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Blood Lead (Pb) Levels: Further Evidence for an Environmental Mechanism Explaining the Association Between Socioeconomic Status and Psychophysiological Dysregulation in Children

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Abstract

Objective: The authors recently reported that blood lead (Pb) was a significant mediator for the positive association between socioeconomic status (SES) and peripheral vascular responses to acute stress in children (B. B. Gump et al., 2007). The present study considers the possibility that Pb may also mediate an association between SES and cortisol responses to acute stress.

Design: Early childhood Pb exposure was tested as a mediator for cross-sectional associations between SES and cortisol responses.

Main Outcome Measures: The primary outcome was cortisol responses to acute stress in 9.5-year-old children ($N = 108$).

Results: Lower family income was associated with significantly greater cortisol levels following an acute stress task. A mediational analysis confirmed that Pb was a significant mediator for this association.

Conclusion: These results reaffirm the importance of considering the chemical environment as well as social and psychological environment when evaluating psychophysiological effects of low SES.

Keywords

cortisol; children; lead; socioeconomic status; environmental toxicants

The association of low socioeconomic status (SES) with physical and psychiatric illness is well documented in children (for review, see E. Chen, Matthews, & Boyce, 2002); moreover, in the absence of any observable clinical consequences of economic disadvantage, low SES might set children at an increased risk for the future development of disease (Galobardes, Lynch, & Smith, 2008). Although there is good evidence for an SES–health association in children, the mechanism underlying this association is less well established. A number of variables have been suggested as potential mechanisms, including those at the societal level (e.g., access and utilization of health care; Parker & Schoendorf, 2000), neighborhood level (e.g., exposure to violence; Singer, Anglin, Song, & Lunghofer, 1995), family level (e.g., parental depression; Sills, Shetterly, Xu, Magid, & Kempe, 2007), and individual level (e.g., psychophysiological reactivity to acute stress; Gump, Matthews, & Raikkonen, 1999). We recently demonstrated that environmental toxicants might represent an additional intervening variable between SES and health in children; specifically, lead (Pb) was shown to serve as a mediator for an association between SES and total peripheral responses to acute stress (Gump et al., 2007). The present study further considered Pb as a mediator for an association in children between SES and cortisol levels following acute stress. Elevated cortisol is associated (perhaps causally) with a number of disease states, including depression (Watson & Mackin, 2006), coronary artery disease (Alevizaki, Cimponeriu, Lekakis, Papamichael, & Chrousos, 2006), and hypertension (Whitworth, Brown, Kelly, & Williamson, 1995).

A number of studies have shown a negative association between SES and salivary cortisol levels in children (Cohen, Doyle, & Baum, 2006; Cohen, & Schwartz, 2006; Flinn & England, 1995; Lupien, King, Meaney, & McEwen, 2004). However, some studies have demonstrated a positive association between SES and salivary cortisol in adults, but specifically for women (Steptoe et al., 2003), those with low job demands (Kunz-Ebrecht, Kirschbaum, & Steptoe, 2004), and when testing responses to acute stress (Gruenewald, Kemeny, & Aziz, 2006; Hellhammer, Buchtal, Gutberlet, & Kirschbaum, 1997; but for exception, see Adler, Epel, Castellazzo, & Ickovics, 2000). It is interesting that the only study to test potential mechanisms for a negative SES–cortisol association found that 62.8% of the association between SES and cortisol could be accounted for by smoking status (Cohen, Schwartz, et al., 2006). This finding is particularly important to the present study because exposure to secondhand tobacco smoke is a known means of Pb exposure in both children (Ozden et al., 2007) and adults (Wolfsperger, Hauser, Gobler, & Schlagenhaufen, 1994). Therefore, this prior mediational finding for smoking status is not inconsistent with our hypothesis that Pb mediates an association between SES and cortisol.

Is there evidence supporting the hypothesis that Pb exposure serves as a mediator for the SES–cortisol association in children? The negative association between SES and blood Pb is well documented (Gump et al., 2007; Schnaas et al., 2004), and we recently demonstrated a negative association between blood Pb measured in early childhood ($M = 2.62$ years of age)

and cortisol levels following acute stress when these children reach 9.5 years of age (Gump et al., 2008). This prior study included a number of covariates, including SES measured with the Hollingshead index (Hollingshead, 1975), and therefore did not consider the SES–cortisol association with and without controlling Pb levels (i.e., the test of mediation). Moreover, we have not yet provided a test of the potential association between different SES measures (e.g., income as well as the Hollingshead index) and cortisol responses to acute stress in these children. It is possible that only particular indices of SES are associated with greater Pb exposure and thereby heightened cortisol levels following acute stress. We are unaware of any studies that have yet considered association with differing SES indices within this particular mediational model. Therefore, the present study tested two new hypotheses: (a) Lower SES children will exhibit heightened cortisol levels following acute stress (perhaps to differing degrees depending on the particular SES measure), and (b) this association will be mediated by underlying differences in Pb blood levels.

Method

Participants

Participants were recruited in the context of an ongoing longitudinal study of the effects of environmental toxicants on development (Lonky, Reihman, Darvill, Mather, & Daly, 1996; P. Stewart, Reihman, Lonky, Darvill, & Pagano, 2000). Of the 202 children currently enrolled in the Oswego Children's Study, we included 118 children (65 girls and 53 boys) in the present analyses. Some children were not included because they were either not tested ($n = 25$), had missing postnatal blood Pb levels ($n = 55$), refused to report their family income ($n = 2$), or could not produce sufficient saliva for testing cortisol at any time period ($n = 2$). Reasons for not being tested included inability to schedule within the testing window ($n = 16$), technical problems ($n = 4$), and refusal ($n = 5$). We do not have data regarding the reasons for blood Pb levels being absent from pediatrician and state records for some children ($n = 55$); however, we compared all available data for this subsample with data from the children included in our analyses and found very few significant differences between the two groups, as previously reported (Gump et al., 2005). Children were tested within 2 weeks of becoming 9.5 years old, and their families were paid \$60 for participation in the current visit.

Procedure

On the day of testing, the participant arrived at the laboratory at about 4:30 p.m. ($M = 4:28$ p.m., $SD = 1$ hr. 36 min.) and first signed an assent form, and his or her parents signed a separate consent form. The laboratory session commenced with measurement of the child's height and weight. Each experimental session comprised the following: (a) an initial rest period (10 min), (b) a cold pressor task (1 min with 2 min recovery), (c) an intertask rest (8 min), (d) a choice reaction time task (3 min), (e) an intertask rest (8 min), (f) a mirror tracing task (90 s, five trials), and (g) a final recovery/rest period (10 min). The cold pressor task occurred first, followed by either the reaction time or mirror tracing tasks (order was counterbalanced). The cold pressor task was always administered first in order to anchor the timing of cortisol samples to this task, a task that is known to reliably evoke an adrenocortical response and therefore is commonly used in protocols designed to test

neuroendocrine reactions to acute stress (e.g., Kapuku, Treiber, & Davis, 2002; Treiber et al., 1990).

Acute Psychological Stressors

Cold pressor task.—The child was asked to submerge his or her dominant arm in a 1-gallon tub with one part ice to one part water for 1 min. Participants were informed of the time remaining during the minute to encourage completion of the task, although the instructions for the task clearly informed the participants that they were free to withdraw the arm if it became too painful. The amount of time for which the child kept the arm submerged was the tolerance time. Only 11.8% of children in our study refused this task, defined as a tolerance time less than 20% of the full 1 min, that is, 12 s. The remaining children tolerated the cold pressor for 40 s, on average. Notably, this tolerance time was not significantly associated with prenatal or postnatal Pb exposure ($ps > .50$).

Mirror tracing.—Using modified Eyelines software (Beagley, 1994), participants were asked to use the mouse and cursor to trace a computer image of a star with inverted vertical mouse control (i.e., moving the mouse up caused the cursor to move down) for four trials. In one final trial, horizontal mouse control was inverted such that movement of the mouse left produced cursor movement right (up and down movement was normal). Trial duration was 90 s. Movement off the star produced a loud beep through headphones.

Reaction time.—A computerized choice reaction time task required the participant to respond as quickly as possible to a 1000-Hz tone presented via headphones by pressing a joystick button, but to refrain from responding to a 2000-Hz tone. Fifteen tones were presented at pseudorandom intervals (with an average interstimulus interval of 16 s) by a microcomputer during the 3-min task. The task was programmed so that participants earned 75 points for each time they performed more quickly than their average reaction time of previous trials and 20 points for correctly withholding a response to the incorrect tone.

Socioeconomic Status

We considered two different indices of family SES: the four-factor Hollingshead index (occupation and education) and income. The Four Factor Index of Social Status (Hollingshead, 1975) measured family SES on the basis of the education and occupation for parents of the participants (averaged, if both available). Occupation was classified into one of nine categories. Validity of the occupational scale was originally established by comparing scores from the four-factor index with scores on the basis of evaluations of occupations and occupational groups from the National Opinion Research Center. Educational attainment was categorized as less than 7th grade, 8th through 9th grades, 10th through 11th grades, high school graduate, some college education, college graduate, some graduate school. The scale value for occupation (multiplied by a factor weight of 5) was added to the scale value for education (multiplied by a factor weight of 3). Higher scores represent higher social status. Self-reported annual family income was measured in 9 increments (from < \$5,000 to \$65,000).

Blood Pb Measurements

Blood Pb data were collected for the children at an average age of 2.62 years (± 1.20 years) through the children's pediatricians and county public health agencies. New York State law requires blood Pb testing for all children entering kindergarten, and only those laboratories certified by the New York State Department of Health's Wadsworth Center can accept and analyze blood Pb specimens drawn in New York State. Although there are more than 80 laboratories certified to perform blood Pb testing in New York State, blood specimens are typically sent to a variety of clinical laboratories from both the commercial and public health sector depending on local screening practices and health insurance coverage. Analytical techniques used for blood Pb are electrothermal atomic absorption spectrometry and anodic stripping voltammetry. Blood Pb levels were determined on venous specimens for 79.9% of the reported data, with the remainder determined on capillary blood specimens.

For those blood Pb results that were reported as less than the method detection limit, the lowest level at which the instrument can accurately quantify, we entered one half the value of the reported method detection limit for those data points (cf. Schantz et al., 2001). Most children had either one ($n = 76$) or two ($n = 35$) blood Pb tests; however, a few had three ($n = 9$) or more ($n = 2$) tests prior to age 9. The median value was selected for those with more than one draw. Blood Pb levels in the Oswego cohort ($n = 122$) ranged from 1.5 to 13.10 $\mu\text{g/dL}$, with only 6 children having levels above 10 $\mu\text{g/dL}$, the threshold defined by the Centers for Disease Control and Prevention (CDC, 1991) as elevated. In addition to early childhood blood Pb levels, cord blood Pb levels were also available. Because these prenatal Pb levels were not significantly associated with SES in our sample (all $ps > .15$) and associations between postnatal Pb and cortisol reactivity were independent of postnatal Pb levels (Gump et al., 2008), we do not provide further details regarding the measurement procedures for prenatal Pb. However, these details are available elsewhere (Gump et al., 2008).

Cortisol Assessment

To measure adrenocortical reactivity, we collected saliva specimens at four points during the stress protocol: during the baseline period, and then 21, 40, and 60 min following the first acute stress task, the cold pressor. Following Granger et al. (2007), we asked participants to imagine chewing a piece of their favorite food, while moving their jaws as if they were really chewing and to gently force the pooling saliva through a short plastic straw into a 5-mL cryovial. All specimens were immediately frozen at -20°C until transported on dry ice to Pennsylvania State University for cortisol assay.

On the day of testing, all specimens were centrifuged at 3,000 rpm for 15 min to remove mucins. Specimens were assayed for salivary cortisol using a highly sensitive enzyme immunoassay that is U.S. Food and Drug Administration (Section 510k) cleared for use as an in vitro diagnostic measure of adrenal function (Salimetrics, State College, PA). The test used 25 μL of saliva, had a lower limit of sensitivity of 0.007 $\mu\text{g/dL}$, a range of sensitivity from 0.007 to 1.8 $\mu\text{g/dL}$, and average intra- and interassay coefficients of variation of less than 5% and 10%, respectively. All samples were assayed in duplicate, with the average of the duplicates used for all test results. Cortisol units are expressed in micrograms per

deciliter ($\mu\text{g/dL}$). To create a more normal distribution, we eliminated a single outlier (with a value that was > 3 SD above the mean for cortisol change at both 40 and 60 min) and used a logarithmic transformation (cf. Baos, Blas, Bartolotti, Marchant, & Hiraldo, 2006).

Cortisol levels follow a circadian cycle, with peak levels in the morning, a steady drop during the morning hours, and a relatively stable plateau in the afternoon to early evening. In addition, cortisol levels are affected by recent meals. Therefore, all participants were scheduled to begin the protocol in the afternoon (at approximately 4:30 p.m.) and were given instructions to have no snacks during the 1 hr preceding the testing. If the child reported having had a recent snack, the session was either rescheduled or briefly delayed, depending on the timing of the snack. In addition, participants were instructed (a) to avoid dairy products for 30 min prior to collections (restriction based on evidence that some bovine hormones cross-react in immunoassay), (b) to rinse their mouths with water 10 min before sample collections (note that no snacks were provided between sample collections), and (c) to not brush their teeth within 1 hr of testing to avoid blood contamination in saliva; two participants were rescheduled because of injuries or surgery in the oral cavity within the preceding 48 hr (Kivlighan, Granger, Schwartz, Nelson, & Curran, 2004).

Potential Confounds

We considered a number of potential confounding effects, including characteristics measured during pregnancy, at birth, at 7 years of age, and at 9.5 years of age. Measures included paternal height and weight, maternal prepregnancy weight and height, maternal weight gain during pregnancy, maternal reported illness during pregnancy, obstetrical complications (using the Ballard and a measure of optimality), head circumference at birth, birth weight, gestational age, maternal substance use during pregnancy (e.g., cigarettes, alcohol), the Home Observation for Measurement of the Environment (Bradley & Caldwell, 1984), the Clinical Epidemiological Studies—Depression (Radloff, 1977) inventory for the mother, and the Child's Depression Inventory (Kovacs, 1982), the child's body mass index ($\text{BMI} = \text{weight (kg)}/\text{height (m)}^2$), and prenatal levels of other toxicants (specifically, Pb, dichlorodiphenyldichloroethylene, hexachlorobenzene, polychlorinated biphenyls, and mercury). Because of skewed distributions, some measures were log transformed before use in any analysis. Further details regarding these covariate measures and a complete list can be found in prior publications (e.g., Lonky et al., 1996).

Data Analysis

As previously reported (Gump et al., 2008), greater blood Pb levels in early childhood were associated with significantly greater cortisol levels following acute stress. We have not previously reported an association between SES and cortisol levels following acute stress (as change scores) and therefore tested this hypothesized association first. To test our mediational hypothesis, we first adjusted measures of cortisol change following acute stress for all control variables related to cortisol change at $p < .20$ by conducting a series of regressions (using SAS PROC REG; SAS Institute, 1996).

These covariate-adjusted values of cortisol at 21, 40, and 60 min (as a repeated measure) were then analyzed using PROC GLM (SAS Institute, 1996), with additional covariate

control for the child's sex and BMI. These additional covariates were added on the basis of prior evidence for their importance in the prediction of cortisol levels (Kudielka & Kirschbaum, 2004; P. M. Stewart, Boulton, Kumar, Clark, & Shackleton, 1999).

Mediation was tested by adding childhood blood Pb levels in the model after entering covariates and family SES. A significant reduction in the effect of family SES after the addition of blood Pb levels was considered evidence for mediation (Baron & Kenney, 1986). Although there are various approaches for testing mediation (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002), these approaches yield point estimates and standard errors for mediated effects that are quite similar for sample sizes greater than 50 (MacKinnon, Warsi, & Dwyer, 1995). An online program (Preacher & Leonardelli, 2001) was used to perform one of the commonly used tests for mediation, the Sobel test (Sobel, 1982). The Sobel test evaluates mediation by dividing the estimate of the mediating variable effect by its standard error and comparing the resulting value to a standard normal distribution.

Results

Sample Characteristics

All children in the present study were drawn from the Oswego Children's Study, an ongoing longitudinal study with a primary focus on the effects of prenatal exposure to polychlorinated biphenyls on children's cognitive development (e.g., P. Stewart et al., 2000). Covariate data and early blood Pb levels were collected as part of this ongoing study. Data for the present analysis of SES and cortisol levels were collected during a special psychophysiological testing session at 9.5 years of age.

Family SES and Cortisol Levels Following Acute Stress

After the addition of covariates, higher family income was associated with significant lower cortisol levels following acute stress in the full repeated measures model, $F(1, 104) = 4.08, p < .05$. Results of the univariate tests at each sample period revealed significant effects of family income at 21 min, $F(1, 104) = 4.46, p < .05$, and a marginally significant effect at 40 min, $F(1, 104) = 2.89, p < .10$. These results are shown in Table 1 (Column 1). In a secondary analysis, tertiles of family income were created and we considered the linear contrast across these groups in the prediction of cortisol levels. This analysis revealed a significant linear contrast at 21 min, $F(1, 103) = 3.91, p = .05$, and a marginally significant linear contrast at 40 min, $F(1, 103) = 2.77, p < .10$. The results of this analysis are shown in Figure 1. The Hollingshead index was notably not associated with cortisol levels following acute stress, $F(1, 104) = 0.15, p > .10$.¹ Separate analysis of the family occupational and educational components within this index were also not significantly associated with cortisol levels following acute stress, $F(1, 102) = 0.13, p > .25$, and $F(1, 104) = 0.12, p > .25$, respectively.

¹In our previous paper (Gump et al., 2008), we reported a significant *univariate* association between the Hollingshead index and cortisol reactivity measured at 21 and 60 min as a method to select appropriate covariates for the analysis of a possible Pb–cortisol association. However, the present study tested these same associations between the Hollingshead index and cortisol reactivity in *multivariate* models, controlling for many other variables (e.g., parent's marital status), and found no significant associations with cortisol reactivity. These two sets of findings are not discrepant, but merely reflect the very different research questions addressed by these two articles.

Blood Pb as Mediator for the SES–Cortisol Association

We next tested our hypothesis that blood Pb might serve as a mediator for the effect of family income on cortisol levels following acute stress. As shown in Table 1 (Column 2), after controlling for early childhood blood Pb levels, family income was no longer a significant predictor of cortisol levels ($p > .20$). In other words, adding childhood blood Pb levels as a covariate resulted in a 39.58%, 33.12%, and 50.00% reduction in the ability of family income to predict cortisol levels at 21, 40, and 60 min, respectively (using the percentage change in β estimates across models). Using the Sobel (1982) test for mediation, the SES–cortisol association was found to be marginally significantly mediated by blood Pb at 21 min ($z = 1.64$, $p < .10$), significantly mediated by blood Pb at 60 min ($z = 1.90$, $p < .05$), and a significant mediator when testing the full repeated measures model ($z = 2.04$, $p < .05$).

Blood Pb as a Potential Moderator for the SES–Cortisol Association

Based on prior evidence for a significant interaction of Pb and SES in the prediction of cardiovascular acute stress reactivity (Gump et al., 2007), we analyzed the interaction of Pb and SES in the prediction of cortisol levels following acute stress. Neither the Hollingshead index nor family income significantly interacted with Pb in the prediction of cortisol ($F_s < 1.00$). Therefore, blood Pb was not a significant moderator for the SES–cortisol association.

Discussion

The present study considered an important environmental toxicant, blood Pb, as a novel mechanism whereby SES might affect children's adrenocortical responses to acute stress. As predicted, we found that family income was negatively correlated with salivary cortisol levels following acute stress in children. Moreover, we found that early childhood blood Pb significantly mediated this association between family SES and salivary cortisol. In other words, lower family income was associated with heightened blood Pb levels and blood Pb was the mechanism whereby family income affected salivary cortisol.

Notably, these associations were found for children with low levels of blood Pb. The geometric mean of Pb levels in our sample ($GM = 3.99$) is comparable to national averages for low income children tested during this same time frame ($GM = 3.80$; CDC, 1997). In addition, the percentage of children with blood Pb levels above 10 $\mu\text{g/dL}$, the level of concern established for children by the Centers for Disease Control and Prevention, were nearly identical in the present sample (4.9%) and the national sample during this same time frame (4.8%). Finally, participants in the Oswego Children's Study are representative of other children born in our geographic area but not participating in the Oswego Children's Study (Lonky et al., 1996). Therefore, the present findings are likely to generalize more broadly to young children with "normal" blood Pb levels.

Although the present finding that Pb mediated an association between SES and cortisol reactivity is consistent with our prior finding that Pb mediated an association between SES and vascular responses to acute stress (Gump et al., 2007), there is a notable difference across these two studies. Pb exposure mediated an association specifically between income

and cortisol reactivity in the present study but mediated an association between the Hollingshead index (occupation and education) and vascular reactivity in our prior study. The possibility that specific SES indices might be differentially associated with particular acute stress responses is not novel (Kapuku et al., 2002; Schmeelk-Cone, Zimmerman, & Abelson, 2003). Particularly relevant to the present study, Cohen, Schwartz, et al. (2006) found that income but not education was negatively associated with cortisol levels among nonsmokers in the Coronary Artery Risk Development in Young Adults Study (CARDIA), a younger subsample within CARDIA that might more closely resemble our 9.5 year participants. Perhaps after we have gained a better understanding of the underlying physiological mechanism(s) explaining the effect of Pb exposures on children's stress responses, the different meditational pathways will be more fully understood.

There are a few concerns with the current study that should be discussed. First, although our findings support a pathway from family income to blood Pb to cortisol reactivity, it is not possible to experimentally test these associations in humans and thereby determine the direction of this pathway. Our assumption of a forward causal direction between Pb and adrenocortical reactivity is based on experimental research with animals (Baos et al., 2006; Cory-Slechta, Virgolini, Thiruchelvam, Weston, & Bauter, 2004). However, reverse causality remains a possibility. For example, adrenocortical reactivity may have effects on the toxicokinetics of blood Pb, affecting the transfer of Pb between blood and bone (Mushak, 2003) and thereby raising blood Pb levels. In addition, perhaps heightened blood Pb in children (and their parents) affects cognitive functioning (e.g., Bellinger et al., 2003) and thereby social and economic selection (failure to reach or keep expected social position) or drift (movement from higher to lower social class) occur.

Second, our assessment of postnatal Pb occurred approximately 7 years prior to our assessment of cortisol responses to acute stress. Therefore, it remains possible that we are underestimating the size of the Pb–cortisol association—by using prior Pb levels to approximate concurrent blood Pb levels. Although Pb levels in children are highly correlated from year to year ($r = .78$, $p < .05$, for a 2-year span), the strength of this association does drop when measures span 5 years ($r = .40$, $p < .05$) or 7 years ($r = .27$, $p < .05$; A. Chen, Dietrich, Ware, Radcliffe, & Rogan, 2005). Alternatively, we may be overestimating the size of the Pb–cortisol association at 9 years of age if Pb exposure is only important when occurring at some critical young age. We are currently engaged in the study of 9-year-olds with the concurrent assessment of blood Pb levels, SES, and cortisol responses to acute stress to address this concern.

Finally, children's cortisol level in the present study was highest during the baseline period and steadily declined during the 60 min following the acute stress task. This pattern suggests that children had elevated cortisol at baseline. Establishing a true adrenocortical baseline is unfortunately not straightforward. Studies have demonstrated a positive association between adrenocortical activity and exposure to a novel situation (al'Absi & Lovallo, 1993; Fishman, Hamburg, Handlon, Mason, & Sachar, 1962), although not all studies have corroborated this association (Hertsgaard, Gunnar, Larson, Brodersen, & Lehman, 1992). Our behavioral medicine protocol was quite novel for the children enrolled in the Oswego Children's Study (a study primarily focused on cognitive development), and therefore it is quite possible that

the children's salivary cortisol levels at "baseline" were already elevated in response to this unfamiliar situation. Future testing should include home cortisol assessment to determine whether the current protocol evokes differences from home levels.

In summary, we found in the present study that low family income is associated with significantly higher blood Pb levels as well as heightened adrenocortical responses to acute stressors. A formal test of mediation demonstrated that blood Pb was a possible mechanism whereby family income affected cortisol responses to acute stressors. The present study contributes to a very small literature considering the association between family income and adrenocortical reactivity in children (cf. Blair et al., 2009; Blair, Granger, & Peters, 2005), and moreover it is the first study to demonstrate that blood Pb might be the mechanism explaining the association between SES and cortisol reactivity to acute stress. These findings reaffirm our prior suggestion that we consider the chemical environment as well as the social and psychological environment when evaluating the effects of low SES.

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Figure 1.
Children's salivary cortisol change from baseline as a function of family income.

Table 1

Association Between Socioeconomic Status (SES) and Cortisol Levels Following Acute Stress, Controlling for Postnatal Lead, and Sobel Test for the Proposed Mediation

Cortisol measure	SES → cortisol <i>F</i> (1, 104)	SES 3 → cortisol (controlling for lead) <i>F</i> (1, 104)	Sobel test (<i>z</i>)
Full model	4.04 *	1.51	2.04 *
21 min ^a	4.46 *	1.44	1.64 †
40 min ^b	2.89 †	1.08	1.50
60 min ^c	2.37	.76	1.90 *

^a Cortisol change at 21 min was adjusted for the following: mother's age, father's age, Home Observation for Measurement of the Environment score, year living near Great Lakes, parent's marital status, birth weight, head circumference at birth, Ballard optimality measures, child's gestational age at birth, maternal decaffeinated coffee consumption during pregnancy, child's gestational age at birth, and maternal coffee consumption during pregnancy.

^b Cortisol change at 40 min was adjusted for the following: father's age, head circumference at birth, parent's marital status, maternal coffee and diet soda consumption during pregnancy, Ballard score, and at-home care (e.g., nanny).

^c Cortisol change at 60 min was adjusted for the following: maternal coffee and diet soda consumption, illness during pregnancy, parent's marital status, father's age, and maternal stress prior to learning of pregnancy.

† $p < .10$.

* $p < .05$.