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Sex Differences in Salivary Cortisol, Alpha-Amylase, and Psychological Functioning Following Hurricane Katrina

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The study examines group and individual differences in psychological functioning and hypothalamic–pituitary–adrenal and sympathetic nervous system (SNS) activity among adolescents displaced by Hurricane Katrina and living in a U.S. government relocation camp (n = 62, ages 12–19 years) 2 months postdisaster. Levels of salivary cortisol, salivary alpha-amylase, depression, anxiety, distress, aggression, and self-esteem for this group were contrasted with a demographically matched no-trauma control group (n = 53). Results revealed that hurricane exposure and SNS activity moderated the relations between lower cortisol and higher internalizing behaviors. Sex-related differences were observed in behavioral adjustment and stress regulation. Implications of sex differences in biobehavioral adjustment to loss, displacement, and relocation are discussed in relation to evolutionary and developmental theory.

In all cultures in which it has been studied, exposure to and social and material losses resulting from natural disasters is associated with increased prevalence of severe psychological distress (e.g., Chae, Kim, Rhee, & Henderson, 2005; Weinstein, Lyon, Rothman, & Cuite, 2000). Patterns of physiological and psychological reactions to natural disasters, however, may vary with the severity and duration of the attendant losses and by normative sex-related differences in biological, social, and behavioral concomitants of the stress response (Geary & Flinn, 2002; Taylor et al., 2000; Vigil, 2009). In both sexes, short-term physiological responses to acute stressors include (a) increased activation of the hypothalamic–pituitary–adrenal (HPA) axis, and the synthesis and secretion of glucocorticoids (i.e., cortisol) and (b) activation of the sympathetic nervous system (SNS) and release of catecholamines (i.e., norepinephrine, epinephrine) into the bloodstream (e.g., Chrousos & Gold, 1992). In contrast, repeated and chronic stress exposure is associated with low or blunted HPA activity (e.g., low cortisol levels or flat-shallow diurnal pattern of cortisol production), potentially reflecting habituation or adaptation to these circumstances and the overall dampening of HPA reactivity (e.g., Burke, Fernald, Gertler, & Adler, 2005; Flinn, Quinlan, Turner, Decker, & England, 1996; Miller, Chen, & Zhou, 2007).

Contemporary theorists speculate that individual differences in HPA axis activity may play a role in why exposure to adverse events results in major psychological disturbances for some individuals but has minimal consequences for others (e.g., Ellis, Jackson, & Boyce, 2006). Individual differences in HPA activity are correlated with internalizing problem behaviors (e.g., low mood), low levels of control-related beliefs, and anxiety during adolescence (e.g., Granger, Weisz, McCracken, Ikeda, & Douglas, 1996; Klimes-Dougan, Hastings, Granger, Usher, & Zahn-Waxler, 2001). These patterns can sometimes result in prolonged symptoms of posttraumatic stress disorder (PTSD) and major depression disorder, specifically, disassociation, emotional numbness, intrusive and distressful thoughts, and feelings of hopelessness, fatigue, idiopathic (cause unknown) pain, and negative self-evaluations (e.g., Ehlert, Gaab, & Heinrichs, 2001). Repeated activation of HPA and SNS has also been linked to higher morbidity, including changes that may induce

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lower immune functioning, increased susceptibility to viral infection, and actual onset of certain diseases (e.g., pulmonary constriction; Cohen et al., 1998; Flinn & England, 2003; Kunz-Ebrecht, Mohamed-Ali, Feldman, Kirschbaum, & Steptoe, 2003; Misra et al., 2004; Rotton & Dubitsky, 2002; Segerstrom & Miller, 2004; Uchino, Cacioppo, & Kiecolt-Glaser, 1996).

Recent laboratory studies show that relations between HPA activity and some health-related consequences such as mood disturbances may in turn be moderated by SNS (e.g., El-Sheikh, Erath, Buckhalt, Granger, & Mize, 2008; Gordis, Granger, Susman, & Trickett, 2006). Bauer, Quas, and Boyce (2002) proposed that the influences of the SNS and HPA axis on child adjustment may be conditional upon one another and put forth two testable hypotheses (Bauer et al., 2002). The first hypothesis is based on an ''additive'' model that assumes HPA activity primarily augments (i.e., operates in parallel with) the SNS, such that symmetrical activity across these systems could result in hypoarousal (low SNS and HPA activity) or hyperarousal (high SNS and HPA activity), and prolonged psychophysiological changes in either direction may leave children susceptible to adjustment problems. Conversely, children would be at least risk for adjustment problems when both systems are only moderately active, or when the activity of the SNS and HPA is asymmetrical (i.e., one is high and the other is low). The second hypothesis is based on an ''interactive'' model that rests on the possibility that HPA and SNS have different functions, and HPA activity, for example, may manifest differently (e.g., behaviorally) or perhaps suppress (counteract) SNS activity. Based on this hypothesis, HPA may modulate the SNS, and asymmetrical activation of these systems would be associated with more pronounced distress behaviors (e.g., depression and/or aggression), and hence greater psychological impairment. Both models assume that homeostatic (medium) levels of arousal are optimal for wellness, and indeed numerous studies have shown that both low and high arousal levels are associated with adjustment problems (e.g., Kagan, Snidman, Arcus, & Reznick, 1994). It is important to note that both additive and interactive models, as proposed by Bauer et al. (2002), are compatible with *statistical interactions* between the systems; that is, the association between the activity of one system and child adjustment is conditional upon activity of the other system.

Gordis et al. (2006) presented the first empirical investigation of the interaction between HPA (cortisol) and salivary alpha-amylase (sAA), which is a surrogate marker of SNS reactivity (Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007; Rohleder, Nater, Wolf, Ehlert, & Kirschbaum, 2004), as a predictor of aggressive behavior in a sample of early adolescents. Results provided partial support for the ''additive'' model. Specifically, at low levels of sAA activity, lower cortisol levels were associated with higher parent ratings of aggression, but at high levels of sAA activity, lower cortisol levels were not associated with aggression (Gordis et al., 2006). That is, the highest levels of aggression were found among adolescents with low levels of both cortisol and sAA activity (i.e., symmetrical activity). More recently, El-Sheikh et al. (2008) reported interactions between basal SNS (i.e., as measured by skin conductance and sAA) and cortisol levels, and variance in children's externalizing and internalizing problems (El-Sheikh et al., 2008). Higher basal cortisol levels were positively associated with higher internalizing and externalizing problems among children with higher SNS activity, compared to children with lower SNS activity. In contrast, a recent study among toddlers found partial support for the interactive or specialization model such that sAA was more predictive of positive affect and approach behaviors, whereas cortisol was more predictive of low mood and withdrawal behaviors (Fortunato, Dribin, Granger, & Buss, 2008). These studies add to an emerging body of research that shows sAA and cortisol provide unique information in the prediction of individual differences in behavioral adjustment to stress of children (e.g., El-Sheikh et al., 2008; Gordis, Granger, Susman, & Trickett, 2008; Nater et al., 2006; Stroud et al., 2009). Moreover, this research suggests that inclusion of information about the coordination between HPA and SNS activity may be particularly important for biosocial models of risk and resilience in development science.

All studies to date, however, have only explored sAA and cortisol in relation to problem behavior using acute stress reactivity paradigms among nontraumatized samples in laboratory settings (but see research on maltreated children; Gordis et al., 2008). The present study is the first to examine coordination of HPA and SNS among displaced adolescents that have experienced chronic and pervasive stress caused by high levels of trauma, loss, and relocation. Specifically, we examined psychological adjustment and stress-related psychobiology of adolescents and young adults who lost their homes as a result of Hurricane Katrina, 2 months after the hurricane and several weeks after relocation to a large, semipermanent, U.S. government-provided housing camp. These individuals experienced multiple forms of severe and uncontrollable trauma, including events (e.g., loss of property) that resulted from the hurricane and flooding, as well as the hardship and uncertainty associated with relocating to an unfamiliar community and living under postdisaster conditions that present a unique suite of ongoing stressors (e.g., inadequate housing facilities) and vulnerability (e.g., isolation from friends and family) onto themselves. Previous research has shown that postdisaster relocation and economic disadvantage can exacerbate the negative psychobiological consequences of the original event (Adams, Boscarino, & Galea, 2006; Cohen, Doyle, & Baum, 2006; McFarlane, 1990; Najarian, Goenjian, Pelcovitz, Mandel, & Najarian, 2001; Pérez-Sales, Cervellón, Vázquez, Vidales, & Gaborit, 2005). These findings suggest that displaced survivors of Hurricane Katrina may be at high risk for negative health consequences and prolonged difficulties in social and economic recovery due to the severity and uniqueness of their shared chronic (prolonged) and acute (daily) stress exposure (Osofsky, Osofsky, & Harris, 2007).

The Katrina sample was compared to a demographically matched comparison group that was not exposed to the hurricane. Comparisons were made between the Katrina and control groups on symptoms of depression, anxiety, psychological distress, aggression, and self-esteem, along with noninvasive measures (in saliva) of individual differences in HPA (cortisol) and SNS activity (sAA). We choose to focus on sex differences in biosocial stress responses, because males and females show baseline differences in certain types of problem behaviors, and may correspondingly develop unique behavioral and physiological patterns for responding to distress (Vigil, 2009). In general, females present greater symptoms of internalizing behaviors, such as depression and worrying, whereas males show greater externalizing behaviors, including higher levels of physical aggression and risk taking (Crick & Zahn-Waxler, 2003; Khan, Gardner, Prescott, & Kendler, 2002; Tolin & Foa, 2006; Vigil, 2008).

In laboratory studies, in comparison to women, men often show greater HPA and sympathetic activation in anticipation of and immediately following stressful stimuli, particularly events that involve a social-evaluative component (e.g., public speaking tasks; Kajantie & Philips, 2006; Kudielka et al., 1998; Uhart, Chong, Oswald, Lin, & Wand, 2006). Other research has found that cortisol spikes immediately following a traumatic experience (e.g., measurements taken at hospital admission centers) are more predictive of boys' rather than girls' subsequent risk for developing PTSD (Delahanty, Nugent, Christopher, & Walsh, 2005). More specific analyses suggest that women's stress systems are more sensitive to social exclusion, whereas men's stress systems are more sensitive to social-competitive situations (Salvador, 2005; Stroud, Salovey, & Epel, 2002). This research suggests that males may be at greater risk for adjustment problems following traumatic events that diminish the individual's relative social standing (Flinn, 2006; Sapolsky, 2004), such as significant material losses and lowering of social status that often result from natural disasters.

From an ultimate level of analysis or evolutionary perspective, normative patterns of behavioral distress, such as sadness and worrying behaviors have been described as *functional* for modifying the individual's behaviors (e.g., lowering risk-taking behavior in states of vulnerability) or the behaviors of others in ways that increase fitness (survival and reproductive prospects; Allen & Badcock, 2003; Fournier, Moskowitz, & Zuroff, 2002; Keller & Nesse, 2005; Sloman & Gilbert, 2000). For example, Vigil (2009) recently proposed a ''sociorelational'' framework that suggests that both sexes may respond to chronic stressors with an overall shift from the expression of dominant behaviors (e.g., assertiveness, aggression, extraversion) to submissive behaviors (e.g., depression and worrying behaviors) to signal trustworthiness to others and to elicit increased social support. Distress behaviors may operate in part to consolidate (strengthen) the reliability of one's relationships to gain additional needed support during adverse life experiences (see also Hagen, 2003).

In terms of sex differences, several theorists have suggested that modern-day masculine and feminine emotive styles (e.g., higher rates of crying and comforting behaviors in females and higher aggression and risk-taking behaviors in males) may by an artifact of unique social ecologies (network characteristics) and relationship demands in which ancestral males and females evolved (Geary, Byrd-Craven, Hoard, Vigil, & Numtee, 2003; Geary & Flinn, 2002; Taylor et al., 2000; Vigil, 2007, 2009). The basic distinction between male's and female's social dynamics pivots on the quality and quantity of relationships that members of each sex typically form and the level of investment behaviors that are needed to maintain different types of social networks. According to Vigil (2009), because girls and women tend to form fewer yet more intimate and more exclusive social relationships than males, on average, they may be similarly sensitive to display their vulnerability (e.g., via internalizing behaviors) in ways that advertise their trustworthiness and demonstrate their reciprocal investment to others (see also Geary et al., 2003; Vigil, 2007). Exaggerated displays of vulnerability and appeasement behaviors may in turn operate to strengthen the formation of more intimate and reliable, yet investment-intensive, social relationships among females.

In contrast, males may be more sensitive to *relax* expressions of trustworthiness cues in favor of behaviors that demonstrate the individual's physical abilities (e.g., strength and prowess) and other dominance-related traits to others. These types of displays are more observable (e.g., flashing body movements and displayed aggression) and require less investment (e.g., time and self-disclosure) to advertise to others, and may therefore be effective for forming and maintaining larger, less intimate, and less exclusive social relationships among coalitions of males (Vigil, 2009; see also Geary et al., 2003; Vigil, 2007). Because males and females show baseline differences in externalizing and internalizing behaviors (e.g., Crick & Zahn-Waxler, 2003; Khan et al., 2002; Vigil, 2008), we therefore predicted that each sex would manifest the expected shift from dominance to submissiveness behaviors differently; for instance, that displaced males would show lower levels of aggression and displaced females would show exaggerated symptoms of depression, compared to same-sex controls.

In all, we expected the main effects of exposure group on cortisol and sAA; specifically, the Katrina sample would show physical symptoms of chronic and acute stress exposure and hence lower salivary cortisol levels and higher sAA activity, respectively. We likewise examined the hypotheses that hurricane exposure moderated the relations between cortisol activity and psychological adjustment, as well as the earlier findings (e.g., El-Sheikh et al., 2008) that sAA activity may similarly moderate relations between cortisol and psychological adjustment. We were particularly interested in the potential moderating influence of these physiological measures on sex differences for anxiety, depression, and aggression (Gordis et al., 2008). We expected females living in the relocation camp would report the highest levels of depression when compared with nonexposed females and to males in general, and expected to find stronger correlations between sAA (a proxy for acute distress reactivity) and depression for females than for males. Finally, on the basis of the hypothesized pattern for people to respond to chronic stressors with an overall shift from dominant to submissiveness behaviors, we expected the Katrina sample would report lower aggression than would the controls and, given higher baseline aggression in males in general, that this difference would be most pronounced among displaced males.

Method

Event and Setting

Hurricane Katrina struck the North-Central Gulf coast (mostly Louisiana and Mississippi) on August 29, 2005. Although structural devastation and displacement was widespread, the most populated region affected by the hurricane was New Orleans, due in part to several breaches in the levees that protected the city from the surrounding Lake Pontchartrain (Travis, 2005). In addition to the direct loss of life, injury, and structural devastation caused by the hurricane, hundreds of thousands of people were either permanently or temporarily displaced from their communities. Many of these refugees were forced to seek shelter in government and community shelters, often being transported across multiple shelter sites throughout the United States. For the most severely affected individuals and families, government sponsored relocation camps were built to provide semipermanent (i.e., indefinitely provided) housing facilities. The largest of these camps, located near the city of Baton Rouge, Louisiana, was the site chosen to conduct the present study. At the time of our data collection, the camp, referred to by the residents and wider community as ''Renaissance Village,'' consisted of approximately 500 travel trailers, each housing an average of three people (not including infants and young children). The site included a central tent and barracks area, which served as the local post office and cafeteria and where supplies (e.g., clothing) were dispersed; several small laundry houses; and a basketball court. Meals were served three times a day; residents typically retrieved these from the central building and brought them back to their trailers to eat with their families. Despite the frequent efforts taken to provide the residents with comfortable conditions (e.g., seasonal festivities), the general mood in the camp at the time of data collection was notably low.

Participants

A convenience sample of 62 adolescents (mean age = 14.9, *SD* = 2.0 years; 42 females) were recruited from the housing camp approximately 2 months after the hurricane and 3 weeks after the relocation camp opened, from October 28, 2005 through November 2, 2005. Researchers solicited participation by introducing themselves to the residents (door-to-door) and targeting families living in the trailer units with children. Parents were then asked if they wanted to participate in the study "Child and Family Wellness after a Major Natural Disaster"; approximately 65% of families agreed to participate. Upon debriefing, the participants were given a small monetary payment. All the participants reported having been relocated from the New Orleans region. The control sample consisted of 53 adolescents (mean age = 15.3, *SD* = 2.1 years, 29 females) recruited from residential neighborhoods in mid-Missouri, USA and selected based on characteristics (e.g., age, race, socioeconomic status [SES]) matching the Katrina participants, from August, 2006 through January, 2007.

Prospective participants were informed about the project goals and their rights, as a research participant outlined by the University of Missouri Institutional Review Board, and once written consent was obtained from the children and their parents, participants were asked to complete a psychological survey. Parents of participants were also asked to provide demographic information. The latter confirmed the Katrina and control groups were similar in terms of race (both groups were over 93% African American) and SES; parents did not differ (ps > .10) for years of education (between 11 and 12 years), history of government assistance (e.g., welfare, food stamps; over 67%), or for indicators of wealth; the average yearly income of both samples was between $4,000 and $6,000, with current (posthurricane) financial assets of less than $200. The adolescent participants from the Katrina and control groups were similar (ps > .15) in age and proportion by sex.

Psychological Measures

The survey consisted of several standardized, self-report instruments designed to measure psychological well-being and family functioning in adolescents and young adults. For some instruments, entire scales were administered to allow for a direct comparison across normative samples; for other instruments, partial scales were used that consisted of items representing the instrument's subscales (this enabled greater breadth in the assessed traits). Each of the instruments have demonstrated reliable psychometric properties in young adult populations, and many of the scales have been used with similar adolescent samples who had recently experienced a large-scale disaster (e.g., Ginexi, Weihs, Simmens, & Hoy, 2000; Kreuger & Stretch, 2003; Sumer, Karanci, Berument, & Gunes, 2005; see also Joseph, 2000; Linton & Marriott, 1996).

Aggression was assessed by 8 items (2 items from each of the instrument's subscales) from the Aggression Questionnaire (Buss & Perry, 1992); the items were scored on a 5-point scale (overall $\alpha = .72$). Anxiety was assessed by the Revised Children's Manifest Anxiety Scale (Reynolds & Richmond, 1978), which consists of 37 items (each scored as yes or no responses; $\alpha = .87$). Depressive symptoms were assessed by the Center for Epidemiologic Studies Depression Scale (Radloff, 1977); the instrument consists of 20 items and each is scored on a 4-point scale ($\alpha = .86$). Subjective psychological distress was measured with the Impact of Events Scale–Revised (IES–R; Weiss & Marmar, 1997). The instrument consists of 22 items (which were revised to refer specifically to Hurricane Katrina; $\alpha = .93$) and four-factor subscales designed to measure symptoms of hyperarousal, disassociation, intrusive thoughts, and avoidance behaviors during the past week (scored on a 5-point scale). The Rosenberg Self-Esteem Scale (Rosenberg, 1965) was used to assess self-described global self-esteem; the instrument consists of 10 items and each is scored on a 4-point scale ($\alpha = .73$). Completion of the psychological measures and survey items usually took between 30 and 45 min.

Determination of Salivary Analytes

The two saliva samples were collected (immediately prior to and subsequent to completion of the survey measures) between the hours of 10:50 and 18:50 via a cotton swab version of the Salivette device (Sartstedt, Newton, NC); the samples were typically collected 60–90 min apart. Two saliva samples were collected, because of the impracticality of obtaining more collections under emergency field conditions and because they provided a more reliable means of measuring sAA and cortisol activity than single sample collections (for the implementation of similar techniques, see El-Sheikh et al., 2008). After collection, all samples were transported on ice and then stored frozen (−20 °C) at the University of Missouri until shipped overnight on dry ice to the Penn State University Behavioral Endocrinology Laboratory. They were stored frozen at −80 °C until assayed for cortisol and sAA. On the day of testing, all samples were centrifuged at 1500 g for 15 min to remove mucins.

Salivary alpha-amylase. Samples were assayed for sAA using a commercially available kinetic reaction assay (Salimetrics, State College, PA). The assay employs a chromagenic substrate, 2-chloro-*p*-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 U/ml of sAA using the formula: [Absorbance difference per minute × total assay volume (328 ml) × dilution factor (200)]/[millimolar absorptivity of 2-chloro-*p*-nitrophenol (12.9) × sample volume (.008 ml) × light path (.97)]. Intra-assay variation (CV) computed for the mean of 30 replicate tests was less than 7.5%. Interassay variation computed for the mean of average duplicates for 16 separate runs was less than 6%. The correlation between the sAA measurements was modest ($r = .43$, $p < .01$), and correspondingly, the analyses used the average levels of the two sAA samples.

Cortisol. All samples were assayed for salivary cortisol using a highly sensitive enzyme immunoassay the U.S. Food and Drug Administration (510 k) cleared for use as an in vitro diagnostic measure of adrenal function (Salimetrics). The test used 25 μl of saliva (for singlet determinations), had a lower limit of sensitivity of .007 μg/dl, range of sensitivity from .007 to 1.8 μg/dl, and average intra- and interassay coefficients of variation of less than 5% and 10%, respectively. As expected, the correlations between the cortisol measurements were positive and strong ($r = .81$, $p < .01$) and thus the average of the two samples was used in all subsequent analyses.

Diurnal course of salivary cortisol and sAA. Both salivary cortisol and sAA show distinct and different diurnal profiles. Under normative-healthy conditions, HPA axis activity (on average) follows a diurnal pattern with cortisol levels high upon waking, then rising to a zenith within 30 min of waking, sharply declining by midday, and then gradually declining through the afternoon and evening (Kirschbaum & Hellhammer, 1989). By contrast, much less is known about diurnal variation of sAA. Recent and systematic studies with adults (ages 18–58 years) reveal sAA activity shows a pronounced decrease within 60 min after awakening and a steady increase of activity during the course of the day (Nater, Rohleder, Schlotz, Ehlert, & Kirschbaum, 2007). More specifically, Nater et al. (2007) report that sAA levels increased an average of 17% with each hour across the day. There was a quadratic curvature of the sAA change across the day, with sAA decelerating from its estimated zenith at 16:25. Noteworthy is the fact that, consistent with findings regarding acute stress reactivity, the pattern of production of sAA and cortisol across the day were uncorrelated. To the best of our knowledge, there are no studies of puberty-related differences in the sAA diurnal rhythm.

Data Analysis

Missing values for either of the two cortisol or sAA measures (3%) were replaced by the other; missing values for the psychological variables (7%) were replaced by the sample means for each sex. Preliminary analyses revealed that the participant's cortisol levels were positively related to his or her awakening time ($r = .23$, $p < .01$) and negatively related to collection time ($r = -.39$, $p < .01$). Cortisol was also positively related to participant's age ($r = .21$, $p < .05$), which may be a proxy for body mass. To help control for these factors, wake time, collection time, and age were entered as covariates (for analyses of covariance [ANCOVAs] and multivariate regressions) or were partialed out (for bivariate correlations) for all analyses involving cortisol. In contrast, wake time, collection time, and age were not related to sAA, and were thus not controlled for analyses using this analyte. Among the self-report measures, only psychological distress was related to wake time ($r = -.18$, $p = .06$) and collection time ($r = .19$, $p < .05$); these variables were therefore controlled for analyses that included symptoms of distress. The Katrina and control samples did not differ for wake time or saliva collection times (*p*s > .23); however, females reported a significantly later wake time than males, $t(113) = -3.79$, $p < .01$. Groups were compared using ANCOVAs; group differences are expressed as effect sizes (*d*s; mean difference/mean standard deviation). Multivariate correlations and descriptive plots were conducted using regression analyses.

Results

Group Differences in Psychological Functioning, Salivary Cortisol, and sAA

Table 1 shows the mean psychological and salivary scores for the Katrina and control groups separately for males and females, as well as the intervariable correlations for the entire sample. Two-way ANOVAs, using sex (males vs. females) and group (comparison vs. Katrina) as predictors for each of the psychological variables revealed significant Sex × Group interactions for depression, $F(1, 111) = 4.46$, $p < .05$, and aggression, $F(1, 111) = 6.15$, $p < .05$, and a trend for a significant interaction term for distress, $F(1, 109) = 3.51$, $p = .06$, but not for anxiety ($p = .21$) or self-esteem ($p = .47$). Follow-up regressions revealed that the interaction for depression emerged due to elevated depression scores for Katrina females compared to control females ($\beta = .32$, $p < .01$, $d = -0.68$), whereas no group difference for depression was found among males ($\beta = -.08$, $p = .61$, $d = 0.16$). In contrast, the interaction for aggression was due to lower aggression scores for Katrina males compared to control males ($\beta = -.55$, $p < .01$, $d = 1.31$), whereas no group difference for aggression was found among females ($\beta = -.13$, $p = .29$, $d = 0.26$). A main effect of sex was also found for self-esteem, $F(1, 111) = 4.58$, $p < .05$, $d = -0.36$, indicating lower self-esteem among males in both groups, compared to females. The Katrina group had significantly lower cortisol levels than the control group, $F(1, 108) = 5.74$, $p < .05$, $d = 0.41$; the main effect of sex and the Sample × Sex interaction term were not significant (ps > .10). Neither the interaction term nor the main effect terms for group or sex were significant for sAA (ps > .19).

Interactions Between sAA and Cortisol Levels and Psychological Functioning

Collapsing across sex, regression analyses were used to examine the relations between sAA and the psychological measures for the comparison and Katrina groups, and between cortisol and the psychological measures for both groups. For the sAA equations, each of the psychological measures was entered as the dependent variable, and the group, sAA, and Group × sAA interaction term were entered as independent variables. For the cortisol equations, group, cortisol, and the Group × Cortisol interaction term were entered as independent variables; wake time, collection time, and age were entered as covariates. The sAA analyses revealed a trend for a significant Sample × sAA interaction term for depression ($\beta = .33$, $p = .10$) and was due to a small negative relation between higher sAA and lower depressive symptoms for the control group ($\beta = -.29$, $p < .05$), but not for the Katrina

Table 1
Group Differences and Correlations for the Psychological and Salivary Analyte Variables

	Males		Females		Sample differences		Sex differences		Correlations							
	Control	Katrina	Control	Katrina	*t*	*d*	*t*	*d*	1	2	3	4	5	6	7	8
1. Sample	—	—	—	—	—	—	—	—								
2. Sex	—	—	—	—	—	—	—	—	—	—						
3. Depression	25.4 (10.0)	23.7 (11.6)	21.0 (9.2)	*27.6 (10.1)*	−1.75	−.33†	−0.16	−.03	.16†	.02	—					
4. Anxiety	22.8 (2.0)	21.2 (3.5)	21.1 (2.3)	20.9 (3.1)	1.73	.32†	2.00	.38*	−.16†	−.19*	−.45**	—				
5. Esteem	29.3 (5.3)	28.8 (6.8)	32.2 (3.5)	30.2 (5.0)	1.14	.22	−1.83	−.36†	−.11	.18*	−.49**	.36**	—			
6. Distress	61.1 (16.4)	54.6 (18.9)	52.0 (15.6)	*63.1 (19.6)*	−1.05	−.23	−0.85	−.02	.10	.08	.52**	−.38**	−.23*	—		
7. Aggression	97.5 (21.5)	*74.5 (12.6)*	95.9 (18.1)	91.0 (20.2)	3.01	.56**	−1.54	−.29	−.27**	.14	.27**	−.11	−.04	.17†	—	
8. Cortisol	0.20 (0.21)	0.15 (0.09)	0.20 (0.08)	*0.15 (0.11)*	2.42	.41*	1.34	.07	−.23*	−.13	.02	.11	.04	.13	.17†	—
9. Amylase	54.6 (51.7)	57.3 (43.4)	42.8 (28.5)	*66.1 (48.1)*	−1.84	−.35†	−0.08	−.02	.17†	.01	−.07	−.08	−.02	−.01	.01	−.02

Note. Values are mean scores; values in parentheses are standard deviations. Italicized values indicate significant ($p < .05$) sample differences across males or females. Group differences for distress were computed by entering collection time and wake time as covariates; group differences for cortisol were computed by entering collection time, wake time, and age as covariates. Partial correlations were computed for distress (controlling for collection time and wake time) and for cortisol (controlling for collection time, wake time, and age).
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$.

group (β = .02, p = .88). The cortisol analyses revealed significant Group × Cortisol interaction terms for self-esteem (β = .47, $p > .01$), anxiety (β = .33, $p > .05$), and distress (β = −.34, $p > .05$), and a trend for an interaction for depression (β = −.31, p = .06). Follow-up regressions revealed that the interactions for self-esteem and anxiety were due to small positive relations between cortisol and self-esteem (β = .36, $p < .05$) and between cortisol and anxiety (β = .26, p = .09) for the Katrina group, and a small negative relation between cortisol and self-esteem (β = −.26, p = .09) for the control group; the relation between cortisol and anxiety was not significant for the control group (p = .64). In contrast, the interactions for distress and depression were due to small positive relations between cortisol and distress (β = .39, $p < .01$) and between cortisol and depression (β = .26, p = .09) for the control group, and nonsignificant relations for the Katrina group (ps = .78 and .21, respectively).

Collapsing across groups and sex, regressions were then used to examine the potential interactions between cortisol and the psychological measures for individuals with varying sAA activity levels. For these equations, each of the psychological measures was entered as the dependent variable, and cortisol, sAA, and the Cortisol × sAA interaction term were entered as independent variables; wake time, collection time, and age were entered as covariates. These analyses revealed a significant Cortisol × sAA interaction term for self-esteem (β = .43, $p < .05$) and a trend for an interaction for symptoms of anxiety (β = .33, p = .10); the interaction terms were not significant for depression (p = .73), distress (p = .84), or aggression (p = .88). Follow-up regressions revealed that the significant interaction emerged as a result a moderate positive relation between cortisol and self-esteem for individuals with sAA levels above the overall mean (β = .43, $p < .05$) but not for those with sAA levels below the mean (β = −.04, p = .74).

Sex Differences in the Relations Between Psychological Functioning and Cortisol and sAA Levels

Regressions were then used to examine the relations between each of the two analytes and the psychological scores, separately among males and females. For these equations, collapsing across groups, each of the psychological measures was entered as the dependent variable, and sex, the salivary analyte (i.e., cortisol or sAA), and the Sex × Analyte interaction term were entered as independent variables; wake time, collection time, and age were entered as covariates for the cortisol equations. These analyses revealed a trend for a Cortisol × Sex interaction for psychological distress, β = −.51, p = .10, and was due to a significant relation between higher cortisol and increased distress among males (β = .36, $p < .05$) and a nonsignificant relation among females (p = .99). None of the remaining main effects for cortisol, or the Cortisol × Sex interaction terms were significant. In contrast, regressions revealed a significant sAA × Sex interaction term for depression (β = 1.18, $p < .01$), and a trend for a sAA × Sex interaction for psychological distress (β = .64, p = .06). As shown in Figure 1, the significant interaction was due to a negative relation between sAA and depression in males (β = −.47, $p < .01$), and a trend for a positive relation between sAA and depression in females (β = .21, p = .08). No other effects of sAA were significant for the remaining psychological variables.

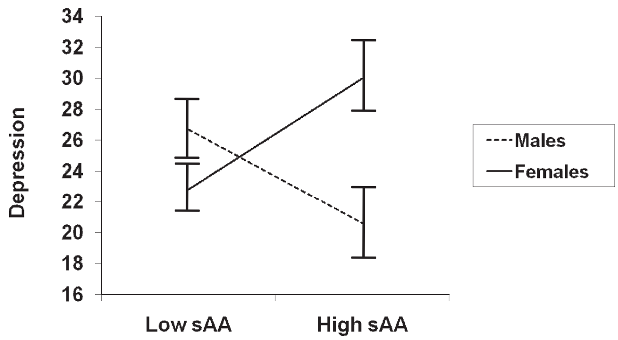

Figure 1. Plot of significant Sex × Salivary Alpha Amylase (sAA) interaction for depression. Slopes represent unstandardized regression coefficients.

Discussion

This study examined psychological functioning and concurrent cortisol and sAA activity levels in adolescents who experienced pervasive stressors resulting from significant social and material losses during and following Hurricane Katrina. In comparison to controls, both sexes in the Katrina sample showed moderately lower cortisol levels and slightly higher sAA activity; however, these differences were more pronounced among displaced females. The finding of lower cortisol among the displaced youth is consistent with other studies showing that chronic stress exposure is associated with blunted cortisol activity, potentially reflecting a general habituation or desensitization of this stress response (Flinn et al., 1996; Miller et al., 2007). Higher sAA activity (reflecting more acute stress reactivity) among the Katrina youth may reflect group differences in daily stressors, such as the temporary housing facilities and the lack of security that were the basis of common complaints from the Katrina youth.

Our findings revealed that hurricane exposure moderated the relations between cortisol activity and psychological adjustment; however, these effects were small and variable and should therefore be considered preliminary findings. Future research should benefit from more detailed theoretical models that differentiate the influences of HPA activity on different aspects of internalizing behaviors, including the respective roles on self-esteem, depression, and symptoms of anxiety, among individuals who have experienced differing levels of stress exposure. We also found support for the hypothesis that sAA moderates the relation between cortisol and internalizing behaviors; lower cortisol was associated with lower self-esteem, but only among individuals with above average sAA reactivity. This finding complements recent laboratory studies (e.g., Fortunato et al., 2008), and suggests that individual differences in HPA axis activity and psychological functioning may be associated with differential sensitivity or functioning of the SNS. Overall, however, the results are most compatible with a modified version of Bauer et al. (2002) interactionist model (p. 106), and suggest that individuals with high sAA activity and low cortisol may be at greater risk for mood problems, whereas high sAA combined with high cortisol may be associated with psychological resiliency.

In terms of sex differences, and consistent with research among normative (nontraumatized) adolescents (e.g., Ge et al., 2003; Rushton, Forcier, & Schectman, 2002; see also Vigil, 2008), the females in our study reported higher symptoms of depression than did the males. Individuals of both sexes and in both groups reported higher levels of depressive symptoms than are found in normative samples (e.g., see Brooks & Kutcherm, 2001, p. 365), but these symptoms were particularly high among the Katrina females. The pattern is consistent with a sociorelational perspective of distress behaviors, and the evolutionary hypothesis that people in general, and especially females, may respond to negative life events with behaviors that exaggerate the displays of vulnerability and increase the perception of trustworthiness to other people (Vigil, 2009). From this perspective, certain types of behavioral distress (e.g., worrying, crying, feelings of hopelessness) may be functional for consolidating one's social network and evoking increased emotional support from intimate confidantes (e.g., family members and close friendships), in coordination with adverse life experiences. These are the types of events that demand the greatest social support from others, and behaviors that explicate individual vulnerability may be particularly effective for evoking dependable and continuous forms of investment from others (Vigil, 2009; see also Hagen, 2003).

Females may be particularly sensitive to display cues of trustworthiness (e.g., via sadness behaviors) and to emotionally invest in their relationships (e.g., via comforting behaviors), compared to males, because these behaviors were beneficial for maintaining more intimate and exclusive dyadic relationships (e.g., see Geary et al., 2003; Vigil, 2007, 2009; see also Geary & Flinn, 2002; Taylor et al., 2000). Females may be particularly vulnerable during adolescence and reproductive maturation and especially in situations of unreliable social support; these are conditions that can result in sexual exploitation and pregnancy. Adolescence is a time when sex differences in the display of trustworthiness cues (e.g., via sadness behaviors) are predicted to emerge, and to function to maintain social-support systems (see Del Giudice, 2009; Geary et al., 2003; Vigil, 2009). This hypothesis is consistent with research on depression during adolescence that shows that symptoms tend to increase in females, but not males, between 12 and 13 years in U.S. samples (e.g., Ge, Conger, & Elder, 2001; Ge et al., 2003). Likewise, recent research shows a relation between HPA activity and intimate relationship dynamics (e.g., quality of relationships) in adolescent females, but not females in middle childhood, or males of either age group (Booth, Granger, & Shirtcliff, 2008).

Reported levels of aggression were similarly higher than that found in normative samples for all groups (Archer, Kilpatrick, & Bramwell, 1995, p. 376), except the Katrina males. Aggression for these males was in the normative range but substantially lower than that reported by the control males or by females of either group. Although counterintuitive, this finding was predicted based on higher normative (no-trauma) levels of aggressive behaviors in males in difficult circumstances and the hypothesis that people respond to chronic, noninterpersonal victimization, stressors with decreased dominance and increased submissive behaviors (Allen & Badcock, 2003; Fournier et al., 2002; Sloman & Gilbert, 2000; Vigil, 2009). Similar patterns emerge in male primates under chronic stress and following loss of status (Sapolsky, 2004, 2005). From a sociorelational perspective, aggressive behaviors may be similarly interpreted as a form of social behavior that may be more adaptive for males than for females under normal (no-trauma) conditions but are associated with added costs when males experience events that decrease their social status or the ability to protect themselves (Vigil, 2009).

Another possibility for our finding of relatively lower aggression in affected males may be that the males in this study are unrepresentative of more general samples; males willing to accept government assistance may be less aggressive than displaced males who are not living in a relocation camp. Lower aggression among displaced males may also reflect environmental rather than conditional or individual differences. For example, the Katrina camp environment may be more mundane than the environment in which the Katrina males were situated prior to the hurricane or in comparison to the acute stressors (e.g., overcrowding conditions at the Superdome, temporary disaster facility), immediately following the hurricane. In any case, males are more sensitive to changes in social standing than are females (Geary, 1998), which may explain our finding of the stronger concordance between cortisol and symptoms of psychological distress in males than among females (for similar results, see Delahanty et al., 2005).

Finally, the results support the hypothesis that sex moderates the relation between sAA and symptoms of depression, such that higher sAA among the youth in both groups was related to lower symptoms of depression (e.g., greater confidence and reported elation) in males and slightly higher depressive symptoms among females. The findings are consistent with a recent study that showed that sAA is distinctly associated with positive affect and overall approach behaviors (Fortunato et al., 2008), and research indicating normative sex differences in behavioral reactivity (i.e., to respond to mild stressors with more externalizing vs. internalizing behaviors; Vigil, 2008). Moreover, our findings suggest that sAA may be a promising marker for identifying depressive symptoms in adolescents, but they are qualified by the collection of only two saliva samples. It is possible, for instance, that sAA activity may follow a diurnal rhythm (see findings by Nater et al., 2006) similar to patterns observed in cortisol. Still, we found no evidence for such a pattern of sAA in our study using controls for the independent influence of collection time and awakening time. Systematic studies are needed to examine the effectiveness of sAA for measuring symptoms of depression among children exposed to ordinary and extraordinary stressors.

Limitations

Future research on individual and group differences in stress responses following large-scale disasters will benefit from addressing specific constraints in the design of these studies. For example, although the window of time we used to collect the saliva samples was reasonable under the constraints of our field study, the use of practical saliva collection techniques that enable researchers to track hormonal fluctuations in the morning and across the day under emergency field conditions is needed. This research is particularly complicated when working with transient families and individuals with low education, as was the case in the current study. It was unfortunate, although understandable, that pre-trauma information was not available, particularly for baseline physical or mental health, and non-trauma-related stressors in either the Katrina or the control group. It would have also been helpful to have been able to examine the role of pubertal timing, especially among females, for examining more specific hypotheses from the theoretical models. The current study was also limited by the small sample size and homogeneous characteristics (e.g., low SES) of our samples. Future research will benefit from assessments of psychological functioning of males and females from representative samples that include adolescents with diverse family and socioeconomic backgrounds. Additional limitations were the single source (self-report) of data collection, lack of information on current illnesses and medication use, and the relatively wide age range of participants that were assessed. It is certainly possible that children undergo systematic psychological and physiological changes that may operate in conjunction with distinct psychoneuroendocrine and behavioral patterns of stress response, at different stages of development (e.g., see Vigil, 2009).

Despite these limitations, the study contributes to our understanding of normal psychobiological distress in males and females, and it is the first study to demonstrate sex differences in psychological functioning and salivary cortisol and sAA activity among adolescents that have experienced pervasive stressors that included significant disruptions in social relationships and widespread loss of property caused by a major natural disaster. It is unclear at this time, however, how these types of experiences and stress recovery mechanisms may actually affect normative and long-term development. Recent laboratory studies have shown that, in comparison to younger children, adolescents may be particularly sensitive to social evaluation and stressors that reduce the individual's social standing (Booth et al., 2008; Stroud et al., 2009). Lower sociometric competitiveness caused by significant social and material losses may in turn have an exacerbating effect for adolescents already in low-resource environments. Based on our findings, such disruptions may be manifested through divergent behavioral patterns in males and females, which in theory may be associated with remedial social benefits, as well as potential mental and physical health-related consequences.

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