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Extending the Toxic Stress Model into Adolescence: Profiles of Cortisol Reactivity

Celina M. Joos[a], **Ashley McDonald**[a], and **Martha E. Wadsworth**[a]

[a]Department of Psychology, The Pennsylvania State University, University Park, PA 16802

Abstract

The toxic stress model posits that extended activation of stress response systems in the absence of a supportive relationship with an adult may over time lead to physiological alterations to these same systems, and ultimately to poorer physical and mental health outcomes. However, empirical tests of model hypotheses in adolescence, a critical period of development, are lacking. This study expands the toxic stress model to include more developmentally-appropriate risk and protective factors for adolescents experiencing overwhelming and uncontrollable stressors. Data were collected for a study of early adolescents from urban low-income households (*N*=101; 10–12 years old; 59% female). Participants and a caregiver completed questionnaires; youths completed the modified Trier Social Stress Task alone and provided six saliva samples. Using latent profile analysis, three profiles of cortisol reactivity were identified in early adolescents exposed to chronic environmental stress: *Elevated and Reactive* (11%), *Moderate and Non-Reactive* (26%), and *Blunted and Non-Reactive* (63%). In accordance with the toxic stress model, exposure to more community violence and less family support were associated with blunted cortisol reactivity, and Reactive profile membership was associated with fewer trauma symptoms. Overall, the findings provide empirical support for the extension of the toxic stress model in early adolescence through the application of developmentally-sensitive measures and provide implications for future interventions.

Keywords

Adolescence; toxic stress; cortisol reactivity

Corresponding Author: Celina Joos, 234 Moore Building, Pennsylvania State University, University Park, PA 16801, Phone: 814-867-4939, cmj192@psu.edu.

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Celina Joos: Conceptualization, Methodology, Data Curation, Writing-Original Draft

Ashley McDonald: Conceptualization, Methodology, Formal Analysis, Data Curation

Martha E. Wadsworth: Conceptualization, Methodology, Writing- Review & Editing, Supervision, Funding Acquisition, Study Design

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We report that we have no conflicts of interest to disclose.

1. Introduction

According to the National Scientific Council on the Developing Child, toxic stress (TS) processes arise when repeated or ongoing activation of the body's stress response systems, particularly the hypothalamic-pituitary-adrenal (HPA) axis, occurs in the absence of adequate social support (Shonkoff et al., 2012). According to Shonkoff and colleagues, the process of toxic stress stems from over-taxation of the HPA and sympathetic adrenal medullary systems and the resulting hormonal dysregulations which then disrupt developing brain architecture. Abundant glucocorticoid receptors in the amygdala, hippocampus and prefrontal cortex (PFC) leave these structures vulnerable to the effects of high levels of cortisol, and over time, excessive exposure to cortisol and other stress hormones limits neurogenesis in the hippocampus, leads to heightened fear responses in the amygdala, and dampens the PFC's ability to regulate stress in a top-down fashion (Chen and Baram, 2016). A stress-altered HPA (e.g., increased or decreased reactivity) is therefore a marker of a TS process and is considered to be a central mechanism linking adverse environments to poorer physical and psychological wellbeing across the lifespan (Evans and Kim, 2013; Shonkoff et al., 2012).

There is increasing empirical evidence supporting the link between early adversity (e.g., neglect, abuse, chronic poverty), altered activity of the HPA axis, and later mental and physical health disparities (Koss and Gunnar, 2018). Individuals who have experienced some form of serious adversity in childhood have been found to exhibit increased diurnal cortisol output (Fisher et al., 2011; Miller et al., 2009), flatter diurnal slopes (Bernard et al., 2015; Pitula et al., 2017), lower levels of cortisol upon waking (Bernard et al., 2017; Fisher et al., 2011, 2007), and either increased (Mielock et al., 2017; Ouellet-Morin et al., 2018) or blunted cortisol reactivity (Gunnar, 2015; Ouellet-Morin et al., 2011b) in response to acute social stressors. Variations in chronicity, timing, and severity of childhood stressors have been hypothesized to explain the contradictory nature of these findings, with some evidence accruing to support these hypotheses (Bernard et al., 2017; Ouellet-Morin et al., 2018; Ursache et al., 2015). Further, associations between atypical HPA axis activity and psychopathology have been identified across the lifespan. For instance, increased diurnal cortisol output and exaggerated HPA reactivity have been consistently linked to internalizing problems, particularly major depressive disorder and anxiety (Eachus and Cunliffe, 2018; Frost et al., 2018; Laurent et al., 2015; Zorn et al., 2017). Conversely, low cortisol (i.e., flatter diurnal slopes, low basal levels, and blunted reactivity) has been associated with externalizing behaviors, including aggression, impulsivity, substance use, and oppositional behavior (Alink et al., 2008; Laurent et al., 2014; Poon et al., 2016). Attenuated HPA reactivity has also been closely linked to posttraumatic stress disorder, fibromyalgia, and anxiety disorders (Crofford et al., 1994; Heim et al., 2000; Raison and Miller, 2003), particularly in the context of childhood poverty or maltreatment. However, less research aimed at understanding TS has been conducted with children than with adults, and often studies that include children focus on exposure to overwhelming stressors in the first 5 years of life (Hunter et al., 2011). More work is needed to better understand how adverse conditions affect development, particularly during the period of early adolescence (Koss and Gunnar, 2018).

Stress alterations in HPA activity are evident in older children and adolescents exposed to adversity (8–16 years old; Bunea et al., 2017; Gunnar et al., 2009a; Peckins et al., 2015), and there are many reasons to expect risk and protective factors associated with TS to change developmentally. However, little is known about the TS process during adolescence, the second decade of life. It is known that stress physiology continues to mature into and beyond adolescence (Joos et al., 2018; Romeo, 2010) and that the hypothalamus and pituitary gland undergo substantial maturation, likely modified by pubertal increases in gonadal hormones and in order to allow for adult-like HPA responses to stressors (Romeo, 2010b; Romeo and McEwen, 2006). Furthermore, adolescence is a period of renewed malleability of pertinent neurological systems and is marked by improved cognitive and behavioral resources with which to respond to stress (Zimmer-Gembeck and Skinner, 2016). Finally, significant social transitions occur, including changes in school and social contexts and within family and peer relationships, which may present new resources and challenges for youth. Thus, understanding the nature of risk and protective forces beyond early childhood may be vital to interrupting TS processes.

1.1. Normative stress response and TS processes in childhood and adolescence.

Decades of research on early life stress have established a strong link between adversity in childhood and later discrepancies in mental and physical wellbeing (Bucci et al., 2016). The toxic stress model proposes that the frequency and perniciousness of overwhelming stress in early childhood physically alters brain and body, therefore increasing the risk of developing physical and mental health problems. The mechanism by which this occurs is broadly understood to include hormones released by the body's stress response axes, as well as the downstream effect of prolonged stress system activation on immunologic, cardiovascular, metabolic, and reproductive systems. For the purpose of this study, our focus will rest on the role of cortisol, the canonic biomarker related to the HPA axis (Glover et al., 2010; Miller et al., 2007), and individual differences in cortisol levels as proxies for alterations of the HPA axis. Other stress mediators are also released and impacted by adverse experiences (Juster et al., 2010); research on the effect of these mediators, however, is beyond the scope of this paper.

An individual's stress response is regulated by a complex interplay of the central and autonomic nervous systems, which activate and regulate the HPA and SAM axes, in conjunction with interactions of endocrine, genetic, and immune regulatory mechanisms (Ulrich-Lai and Herman, 2009). Activation of the HPA axis consists of the cascading secretion of stress-induced hormones, starting with corticotropin- releasing hormone (CRH) and arginine vasopressin (AVP) in the hypothalamus, which in turn activate the release of adrenocorticotropin hormone (ACTH) by the pituitary gland. The cascade ends when ACTH stimulates the adrenal cortex to secrete glucocorticoids, including cortisol (Tarullo and Gunnar, 2006). In an HPA-axis that is functioning physiologically normally, cortisol inhibits the secretion of CRH and ACTH at the hypothalamus, creating a negative feedback loop that limits tissue exposure to glucocorticoids once exposure to the stressor has ceased (Bucci et al., 2016).

Thus, humans are believed to have a typical cortisol response pattern to acute stressors. A study by Stroud and colleagues (2009) represents the only study, to our knowledge, of normative stress responses in a community sample of children 7–17 years old. Participants were 39 children (7–12 years old, 56.5% female) and 43 adolescents (13–17 years old, 46.5% females), with most identifying as Caucasian (75.5%) or Hispanic (14.5%). Participants were recruited through online and community postings, and were excluded if parents reported a history of psychological or behavioral problems. The sample represented a range of socioeconomic backgrounds, with the average participant residing in a two-parent household, in which both parents had completed some college or an associate's degree, and together earned $60,000 to $80,000 annually. The study found that both children and adolescents exhibited a steady increase in salivary cortisol concentration from the onset to completion of the Trier Social Stress Test for Children (TSST-C; Buske-Kirschbaum et al., 1997), followed by a steady decrease back to baseline in the hour after the stressor task ended. The study authors graphed group means of salivary cortisol levels over the course of the study procedure, with children exhibiting lower baseline (approx. 0.10 μg/dl), peak (approx. 0.15 μg/dl), and recovery (approx. 0.09 μg/dl) than adolescents (approx. 0.12 μg/dl, 0.20 μg/dl, and 0.13 μg/dl, respectively; Stroud et al., 2009). This developmental increase in stress reactivity is consistent with other findings that baseline and acute stress levels of cortisol increase with the progression of pubertal development (Gunnar et al., 2009b). As one of the few studies to provide untransformed salivary cortisol levels from community samples of youth in response to a standardized stress task, the work of Stroud and colleagues serves as a valuable reference for researchers interested in normative and stress-altered HPA activity across childhood and adolescence.

The TS model, as proposed by the National Scientific Council on the Developing Child (see Figure 1; Shonkoff et al., 2012), outlines the process by which chronic or overwhelming stressors lead to mental and physical health disparities via dysregulation of the stress response system. A child exposed to uncontrollable stress likely experiences prolonged activation of the HPA and SAM axes, particularly in the absence of a supportive caregiver or effective coping strategies to help the child return physically and emotionally to homeostasis (Bucci et al., 2016). Prolonged activation of the stress response systems leads to disruptions in the negative feedback mechanism that otherwise regulates the production of stress-induced hormones. Brain and body tissues are thus over-exposed to these stress hormones, including cortisol, which over time leads to structural and functional damage (Chen and Baram, 2016). This further interferes with the learning and use of effective coping skills, physiologically and psychologically inhibiting a child's ability to deal with everyday stressors (Evans and Kim, 2013). Recalibration of the HPA axis itself results over time in a lower daily cortisol volume (Miller et al., 2007) and atypical acute stress response, either elevated (hyper-reactive) or blunted (non-reactive) cortisol responses to acute stress (Gunnar et al., 2009a; Koss et al., 2016; McLaughlin et al., 2015; Peckins et al., 2012), though findings from Hackman and colleagues (Hackman et al., 2012) suggest that race and gender could moderate this association. For instance, in the face of everyday stressors, an individual with a stress-altered HPA may exhibit an exaggerated increase in cortisol and slow or no return to baseline (e.g., Dougherty et al., 2013), or may exhibit a diminished response or no response at all (e.g., Ouellet-Morin et al., 2011b, 2011a); both patterns in the context of

childhood adversity have been associated with psychopathology (Kuhlman et al., 2018). Thus, either elevated or blunted cortisol response may be an indicator of damage to the stress response system and a marker of experiencing TS processes (Gunnar et al., 2009a).

1.2. Developmental considerations to the TS model.

Adolescence is increasingly recognized as a sensitive period for the HPA and associated brain structures and functions (Steinberg, 2014) and therefore represents a period of heightened vulnerability to damage, and opportunity for intervention. Given significant biological and social differences between early childhood and adolescence, risk and protective factors related to TS may be expanded in the second decade of life. Below we discuss select risk and protective factors that we propose are developmentally appropriate to consider in a model of TS applied to adolescents.

1.2.1 External risk factors.—External risk factors typically linked to stress-altered HPA include childhood experiences of maltreatment, parental psychopathology, and chronic poverty (Shonkoff et al., 2009; for a discussion of internal risk factors, see Lapp et al., 2019). Early in life, these stressors are primarily experienced in the home, transmitted through emotions and behaviors of caregivers (Conger et al., 2010). Adolescents, however, are more likely to also have direct exposure to overwhelming peer and community-level stressors (McBride Murry et al., 2011). Exposure to interpersonal and community violence, for example, has been associated with attenuated or “blunted” cortisol responses in multiple samples of adolescents and adults (Busso et al., 2016), even after accounting for other dimensions of adversity such as poverty exposure (Aiyer et al., 2014; Busso et al., 2016; Peckins et al., 2012). There is little a child or adolescent can do to cope actively with community violence, for example, and keeping calm while taking steps to avoid sources of violence may be what is most adaptive. Such avoidant coping in the face of uncontrollable stress has been found to be associated with attenuated cortisol reactivity in this age group (Bendezú and Wadsworth, 2017). Therefore, whereas blunted cortisol responses are generally attributed to chronic overuse and a damaged HPA, they could also stem from repeated intentional efforts to avoid dangerous neighborhood contexts, for example (e.g., Elzy et al., 2013). Either way, a developmentally sensitive model of the processes associated with TS should include sources of stress reflecting adolescents’ wider spheres of influence, including among both peers and the community.

1.2.1. External protective factors: The role of caregiver.—The TS model identifies caregivers as critical to buffering a child from overwhelming adversity by helping them cope (Shonkoff et al., 2012), with warm, sensitive parenting predicting children’s efficient return to HPA homeostasis (Dougherty et al., 2013). Adolescence is, however, marked by growing autonomy from caregivers, and the effect of parental validation and warmth on stress reactivity lessens with age (Hostinar et al., 2015). Given changes in adolescents’ relationships and exposures in and out of the home, different dimensions of parenting may become important for buffering youth from stressors. Evans and colleagues (2013), for instance, found that whereas cortisol reactivity was associated with parental *emotional warmth* in school-age children, reactivity was associated with parental *involvement* in adolescents.

In particular, environmental structure (i.e., consistency, organization; Skinner et al., 2005) may become increasingly important in giving adolescents the tools and capabilities with which to navigate stressful encounters out in the world. Low levels of parental structure are associated with greater cortisol reactivity across childhood (Ellenbogen and Hodgins, 2009). Structure within the home creates a predictable environment where children are provided with consistent pathways to desirable and undesirable outcomes, and children's activities are monitored and supervised. Parental structure facilitates the development of numerous competencies in important life domains such as self-regulation, peer relationships, and academic engagement, competencies which may underlie the stress-buffering effects of parental structure (Zimmer-Gembeck and Skinner, 2016). High environmental structure may therefore help to buffer children against the effects of chronic poverty and other overwhelming challenges.

1.2.3. Internal protective factors: Coping and perceived control.—

With its initial focus on very young children, the TS model omitted discussion of internal protective factors such as coping skills that could buffer adolescents. Adolescents attain greater biological and cognitive capacity for coping that can protect against the deleterious effects of stress (Skinner and Zimmer-Gembeck, 2011). Adolescents who report feeling greater efficacy to produce a desired outcome are more likely to use engagement coping (e.g., problem solving) than disengagement coping (e.g., avoidance, denial; Compas et al., 1991). Both higher perceived control and greater use of engagement coping are associated with fewer emotional/behavioral problems in the face of uncontrollable stressors (Scott and House, 2005; Wadsworth et al., 2011). Thus, a developmentally extended TS model ought to include internal protective factors, particularly coping and perceived control, that serve an increasingly large role in adolescent adaptation. In summary, there are several ways in which the TS model could be expanded to account for developmental change. The sphere of influence around young children is limited primarily to the home and to caregivers. As children mature, they are exposed to stressors across a variety of settings and may experience an expansion of protective factors, both of their own capabilities and from their home environment. Inclusion of developmentally appropriate factors may facilitate better understanding of TS processes in adolescence.

1.3. Person-centered approaches to understanding cortisol reactivity.

The majority of research on cortisol reactivity utilizes variable-centered approaches to estimate the strength of the effect of risk and protective factors on cortisol reactivity, or linking indices of cortisol reactivity to psychopathology and other outcomes. However, variable-centered analyses can obscure relationships among individuals. Person-centered analyses, alternatively, assumes that individuals are heterogeneous and allows researchers to identify subgroups of individuals that exist based on shared attributes (Laursen and Hoff, 2006; Muthen and Muthen, 2000). Given the heterogeneity of cortisol reactivity observed within and between studies (Ji et al., 2015), particularly among children who have experienced adversity (Gunnar et al., 2009a), the current study utilized a person-centered analytic approach to identify profiles of HPA-axis activation.

Studies using person-centered analyses of cortisol reactivity are limited, with no study to our knowledge including both risk and protective factors associated with toxic stress. In a study of the effect of maltreatment on HPA reactivity among 10–13 year olds, Peckins and colleagues (2015) utilized latent profile analysis (LPA) to identify subgroups of cortisol reactivity within a diverse sample of young adolescents that had and had not experienced maltreatment. The study authors reported finding 3 classes of reactivity in response to the TSST-C: (1) blunted reactivity (34%), (2) moderate reactivity (55%), and (3) elevated reactivity (11%). A history of maltreatment and non-white race predicted membership in the blunted profile, while older children were more likely to have the elevated reactivity profile. Gunnar and colleagues (2009a) assessed cortisol reactivity to the TSST-C among groups of youth (M=11.25, SD = 0.68; range: 10–12 years) who had experienced severe, moderate, or little early life stress (ELS), with severe and moderate groups recruited from internationally-adopted children. Using group-based trajectory modeling, they found five groups, of which 3 trajectories (68.9% of participants) were non-responsive and only 1 trajectory (14.0%) followed the prototypical cortisol response curve. Unexpectedly, 76% of the children in the comparison group, who were non-adopted and presumably typically developing, exhibited no change or decreasing levels of cortisol to the TSST-C, while children who had experienced severe ELS (i.e., adopted at a year old or older from orphanages or other overseas institutions) did not significantly differ in cortisol response from children who were non-adopted. In addition, child age was significantly associated with group membership, with being older predictive of belonging to the sole trajectory that exhibited a prototypical cortisol response. The authors suggested that high quality care post-adoption may have ameliorated some of the effects of severe ELS, a contention for which there is emerging evidence (Fisher et al., 2011; Purewal Boparai et al., 2018; Slopen et al., 2014), and emphasized the importance of examining the impact of age and pubertal development in such studies of HPA activity (Gunnar et al., 2009a).

While findings across studies suggests the existence of at least three reactivity profiles among young adolescents, it is unclear whether the effects of toxic stress may be different for those with past compared to ongoing exposure. In addition, little exploration of the variables related to profile membership has been performed. This study aims to address these gaps by identifying variables proposed by the toxic stress model and testing their association with cortisol reactivity profiles.

1.4. Study hypotheses.

The present study identified profiles of cortisol reactivity in low-income youth residing in highly disadvantaged urban communities. We examined how reactivity profiles are associated with variables in the TS model, mainly youths' stress exposures, internal and external supports, and psychological wellbeing. Based on previous research (Gunnar et al., 2009a; McLaughlin et al., 2015; Peckins et al., 2015), we hypothesized that at least three distinct patterns of reactivity would emerge from the data, with profiles capturing blunted, elevated, and perhaps adaptive reactivity. We operationalized blunted reactivity as percentage baseline-to-peak increase of less than 15.5%, following criteria recommended by Miller et al. (2013). We also hypothesized that adolescents who reported experiencing greater number of stressors would be more likely to present with blunted reactivity, given the

findings of recent meta- analyses (Bunea et al., 2017). Greater family cohesion and structure were predicted to be associated with a non-stress-altered (i.e., adaptive) reactivity profile, in accordance with the TS model. Blunted and elevated reactivity profiles were hypothesized to be associated with poorer psychological wellbeing. Finally, we explored how reactivity profiles are associated with self-reports of coping and perceived control.

2. Materials and methods.

2.1. Sample characteristics.

The present study used pretest data from the efficacy trial of the Building a Strong Identity and Coping Skills (BaSICS) preventive intervention, developed to address chronic stress and coping in young adolescents facing ongoing poverty-related stress. The study recruited families that were low-income with an eligible child enrolled in one of two urban school districts in a mid-Atlantic state. For more information on the BaSICS efficacy trial, see Wadsworth et al (2018a).

2.2. Sample recruitment and procedures.

Participants were recruited via in-person contacts with recruitment staff at local community and school events and through community partners. Interested families were screened at home or over the phone by trained recruitment staff, and their interest and availability to complete the larger intervention efficacy study were confirmed. Eligibility criteria for this study included: child age of 10–12 years old at time of pre-assessment; family income at or below 200% federal poverty level for year of enrollment; child fluency in English; and parent fluency in English or Spanish. Exclusion criteria included parent reports of lifetime diagnoses of child intellectual disability or autism spectrum disorders, enrollment in special education services for more than 50% of the school day, and meeting clinical cut-off criteria for current depression on the Children's Depression Inventory, 2nd edition (Kovacs, 2012) or anxiety on the Beck Anxiety Inventory (Beck et al., 1988). Families who were not eligible due to child symptoms of severe anxiety or depression were provided referrals for mental health services in the area.

Eligible children and one caregiver were consented and scheduled for a three-hour assessment starting between 3 and 5pm. During the assessment, participants and their parent completed interviews and questionnaires, including questions related to child medication use. While parents completed questionnaires in a separate room, children completed the Trier Social Stress Test-Modified (TSST-M; Yim et al., 2010), a standardized protocol previously demonstrated to elicit a cortisol response in typically developing early adolescents. Youth were instructed by a two-person panel of "experts" to prepare and deliver a 5-minute speech introducing themselves to a new class, then completed oral serial subtraction for 5 minutes. Participants provided 6 saliva samples before and after the TSST-M. In this study protocol, the following activities occurred post-TSST: (1) between S3 and S4, children alone in room to cope while "performance was being scored", (2) between S4 and S5, children were interviewed about how they coped with the TSST-M, and (3) between S5 and S6, children listened to a 10-minute progressive muscle relaxation (PMR) tape, after which they were debriefed. PMR was used at the end of the protocol to ensure that children

did not leave the laboratory emotionally dysregulated, as per our agreement with the participating elementary schools. This very same protocol has been used to successfully elicit significant cortisol reactivity in similar-aged but less at-risk samples (e.g., Bendezú and Wadsworth, 2017; Wadsworth et al., 2018b). Participants were informed that they were (and they assented to) being videotaped during the TSST-M. Children's ratings on six different emotions (sad, nervous, angry, happy, excited, surprised) were taken alongside each of the six saliva samples. Caregiver and child received $20 each upon completion of the assessment. All procedures were approved by the Pennsylvania State University IRB.

2.3. Measures.

2.3.1. Cortisol reactivity.—Cortisol reactivity was measured in response to the TSST-M via saliva, collected by passive drool into a 5-mililiter tube. Participants came to assessments directly after school, and were instructed not to eat a large meal or brush their teeth one hour prior to arriving at their appointment time, nor to have a dairy, surgary, or acidic snack within 20 minutes of their appointment. All children were given a light (non-sugary) snack and small amount of water to drink upon arrival. Forty minutes later (immediately prior to beginning the TSST-M) participants provided the first saliva samples (S1). The second saliva sample (S2) was taken immediately following completion of the TSST-M, and four additional samples were taken at 10-minute intervals (S3-S6) thereafter. Saliva samples were frozen and stored at −80°C until sent to the Core Biomarker Lab in the Biobehavioral Health department at Penn State, where they were assayed in duplicate. The mean for each sample was used in analyses. Values were windsorized at three standard deviations and fourth-root transformed to account for positive skew (Miller and Plessow, 2013). Transformed cortisol samples were used in all subsequent analyses, though raw values are reported in figures and tables.

2.3.2. External risk factors: Sources of stress.—Youth completed the Multicultural Events Scale for Adolescents (MESA; Gonzales et al., 1995), an 86-item measure of family, peer, and community stressors specific to inner-city, multi-ethnic adolescents. Family stress was comprised of 22 items assessing extra-familial problems (e.g., "A close family member or someone you live with had serious emotional problems"), intra-familial problems (e.g., "You had a serious disagreement or fight with a parent/step-parent"), and financial hardship (e.g., "Your parent could not find a job"). Peer stress included 14 items reflecting interpersonal conflicts and hassles at school or with peers (e.g., "You were pressured against your will to join a gang"). Community stress included 13 items reflecting witnessing or experiencing community violence or crime (e.g., "You saw someone threatened with a knife or gun"). Adolescents indicated whether each event happened or not in the last six months.

2.3.3. Protective factors: Family support.—Adolescents and a caregiver each completed the Family Environment Scale (FES; Moos and Moos, 1994), which measures perceptions of relationship cohesion within the family (e.g., "Family members really help and support one another") and the importance of clear structure in the home (e.g., "Each person's duties are clearly defined in our family"). To confirm internal reliability, exploratory factor analyses were conducted for each subscales, and data from these procedures were used to create modified subscales of child- and parent-reported cohesion (4

items each, αs=.62-.63) and organization (5 and 8 items, αs=.63-.65). Items removed were predominantly reverse-scored questions which may not have been clear to participants.

2.3.4. Protective factors: Internal resources.—The Responses to Stress Questionnaire (RSQ; Connor-Smith et al., 2000) was used to measure youths' coping with family stress. The RSQ consists of 57 items rated on a scale from 1 (not at all) to 4 (a lot) that measure 5 voluntary and involuntary coping factors. Factor ratio scores were used as recommended by instrument authors. Primary (problem solving, emotion regulation) and secondary engagement (acceptance, distraction) coping factors have generally been associated with similar outcomes of greater wellbeing, while the disengagement coping (avoidance, denial) factor has traditionally been associated with poorer psychological wellbeing. Due to similarities in outcomes, the current study included a composite of engagement coping factors (r=.22, p=.03; αs=.74−.76), as many other researchers have (Flynn and Rudolph, 2014; Rudolph et al., 2011; Swanson et al., 2011). In addition, the current study included voluntary disengagement coping factor (α=.77).

The Perceived Control Scale (PCS; Savla et al., 2013) is a 12-item measure of personal mastery (e.g., "I can do just about anything I really set my mind to do") and perceived constraint (e.g., "There is little I can do to change the important things in my life"). Responses range from 1 (strongly disagree) to 7 (strongly agree). An overall mean score was used (α = .70).

2.3.5. Psychological wellbeing.—Adolescents and a caregiver completed the Youth Self Report and Child Behavior Checklist, respectively (YSR, CBCL; Achenbach and Rescorla, 2001). The scales contain 112 and 113 items which are rated from 0 (never true) to 2 (very often true). The instruments yield a Total Problems score covering a broad range of problems, including internalizing (e.g., depression, somatization) and externalizing (e.g., delinquency, aggression) behaviors (αs=.90−.93).

The Trauma Symptom Checklist for Children (TSCC; Briere, 1996) and Trauma Symptom Checklist for Young Children (TSCYC; Briere et al., 2001) were used to assess for trauma-specific child symptoms of distress. The measures include 53 items for children and 90 items for caregivers on trauma- related symptoms; respondents indicate how often the adolescent experienced each symptom from 0 (never) to 3 (almost all of the time). Sex-normed standardized scores on parent- and child-reported posttraumatic stress (αs=.86−.87), dissociation (αs=.84−.91), and anger (αs=.87−.89) were used in analyses.

Fleming et al.'s (2008) 10-item survey was used to assess children's involvement in antisocial activities. Adolescents were asked to report the number of times they had engaged in rule-breaking behaviors (e.g., "started a fight") during the last three months. Answers were dichotomized as 0 (did not engage in this behavior) and 1 (engaged in this behavior at least once) then summed for a count score of delinquent activities (α=.73).

2.3.6. Demographics, markers of socioeconomic status, and other personal characteristics.—Adolescents and a parent reported demographic information including the child's age, sex, race, and ethnicity. Caregivers provided information about the family's

annual income, parents' level of educational attainment, and the number of people (adults and children) currently residing with the child. An income-to-needs ratio (INR) was calculated by dividing the total family income by the federal poverty threshold for the year of their participation (2016 or 2017) after accounting for the size of the family (Luby et al., 2013). An INR of 1.0 indicates that a family is living at the federal poverty threshold.Caregivers also completed the 10-item Economic Hardship Questionnaire (EHQ; Lempers et al., 1989) to assess the degree of perceived financial problems in the past 6 months. Respondents rated how often they made changes or adjustments to make ends meet from 1 (never happened) to 4 (very often happened). The EHQ demonstrated acceptable reliability in the current sample (α = .85).

Parents also reported on their child's pubertal development by completing the Pubertal Development Scale (PDS; Petersen et al., 1988), a widely used and clinically validated questionnaire. For girls, caregivers indicated on a Likert-type scale from 1–4 (with higher scores indicating more advanced development) the progression of the daughter's physical changes (growth spurt, body hair, and breast development) and whether she had begun to menstruate (no=1; yes=4). Parents of males rated their son's development of height (growth spurt), body hair, facial hair, and voice deepening on similar Likert scales from 1–4. Scores were averaged to create a pubertal development score for each child (αs = .58 and .62 for boys and girls, respectively). Pubertal development is associated with HPA activity (Gunnar et al., 2009b), and was included in analyses.

2.4. Analysis plan.

Data analysis was completed in two steps. First, latent profiles of cortisol reactivity were identified and described using latent profile analysis (LPA). Model estimation was conducted using Mplus (Muthén and Muthén, 2007, 1998–2015). Missing data were handled with maximum likelihood estimation. Model selection was guided by the Akaike information criterion (AIC; Akaike, 1974), Bayesian information criterion (BIC; Schwarz, 1978), sample size adjusted BIC (a-BIC; Sclove, 1987), entropy (Celeux and Soromenho, 1996), and bootstrap likelihood ratio test (BLRT; Nylund et al., 2007), as well as model stability, interpretability, and parsimony. Lower AIC, BIC, and a-BIC values indicate more optimal model fit, and higher entropy values indicate higher classification utility. Model identification for all models was checked using 1000 initial stage starts and 500 final stage starts. While traditional power analysis techniques are not appropriate for use in latent profile analysis, a power analysis simulation study found that using a-BIC in a sample size of 50 achieved a power of .94, while using BLRT at a standard α=.05 achieved a power of .8 with a sample size of approximately 100 (Dziak et al., 2014).

After the optimal profile solution was selected based on theoretical rationale and fit indices, we examined whether profile membership was associated with proposed variables of interest, expressing these as pairwise differences. Thus, in this second step, we examined whether profile membership was related to stress exposure, family support, coping behaviors, perceived control, and psychological wellbeing, using profile-specific means. The BCH approach (Bolck et al., 2004) was used in Mplus to estimate these pairwise differences, and is currently the recommended approach for analyses of this type (Dziak et al., 2016).

Youth sex, age, race and ethnicity, family socioeconomic status, and pubertal development were also included in the analyses. The use of medications known to affect cortisol activity (e.g., steroids, anti-inflammatory medications) was coded following recommendations made by Granger et al (2009), and when included in the analyses did not impact results.

3. Results.

Table 1 contains descriptive statistics and correlations between study variables. At baseline, 101 adolescents, ages 10–12 years old (M_{age}=11.83 (.58); 59.4% female) comprised the sample. On average, caregivers (85.6% mothers, 4.4% fathers, 6.7% grandparents) reported their child as having recently started pubertal development (M=2.29 (0.68), range: 1.0–3.5). The majority of youth identified as Black or African American (61.4%), Caucasian or white (14.9%), or mixed race (13.9%), and 38.6% reported ethnicity as Hispanic/Latino. On average, families lived below the federal poverty line (M_{INR}=.77 (.58), range: .00–3.05; M_{income}=$21,690 ($17,530)) and reported sometimes having to change spending habits to make ends meet (M_{EHQ}=1.90 (.66), range: 1.0–3.5). The majority of caregivers had a high school diploma/GED (27.7%) or less (28.7%).

3.1. LPA.

LPA models with 1 through 5 profiles were considered; fit statistics are provided in Table 2. As is common in LPA, the AIC, BIC, and a-BIC were not minimized and continued to decrease as additional profiles were added. Models with greater than five profiles were not considered due to difficulty with model identification. Decrements in fit criteria slowed for three or more profiles, and models 3–5 were considered carefully for fit and profile interpretation. We chose the 3-profile solution due to consistency with previous studies, and because solutions with 4 or more profiles resulted in at least one group with too few participants to be meaningful (e.g., less than 10% of cases; Osborne and Weiner, 2015).

Parameter estimates for the 3-profile model are presented in Table 3. Three cortisol reactivity profiles were identified as *Elevated and Reactive, Moderate and Non-Reactive*, and *Blunted and Non-Reactive* (Figure 2). Eleven percent of the sample belonged to the *Elevated and Reactive* (Reactive) cortisol profile, exhibiting an elevated baseline compared to normative samples (Stroud et al., 2009), an increase in cortisol output immediately following the stressor (S2-S4), then a return to pre-stressor levels. In contrast, participants in the *Moderate and Non-Reactive* (Moderate, 26%) and *Blunted and Non-Reactive* (Blunted, 63%) profiles exhibited little or no response to the stressor task (decrease or less than 15.5% increase from pre-TSST levels). Those with a Moderate profile presented with moderate cortisol at baseline compared to normative samples and a gradual decrease in cortisol output over time, without a strong cortisol response to the stressor. Those in the Blunted profile exhibited low cortisol levels across all samples, with no clear reactivity or recovery period following exposure to the stressor.

3.2. Pairwise differences.

Within-profile means and pairwise comparisons between profiles for key study variables are presented in Table 4. Chi-square results from overall difference tests are included in the table

unless otherwise provided; individual pairwise difference tests are reported in text below. To account for familywise Type I error, we calculated the False Discovery Rate (FDR; Benjamini and Hochberg, 1995), the recommended method for accounting for multiplicity within pairwise multiple comparison procedures (Keselman et al., 1999). Pairwise difference tests for which the p-value is below .05 are reported; those that fail the FDR test of significance are marked as non-significant in the text. In addition, effect sizes for significant individual pairwise differences are reported using Hedges' *g* to account for group differences in size ($d_{unbiased}$; Hedges, 1981). Effect size classes for Hedges' *g* are small (0.20), medium (0.50) and large (0.80).

3.2.1. Individual and family characteristics.—Sex, age, pubertal status, and ethnicity were not significantly associated with profile membership. Identifying as mixed race was significantly associated with profile membership, with individuals with the Reactive profile less likely to identify as mixed race compared to individuals with the Moderate profile(overall: $\chi^2=15.47$, $p<.001$; Reactive v. Moderate: $\chi^2=10.91$, $p=.001$, $d_{unbiased}=.47$; Reactive v. Blunted: $\chi^2=4.61$, $p=.03$ (ns), $d_{unbiased}=.53$). No other racial category or markers of socioeconomic status (income, parent education, income-to-needs, economic hardship) were significantly associated with profile membership.

3.2.2. External risk factors: Sources of stress.—Of the three types of stressors measured, only community stress was significantly associated with profile membership, with individuals exhibiting the Reactive cortisol profile reporting significantly less community violence and victimization than those exhibiting the Blunted cortisol profile (Reactive v. Blunted: $\chi^2=7.33$, $p=.01$, $d_{unbiased}=.55$; Reactive v. Moderate: $\chi^2=3.97$, $p=.05$ (ns), $d_{unbiased}=.58$;. Peer and family stress were not associated with profile membership.

3.2.3. Protective factors: Family support.—Contrary to hypotheses, of the family support variables, only child-report of family organization was related to profile membership; family cohesion was not associated with profile membership for either child or parent-report. Youth reports of greater family organization were associated with membership in the Reactive profile over either of the non-reactive profiles (Reactive v. Moderate: $\chi^2=12.50$, $p\leq.001$, $d_{unbiased}=1.04$; Reactive v. Blunted: $\chi^2=16.95$, $p\leq.001$, $d_{unbiased}=.72$). There was no significant difference in child reports of family organization between the Moderate and Blunted profiles ($\chi^2=.23$, p=.63). Parent reports of family support were not associated with profile membership.

3.2.4. Protective factors: Coping and perceived control.—Youths' perceived control over life stressors was significantly associated with profile membership; on average, those who exhibited the Moderate profile reported a greater sense of control than those exhibiting the Blunted profile (Blunted v. Moderate: $\chi^2=8.72$, $p=.003$, $d_{unbiased}=0.77$). The Reactive profile did not differ significantly from either Moderate or Blunted profiles in ratings of perceived control. Self-reported coping skills were not related to profile membership.

3.2.5. Psychological wellbeing (child report).—Youth-reported emotional and behavioral problems were significantly different across profiles, with membership in the

Reactive profile generally associated with less psychopathology than the non-reactive profiles. For instance, adolescents in the Blunted profile reported significantly more anger and dissociative symptoms than those exhibiting a Reactive profile (Reactive v. Blunted, anger: $\chi^2=25.12$, $p<.001$, $d_{unbiased}=0.83$; Reactive v. Blunted, dissociation: $\chi^2=5.90$, $p=.02$, $d_{unbiased}=.52$). Youth exhibiting a Moderate profile reported more anger symptoms than youth in the Reactive profile (Reactive v. Moderate, anger: $\chi^2=11.12$, $p=.001$, $d_{unbiased}=.89$). Similarly, delinquency behaviors were significantly lower for youth in the Reactive profile than those in either non-reactive profile (Reactive v. Blunted: $\chi^2=21.98$, $p<.001$, $d_{unbiased}=.67$; Reactive v. Moderate: $\chi^2=6.07$, $p=.01$, $d_{unbiased}=.61$). YSR Total Problems did not differ significantly across profiles.

3.2.6. Psychological wellbeing (parent report).—Parent-reported symptoms regarding trauma-related psychopathology, delinquent behaviors, and symptoms of internalizing or externalizing behaviors were not associated with profile membership.

4. Discussion

This study developmentally expanded the TS model by testing whether adolescents living in urban poverty exhibit profiles of cortisol reactivity predicted by the TS model, and provided empirical evidence of concurrent risk and protective factors associated with a stress-altered HPA response. Figure 1 outlines the process of TS, as put forth by the National Scientific Council on the Developing Child (Shonkoff et al., 2012) and with theoretically-supported developmentally-sensitive adaptations as put forth and partially supported by this paper. Three distinct profiles of cortisol reactivity were identified: Elevated and Reactive, Moderate and Non-Reactive, and Blunted and Non-Reactive. Lack of reactivity to the TSST-M, a standardized stress task designed to elicit a cortisol response in children, according to the TS model, may be indicative of stress-altered HPA activity. Consistent with hypotheses of the TS model, adolescents who exhibited attenuated cortisol reactivity reported more uncontrollable stressors, less family support, and more psychological distress. The Elevated and Reactive profile was associated with less psychological distress, more family structure, and less community violence exposure, and exhibited the expected cortisol response to a standardized stress protocol, suggesting an HPA axis whose functioning was still intact. Interestingly, this profile also exhibited baseline cortisol concentrations that were elevated compared to others in this study and in normative samples (Stroud et al., 2009), indicating that at-risk youth who are able to adequately respond to social stressors may still experience persistent activation of the HPA axis. Persistent activation of the HPA axis in other studies has been linked to poorer physical and mental health and contributes to long-term health disparities (Koss and Gunnar, 2018). Thus, although less psychological distress was associated with a cortisol profile with elevated reactivity than either non-reactive profile in this study, extensive empirical evidence suggests that patterns of either elevated or blunted cortisol activity may be harmful (Evans and Kim, 2013; Shonkoff et al., 2012). Follow up studies examining developmental trajectories of these profiles would illuminate whether differences in cortisol reactivity and psychosocial wellbeing persist following continued stress accumulation.

Although the TS model historically attends to stressors and protective factors that are highly relevant to young children, this study included risk and resilience variables that are more salient to adolescent experiences, including community-level and peer stress, parenting characteristics other than warmth, and internal resources of coping and perceived control. We found evidence to support a developmentally extended TS model that includes community violence and other neighborhood-based stressors as a risk factor associated with a stress-altered HPA axis. While the home environment is often considered the primary setting through which environmental stressors impact young children, school-aged and older children interact with their communities more directly and experience disadvantage and advantage forces first hand (McBride Murry et al., 2011). Our findings support the importance of intervening at both the neighborhood and family level in order to interrupt risk processes associated with HPA alteration.

In addition, these findings suggest that protective family factors may differ for young children and adolescents. While parental warmth and emotional support are consistently found to be protective for young children, family structure, the conceptual opposite of chaos, is protective against the negative effects of chronic stressors across childhood (Evans et al., 2005) and may take on increased significance for older children. As children spend less time with their parents, predictability in the home may serve as an increasingly important template that they can apply to the world, allowing them to cope more independently with unpredictable stressors. Family structure may be particularly beneficial to children experiencing uncontrollable, unpredictable, and overwhelming stressors outside of the parent-child relationship (Evans et al., 2005).

An examination of the association of internal resources with stress-altered HPA response resulted in mixed findings. Youth's perceived control over daily and life stressors was significantly different between the two non-reactive profiles, with greater sense of control associated with less blunted overall cortisol concentration. Perceived control was not, however, significantly associated with the Elevated and Reactive profile, which was associated with fewer experiences of community violence and overall youth wellbeing. Consistent with other studies, a greater sense of control was correlated with better mental health outcomes, less stress at home, with peers, and in the community, as well as with the use of more engagement coping (Scott and House, 2005), yet was not associated with the profile reflecting a less stress-altered HPA axis. Thus, although children exposed to stressors in moderation may develop greater perceived control over themselves and what happens to them and may impact basal cortisol levels, it does not appear to be related to cortisol reactivity.

Children experiencing persistent or repeated uncontrollable stressors, including maltreatment and poverty, are likely to report using fewer active coping skills and perceiving lower control (Culpin et al., 2015). Evans and Kim (2013) proposed that over time, the inability to physiologically react to and recover from stressors efficiently may disrupt the development of effective coping strategies and other self- regulatory skills. Use of engagement coping was not associated with cortisol reactivity profiles in this study, which could reflect that this process has either not yet occurred or is already complete in these

youths. Longitudinal studies are clearly needed to track the simultaneous and sequential effect of stress exposure on the development of coping strategies and HPA reactivity.

Youth in this study exhibiting blunted cortisol reactivity profiles were likely to report more trauma symptoms than peers with elevated and reactive cortisol trajectories, but were not likely to report more problem behaviors on a general measure of psychopathology. This may reflect the traumatic nature of the stressors that differentiated the youth in each profile: adolescents in both of the Non-Reactive profiles reported witnessing or being victim to significantly more experiences of community violence, including being threatened with a weapon or witnessing a crime. Previous studies of posttraumatic stress symptoms in response to community violence have found exposure to be associated with disruptions in diurnal cortisol and cortisol reactivity (Busso et al., 2016). Our findings support recent recommendations that processes related to toxic stress be viewed through a trauma lens (Hornor, 2015).

Results suggest that blunted cortisol response may be the norm, rather than the exception, among youth experiencing ongoing and overwhelming stressors associated with poverty, particularly community violence. Youth who did exhibit a significant reaction to the TSST-M began the task with atypical (elevated) levels of cortisol in comparison to the normative sample reported by Stroud et al. (2009). In contrast, nearly two-thirds of our sample exhibited overall attenuated cortisol concentration, with no discernible reaction to the TSST. The moderate group exhibited a baseline that was consistent with Stroud et al.'s normative sample, but like the blunted group did not respond as expected to the stress task. Without prospective data, it is impossible to know whether these three groups represent three levels of adaptation to chronic stress (Susman, 2006; Trickett et al., 2010); such as would result from (a) stress- induced hyperarousal and hyperactivation of the HPA (Elevated and Reactive), leading over time to (b) decreasing hyperarousal and decreasing activation (Moderate and Unreactive), ultimately leading to (c) hypoarousal and hypoactivation (Blunted). Such prospective data are sorely needed.

Future research is needed to address the limitations of the present study. The current study included 101 early adolescents living in urban, low-income households, of which 11% exhibited a cortisol response to the TSST. Other studies of early adolescents who had experienced early life stress or chronic stressors reported a normative stress response in 46–81% of their samples (Gunnar et al., 2009a; Peckins et al., 2015). Differences in the prevalence of blunted reactivity may reflect the ongoing nature and severity of the stressors experienced by the youth in the current study, who remain embedded in a context of urban poverty and report recent exposure to community violence. Replication of the study in other samples experiencing ongoing and overwhelming stressors is necessary to confirm the extensiveness of blunted cortisol reactivity in the context of toxic stress.

While findings from this study suggest that cortisol reactivity profiles indexing toxic stress processes are associated with risk and protective factors that might be unique to adolescents, longitudinal research is necessary to differentiate between causal mechanisms and purely correlational links. In addition, our focus in this study has been limited to cortisol, which is undoubtedly only a small piece of the endocrine puzzle on the impact of chronic,

uncontrollable stressors on the body. A litany of other neurobiological pathways exist outside of the HPA axis, including structural and functional changes in the brain, the noradrenergic system, and central oxytocin pathways, which confer resilience to stress and may interact with the same risk and protective factors studied here (Ozbay et al., 2007; Teicher et al., 2003). Future tests of the toxic stress model, particularly among adolescents, that examine the role of other stress hormones or even neurobiological pathways outside of the HPA are needed.

In this study, both parent and youth report of psychological wellbeing and family support were used, but only youth responses were associated with profile membership; further analyses are needed to understand whether adolescent differences in cortisol reactivity manifest in ways that are apparent to caregivers. Our TSST-M protocol mirrored that of Yim and colleagues with the exception that, at the request of our community partners, we added a PMR exercise during the last ten minutes of the visit. Given the time lag in the appearance of cortisol in saliva, any effect from the PMR would not have been detectable in S6 as it occurred immediately at the end of the PMR.

Risk for TS has traditionally been inferred from demographics. Identifying children who may experience TS because of their socioeconomic status and racial background may be efficient and appropriate for policy work, but it leaves health providers who work with these populations with little understanding of their assets and liabilities—and even less knowledge of those beyond early childhood. Our findings suggest that there are children who still exhibit a response to social stressors, although they were identical in demographics to those children who exhibited a blunted response. Understanding the ways in which chronic, overwhelming stress presents itself and is dealt with in a population of at-risk adolescents is essential to care providers and interventionists who are dedicated to buffering children from the effects of TS. Pediatricians and child clinical psychologists may benefit from understanding the actual experiences and psychophysiological functioning of these vulnerable children. By better understanding the nature and course of stress responses and identifying resources and sources of support within the community, clinicians can better bolster children’s efforts to cope with the challenges of their lives, helping them keep stress tolerable. As children approach adulthood, their ability to take on these challenges without the immediate help of a parent or caregiver becomes increasingly important to meeting developmental goals and expectations. Given the long-term implications of TS processes, it is critical that researchers identify effective means of intervening and interrupting the HPA alterations created by experiencing uncontrollable stressors (Wadsworth et al., 2018a).

4.1 Conclusions

In sum, we identified three profiles of cortisol reactivity among low-income early adolescents: Elevated and Reactive, Moderate and Non-Reactive, and Blunted and Non-Reactive. Membership in the Elevated and Reactive profile was associated with experiencing less community violence, greater structure at home, and fewer symptoms of psychopathology than membership in non-reactive profiles. This study adds to a growing body of work that supports the hypotheses of the toxic stress model beyond early childhood. Our findings suggest that the risk and protective factors included in the toxic stress model

could be expanded to include more developmentally-sensitive measures to account for the social, behavioral, and cognitive changes that proliferate in adolescence. Overall, this study underscores the importance of community and family characteristics that may threaten or bolster adolescents' ability to recover from acute as well as chronic stressors.

Toxic stress model, based on description outlined in Shonkoff et al (2012). Risk and protective factors that are linked empirically to stress-altered HPA activity are marked by subscripts indicating the relevant age range ([1] = ages birth - 9.9 years, [2] = 10.0–19.9 years). Risk and protective factors without subscripts are theoretically but not yet empirically supported. Factors in italics are included in the current study. Outcomes are similarly provided with subscripts to indicate in which age range(s) ([1] = birth - 9.9 years, [2] = ages 10.0–19.9 years, [3] = 20 and older) toxic stress-related health disparities have been demonstrated.

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Highlights

- Hypothesized relationships of the TS model were tested among adolescents
- Profiles of cortisol reactivity were Reactive, Non-Reactive-Moderate, Non-Reactive-Blunted
- Membership in non-reactive profiles was related to more violence and less family support
- Membership in the reactive profile was associated with greater wellbeing
- Risk and protective factors of TS model warrant developmental expansion

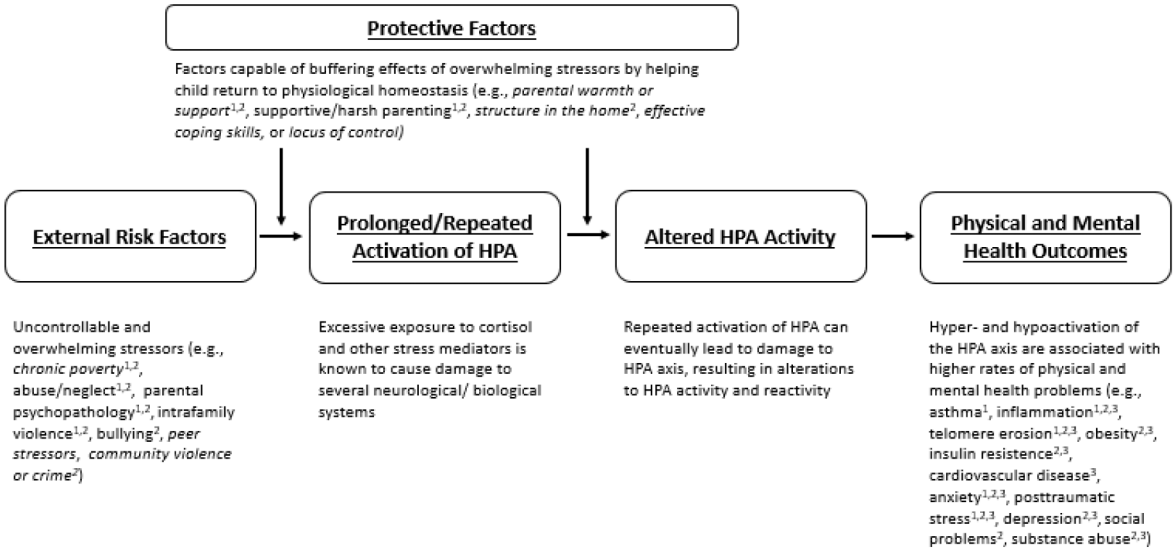

Figure 1.
Developmentally-sensitive summary model of the process of toxic stress.

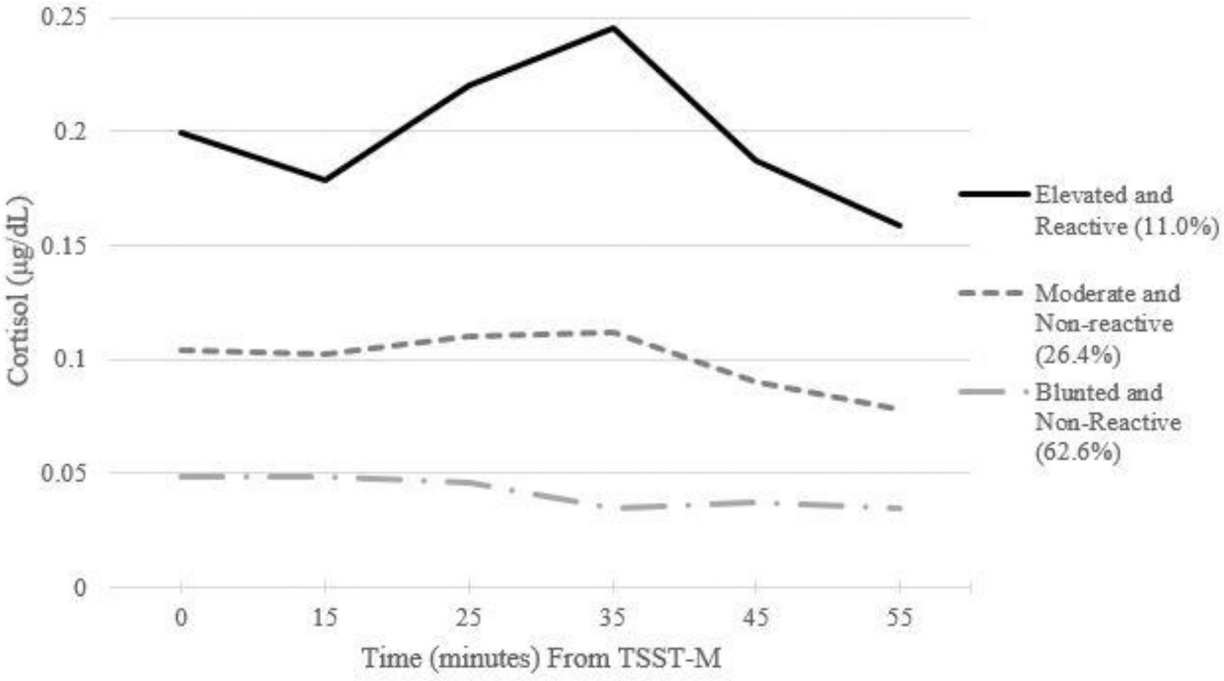

Figure 2.

Latent profile analysis three-profile solution.

Analyses performed with fourth-root transformed cortisol; nontransformed values are plotted here for comparison purposes.

Table 1.

Descriptive Statistics and Correlation Estimates for Risk and Protective Factors related to TS and Psychological Wellbeing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1 Family stress (s)																			
2 Peer stress (s)	.57**																		
3 Comm. stress (s)	.61**	.59**																	
4 Cohesion (m)	.12	.07	.13																
5 Organization (m)	−.14	0.5	0.2	0.49**															
6 Cohesion, PR (m)	0.2	.16	0.7	−0.16	−.07														
7 Organization, PR (m)	−.20	−.15	−.27*	−.18	.05	.26*													
8 Engag. Coping (r)	−.28**	−.21*	−.14	.23*	.26**	−.08	.12												
9 Diseng. Coping (r)	.05	.02	−.03	−.19	−.18	−.14	−.04	−.44**											
10 Perc. Control (s)	−.30**	−.30**	−.25*	.28**	.28**	−.11	.06	.65**	−.28**										
11 Anger	.40**	.45**	.50**	.01	−.08	.06	−.04	−.38**	.05	−.38**									
12 Dissociation	.46**	.52**	.46**	−.03	−.14*	−.06	−.14	−.47**	.08	−.47	.70**								
13 PTS	.40**	.37**	.45**	−.02	−.07	.02	−.14	−.48**	.00	−.48	.58**	.78**							
14 Total Prob.	.40**	.44**	.41**	−.01	−.06	.10	−.16	−.46**	.14	−.46**	.66**	.68**	.59**						
15 Delinquency (s)	.31**	.46**	.58**	.15	.05	−.00	−.12	−.07	−.05	−.07	.41**	.18	.11	.27*					
16 Anger, PR	.10	−.03	.04	−.06	−.06	−.08	−.13	.13	.09	.13	−.14	−.13	−.18	−.23*	−.07				
17 Dissociation, PR	.19	.14	.13	−.16	−.24*	−.14	−.39**	.02	.02	.07	−.06	.00	−.11	−.08	.05	.54**			
18 PTS, PR	.24*	.12	.14	.08	−.08	−.26*	−.26**	.07	−.02	.02	−.03	−.01	−.10	−.12	.10	.61**	.69**		
19 Total Prob., PR	.23*	.16	.08	.15	−.01	−.30**	−.38*	.10	−.02	.01	.02	.03	−.03	.11	.07	.53**	.53**	.57**	
M	4.90	3.15	2.14	3.37	3.85	3.29	5.52	.43	.15	4.58	47.05	49.27	48.17	53.57	.80	52.15	51.28	52.96	55.76
SD	4.23	2.47	2.62	.99	1.34	1.05	1.87	.07	.03	.99	11.33	11.66	11.59	10.58	1.44	12.52	11.07	11.10	12.27
Range	0–20	0–9	0–10	0–4	0–5	0–4	0–7	.28-.59	.09-.22	2.20–6.45	35–80	35–92	35–89	28–85	0–6	41–95	43–94	40–99	32–90
N	95	95	95	97	97	93	93	99	99	98	95	95	95	88	97	91	90	89	88

Unless otherwise specified, profile indicator values are standardized T scores and represent children's self-report. s=sum; m=mean; r=ratio; PR=parent report; Comm.=Community; Engag.=Engagement; Diseng.=Disengagement; Perc.=Perceived; PTS=Posttraumatic Stress; Total Prob= Total Problems.

* p<.05;
** p<.01

Table 2.

Indices of fit for model solutions with two to five profiles.

No. of classes	No. of Free Parameters	Log Likelihood	AIC	BIC	a-BIC	Entropy	BLRT
1	12	−770.48	1564.97	1595.10	1557.22	--	--
2	19	−609.52	1257.03	1304.74	1244.77	0.92	<.0001
3	**26**	**−557.21**	**1166.42**	**1231.71**	**1148.64**	**0.95**	**< .0001**
4	33	−520.64	1107.28	1190.14	1085.98	0.94	<.0001
5	40	−492.55	1065.10	1165.54	1039.28	0.95	<.0001

Notes. N = 91. Dashes indicate criterion was not applicable. Bold font indicates selected model. Models run using standardized values of cortisol, fourth-root transformed.

No.=Number; AIC=Akaike information criterion; BIC=Bayesian information criterion; a-BIC=sample size adjusted BIC; BLRT=Bootstrap likelihood ratio test.

Table 3.

Parameter Estimates for the three-profile model

				1 Elevated and Reactive	2 Moderate and Non-Reactive	3 Blunted and Non-Reactive
				Latent Profile Membership Probabilities		
Salivary cortisol	***Sample Mean (μg/dL)***			**.11**	**.26**	**.63**
		Min	***Max***	***Item-Response Probabilities***		
SI	.091 (.09)	.020	.460	0.199 [b]	0.104 [b]	0.048 [a]
S2	.086 (.08)	.018	.449	0.179 [b]	0.102 [b]	0.048 [a]
S3	.088 (.07)	.012	.365	0.220 [b]	0.110 [b]	0.046 [a]
S4	.093 (.10)	.020	.468	0.246 [b]	0.112 [b]	0.035 [a]
S5	.074 (.07)	.008	.347	0.187 [b]	0.090 [b]	0.037 [a]
S6	.064 (.05)	.007	.259	0.159 [b]	0.078 [b]	0.035 [a]

[a] Significantly below sample mean.

[b] Significantly above sample mean.

Note. Cortisol values presented here are raw, non-transformed values.

Table 4.

Within-profile means for risk and protective factors associated with toxic stress, and psychological wellbeing.

Measures	Sample Mean	1 Elevated and Reactive		2 Moderate and Non-Reactive		3 Blunted and Non-Reactive		χ^2
	0.11			**0.26**		**0.62**		
		Mean	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	
Risk and Protective Factors								
Family stress (s)	4.90	3.67	1.22	4.83	.81	5.13	.63	**1.14**
Peer stress (s)	3.15	2.17	.84	3.48	.56	3.12	.31	**1.63**
Community stress (s)	2.14	.77[2,3]	.38	2.10[1]	.53	2.19[1]	.36	**8.26** *
Family Cohesion	3.37	3.40	.33	3.37	.17	3.42	.13	**0.04**
Family Organization	3.85	4.72[2,3]	.15	3.83[1]	.20	3.69[1]	.20	**22.04** **
Family Cohesion, PR	3.29	3.61	.30	3.22	.24	3.23	.15	**1.37**
Family Organization, PR	5.51	6.22	.54	5.21	.38	5.50	.27	**2.31**
Engagement Coping (r)	.43	0.43	0.02	0.44	0.01	0.42	0.01	**0.51**
Disengagement Coping (r)	.15	.16	.01	.15	.01	.15	.00	**1.54**
Perceived Control (s)	4.58	4.70	.37	5.05[3]	.21	4.33[2]	.12	**9.05** *
Psychological Wellbeing								
Anger Problems	47.05	38.81[2,3]	1.02	46.83[1]	2.12	48.75[1]	1.70	30.37 **
Dissociation	49.27	43.85[3]	1.97	50.14	2.62	50.17[1]	1.70	6.68 *
PTS	48.17	42.14	2.86	48.85	2.45	49.06	1.68	4.63
Total Problems	53.57	49.03	3.24	52.43	2.60	55.01	1.37	3.24
Delinquent Behaviors (s)	.80	−.02[2,3]	.01	.71[1]	.29	.97[1]	.21	27.99 **
Anger Problems, PR	52.15	51.45	2.77	53.97	2.94	50.20	1.43	1.33
Dissociation, PR	51.28	50.50	2.33	50.33	2.12	50.31	1.53	.01
PTS, PR	52.96	50.33	2.54	53.50	1.99	52.79	1.79	.99
Total Problems, PR	55.76	52.89	4.02	57.92	2.46	55.14	1.85	1.34

* $p < .05$;

** $p < .01$.

Note. Gender, age, perceived pubertal status, ethnicity, and markers of socioeconomic status were not significantly associated with profile membership. Superscripts indicate significant differences with other profiles (1=Elevated and Reactive, 2=Moderate and Non-Reactive, 3=Blunted and Non-Reactive, *p<.05*). Unless otherwise specified, profile indicator values are standardized T scores and children's self-report. TS=Toxic Stress. s=sum, r=ratio, PR=parent/caregiver report, PTS=Posttraumatic Stress.