

Figure 1. Graph of the sex by time interaction. Graph depicts that adolescents girls exhibited higher baseline global subjective stress and greater increase in global subjective stress over time compared to adolescent boys

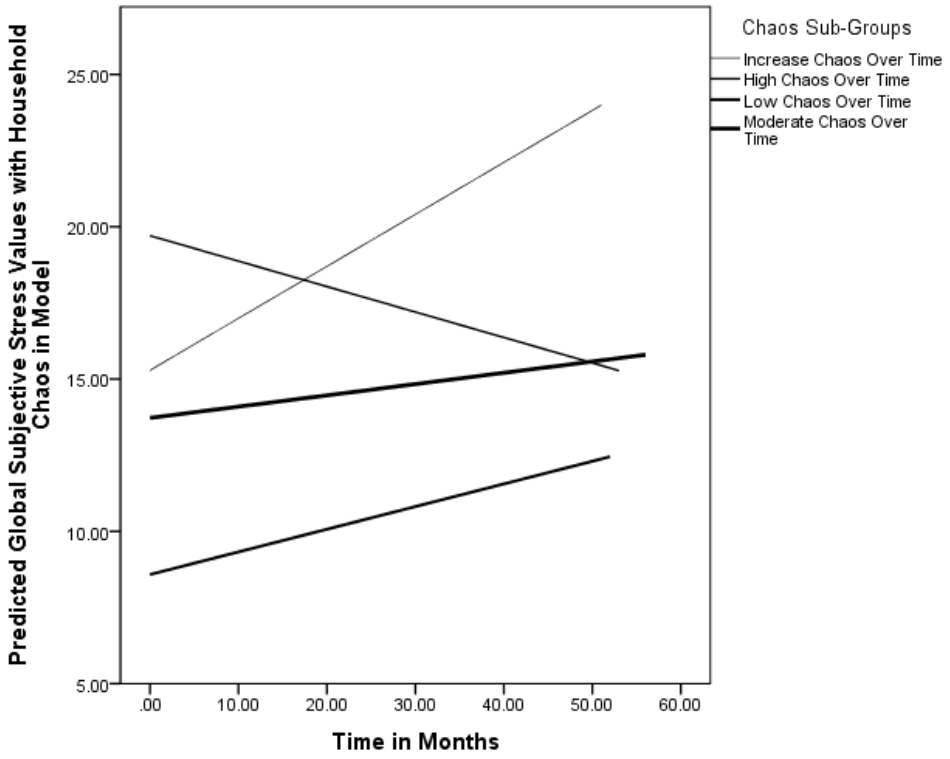

Figure 2. Graph of the household chaos by time interaction. Graph depicts rate of change in global subjective stress varied for adolescents with different household chaos trajectories. Adolescents with consistently low (*n*=90) or moderate (*n*=224) household chaos over time had similar rate of increase in global subjective stress. Adolescents with increasing levels of household chaos over time (*n*=29) had the fastest rate of increase in global subjective stress. Adolescents with consistently high household chaos over time (*n*=30) showed decrease in global subjective stress. Thickness of line is proportionate to the sub-group sample size.

GENERAL DISCUSSION

The objective of this dissertation programme was to address certain knowledge gaps related to the conceptualization and measurement of stress during childhood and adolescence. First, stress research with children and adolescents has predominantly focused on stressor exposure, with inconsistent consideration of stressor attributes (e.g., timeframe, proximity, timescale, chronicity, life domains). Second, there is a paucity of research disentangling conceptualization and measurement differences in the constructs of stressor exposure and psychological response that may account for their relation to health outcomes. Third, findings from numerous adult studies suggest that global subjective stress may reflect greater stability; however, there is limited research investigating repeated measurements of global subjective stress in younger populations. Together, this dissertation was opportune, given the increasing critiques in the literature regarding the lack of standardization in the conceptualization and measurement of stressor exposure and psychological response.

Summary of Results

Study 1. Although considerable findings have linked stress to health outcomes in children and adolescents, the majority of studies have measured stressor exposure with much less research attention on psychological response. Researchers have also recently articulated the importance of assessing specific stressor attributes in addition to event count when measuring stressor exposure (Epel et al., 2018). However, these stressor attributes have been minimally or inconsistently assessed in pediatric research. Thus, Study 1 was a timely systematic review, synthesizing available measures of stressor exposure and psychological response for use with children and adolescents. Overall, three key findings emerged: (1) as expected, results indicated that the majority of measures assessed stressor exposure (particularly life events), with minimal measures examining global subjective stress or daily hassles; (2) stressor attributes, such as timeframes, severity, chronicity, and life domains, were not comprehensively assessed in these measures; and, (3) there was a dearth of psychometric data supporting existing stress measures for use with children and adolescents. More specifically, half of the measures included children and adolescents as informant of their own stressor exposure. The choice of informant is particularly relevant for children, as previous research has demonstrated that parents over- or underreport their child's stressor exposure and psychological response (Allen et al., 2012; Anderson & Jimerson, 2007; Bailey & Garralda, 1990; Sandberg et al., 1993). Half of the

measures included self-report rating scale as opposed to using investigator-assigned ratings to determine the severity of stressor exposure. Traditional use of investigator-assigned severity ratings is problematic, as it assumes a ubiquitous level of severity for the same event across all children and adolescents. It is important to move away from only using adults or investigator-assigned ratings as proxy of children and adolescents' psychological response for more accurate measurement. Findings from Study 1 also highlighted an important gap with respect to the narrow assessment timeframes used in existing stressor exposure measures, which are often limited to 1 year, thus only capturing recent stressor exposure. There is a need to broaden the assessment timeframes to capture both proximal and distal stressor exposure, including multiple time windows within the same measure. We recognize that mood state and memory may affect one's ability to reliably recall more distal stressor exposure. Alternatively, we recommend that studies use repeated measurements of stressor exposure at the same time interval as the assessment timeframe. As example, prospective studies can assess individuals' stressor exposure in the past year, with subsequent data collection occurring at 1-year intervals.

Study 2. Previous findings demonstrated that global subjective stress better predicts health outcomes, compared to life events in both adults and youth (Cohen et al., 1983; Ly et al., 2015). Study 2 ambitiously attempted to address key conceptual and measurement differences between global subjective stress and life events that may account for these disparate results. Additionally, Study 2 also targeted specific gaps related to the stress and health association. Namely, there was a need to examine whether the relation of health outcomes with stressor exposure and psychological response varied by informant source or health outcomes measured, as previous studies suggested that mono-informant bias may inflate the strength of the associations (Naicker et al., 2017; Reuben et al., 2016). Our findings showed that global subjective stress (i.e., psychological response) better predicted health outcomes than life events (i.e., stressor exposure). We demonstrated the relevance of improving the measurement of stressful life events by considering current severity level (i.e., past month) in addition to retrospective severity level for stressor exposure. Despite the improved results, global subjective stress still better predicted health outcomes compared to current severity levels. In other words, one's general psychological response had a stronger predictive value than one's specific psychological response. Interestingly, the association between stress and health outcomes were stronger when a single informant was used for both predictor and outcome variables, suggesting

mono-informant bias may have inflated the strength of associations. Stronger stress and health associations were also observed for emotional health outcomes, compared to physical health outcomes. These findings highlight that global subjective stress alone, in the absence of stressor exposure, may be most predictive of health outcomes; however, research should carefully consider informant source and health outcomes measured.

Study 3. In addition to the targeted gaps related to measurement of stressor exposure that were the basis of Study 2, there were unanswered questions related to global subjective stress and the broader construct of general psychological response. Past research conceptualized global subjective stress as a more dynamic construct, sensitive to recent changes and stressor exposure (Cohen et al., 1983). Accumulating adult findings suggest that this psychological response may actually reflect a stable individual difference, demonstrating moderate to high stability in global subjective stress over time. There is a paucity of longitudinal studies examining global subjective stress in younger populations; thus, it remains largely unexplored whether individual differences in global subjective stress also exist in adolescents. Our results indicated that there was a moderate, 48.0% stability in global subjective stress across eight measurement timepoints over a 4-year period. Stability observed in Study 3 was lower than previous adult studies, suggesting that the stable individual differences in global subjective stress emerge early during adolescence, and may only become more stable later in the developmental lifecourse. When examining the contribution of covariates on global subjective stress over time, an interesting pattern of results emerged for sex and household chaos. Adolescent girls reported greater global subjective stress, and also showed higher increase compared to boys, whose trajectory remained lower and more stable over time. The sex difference in global subjective stress trajectory observed in the present study has important implications, suggesting that stability of psychological stress response is different for boys versus girls, and that this difference emerges early. We found that household chaos accounted for the most variance in global subjective stress over time, compared to other covariates, including sex, subjective social status, and life events. Although household chaos is more commonly used to capture the degree of disorganization and lack of routine in adolescents' home environment, we conceptualized household chaos in Study 3 more as a proxy of adolescents' stressor exposure in the household. We demonstrated that changes in global subjective stress over time was in large part influenced by stressors in adolescents' home environment. Overall, Study 3 provided preliminary support

for moderate stability of global subjective stress among adolescents, that was still sensitive to dynamic changes and stressors in one's life and household. Importantly, the measurement of both global subjective stress and household chaos were based on adolescent self-report; thus, it cannot be ruled out that mono-informant bias may be driving this association. Potential research avenues to further decipher the stability of global subjective stress are discussed below.

Theoretical and Methodological Contributions

Stressor Exposure and Stressor Attributes. Research from the Adverse Childhood Experiences (ACE) literature has demonstrated childhood stressor exposure as an important determinant of adverse health outcomes later in adulthood. Evidence also suggests that risk associated with stressor exposure is cumulative, with the number of childhood stressful life events determining adverse health outcome in a dose-response manner (Felitti et al., 1998; Flaherty et al., 2013). However, the ACE literature has primarily focused on event count as the sole indicator of stressor exposure (Dube et al., 2004; Naicker et al., 2017; Patten et al., 2015; Reuben et al., 2016). Prominent theoretical models of stress and health emphasized the importance of considering stressor attributes, which may add to the prediction of health outcomes (Cohen et al., 2016; Epel et al., 2018; Lazarus & Folkman, 1984). Study 1 provided a review of existing measures of stressor exposure for children and adolescents, synthesizing how stressor attributes are assessed in these measures. Study 1 showed that there was a relative lack of psychometric evidence for stressor attributes, and highlighted an important gap regarding the narrow assessment timeframes used in existing stressor exposure measures. Study 2 attempted to address this gap, by asking children and adolescents to endorse events they have experienced in their lifetime to better quantify cumulative stressor exposure. In addition to event count, Study 2 included the measurement of different severity ratings for each stressor exposure to more accurately capture children and adolescents' stress experience (see section below for detailed discussion).

Psychological Response. Apart from the consideration of stressor attributes, two interrelated constructs are delineated in prominent stress models: stressor exposure and psychological response (Cohen et al., 2016, 1995; Epel et al., 2018). Stressor exposure alone is not sufficient to influence health; rather, it is individuals' subjective perception (i.e., psychological response) that also determines health risk. The Cognitive Appraisal Theory posits that individuals engage in an ongoing process of evaluation and re-evaluation, wherein

individuals' psychological response to an event is calibrated relative to other stressor exposure in their lives (Lazarus & Folkman, 1984). Study 2 supported the Cognitive Appraisal Theory, demonstrating the incremental utility of including the measurement of current (i.e., past month) and retrospective severity ratings (i.e., at the time) for each stressor exposure. Study 2 offered a novel approach to capturing event severity for more precise measurement.

Despite improved results with the measurement of current event severity in Study 2, it was intriguing that global subjective stress was still the best predictor of health outcomes. This finding raised the question whether another approach to conceptualizing specific psychological response may be warranted. The idea that stressor exposure and psychological response are relatively orthogonal constructs, reflecting independent processes, has been implied in the field of stress science. The Cognitive Model (Ehlers & Clark, 2000) and Stress Response Theory (Horowitz, 1986) of post-traumatic stress disorders suggest that stressor exposure (i.e., exposure to traumatic events) only becomes problematic when individuals appraise the stressor as serious and threatening. This sense of threat partly arises as a consequence of repeated negative appraisals or memory of one's previous psychological response to the stressor (Buckley, Blanchard, & Neill, 2000). Thus, we could speculate that one's current psychological response can constitute in and of itself a source of stressor exposure, and that it is this psychological response that poses health risk. A similar hypothesis has been raised by Epel et al., 2018, who suggested that one's *habitual* psychological response may be more predictive of health outcomes. Our findings in Study 2 also has important implications for research in the Adverse Childhood Experience (ACE) literature, which showed that adult retrospective report of childhood stressor exposure is predictive of adult health outcomes (Chapman et al., 2004; Chartier et al., 2010; Felitti et al., 1998). We speculate that endorsing childhood stressor exposure in adulthood may inadvertently elicit psychological response, and it is this psychological response that is predictive of health outcomes. This may also partly explain why the associations between ACEs and health outcomes are attenuated when ACEs are measured prospectively as opposed to retrospectively (Naicker et al., 2017; Reuben et al., 2016). More prospective studies are required to elucidate the direct and indirect effects of psychological response in the association between stressor exposure and health outcomes. Finally, Study 3 demonstrated that one's general psychological response to stressors may have greater stability than originally conceptualized. Global subjective stress or stress appraisal may be a stable

individual difference that is closely intertwined with mood and personality. Further research with parallel measurement of mood state and personality traits is required to consider whether there is a trait-like dimension to the construct of global subjective stress.

Strengths, Limitations, and Future Directions

The current research programme demonstrated a number of strengths that increase its contribution to the field of stress science. First, this research programme was a first attempt at harmonizing conceptualization and measurement of stressor exposure and psychological response in children and adolescents. Given the wide-ranging stress measures that have been used with children and adolescents, Study 1 also provided a reference guide for selecting evidence-based stress measures to address specific research questions. For instance, if the association of specific life domains and health outcomes is of interest, this reference guide will help researchers select measures that most comprehensively assess life domains. Second, founded in theoretical assumptions and empirical findings from our own previous work, Study 2 and Study 3 pushed the boundaries of our understanding, providing a new lens through which we can conceptualize and measure stressor exposure and psychological response. We advocate the importance of assessing current severity levels when measuring stressor exposure. As well, we propose greater stability in global subjective stress than originally conceptualized, and hope to stimulate additional research to carefully disentangle how covarying mood state and personality traits are associated with stress appraisal and how global subjective stress is related to health outcomes.

There are also a number of limitations in the present research programme that warrant discussion. Many of the limitations present potential areas for future investigation and ongoing research effort to improve the conceptualization and measurement precision in the field of stress science. First, unanswered questions remain regarding specific stressor attributes. Psychometric data for stressor attributes in measures of stressor exposure remains lacking. There is also a need to better understand the associations between individual stressor attributes (e.g., timescale, life domains) and health outcomes. For example, a meta-analysis of experimental studies showed that stressors that are most unpredictable and uncontrollable produced the strongest physiological reactivity (Dickerson & Kemeny, 2004). Second, Studies 2 and 3 did not include measurement of current mood state. Mood-congruency hypothesis posits that negative mood state facilitates the recall of negatively-valenced information (Bower, 1981). This hypothesis is supported by

Colman et al.'s study, which showed that negative mood state favoured the recall of stressful life events at follow-up assessment (Colman et al., 2016). Third, our dissertation research programme was limited to the examination of stressful life events, daily hassles, and global subjective stress in children and adolescents, precluding other constructs (e.g., physiological stress reactivity) discussed in other prominent stress models.

Conclusions and Implications

The Integrated Lifespan Model of Stress and Health emphasizes that stressor may have an impact on health at multiple points across the lifespan (Epel et al., 2018). Childhood and adolescence are relevant periods during which stressor exposure and psychological response have imprinting effects on health. This research programme was a first attempt to synthesize a large, disjointed literature on stressor exposure and psychological response, as well as to address select knowledge gaps relevant to children and adolescents. The results of this programme of research highlights the importance of considering global subjective stress over life events, even though the measurement of one's current psychological response (i.e., current event severity) may improve the predictive utility of life events. By examining the influence of informant source on the association between stress and health, the results from this research programme helped clarify that mono-informant bias may inflate some of the associations observed in existing findings. Researchers need to be cautious with interpretation of findings when a single informant is used for both stressor exposure, psychological response, and health outcomes. Finally, the results from this research programme suggest that one's stress appraisal (i.e., psychological response to stress) is stable and emerges early in the developmental lifecourse. Compared to even greater stability during adulthood, global subjective stress was only moderately stable during adolescence, suggesting that there is still time to offset this trajectory. This finding has important implications. One potential avenue to address these issues may be to provide targeted stress management programs to offset the early health effects of stress. Taken together, the current research programme consisted of three interrelated studies that addressed gaps relevant to the conceptualization and measurement of stressor exposure and psychological response in children and adolescents.

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