Socioeconomic Status Is Associated With Stress Hormones

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Objective: We assess whether socioeconomic status (SES) is associated with basal levels of cortisol and catecholamines and determine if any association between SES and these hormones can be explained (is mediated) by behavioral, social, and emotional differences across the SES gradient. **Methods:** One hundred ninety-three adult subjects, including men and women and whites and African-Americans, provided 24-hour urine catecholamine samples on each of 2 days and seven saliva cortisol samples on each of 3 days beginning 1 hour after wakeup and ending 14 to 16 hours later. Values for both hormones were averaged across days to obtain basal levels. **Results:** Lower SES (income and education) was associated with higher levels of cortisol and epinephrine and marginally higher levels of norepinephrine. These associations were independent of race, age, gender, and body mass. Low SES was also associated with a greater likelihood of smoking, of not eating breakfast, and with less diverse social networks. Further analyses provided evidence consistent with the hypothesis that these behavioral and social variables mediate the link between SES and the three stress hormones. **Conclusions:** Lower SES was associated in a graded fashion with higher basal levels of cortisol and catecholamines. These associations occurred independent of race, and the data were consistent with mediation by health practices and social factors. **Key words:** cortisol, education, epinephrine, income, norepinephrine, socioeconomic status.

AUC = area under the curve; **BMI** = body mass index; **CARDIA** = Coronary Artery Risk Development in Young Adults Study; **ELISA** = enzyme-linked immunosorbent assay; **HPA** = hypothalamic-pituitary adrenocortical axis; **ISEL** = Interpersonal Support Evaluation List; **LET** = Life Engagement Test; **SES** = socioeconomic status; **SNS** = sympathetic nervous system.

INTRODUCTION

Socioeconomic status (SES), whether measured in terms of income, education, or occupation, has been found to be negatively associated with rates of mortality and morbidity from almost every disease condition (e.g., 1–3). These relationships exist across countries with different levels of state-sponsored health care, suggesting that access to care is not the underlying causal mechanism. Alternatively, it has been hypothesized that persons of lower SES are embedded within environments characterized by high levels of psychosocial disruption that increase the risk for disease by continuously provoking stress-elicited dysregulation of key behavioral and biological systems (1,4,5).

Two biological systems are thought to be central in linking stressor exposure to disease: the sympathetic nervous system (SNS) and the hypothalamic-pituitary adrenocortical (HPA) axis (e.g., 6,7). Primary markers of SNS activation, the hormones epinephrine and norepinephrine, are increased by stress and cause 1) suppression of cellular immune function e.g., 8; 2) hemodynamic changes, including increased blood pressure and heart rate (9); 3) abnormal cardiac rhythms (ventricular arrhythmias) that have been linked to sudden death (10); and 4) neurochemical imbalances that contribute to the development of psychiatric disorders (11). Similarly, elevations in a primary marker for HPA activation, cortisol, have been associated with stressful situations such as caregiving and work strain (e.g., 12,13; for exceptions see 14,15). Elevated levels of cortisol have been found to 1) suppress immune function (8); 2) facilitate central adiposity, a risk factor for coronary heart disease and diabetes, e.g., 16; and 3) be associated with (and possibly contribute to) major depression (11).

Several studies have examined the relationships between indices of SES and diurnal cortisol using ambulatory repeated saliva collections. However, between-study comparisons of the results are made difficult because the protocols differed in timing and number of cortisol samples, differed in cultural context, and were inconsistent in whether they addressed the potential confounding effects of race/ethnicity. The early studies were conducted outside of the United States. For example, higher SES as indicated by job grade of 45- to 58-year-old subjects in the British Whitehall Study was associated with lower average working-day cortisol levels in men but *higher* working-day levels in women (17). Increasing SES, defined as education, occupational, and employment status, was associated with *higher* morning cortisol levels in 35- to 65-year-old German men and women (18). In contrast, both a study of 17- to 49-year-old men from Dominica, a Caribbean Island nation (19), and the Whitehall Study (17) found no associations of SES and morning cortisol. All of these studies failed to find SES differences in late and end-of-the-day cortisol levels.

In contrast, data from the Coronary Artery Risk Development in Young Adults Study (CARDIA), a multisite study conducted in the United States of 35- to 45-year-old men and women, indicated that lower income and education were associated with higher cortisol levels in the late afternoon and evening (20). Moreover, elevated levels among those with lower SES could be mostly explained by differences in health practices, primarily smoking but also, to a lesser extent, by social network diversity, depression, perceived social support, and mastery. The CARDIA analysis was based on a large sample (nearly 800) and controlled for potential effects of race and other spurious factors. However, the median household income in the CARDIA sample was $77,800 suggesting that

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the sample represented primarily the higher parts of the SES gradient.

Here, we present the results from a study that provides the opportunity to assess whether the cortisol findings from CARDIA can be replicated in a US sample that represents the lower end of the SES income strata. It also allows us to extend the exploration of the effects of SES to measures of SNS. Our primary hypotheses are that increased SES will be associated with lower levels of both SNS (catecholamines) and HPA (cortisol) activation and that these relationships are attributable to differences in health practices and psychosocial factors among SES strata. The sample's household median income was $17,500 per annum. There were approximately equal numbers of male and female subjects and substantial numbers of both whites and African-Americans. We included two different measures of SES (education and income), repeated the measurements of cortisol (3 days, seven saliva samples/day) and catecholamines (2 days, 24-hour urines), and assessed social network, psychological, and health-practice variables that were found in the CARDIA study to mediate the SES-cortisol associations.

METHODS

Data were collected between 2000 and 2004. The participants were 95 men and 98 women aged 21 to 55 years (mean age = 37.3, SD = 8.8) who responded to newspaper advertisements soliciting participants for studies of psychosocial risk factors for upper respiratory infections. One hundred eight were white, 72 African-American, and 13 indicated other racial/ethnic categories. The median income was $17,500 (range, $2500 to $162,500); and mean education, 13.76 years (SD = 2.21). Finally, 47.2% were smokers, and the mean body mass index (BMI) was 28.98 kg/m^2 (SD = 7.08 kg/m^2). Here, we report an analysis of baseline data obtained before any of the parent study-related interventions. All components of the study received IRB approval, and subjects were paid $820 for completing all aspects of the parent study.

Subjects were screened on the telephone and later interviewed by a physician. The were excluded if they were pregnant or currently breast feeding, if they had been diagnosed with a chronic illness or a psychiatric disorder, if they had nasal surgery, or took any medications regularly (with some exceptions; for example, birth control, hormone replacement therapy, analgesics, and topical eczema/psoriasis medications).

After a physical examination found them to be in good health (no acute or chronic illnesses), subjects filled out the SES measures, as well as demographic, psychological, and health practice questionnaires. They were subsequently trained to collect saliva (for cortisol) and urine (for catecholamine) samples.

Socioeconomic Status

We employed three measures of SES: income, education, and a composite score.

Income

Income was assessed by the question, which category best describes your yearly household income before taxes? There were 13 categories, ranging from "less than $5000" to "$150,000 or more." The categories were narrower in the bottom range of incomes ($5,000 differences) and progressively increased with increases in income (e.g., $10,000 differences at $30,000–$50,000 and $25,000 differences at $100,000 and above). Income was defined as the median income of the identified category. The income score was log transformed to better approximate a normal distribution.

Education

Education was assessed by the question, what is the highest grade or year of school you have completed? There were 18 categories ranging from "no formal education" to "doctoral degree" (PhD, MD, EdD, DVM, DDS, JD, etc.). They were assigned a number of years of education based on their response (e.g., high school education = 12 years, associate's degree = 14 years, and a PhD = 20).

Composite SES

A composite SES score was calculated by standardizing (Z scores) income and education and adding the standard scores.

Catecholamines and Cortisol

Participants were given materials and instructions regarding the collection of urinary catecholamines and salivary cortisol at a training session following screening. We employed multiple-day measurement procedures for both hormones because we were interested in relatively stable individual differences in these hormones rather than acute (day-to-day) responses. Cortisol was sampled on 3 different days and catecholamines on 2 days.

Catecholamines

Epinephrine and norepinephrine were assessed by averaging two 24-hour urine samples collected approximately 2 weeks apart. One was collected in the subjects' natural settings, whereas the other was collected under controlled conditions during 24 hours in a hotel. Subjects were instructed to collect all urine voids during the target period. Samples were collected in 1-l specimen containers with a preservative (sodium metabisulfite) added to the container. Samples were frozen until later assay using high-performance liquid chromatography with electrochemical detection. Interassay reliabilities for epinephrine and norepinephrine exceeded 0.99, and the average variability was less than 1.5%. Between-day correlations were 0.39 for epinephrine and 0.47 for norepinephrine, $p < .001$ for both.

Cortisol

Saliva cortisol concentrations are closely correlated with free (unbound) plasma cortisol concentrations (21). Seven saliva samples were collected on each of three different days. To provide a sample, participants placed a roll of cotton in their mouths, chewed on it for approximately 30 seconds or until it became saturated, and placed it in a tube called a salivette (Sarstedt, Rommelsdorft, Germany). They then filled in the time of the sample on the tube label. Compliance was enhanced by an alarm watch that beeped at each sampling time and presented a unique code that the subject wrote on the collection tube.

The first 2 days of cortisol measurement were separated by approximately 1 day, and the second and third, by about 3 weeks. On each day, the samples were collected by the subjects in their natural environments at 1, 2, 4, 7, 9, 11, and 14 hours after wakeup. Subjects recorded the time they woke up on a form provided to them. Samples were stored in Baggies at room temperature in participants' homes and were returned to the clinic within 2 days of collecting the last sample. A third-day sample was collected under controlled conditions during 24 hours in a hotel immediately at wakeup (approximately 7:15 AM); 1 hour after wakeup; at 10:00 and 11:55 AM; and at 1:00, 3:00, 5:00, and 10:00 PM. The salivettes from all three sampling days were frozen until they were assayed.

Cortisol level was determined by enzyme-linked immunosorbent assay (ELISA)–based competitive binding assay procedures (Salimetrics, State College, PA). The intra-assay coefficient of variation ranges from 3.9% to 7.1%. Interassay variability was less than 7%. Each daily cortisol value was corrected (residualized score) for wakeup time on the day of measurement. Area under the curve (AUC) was then calculated for each day to measure total free-cortisol release. Correlations between daily adjusted AUCs ranged from 0.46 to 0.79 ($p < .001$ for all). Average cortisol level was calculated as the log of the average of the three adjusted daily AUCs.

Not every cortisol sample was taken at the precise time we intended. For each of the seven targeted times, we determined a window within which there was little if any relationship between time since awakening and cortisol level.

This window was narrowest (±1/2 hour) for the first sample due to the general pattern of a rapid increase in cortisol during the first 60 minutes after awakening, followed by a more gradual decrease during the rest of the day (window of ±1 hour). A sample provided outside the acceptable window was excluded from analyses of samples for that targeted time. The AUC measures were computed only for those who had data for the first three samples (where decline in the rhythm is steeper) and at least two of the remaining four samples (when the rhythm is flatter). Seven subjects were excluded for not meeting these criteria.

Potential Mediators

Health Practice Measures

We assessed smoking rate, alcohol consumption, exercise frequency, breakfast frequency, and sleep efficiency by questionnaire. Smoking rate was defined as the number of cigarettes smoked on an average day and alcohol consumption as the number of alcoholic drinks consumed per day (weighed average of weekend and weekday drinking) with a bottle/can of beer, glass of wine, or shot of whiskey each counted as a single drink (22). Exercise frequency was scored as the usual number of days per week engaged in an activity long enough to "work up a sweat," "get the heart thumping," "or get out of breath" (23) and breakfast frequency as the usual number of days per week that the subject eats breakfast. Sleep efficiency, the percent of time spent in bed sleeping (total time in bed − [time to fall asleep + time lost to wakeups + time awake before rising]) was assessed using the Pittsburgh Sleep Questionnaire (24).

Psychosocial Measures

The psychosocial variables were measured by questionnaire and included social integration, social support, mastery, and purpose in life. Social integration was assessed using the Social Network Index (25). There, 1 point is assigned to each of 12 relationship categories (i.e., spouse, parents, parents-in-law, children, other family members, neighbors, friends, coworker, classmates, fellow volunteers, members of groups without religious affiliations, and members of religious groups) whose member(s) the respondent reported having spoken to (in person or by phone) at least once every 2 weeks. The points were summed to create the social integration score. Social support was assessed using a short (12-item) version of the Interpersonal Support Evaluation List (ISEL; 26) that included 4 items assessing each of three dimensions of support: appraisal, belonging, and tangible support. Mastery over important life outcomes was assessed using the seven-item Mastery Scale (27). Purpose in life, defined as the extent to which a person engages in activities that are of personal value, was assessed using the six-item Life Engagement Test (LET; 28). For all the scales, the appropriate items were reversed and the scale scores were summed. The internal reliabilities were 0.80 for the ISEL, 0.72 for the Mastery Scale, and 0.73 for the LET.

RESULTS

We used multiple linear regression analysis, forcing covariates into the regression first, followed by SES entered as a continuous variable. Covariates for all analyses included age (continuous variable), gender (male or female), race (white, African-American, other), and the log of BMI (weight in kilograms/height in meters^2). For overall analyses examining associations of SES and the endocrine markers, we first present the association with composite SES and then the associations with income and education separately. For the mediation analyses, we use only the composite measure of SES, although the individual markers indicate similar results. Although all analyses used continuous measures of SES, the figures are based on tertiles.

Correlations Within Predictors and Outcomes

Education and income were correlated, $r = 0.52$, $p < .001$; education and composite SES, $r = 0.87$, $p < .001$; and income and composite SES, $r = 0.87$, $p < .001$. Average epinephrine and norepinephrine were correlated, $r = 0.59$, $p < .001$. Neither average epinephrine nor norepinephrine was correlated with average cortisol AUC ($r = 0.08$ and 0.02, $p > .25$).

Correlations of Control Variables (Covariates) and Outcomes

Higher levels of epinephrine were associated with being younger ($r = -0.21$, $p < .004$) and with being male (mean for men = 0.89 and women 0.84, $\log_{10}$ ng/ml; $t = 2.5$, $p < .02$). Higher norepinephrine levels were associated with a greater BMI ($r = 0.23$, $p < .001$) and higher cortisol with being male (means for men 2.40 and women 2.32, $\log_{10}$ ug/ml; $t = 2.1$, $p < .04$). Race was not associated with any of the three hormones.

SES and Cortisol

As apparent from Figure 1, higher levels of composite SES were associated with lower levels of total cortisol concentration over the day (b = −0.03, $p < .03$, 2.9% variance). Education showed a similar relation (b = −0.02, $p < .03$, 2.7%) and income a similar but marginal association (b = −0.08, $p < .10$, 1.6%).

In order to determine whether the association between SES and cortisol was driven by differences at specific times during the day, we conducted similar analyses treating the log of the average (across 3 days) of each of the seven cortisol samples as the outcomes. Slope analyses excluded any subject missing data for the first sample of the day. One subject was excluded. All seven samples were negatively associated with SES (regression coefficients ranging from $-0.04^{-3.}$ to -2.7^{-3}) although none of these differences approached statistical significance. Hence the overall difference in cortisol concentration over the day is attributable to small differences throughout the day that accumulate to an overall difference in total concentration. To obtain a more sensitive assessment of daily rhythm, we used a multilevel model (29) to generate a slope of the relationship between cortisol level and time of each of the seven assessments for each subject. We then averaged the slopes for the 3 days and

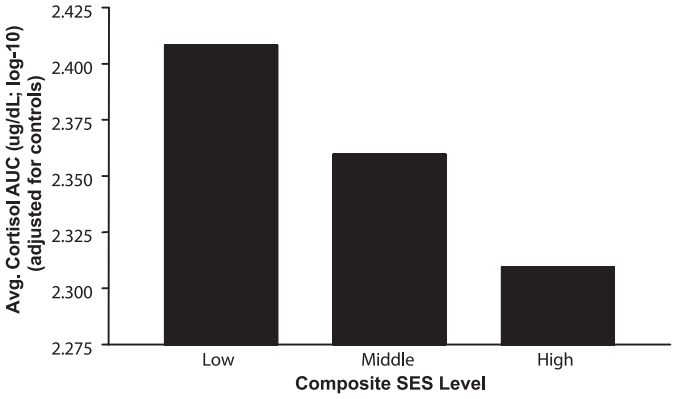

Figure 1. Association between composite (income + education) SES and saliva cortisol (area under the curve) averaged across 3 days of sampling. The y axis range corresponds to the 25th and 75th percentiles.

regressed the average slope on composite SES and the covariates. There was no association.

SES and Catecholamines

Higher levels of composite SES were associated with lower levels of urine epinephrine ($b = -0.01$, $p < .05$, 2.2% variance; Figure 2a). Similar, but smaller, associations were found with the separate measures of income ($b = -0.05$, $p < .08$, 1.7%) and education ($b = -0.01$, $p < .10$, 1.5%). In the case of urine norepinephrine, there was only a marginal association with higher composite SES resulting in lower levels ($b = -0.01$, $p < .15$, 1.2% variance; Figure 2b), an association with income and lower levels ($b = -0.08$, $p < .05$, 2.2%), but no association with education ($b = 0$).

Potential Mediators

Health Practices

First, we tested whether each of the health practices was correlated with composite SES. Higher SES was associated with less likelihood of smoking ($r = -0.33$, $p < .001$), better sleep efficiency ($r = 0.15$, $p < .04$), and greater likelihood of eating breakfast ($r = 0.19$, $p < .01$). SES was not correlated with alcohol consumption or exercise.

To determine the extent to which these health practices may have mediated the SES association with total cortisol concentration, epinephrine, or norepinephrine, we fit four additional regression models for each outcome. Each of these models added one or more of the health practices to the base (standard controls and SES) equation (see Table). We calculated the percent reduction in the effect size attributable to each hypothesized mediator, as well as the combination of the three health practice mediators. Percent reduction was defined as effect size of SES in the base regression minus effect size of SES when proposed mediators were added to the regression divided by the effect size of SES in the base regression. In cases where there were subjects who had missing data on proposed mediators, we recalculated the base regression using the same sample as the regression with the mediators included and used the recalculated effect size in the percent reduction formula.

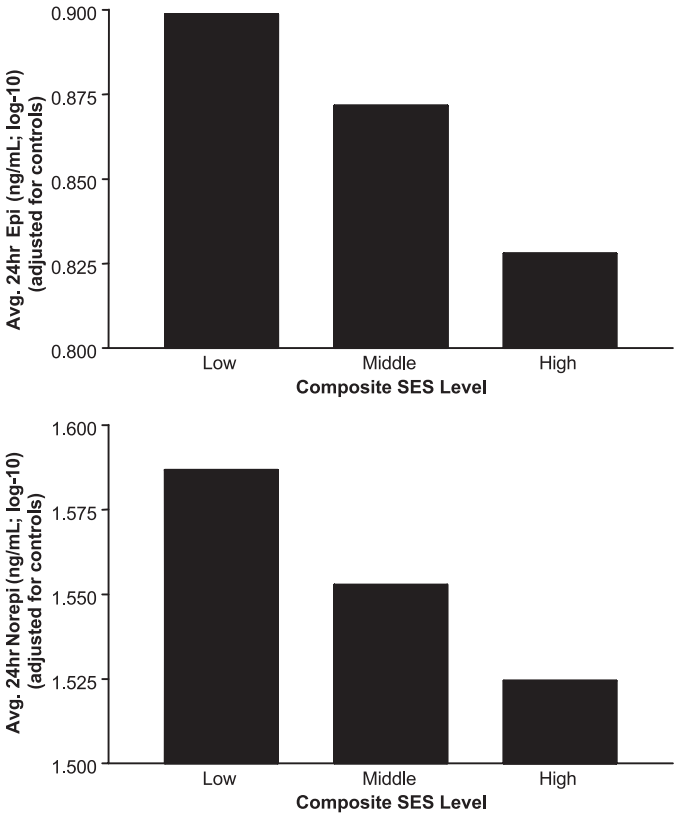

Figure 2. Association between composite (income+education) SES and 24-hour urine epinephrine (A) and norepinephrine (B) averaged across two days of sampling. The y axis range corresponds to the 25th and 75th percentiles.

As apparent from Table 1, 62.8% of the association of SES and cortisol could be explained by smoking status, with smokers having lower SES and higher cortisol. Eating breakfast accounted for a smaller reduction (22.3%). Adding all three health practices reduced the total effect size by 77.4% and below significance. Breakfast played a larger role in the case of epinephrine (33.0%) and norepinephrine (53.1%), with smoking status accounting for approximately 20% of these effects. Adding all the three health practices reduced the total effect sizes by 40.4% for epinephrine and 67.4% for norepinephrine.

Psychosocial Factors

We tested the potential mediation of psychosocial variables using the same technique (see Table). Composite SES was correlated with a more diverse social network ($r = 0.26$, $p < .001$), less depression ($r = -0.16$, $p < .03$), and more perceived social support ($r = 0.15$, $p < .04$). SES was not correlated with either mastery or purpose. Social network diversity substantially reduced the effect sizes for cortisol (47.3%), epinephrine (23.9%), and norepinephrine (22.6%). Depression and social support played no part in mediating the cortisol effect and a small role (5.5% to 9.2%) in mediating the association between SES and catecholamines. Adding all the psychosocial factors reduced the total effect size 45.5% for cortisol, 27.4% for epinephrine, and 22.6% for norepinephrine.

Total Mediation

Finally, we fit an equation in which we included all the health practice and psychosocial variables described above. The total reduction in the effect size was 94.4% for cortisol, 57.6% for epinephrine, and 80.4% for norepinephrine. In all cases, the association between SES and the outcomes were no longer significant. Most of the reduction could be obtained by controlling for smoking status and social network diversity (85% for cortisol, 51% for epinephrine, and 75% for norepinephrine).

Analysis of Nonsmokers

Given the sizable effect of smoking status on the various hormone measures, we wondered whether the pattern of findings described above would hold if the analysis were restricted

TABLE 1. Reduction in Variance Explained by the Association Between Composite SES and Cortisol (Area Under the Curve) and SES and Catecholamines as Each Mediator Is Added to the Equation[a]

Predictor	Cortisol						Epinephrine						Norepinephrine					
	N	B*	SE*	*p* <	%σ^2	%Δ	*N*	B*	SE*	*p* <	%σ^2	%Δ	*N*	B*	SE*	*p* <	%σ^2	%Δ
SES alone	184	−2.5	1.1	.03	2.86	—	190	−1.3	0.6	.05	2.22	—	190	−1.3	0.9	.15	1.17	—
Health practices																		
SES with smoking status	184	−1.6	1.1	.17	1.06	62.8	190	−1.2	0.7	.07	1.80	19.1	190	−1.2	0.9	.20	0.92	21.0
SES with breakfast	184	−2.2	1.1	.05	2.22	22.3	190	−1.1	0.7	.10	1.49	33.0	190	−0.9	0.9	.32	0.55	53.1
SES with sleep efficiency	182	−2.4	1.1	.04	2.62	0.0	188	−1.4	0.7	.04	2.31	−4.1	188	−1.3	0.9	.16	1.12	10.4
SES with all three of above	182	−1.2	1.2	.32	0.59	77.4	188	−1.1	0.7	.13	1.32	40.4	188	−0.8	1.0	.40	0.41	67.4
Psychosocial factors																		
SES with SNI	183	−1.8	1.2	.11	1.49	47.3	189	−1.2	0.7	.08	1.69	23.9	189	−1.2	0.9	.20	0.90	22.6
SES with depression	184	−2.5	1.1	.03	2.82	1.2	190	−1.3	0.7	.06	2.02	9.2	190	−1.3	0.9	.16	1.10	5.5
SES with social support	184	−2.6	1.1	.03	2.86	0.0	190	−1.3	0.7	.06	2.04	8.2	190	−1.3	0.9	.16	1.12	3.7
SES with all three of above	183	−1.9	1.2	.11	1.54	45.5	189	−1.2	0.7	.09	1.61	27.4	189	−1.2	0.9	.21	0.90	22.6
SES with all six of above	181	−0.6	1.2	.62	0.14	94.4	187	−1.0	0.7	.20	0.94	57.6	187	−0.7	1.0	.51	0.25	80.4

N = sample size for analysis; %σ^2 = percent variance explained by regression; SNI = Social Network Index; B = regression coefficient $\times 10^{-2}$; %Δ = percent mediation of SES effect by added variable; SE = standard error of B$\times 10^{-2}$; SES = socioeconomic status.

[a] The % reduction in variance (%Δ) is calculated as follows: original variance accounted for by SES minus variance accounted for by SES when covariates are added divided by the original variance. The reduction is an estimate of the extent which the covariates mediated the association.

to the 53% of the sample that had never smoked. Although not quite meeting standard levels of significance in this reduced sample (B = −0.02, $p < .08$), the relationship between SES and AUC cortisol was very similar to the earlier analysis of the entire sample when smoking was statistically controlled. Moreover, as in the analysis of all subjects, breakfast (32% of the effect) and social integration (25%) were most strongly supported as possible mediators, with 68% of the total effects accounted when all five of the proposed health practice and psychosocial mediators were entered. In contrast, the associations between SES and epinephrine and norepinephrine did not approach significance when only nonsmokers were included (p values >.55). That SES was not associated with catecholamines in the analysis of nonsmokers is probably attributable to the fact that the effect sizes of these associations were small (approximately half that of the SES and cortisol association) in the entire sample (see Table). Consequently, there was probably insufficient power in the analysis with the reduced sample. However, this does emphasize that these relations are driven to a great extent by higher rates of smoking among low SES subjects.

DISCUSSION

Higher SES was associated with lower levels of cortisol and epinephrine and marginally lower levels of norepinephrine. These associations were independent of race, age, gender, and body mass. The association with cortisol also occurred relatively equally across time of day the sample was collected. In all cases, the associations were graded with each increase in SES associated with a decrease in hormone concentration. The effect size was small for all three associations. This is consistent with earlier studies and reflects the variability inherent in measuring these hormones in natural settings, as well as the existence of multiple unspecified determinants of hormone levels.

Although both the CARDIA study and the data reported here found elevated cortisol levels with lower SES, CARDIA found this association occurred only in the late afternoon and evening, whereas we found the effect was fairly equal across the day (no difference in slopes). A major difference between this study and CARDIA is that we averaged cortisol measures over multiple (3) days. This results in a better estimate of the true basal level and possibly more sensitivity to differences that occur during the morning–early afternoon decline in the cortisol rhythm where small differences in the timing of samples contribute to measurement error that obscures associations. The other difference is that this sample had a relatively low median income, whereas CARDIA had a high median income. It is possible that rises at different points of the SES gradient influence cortisol levels at different times of the day, possibly due to different activity levels of higher- versus lower-income jobs.

The difference between the US findings and those reported in Europe (17,18) and the Caribbean (19) are more difficult to explain. It is noteworthy that there was little consistency across the results of the three studies done outside of the US, and hence there is no

clear US versus other culture effect. It is possible that these differences are attributable to differences in the sampling of the cortisol rhythm, the SES measures that were used, or the employment histories of the subjects (e.g., everyone was employed in the Whitehall Study). It is also possible that the inconsistencies found are primarily attributable to cultural differences among samples. However, the cross-cultural consistency of SES associations with morbidity and mortality do not support a "cultural difference" hypothesis (e.g., 4).

This is the first evidence from an adult sample linking SES to basal levels of circulating catecholamines. Interestingly, our results mimic that of a study that compared elementary school children in poverty to a middle class sample. Evans and English (30) found that the poverty sample had both higher cortisol and higher epinephrine levels, but they did not find a difference for norepinephrine. We found only a marginally significant association of SES and norepinephrine. That the association with epinephrine is stronger than that with norepinephrine is likely due to norepinephrine being released as a neurotransmitter, as well as an adrenal hormone, and hence providing a noisier measure of its function as a "stress hormone." The associations of SES and higher levels of both of these catecholamines are consistent with the hypothesis that SNS activation plays a role in linking SES to health outcomes. This would be especially relevant for diseases where the SNS has been identified as a modulator of pathophysiology. For example, SNS activation may mediate the graded association of SES and heart disease risk (e.g., 31) or explain the SES associations with diseases where the immune system plays a key role such as infectious and autoimmune diseases (e.g., 8).

The lack of a correlation between average cortisol and catecholamine levels suggests that these systems are not closely associated when measured as average response over several weeks. (In the one instance we collected both on the same day [first day of quarantine samples], they were correlated: cortisol and epinephrine, $r = 0.28$, $p < .001$; and cortisol and noreprinephrine, $r = 0.21$, $p < .01$.) The lack of correlation of the levels averaged over days may have to do with different rates of degradation and uptake of catecholamines and cortisol. Even though cortisol and the catecholamines are not correlated, our data suggest that both the SNS and HPA are activated among those with lower SES and hence may each contribute separately to the dysregulation of physiological systems and consequently to disease risk.

The results of the mediational tests for cortisol were strikingly similar to those in CARDIA. In the current study, low SES was associated with smoking, with less diverse social networks, and with not eating breakfast, and these three variables accounted for a substantial portion of the SES association with cortisol. The CARDIA study similarly found that smoking and social networks played the primary roles in mediating the SES association with cortisol. CARDIA did not include a measure of eating breakfast, which is likely a surrogate for a healthy lifestyle. These overall similarities are even more interesting, given that the CARDIA sample represented the higher part of the SES curve and the current sample the lower part, suggesting similar mediation across the gradient.

The mediation tests for the catecholamines similarly suggested the primary importance of smoking, breakfast, and social networks. However, there was a difference. When examining only nonsmokers, the SES association with cortisol held up, and the data for mediational role of other factors were unchanged. However, in the case of the catecholamines, there were no associations with SES among nonsmokers. Although the reduction below significance in the nonsmokers is primarily attributable to insufficient power to detect the relatively small associations between SES and the catecholamines (about half the effect size of the SES association with cortisol), this result emphasizes the importance of smoking in triggering SNS activation as the lower end of the SES gradient.

Overall, these data may be viewed as biological verification that increasing SES is associated with decreasing psychophysiologic distress (1,5). They also provide plausibility for the argument that at least some of the SES associations with disease may be mediated by differential levels of stress hormones. The great strength of this study is the within- (for cortisol) and across- (for both hormones) day multiple measurements. The weakness is its cross-sectional design, although it seems unlikely that elevated stress hormones determine SES and the most obvious spurious factors were controlled for in our analyses. Finally, the volunteer nature of the sample, the demands of the study, and the relatively high smoking rate (47% versus 33% among those below the poverty level in representative US samples) make this a less-than-representative group. However, the similarity in results across this study and CARDIA suggests that these differences did not play a major role in influencing the associations between SES and outcomes at least for young and middle-aged adults. Overall, these data provide strong evidence for decreasing concentrations of stress hormones with increasing levels of SES, at least for young adults at the bottom third to half of the SES gradient.

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