Cumulative Risk and Physiological Stress Responses in African American Adolescents

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Abstract

Objective: To investigate associations between components of cumulative risk (CR) and physiological stress responses in African American adolescents and evaluate emotion regulation as a mediator and sex as a moderator of these associations. **Methods:** Cortisol and salivary alpha amylase (sAA) were collected in adolescents ($N = 205$; 55% female; 12.1 ± 1.6 years at baseline) as part of a longitudinal study of stress and adjustment in families. CR was assessed at baseline and emotion regulation was assessed at baseline and 2 years later at Wave 3 (W3) using caregiver and adolescent reports. Cortisol and sAA responses to the social competence interview were assessed at W3. **Results:** Repeated-measures analyses of variance predicting cortisol and controlling for time of day, adolescent age, medication usage, and pubertal status revealed significant interactions of time with both psychosocial and sociodemographic risk. In both analyses, youths with higher levels of risk showed a steeper decline in cortisol than youths with lower levels of risk. In parallel analyses predicting sAA, time interacted with psychosocial but not with sociodemographic risk. There were no interactions with sex in any of the analyses. Although CR was associated with changes in emotion regulation, there was no evidence that these changes accounted for the observed CR–stress response associations. **Conclusions:** These findings illustrate the potential importance of disentangling CR and suggest that additional work is needed to help explicate why and how CR is associated with specific physiological responses to stress.

Keywords

cumulative risk, salivary cortisol, salivary alpha amylase, emotion regulation, adolescents

Over the last decade, a growing body of research has documented the effects of cumulative risk (CR)—the piling up of demographic, psychosocial, and environmental stressors—on youths' psychological, emotional, and behavioral well-being (Evans, Li, & Whipple, 2013). Research on CR and physiological well-being is less well-developed but has found positive associations between CR and allostatic load (AL; Brody et al., 2013; Evans, 2003; Evans, Kim, Ting, Teshler, & Shannis, 2007) and dysregulated cortisol (Kliewer, Reid-Quinones, Shields, & Foutz, 2009). This work is important because these physiological responses to stressors predict future health, including cardiometabolic disorders (Karlman-gala, Singer, McEwen, Rowe, & Seeman, 2002; Seeman, McEwen, Rowe, & Singer, 2002).

Many of the factors that comprise commonly used CR indexes, including single parenthood, adolescent parenthood, low parental education, poverty, and exposure to neighborhood violence, are more prevalent in the lives of African American youths than in the lives of Caucasian youths (Crouch, Hanson, Saunders, Kilpatrick, & Resnick, 2000; U.S. Census Bureau, 2012). These factors often are chronic stressors in youths' lives and, when experienced, can strain and damage the nervous, endocrine, and immune systems, which are responsible for maintaining health (McEwen & Stellar, 1993). Thus, the health disparities researchers have

observed between Caucasian and ethnic-minority adults in the United States likely have their roots in the differential childhood experiences of members of these groups. Nonetheless, there is considerable within-group variability on health outcomes among individuals reared in low-resource environments, pointing to the need for additional research in this area. The present study extends prior research on associations between CR and physiological stress responses in several important ways. First, we focus on physiological stress responses in both the autonomic nervous system (ANS) and hypothalamic–pituitary–adrenal (HPA) axis. Second, we

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examine the contributions of psychosocial and sociodemographic sources of risk separately. This aspect of the study has specific implications for prevention, as sociodemographic sources of risk tend to be less amenable to change than psychosocial sources. Third, we evaluate sex differences in physiological responses to stress. Fourth, we test changes in emotion regulation as a mediator of linkages between CR and physiological stress responses. Lastly, we focus on urban, African American youths. Most prior work (e.g., Brody et al., 2013; Evans, 2003; Evans et al., 2007) has focused on rural populations.

Background

Psychobiology of Stress

Allostasis is the dynamic interplay of physiological systems focused on adjusting the body's operating range in response to physical, psychological, and environmental demands. In the short-term, these processes are protective and adaptive. The brain is the primary regulator of stress responses. The nervous, endocrine, and immune systems are highly integrated and mediate allostatic processes such that activation in one system results in activation in all systems. In the nervous system, an acute stress-response cascade involves the amygdala, hippocampus, and prefrontal cortex. The amygdala activates the paraventricular nucleus of the hypothalamus, which stimulates the HPA axis to mobilize energy reserves. The parasympathetic nervous system then extinguishes the arousal response (Danese & McEwen, 2012).

With chronic or repeated stress exposure, ongoing allostatic processes result in allostatic load (AL) or cumulative wear and tear on the body. Structural and functional changes occur in the amygdala, hippocampus, and prefrontal cortex. Enhanced dendritic growth in the amygdala is associated with heightened fear responses. The hippocampus undergoes remodeling and volume decrease, which yields related behavioral changes such as altered declarative, contextual, and spatial memory. Both the endocrine and immune systems contribute to changes in brain plasticity, which are thought to augment subsequent endocrine and immune stress responses (Danese & McEwen, 2012; Frodl & O'Keane, 2013). Corticotropin-releasing hormone (CRH) is released from the hypothalamus in response to somatic and psychosocial stress and activates the HPA axis, the major stress system in the body. Increased levels of CRH reflect chronic activation of the HPA axis, with decreased morning cortisol levels and increased afternoon levels. These alterations in cortisol production result in a blunted circadian pattern and higher daily cortisol production. In response to CRH, the anterior pituitary produces adrenocorticotrophic hormone, triggering the release of glucocorticoids from the adrenal cortex. Cortisol mediates the negative feedback loop for CRH and ACTH (Charmandari, Tsigos, & Chrousos, 2005; Frodl & O'Keane, 2013). In response to chronic stress, HPA-axis hyperactivity may abate or the axis may become hypoactive (Miller, Chen, & Zhou, 2007). Inflammation likely contributes to HPA-axis

hyperactivity. Persistent inflammation develops in response to recurrent sympathetic nervous system activation and down-regulation of anti-inflammatory pathways including the HPA axis and parasympathetic nervous system (Danese & McEwen, 2012). When exposure to demands remains high, a higher level of activity is required to adapt. Subsequently, in calmer periods, the body becomes less efficient at turning off the processes triggered during high-demand times (Evans, 2003; McEwen & Stellar, 1993). Thus, the accumulation of stressors affects multiple physiological systems in the body responsible for maintaining health. Because the nervous, endocrine, and immune systems are not fully matured at birth, with the brain, for example, continuing to develop into young adulthood, exposure to psychosocial stressors may alter the development and maturation of these systems resulting in altered allostasis and increased AL (Danese & McEwen, 2012).

CR, HPA-Axis and ANS Reactivity

HPA-axis reactivity varies based on age and sex, with one previous study reporting that older children (age 9) have heightened responses, which become blunted in preadolescence (age 11) then heightened again at ages 13 (in girls) and 15 (Gunnar, Wewerka, Frenn, Long, & Griggs, 2009). Cortisol is the most frequently used indicator of HPA-axis activation (Aiyer, Heinze, Miller, Stoddard, & Zimmerman, 2014). Investigators have observed positive (Evans, 2003), negative (Kliewer et al., 2009), and curvilinear (Gustafsson, Anckarsater, Lichtenstein, Nelson, & Gustafsson, 2010) relations between CR and salivary cortisol in youths. These differences across studies may be a function of the samples studied, the time at which cortisol was assessed (e.g., overnight or upon awakening) or the types of risks examined. Given recent work showing blunted cortisol responses to chronic stress among urban, African American youths (Aiyer et al., 2014; Kliewer, 2016), we anticipated that, in the present study, youths with higher levels of CR would show a reduced cortisol response to the stress task relative to youths with lower levels of CR.

In concert with the growing interest in stress responses that represent different physiological systems in the body, researchers working with youths have begun to assess the enzyme alpha amylase (AA) as a surrogate marker of ANS activity in addition to studying cortisol. Salivary AA (sAA) is a sensitive, reliable, and valid biomarker of stress-related changes in the sympathetic nervous system (Nater & Rohleder, 2009). Although no studies to date have examined CR and sAA, several studies have addressed relations between aspects of stress and sAA responses. For example, in one study, high task-related sAA activity in preadolescent girls was associated with a history of peer victimization and heightened frustration (Rudolph, Troop-Gordon, & Granger, 2010). In a family study of teenage youths that included a conflict-discussion task, families with more interparental aggression demonstrated greater father-adolescent sAA response symmetry compared to families without interparental aggression (Gordis, Margolin, Spies, Susman, & Granger, 2010). In a study of 153 youths aged 10–17 years,

parental marital conflict predicted increased levels of sAA reactivity and decreased levels of heart rate reactivity, particularly if the parent–child relationship was of low quality (Lucas-Thompson & Granger, 2014). In summary, in studies of children and adolescents, sAA reactivity has been linked to heightened risk, particularly risk that is personally threatening and meaningful. The first purpose of the present study was to extend prior research by examining associations of CR with both salivary cortisol and sAA. Based on the extant literature, we hypothesized that youths with higher levels of CR would show a heightened sAA response to the stress task relative to youths with lower levels of CR.

Sociodemographic Versus Psychosocial Risk

In addition to examining associations between CR and stress responses in both the adrenocortical and ANSs, a second purpose of the study was to examine whether the risk factors that were more psychosocial versus sociodemographic in nature were differentially associated with patterns of stress responses. We conceptualized sociodemographic risk factors (e.g., maternal adolescent parenthood, low maternal education, single parenthood, and poverty) as less modifiable sources of risk, whereas psychosocial risk factors or exposure to them (e.g., family stress, maternal mental health, daily hassles, neighborhood violence) were considered relatively malleable (Kliewer et al., 2017). Specifically, we sought to understand whether sociodemographic risk had similar or different patterns of association with changes in emotion regulation and with changes in physiological stress responses relative to the theoretically modifiable (malleable) psychosocial risk factors. This question is important because, to be most effective, prevention and intervention programs need to target modifiable risk (National Institutes of Health [NIH] Prevention Research Coordinating Committee, 2007). Based on our ongoing cross-cultural research (Kliewer et al., 2017) disentangling psychosocial and sociodemographic risk and demonstrating differential associations with both emotion regulation and adjustment, we anticipated some differences in the patterns of findings between these two sources of risk. However, given the differences between the outcomes in our cross-cultural study (e.g., internalizing and externalizing behavior problems) versus the present study (physiological stress responses), we made no specific hypotheses.

Sex Differences in Physiological Responses to Stress

Research with adolescents has demonstrated sex-based differences in response to stressors (Hackman, Betancourt, Brodsky, Hurt, & Farah, 2012; Stroud, Salovey, & Epel, 2002). Thus, a third purpose of the present study was to examine the extent to which sex moderated the hypothesized association between CR and physiological responses to stress. Because research on sex differences in HPA-axis functioning is equivocal (Aiyer et al., 2014) and because the social competence interview (SCI; Ewart Jorgensen, Suchday, Chen, & Matthews, 2002), the task

we used to elicit a stress response, allows youths to discuss stressors that are personally threatening and meaningful, we did not anticipate sex differences in youths' physiological responses to CR in the present study.

Emotion Regulation as a Mediator of CR and Stress Responses

Little of the work to date on CR in youths has focused on mediating processes (Evans et al., 2013). Emerging evidence suggests that emotion regulation, particularly suppression and reappraisal, may mediate the effects of CR on physiological responses to stress tasks. In 158 10-year-old children, there were increases in both salivary cortisol and sAA in response to a stress task, with girls exhibiting greater cortisol reactivity compared to boys. State suppression was associated with lower cortisol reactivity in girls as well as lower sAA reactivity and more efficient sAA recovery in all youths, while the authors found no associations between state reappraisal and sAA or cortisol responses (de Veld, Riksen-Walraven, & de Weerth, 2012). In another study, Lam, Dickerson, and Zaldivar (2009) found that both trait suppression and trait reappraisal predicted increased cortisol reactivity in response to a speech task. The fourth aim of the study was to contribute to the literature by testing the role of emotion regulation as a mechanism linking CR and stress responses, using both adolescent and caregiver reports of emotion regulation, in a sample of urban, African American youths. We hypothesized that changes in emotion regulation capacity would at least partially explain linkages between CR and physiological stress responses in our sample.

Method

Participants

Participants included 205 African American/Black adolescents (55% female; M age = 12.1 years, SD = 1.6 years at baseline; 14.1 years, SD = 1.6 years at Wave 3 [W3], which was, on average, 2 years after baseline) from Richmond, VA, a community with a large population of African American adolescents and high levels of violence and/or poverty according to police statistics and U.S. census data, who participated in the first and third waves of a larger longitudinal study on violence, physiological stress responses, and adjustment and had valid physiological protocols. According to these census data (2000), 61% of 15- to 24-year-olds in Richmond were African American, and 61% of children lived in neighborhoods classified as high in poverty (Annie E. Casey Foundation, 2004). Families living in 99 different census tracts were sampled for the study, and most census tracts contributed 10 or fewer families to the sample. We began recruitment by contacting agencies and housing-project authorities and made presentations at community meetings in order to meet potential participants and answer questions. After those efforts yielded few enrolled families, we began a door-to-door recruitment strategy in qualified neighborhoods. We screened respondents for eligibility over the

telephone. Potential participants were informed that the study would involve annual in-home interviews. To be eligible, participating families had to have a fifth or eighth grader living in the home, and an adult female caregiver needed to be willing to participate in the interview. We recruited only English-speaking participants. Consistent with studies using similar designs and populations, 63% of eligible respondents chose to participate.

Although the nature of the research questions meant that many of the participating families would be of lower socioeconomic status, there was some diversity in the sample. At the start of the study in 2005, half of the sample had household incomes of US\$301 to US\$400/week or less, and 9.3% made US\$901/week. About a quarter (27.3%) of the caregivers had not completed high school, 25.9% had completed high school or had a general education diploma, 23.4% had some college but no degree, and remaining percentages had completed associates (6.3%), vocational (8.3%), bachelor's (7.3%), or master's (1.5%) degrees. A range of family structures was represented in the sample, although many (39.0%) of the caregivers had never married. A third (34.4%) of caregivers were married or cohabitating at the time of the study, 13.7% were separated, 9.8% were divorced, and 2.9% were widowed.

Measures

CR. In order to examine sociodemographic and psychosocial risk separately, we created two CR indexes from Wave 1 (W1) data based on the work of Evans (2003). The sociodemographic risk index included four risk factors assessed via caregiver report: (1) maternal high school dropout, defined as neither completing high school nor earning a general education development diploma, (2) maternal single parenthood, (3) household income level below the poverty line (2005–2006 Federal Health and Human Services Guidelines), and (4) maternal adolescent parenthood (mother < 19 at the time of the adolescent's birth). Each family received a score of 0 for each risk factor that was absent and 1 for each that was present for a possible range on this index of 0–4.

The psychosocial risk index included four risk factors assessed via both caregiver and adolescent report: (1) family stress, (2) mother's level of adjustment problems, (3) daily hassles, and (4) neighborhood risk. Each family received a score of 0 or 1 for each risk factor, indicating that the factor was absent or present, respectively. The family stress measure was adapted from a measure used by the Multisite Violence Prevention Study (Miller-Johnson, Sullivan & Simon, 2004) and included a list of 20 items that caregivers rated as not occurring (scored 0), occurring and causing minor stress (scored 1), or occurring and causing major stress (scored 2) in the past year. These items included moving; experiencing medical problems with the adolescent or with close family members; death of an important person in the family; divorce, breakup, separation, or reunion between the caregiver and her partner; parent–adolescent separation; loss of income; legal

problems; caregiver drug or alcohol problems or addiction; stress or conflicts in the extended family; caregiver pregnancies, miscarriages, or births; caregiver job-related stress; caregiver job loss; unexpected family expenses; caregiver experience of crime or violent victimization; family members' problems with police or court; problems with people to whom the caregiver owes money; problems with the living situation (e.g., vandalism and lack of repairs); and problems with neighbors. The Cronbach's α for the scale was .75. Families who were 1 *SD* or more above the mean were considered at risk and received a score of 1, with all others receiving a score of 0 for this factor. The measure of maternal adjustment problems was created by standardizing and combining the 6-item anxiety, 6-item depression, and 5-item hostility subscales from the Brief Symptom Inventory (Derogatis & Melisaratos, 1983). The Cronbach's α s for the subscales were .84, .88, and .75, respectively; the subscales were intercorrelated from .59 to .74. Caregivers who scored 1 *SD* or more above the mean were considered at risk and received a score of 1, with all others receiving a score of 0. We asked adolescents to rate daily hassles using the 30-item Daily Hassles Scale (Seidman et al., 1995). Cronbach's α was .91. Adolescents who scored 1 *SD* or more above the sample mean were considered at risk and received a score of 1, with all others receiving a score of 0. Finally, we measured neighborhood by standardizing and combining adolescents' reports of experiencing (10 items), witnessing (21 items), and hearing about (16 items) violence in the community during their lifetime (Richters & Saltzman, 1990). First, we combined the measures of witnessing and hearing about violence, which were correlated at .66. We then combined this measure of indirect exposure with the measure of victimization ($r = .39$) in order to equally weight both direct and indirect exposure in the index. Adolescents with scores 1 *SD* or more above the mean were considered at risk and received a score of 1, with all others receiving a score of 0. Possible range on this index was 0–4. In the current study, the sociodemographic and psychosocial risk indexes were uncorrelated, $r(205) = .10$, $p = .17$.

Physiological stress responses. We assessed the changes in cortisol and sAA levels in response to a stress task, the SCI (Ewart et al., 2002), at W3. The SCI is a 15- to 20-min audiotaped interview designed to promote physiological arousal. Research has repeatedly found correlations between administration of this interview and changes in blood pressure and heart rate (Ewart, Elder, Smyth, Sliwinski, & Jorgensen, 2011). We administered the SCI to the adolescents at home interviews. As Ewart, Elder, Smyth, Sliwinski, and Jorgensen (2011) noted, there are several phases to the SCI:

Participants first describe and relive a problem situation that causes them recurring personal stress. Then they pretend that they are a movie director making a film about a person like themselves with a similar problem. They are invited to invent a desirable but realistic ending for the film, and to construct an appropriate plot line. (p. 512)

SCI interviewers ranged in age from 20 to 55 and included both men and women. Approximately half of the interviewing staff was African American. The interviewers typically had bachelor's or master's degrees, although a small percentage had not yet completed a degree. Research staff trained and gave feedback to the interviewers over the course of 4 weeks before they began the actual interview process. The training covered research protocols and interview techniques and included practice sessions, paperwork, and related assignments. We also obtained feedback on the interviewers by phone from a subsample of participating families within 2 weeks of their having completing their interviews to make sure that the interview staff members were professional and adhered to the protocol throughout the study.

We collected saliva samples from the adolescents (1) directly before the start of the SCI, (2) once the adolescent had relived the problem situation but prior to them describing the movie (i.e., at the end of the "hot" phase; this averaged 15 min from the initial saliva assessment), (3) 10 min after they began their description of the movie, and (4) 20 min after they began their description of the movie. We instructed participants not to exercise, eat, or drink caffeinated beverages within the 2 hr prior to the SCI. We collected saliva using salivettes. The interviewer asked adolescents to place a cotton swab in their mouth and chew for about 1 min. The adolescent spit the swab into the salivette tube, and we froze the samples at -20°C or below until we took them to the laboratory for analysis.

Saliva samples were thawed, spun, and refrozen for batch processing. They were assayed at the General Clinical Research Center at Virginia Commonwealth University using enzyme immunoassays specifically designed for saliva analysis. On the day of the assay, samples were thawed and assayed directly with no further centrifugation. The assay for sAA employed a chromagenic substrate, 2-chloro-4-nitrophenol, linked to maltotriose. The enzymatic action of sAA on this substrate yields 2-chloro-p-nitrophenol, which can be spectrophotometrically measured at 405 nm using a standard laboratory plate reader. The amount of sAA activity present in the sample is directly proportional to the increase (over a 2-min period) in absorbance at 405 nm. Results are computed in units/milliliter of sAA using the following formula: $(\text{Absorbance difference per minute} \times \text{Total assay volume [328 ml]} \times \text{Dilution factor [200]}) / (\text{Millimolar absorptivity of 2-chloro-p-nitrophenol [12.9]} \times \text{sample volume [0.008 ml]} \times \text{light path [0.97]})$. The assay for cortisol used 25 μl of saliva and has a lower sensitivity limit of .007 $\mu\text{g/dl}$. Staff determined method accuracy by spike recovery and linearity by serial dilution of 105–95%.

Emotion regulation. Both caregivers and youths provided data on emotion regulation at W1 and W3. Maternal caregivers completed the emotion regulation checklist (ERC; Shields & Cicchetti, 1998), which contains a 16-item lability subscale and an 8-item emotion-regulation subscale. Respondents rate items on a 4-point Likert-type scale from 1 (*never*) to 4 (*always*). The Lability Scale taps constructs including lack of flexibility,

mood lability, and anger dysregulation. A sample item is, "exhibits wide mood swings." The Emotion-Regulation subscale captures adaptive regulation including situationally appropriate positive and negative emotional displays and empathy. A sample item is, "can say when she or he is feeling sad, angry or mad, and fearful or afraid." The ERC has excellent reliability and validity (Shields & Cicchetti, 1998). Cronbach's α s in the current study were .85 at W1 and .84 at W3 for lability and .70 at W1 and .69 at W3 for emotion regulation.

Adolescents completed the 5-item anger coping regulation and 5-item sadness coping regulation subscales from the Children's Emotion Management Scales (CEMS; Zeman, Shipman, & Suveg, 2002). Respondents rate items on a 3-point Likert-type scale from 1 (*hardly ever*) to 3 (*often*). Sample items include, "when I am feeling mad, I control my temper" and "I can stop myself from losing control over my sad feelings." The CEMS has good reliability and validity (Zeman et al., 2002). Cronbach's α s in the current study were .60 at W1 and .61 at W3 for anger regulation and .60 at W1 and .64 at W3 for sadness regulation.

Control variables. We included time of day, participant age, medication usage that could affect cortisol or sAA values, and pubertal status at the time of assessment in our analyses as control variables, as these are known correlates of either cortisol or AA. Home interviews were scheduled when both the caregiver and adolescent were available. Regarding interview times, most SCIs (73.2%) began between noon and 7 p.m. However, due to scheduling challenges with these participants, 14.6% of participants began the SCI prior to noon, 10.7% began between 7 and 8 p.m., and 1.5% began after 8 p.m. The interviewer asked all youths about their medication usage, and we coded medications independently as having the potential to affect cortisol or sAA or not using a dichotomous coding system (i.e., 1 or 0, respectively). Because a substantial proportion of the sample used medications that could affect the physiological outcomes, we controlled for medication usage versus eliminating these participants from analyses. We measured pubertal status using the Pubertal Development Scale developed by Peterson, Crockett, Richards, and Boxer (1988). This 5-item written assessment of pubertal status requires an adolescent to answer questions pertaining to the degree of his or her own pubertal status. All adolescents answer items on growth spurt, pubic hair, and skin change, while males have additional questions about facial hair and females have additional questions about menarche and breast development. Adolescents provide responses on a 4-item scale: 1 (*has not yet begun*), 2 (*has barely started*), 3 (*is definitely underway*), and 4 (*growth or development is complete*). The reliability of the items ranges from .68 to .83 (Peterson, Crockett, Richards, & Boxer, 1988). Cronbach's α in the current study was .82 for males and .76 for females.

Procedure

The institutional review board at Virginia Commonwealth University approved the project. As part of the parent study,

investigators conducted separate interviews with caregivers and youths annually for 4 years. Interviews were conducted in participants' homes unless a family requested another location. Prior to initiating the interview each year, study staff thoroughly reviewed the parental consent and adolescent assent forms with the family and answered any questions. The caregiver received a copy of the signed consent form. After the maternal caregiver provided written consent, the caregiver and adolescent separated for the interviews. The adolescent provided assent before the study staff member initiated the interview. Researchers obtained a certificate of confidentiality from the NIH to protect families' responses since adolescents were reporting on illegal behavior (e.g., substance use) as part of the study. Investigators distributed information about Family Access to Medical Insurance Security Plan (FAMIS) (discounted health insurance for children) and other community resources to caregivers at the time of each interview. We used face-to-face interviews including visual aids to collect the data, and interviewers read all questions aloud, with the exception of a small portion of the adolescent interview: Adolescents who had passed a reading screening test answered several (primarily sensitive) questions in a booklet without interviewer assistance. Tests for interviewer race and gender effects revealed no systematic biases, $ps > .10$. Interviews with the caregiver and adolescent lasted approximately 2.5 hr, and participants received US\$50 in gift cards per family at each wave.

Attrition Analyses

The parent study included 358 families, 326 of whom were African American/Black. Using χ^2 and t tests, we compared demographic characteristics and scores on the two CR indexes of African American youths whom we included in the present analytic sample (i.e., participated in the first and third waves of data collection and had valid physiological protocols at W3, $N = 205$) with African American youths who left the study after the first or second wave or who were interviewed at W3 but did not have valid physiological protocols ($N = 121$). There were no significant sex differences between youths who were included in the present analysis and those who attrited, $\chi^2(1) = 0.46, p = .57, \phi = .04$, nor any differences in youth age, $t(324) = 0.29, p = .78, 95\% \text{ CI } [-.31, .42]$, caregiver education, $t(323) = -0.32, p = .75, 95\% \text{ CI } [-.52, .37]$, household income, $t(322) = 0.42, p = .67, 95\% \text{ CI } [-.48, .74]$, psychosocial risk, $t(311) = -0.61, p = .54, 95\% \text{ CI } [-.23, .12]$, or sociodemographic risk, $t(311) = -0.93, p = .35, 95\% \text{ CI } [-.37, .13]$, indicating no systematic biases due to attrition.

Results

Data Cleaning, Data Transformation, and Descriptive Information

Although 244 African American youths participated in W3 of the study, yielding a 75% retention rate across the 2-year span between W1 and W3, 10 did not complete an SCI at W3. The

Table 1. Descriptive Information on Cumulative Risk (CR) Indexes, Biological Stress Response Outcomes, and Control Variables by Adolescent Sex.

Variable	Female ($n = 113$) M (SD)	Male ($n = 92$) M (SD)	Total ($N = 205$) M (SD)
Psychosocial CR	0.54 (0.67)	0.71 (0.83)	0.61 (0.75)
Sociodemographic CR	1.62 (1.15)	1.63 (1.09)	1.62 (1.12)
Cortisol			
Time 1	0.084 (0.076)	0.104 (0.071)	0.093 (0.074)
Time 2	0.075 (0.070)	0.092 (0.057)	0.083 (0.065)
Time 3	0.068 (0.053)	0.086 (0.052)	0.076 (0.053)
Time 4	0.064 (0.049)	0.077 (0.048)	0.070 (0.049)
sAA			
Time 1	25.90 (21.11)	25.90 (21.11)	26.58 (21.07)
Time 2	27.30 (21.11)	27.30 (21.11)	28.97 (24.04)
Time 3	25.33 (20.81)	25.33 (20.81)	25.88 (20.74)
Time 4	26.11 (21.03)	26.11 (21.03)	26.69 (21.28)
Pubertal status	12.21 (2.77)	14.71 (3.51)	13.34 (3.35)

Note. CR measures were assessed at baseline. Biological measures and pubertal status were obtained 2 years later at Wave 3. Time 1 = pre-social competence interview; Time 2 = end of hot phase; Time 3 = 10 min after the end of hot phase; Time 4 = 20 min after the end of hot phase; sAA = salivary alpha amylase.

most common reason they gave was that, "nothing bothers me," or "I can't think of anything to talk about." We thoroughly reviewed protocols for the participants who did complete the SCI prior to beginning analysis. We excluded protocols from the analyses for the following reasons: (a) youth had difficulty generating a stressful event to discuss ($n = 3$), (b) the timing of one or more saliva collection time points was off ($n = 20$), or (c) the interviewer rated the adolescent a 4 or 5 on an honesty scale, where 5 equates to *not at all honest* ($n = 2$). Additionally, data from four participants were lost due to research assistant error (i.e., incorrect sample storage). Our final possible sample was, thus, 205 African American youths. Based on best practices, we reviewed the descriptive statistics for cortisol and sAA and truncated outliers to 3 SD from the mean (Granger, Johnson, Szanton, Out, & Schumann, 2012), including four outliers from each time point for cortisol and four to seven outliers for each time point for sAA. Less than 1% of the cortisol and sAA data were missing. We imputed this missing data using mean substitution to capture as many cases as possible in the analyses. Table 1 presents descriptive information on the two CR indexes, the cortisol and sAA measures, and pubertal status by sex and for the sample as a whole. Figure 1 depicts the patterns of cortisol and sAA responses during the SCI. Notably, there was a spike in sAA but not an increase in cortisol in response to this task. Figure 1 also illustrates what a typical, or nonblunted, cortisol pattern might look like.

Youths discussed a variety of topics during the SCI, prompted by an initial set of eight cards depicting different types of stressful events. Exposure to community violence was discussed most frequently (26%), followed by relational victimization by peers (14%), witnessing or hearing about others being victimized (12%), verbal victimization by peers (11%),

Figure 1. Mean values of salivary alpha amylase and cortisol across the four time points in the social competence interview and a hypothetical typical cortisol response.

physical victimization by peers (10%), and issues related to school (8%). Other types of events (e.g., losses, family stressors, and legal issues) were discussed less often. There were no sex differences regarding the type of event discussed, $\chi^2(7) = 1.67$, $p = .98$. Sociodemographic risk was not significantly associated with the type of event discussed in the SCI. However, adolescents who discussed loss events, $t(195) = -3.01$, $p = .003$, or school issues, $t(195) = -2.04$, $p = .043$, had higher psychosocial risk scores than youths who did not discuss loss or school issues. Youths who discussed others being victimized versus focusing on their own loss or victimization had lower psychosocial risk scores than youths who did not discuss these types of events, $t(35.88) = 2.57$, $p = .015$.

We computed partial correlations between the risk indexes at W1 and emotion-regulation variables at W3, controlling for the same emotion-regulation variables at W1. Psychosocial risk was unrelated to caregiver-rated lability, $r(200) = -.02$, $p = .81$, caregiver-rated emotion regulation, $r(200) = .02$, $p = .80$, or adolescent-rated sadness regulation, $r(195) = -.07$, $p = .31$, but was associated with adolescent-rated anger regulation, $r(195) = -.19$, $p = .009$. Adolescents with higher psychosocial risk scores showed reductions in their capacity to regulate their anger. Sociodemographic risk was associated with caregiver-rated lability, $r(200) = .18$, $p = .009$, and with caregiver-rated emotion regulation, $r(200) = -.15$, $p = .038$, but not with adolescent-rated sadness regulation, $r(195) = -.11$, $p = .14$, or anger regulation, $r(195) = -.05$, $p = .53$. Adolescents with higher sociodemographic risk scores showed increases in their mood swings and emotional dysregulation and decreases in their emotional control.

Associations Between CR and Biological Stress Responses

In order to evaluate the hypotheses that CR would disrupt adolescents' normal physiological responses to stress, we conducted a series of repeated-measures multivariate analyses of variance with either the four cortisol values or four sAA values as the dependent measures. In two analyses, the psychosocial CR index, dichotomized for the analyses, was the predictor; in the other two analyses, the sociodemographic CR index,

dichotomized for the analyses, was the predictor. Adolescent sex was a second predictor of each model, and time of day, adolescent age, medication usage, and pubertal status were included as covariates (see Table 2 for a summary of the results of the four repeated-measures analyses).

In the first model, with cortisol as the outcome and psychosocial risk as the predictor, time interacted with risk at a marginally significant level, indicating that the pattern of change in cortisol over the course of the SCI differed for youths with low versus high levels of psychosocial risk. There were no interactions with sex, indicating that the pattern was similar for males and females. Inspection of the pattern of findings (see Figure 2, top panel) revealed that, while most youths had a drop in their cortisol values during the task, youths with more psychosocial risks tended to drop faster than youths with fewer psychosocial risks. This difference was especially evident from the first to the second time point. In the second model, with cortisol as the outcome and sociodemographic risk as the predictor, the pattern of results was very similar to that of psychosocial risk (see Figure 2, bottom panel).

The models with sAA produced mixed results. For the model with psychosocial risk as the predictor, time significantly interacted with risk, indicating that the pattern of change in sAA over the course of the SCI differed for youths with low versus high levels of psychosocial risk. There were no interactions with sex, indicating that the pattern was similar for males and females. Inspection of the pattern of findings (see Figure 3) indicated that, for youths high in psychosocial risk, there was no reactivity to the stress task, whereas youths with low levels of psychosocial risk showed a normal stress-response pattern. For the model with sociodemographic risk as the predictor, time did not interact with risk or sex.

Evaluating Emotion Regulation as a Mediator of Associations Between CR and Cortisol and sAA

Based on the analyses above, we examined emotion regulation as a mediator of the associations between psychosocial risk and cortisol and sAA and between sociodemographic risk and cortisol (but not sociodemographic risk and sAA). In the models with psychosocial risk, we entered adolescent-reported anger-regulation coping at W1 and W3 as additional covariates, based on the pattern of correlations presented in Table 2. In the analysis with cortisol, the Time $\times$ Psychosocial Risk interaction was no longer significant, $F(3, 186) = 2.04$, $p = .11$, partial $\eta^2 = .032$; however, anger-regulation coping was not associated with cortisol, thus there was no evidence for mediation. In the analysis with sAA, the Time $\times$ Psychosocial interaction remained significant, $F(3, 186) = 2.76$, $p = .04$, partial $\eta^2 = .043$, again providing no evidence that changes in anger regulation accounted for the association between psychosocial risk and stress response. Next, we respecified the model with sociodemographic risk, first entering caregiver-reported lability at W1 and W3 as covariates. In this model, the Time $\times$ Risk interaction remained significant, $F(3, 191) = 4.29$, $p = .006$, partial $\eta^2 = .063$, and lability was not associated with cortisol,

Table 2. Summary of Repeated-Measures Analyses of Variance Models With Biological Stress Responses as the Outcomes and Cumulative Risk and Adolescent Sex as the Predictors.

Multivariate Effect	Model With Psychosocial Risk as Predictor and Cortisol as Outcome			Model With Sociodemographic Risk as Predictor and Cortisol as Outcome			Model With Psychosocial Risk as Predictor and sAA as Outcome			Model With Sociodemographic Risk as Predictor and sAA as Outcome		
	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2
Time (four repeated measures)	2.32	.076	.035	2.25	.084	.034	0.91	.439	.014	0.99	.398	.015
Time $\times$ Adolescent Age (covariate)	1.77	.160	.027	1.68	.173	.025	1.09	.357	.016	1.07	.362	.016
Time $\times$ Time of Day (covariate)	7.07	.001	.099	7.76	.000	.107	0.86	.462	.013	0.84	.474	.013
Time $\times$ Pubertal Status (covariate)	0.00	1.00	0	0.17	.919	.003	1.25	.292	.019	1.46	.228	.022
Time $\times$ Medication Usage (covariate)	0.00	.990	.001	0.04	.990	.001	1.21	.308	.018	1.34	.264	.020
Time $\times$ Risk Level (low vs. high)	2.64	.051	.039	5.22	.002	.075	2.88	.037	.043	0.68	.565	.010
Time $\times$ Adolescent Sex	0.50	.680	.008	0.53	.660	.008	1.01	.390	.015	1.17	.322	.018
Time $\times$ Risk Level $\times$ Sex	0.79	.500	.012	0.42	.736	.007	1.54	.206	.023	1.04	.377	.016

Note. *df* for all effects equals 3,194. Multivariate effect reported is Wilks' λ . sAA = salivary alpha amylase.

Figure 2. Values of cortisol across the four time points in the social competence interview by level of risk, adjusted for time of day, adolescent age, medication usage, and pubertal status. Top panel (A) depicts interaction of time with psychosocial risk; bottom panel (B) depicts interaction of time with sociodemographic risk. Standard errors are shown in the graph.

thus providing no evidence for mediation. The final model included sociodemographic risk and caregiver-rated emotion regulation at W1 and W3 as covariates. In this model, the Time $\times$ Risk interaction also remained significant, $F(3, 191) = 4.53$,

Figure 3. Values of salivary alpha amylase across the four time points in the social competence interview by level of psychosocial risk, adjusted for time of day, adolescent age, medication usage, and pubertal status. Standard errors are shown in the graph.

$p = .004$, partial $\eta^2 = .066$, and emotion regulation was not associated with cortisol, thus providing no evidence for mediation.

Discussion

The present study extended prior research by examining associations between CR and physiological responses to stress in the adrenocortical and ANSs. We disentangled risk to examine the associations of stress responses with sociodemographic and psychosocial risk indicators separately. We found that psychosocial risk was associated with an increased likelihood of both a blunted cortisol response and a blunted sAA response to a stress task, and sociodemographic risk was associated with an increased likelihood of a blunted cortisol response to a stress task. These associations were consistent across males and females in the study. The analyses accounted for a number of factors known to affect physiological stress responses including age, medication usage, and pubertal status.

The observed association between risk and a blunted cortisol response is consistent with the findings from several other

research groups (Brenner, Zimmerman, Bauermeister, & Caldwell, 2013; Ouellet-Morin et al., 2011; Peckins, Dockray, Eckenrode, Heaton, & Susman, 2012). For example, Brenner, Zimmerman, Bauermeister, and Caldwell (2013) found, in a sample of 201 at-risk young adults, that participants who lived in high-poverty neighborhoods who also reported a high number of daily hassles had reduced cortisol reactivity compared to participants with an average number of hassles living in less impoverished neighborhoods. In a longitudinal study of 124 8- to 13-year-olds, Peckins, Dockray, Eckenrode, Heaton, and Susman (2012) demonstrated that exposure to violence was associated with lower cortisol reactivity in boys but not in girls. Ouellet-Morin et al. (2011) compared the cortisol responses of 12-year-old maltreated and comparison children and found that maltreated children had lower cortisol responses to a stress task than comparison children. Collectively, these data suggest that, in response to chronic exposure to stressors, HPA-axis hyperactivity may abate or the axis may become hypoactive (Miller et al., 2007).

A second major finding from the present study was that psychosocial risk and sociodemographic risk were associated in different ways with sAA response. Specifically, high psychosocial risk, but not high sociodemographic risk, was associated with an anomalous stress response to the SCI. This finding suggests that, among our sample, urban, low-income, African American youths experience these two types of risks differently. More work is needed to replicate and understand this finding. The pattern of associations with measures of emotion regulation in this sample also suggests that more exploration is warranted. Youths' own perception of their anger regulation was associated with psychosocial risk but not with sociodemographic risk.

In our sample, psychosocial and sociodemographic risk measures were not correlated. To understand this finding, it is important to remember that our sample consisted of African American youths living in underresourced neighborhoods with moderate to high levels of crime. The majority of these youths, more than 80%, were exposed to one or more of the sociodemographic risk factors in our index: low maternal education, living in a single-parent family, poverty, or maternal adolescent parenthood. In contrast, just under half, 47%, were exposed to one or more of the psychosocial risk factors in our index: family stress, maternal adjustment problems, youth daily stress, and neighborhood violence.

The lack of correspondence between the sociodemographic and psychosocial risks we examined suggests several possibilities. First, there likely are factors that we did not assess in this study that moderate associations between sociodemographic and psychosocial risk, and this absence might account for some of the lack of association. For example, some mothers, although poor, may draw upon other strengths such as strong religious faith or family support, which might reduce the likelihood that these mothers would experience adjustment problems. Other mothers, although poorly educated, might do a good job of monitoring their children, thus reducing their children's exposure to neighborhood violence. Whatever the

reasons for the lack of associations between the two types of CR, our data confirm the importance of disentangling socio-demographic risk, which is less malleable, from psychosocial risk, which is potentially amenable to change, especially in at-risk populations, which researchers have not, historically, done. Our data also suggest that, because psychosocial risk is linked to anomalous stress responses in two biological systems, these risk factors—or the processes they affect—should be the focus of intervention efforts.

Consistent with our expectations, there were no sex differences in the pattern of associations between CR and biological stress response. These findings are consistent with the conclusions of Ordaz and Luna (2012), whose review of sex differences in physiological reactivity to acute psychosocial stress in adolescence revealed that greater male reactivity to social-evaluative stressors, expressed in cortisol responses, does not emerge until late adolescence.

Contrary to expectation, although there was evidence that CR was associated with diminished emotion-regulation capacity, emotion regulation did not explain linkages between CR and stress responses. Although several studies have established links between CR and physiological stress responses and have identified moderators of these links, the mechanisms that account for these associations remain unclear (Brody et al., 2013; Evans, 2003; Evans et al., 2007; Kliever et al., 2009). Further, it is possible that there are subgroup differences in the processes that link CR with physiological stress responses. Future research might investigate how adolescents' exposure to CR interacts with the topics they discuss during the SCI, as this might provide some insights into the role of emotion regulation. For example, using the SCI, Ewart et al. (2011) found that chronic stress emanating from constant attempts to influence and control others was more amenable to the influence of emotion regulation than stress coming from trying to control oneself or stress arising from an inability to assert control.

Interestingly, youths who discussed others being victimized as their most recent stressful event had lower psychosocial risk scores than youths who discussed a personal loss or victimization experience or another type of experience. These data suggest that adolescents who are outwardly focused and attuned to others' experiences, and thus empathize with others' victimization experiences, are exposed to less family stress, community violence, and emotionally unavailable parents than youth who discuss their own loss or victimization experiences.

While the cortisol responses to psychosocial and sociodemographic risk factors were fairly similar, the sAA responses were not. Another way of thinking about these results is that, for psychosocial risk, cortisol and sAA showed similar response patterns, while for sociodemographic risk, cortisol and sAA showed disparate response patterns. Because ours is the first study to compare cortisol and sAA responses in adolescents using the SCI, we have no *a priori* ideas about why these results emerged. However, studies comparing cortisol and sAA responses using the Trier Social Stress Test for Children have found that, among youth with a history of risk exposure (e.g., maltreated youth), there is no correspondence

between cortisol and sAA responses, while for comparison youth, the stress-response patterns are similar (Gordis, Gran-ger, Susman, & Trickett, 2008). It might be the case in the present study that the events discussed during the SCI activated a response to the psychosocial risk factors in the adolescents' lives. However, this is mere conjecture, and further research would need to be conducted to test this notion.

Directions for Future Research

In addition to investigating why different types of risk produce a differential sAA response and the relation of emotion regulation and other potential mediators to different types of risk, researchers might incorporate measures of heart rate variability in future studies along with cortisol and sAA. Heart rate variability has been used as an outcome in research using the SCI but not in combination with cortisol and sAA (Chen, Matthews, Salomon, & Ewart, 2002).

Study Limitations

Although this study had a number of strengths, including a prospective design, two measures of stress-system dysregulation, data from multiple reporters, and focus on an understudied area, it did also have limitations. First, the study sample was African American; therefore, our findings may not generalize to other groups of youths, particularly if the stress profiles look different. Second, although we used data from adolescent and maternal caregiver reports in calculating a CR index, we did not obtain data from adolescents' social or biological fathers. Data from fathers may have enriched the profile of the youth in our study. Third, we based our assessment of CR on factors that previous research had examined. However, it is possible that we neglected to include a factor that might be particularly important or have overemphasized other factors. For example, we did not assess racial discrimination, yet this is a stressor that many African American youths encounter. Adolescents could have discussed discrimination during the SCI, however, and it did not come up, indicating it was not as salient as other topics. Fourth, as Evans et al. (2013) noted, although CR scores have several strengths including parsimony, statistical sensitivity with small samples, lack of assumptions regarding the relative strengths of multiple risk factors, and consistency with theoretical notions of why multiple risks are more harmful than singular risks and have more than a linear impact on child outcomes, they also have limitations, including their arbitrary nature and their inability to capture intensity. Using a CR index that is additive also precludes the possibility of modeling statistical interactions between risk factors. Fifth, although we controlled for medication usage and pubertal status in the analyses, we did not screen participants for health conditions that could have affected their physiological stress responses. Finally, although the SCI produces reliable ANS-activation responses (Ewart et al., 2002, 2011), it has not been validated with sAA or with cortisol, a product of the HPA axis.

Clinical Implications

A strong evidence base exists demonstrating that CR is associated with lifelong psychological and physical health risks. Research has also elucidated underlying mechanisms of these associations, including early dysregulation of the HPA axis as evidenced in the present study. These alterations in physiological response to stressors result in AL, or cumulative wear and tear on the body, which is associated with increased disease risk across the life span. While additional research is needed to identify mechanisms by which CR is associated with increases in AL, raising clinician awareness that this risk trajectory begins in childhood and may be further heightened in adolescence may foster early identification and intervention in at-risk individuals and families. Nurses working in multiple practice settings including schools and primary-care clinics may convey this information to parents and to other individuals who work with and treat youth. Recognition of the physical effects and risks associated with chronic, cumulative stressors highlights the need for health-promotion efforts including screening, education, and stress-management interventions.

In terms of other intervention efforts, directly intervening to reduce the sources of CR would be optimal. However, such an intervention would require policy efforts at the national, state, and local levels; neighborhood-focused interventions to reduce exposure to violence; and parent- and family-focused efforts to encourage parent educational attainment, treat parent mental health problems, bolster individual and family coping capacities, and promote positive family interaction. Given that risk factors are highly prevalent in underresourced families and communities, the move toward multidisciplinary primary care that includes mental health services would provide more affordable and accessible care to parents and families and be one step in the right direction (Sadock, Auerbach, Rybarczyk, & Aggarwal, 2014).

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Authors' Contribution

Wendy Kliwer contributed to conception, design, acquisition, analysis, and interpretation; drafted the manuscript; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. Jo Lynne W. Robins contributed to interpretation; drafted the manuscript; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of Conflicting Interests

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