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Family Socioeconomic Status, Cortisol, and Physical Health in Early Childhood: The Role of Advantageous Neighborhood Characteristics

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Abstract

Objective—Children from families with lower socioeconomic status (SES) evidence greater physiological dysregulation and poorer health. Despite recognition of environmental contributors, little is known about the influence of neighborhood characteristics. The present study examined the moderating role of community-level risks and resources on the relation of family SES to children's daily cortisol output and physical health during the kindergarten year.

Methods—In fall and spring of kindergarten, children's (n = 338) daily total cortisol was measured and parents and teachers rated children's global physical health. Parents reported family SES. Neighborhood characteristics were assessed using the Child Opportunity Index (COI), a population-level tool that evaluates the quality of multiple domains of neighborhood attributes.

Results—In fall, children reared in lower SES family environments had higher cortisol when residing in lower quality (*lower opportunity*) neighborhoods ($b = -.097$, $p < .001$), but there was no relation between family SES and children's cortisol in more advantaged (*higher opportunity*) neighborhoods ($b = -.023$, p = .36). Lower family SES was prospectively associated with poorer physical health in spring (controlling for fall health) only among children living in lower opportunity neighborhoods ($b = -.250$, $p = .018$) and was unrelated to physical health among children residing in higher opportunity neighborhoods ($b = .042$, $p = .70$).

Conclusion—Higher opportunity neighborhoods may protect against the negative consequences of low family SES on children's stress physiology and physical health. Public health interventions that bolster neighborhood opportunities may benefit young children reared in socioeconomically disadvantaged family environments.

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Keywords

Socioeconomic status; neighborhood quality; child; cortisol; physical health

Ecological models of development emphasize the multiple, overlapping influences of the varied environments in which children are reared (1). Socioeconomic contexts are well-known contributors to children's health and well-being (2, 3). At the family-level, such factors are often assessed through measures of parental socioeconomic status (SES), while parallel measures of neighborhood-level SES may be derived from census aggregates of community poverty or level of educational attainment. However, the influence of the neighborhood context on children's health may extend beyond traditional socioeconomic indicators and reflect the effects of the community's physical environment, availability of social services, and other resource-related conditions (4). Extant research has largely explored the effects of family SES and traditional neighborhood SES separately, with less regard for potential interactive influences on children's health. To address this gap in knowledge, the present examination explored children's multi-day daily cortisol output and a multi-reporter measure of children's physical health impairment in fall and spring of the kindergarten year as a function of the interaction between two contexts of resources: family SES and neighborhood conditions.

Family SES and children's physical and physiological health

Extensive research supports pervasive linkages between lower family SES and poorer health in childhood (5, 6). As family SES decreases, there is an increase in all-cause mortality and morbidity, injuries, respiratory and general illnesses, asthma, obesity, general infections, and functional impairment associated with chronic conditions across childhood and adolescence (7–10). The consequences of family economic hardship may also manifest in the dysregulation of stress-sensitive physiological pathways, resulting in hyper- or hypo-secretion of the stress hormone cortisol (11). Family poverty has been associated with higher levels of children's basal cortisol (12, 13) and within the current sample of children, negative associations between household SES and children's diurnal cortisol have been observed (14). Intervention studies are limited, but provide a particularly strong test of the physiological implications of family SES. For example, lower levels of basal cortisol have been observed among children of families randomized to a family poverty reduction program compared to those in a control condition (15).

Despite these robust associations, the influence of family socioeconomic status on children's physiological and physical health is likely neither uniform nor absolute (16). As such, it is critical to address the questions of "how, when, and for whom" such environmental conditions exert their effects on child health (17). For example, there have been instances of non-significant relations between family SES and offspring basal cortisol (18), as well as reverse associations in which higher SES is associated with poorer greater physical health (5). Although variables at multiple levels of children's development may shape the extent to which SES influences children's health (19, 20), empirical investigations of such multi-level factors and their moderating role are limited, particularly in ethnically diverse samples of

children during the early years of life. It may be the case that neighborhood-level social and contextual factors operate to enhance or attenuate the effects of low family-level socioeconomic status on children's health.

Neighborhood conditions and children's physical and physiological health

Research shows that negative health outcomes associated with residing within lower resourced neighborhoods parallel those related to lower family SES and include low birth weight, higher rates of injuries, greater prevalence of chronic conditions, higher prevalence of childhood obesity, and poorer general health status (4, 21, 22). Notably, neighborhood and housing redevelopment programs have demonstrated promising physical health benefits (23, 24). In a national voucher-based public housing initiative, adults who moved from higher- to lower-poverty neighborhoods had a lower prevalence of obesity, diabetes, and self-reported physical health limitations, and children who spent a larger proportion of their early years in more disadvantaged areas showed improvements in physical health (25).

Neighborhood conditions may also affect certain neurobiological underpinnings of physical health problems, but are less commonly included in empirical investigations of SES-stress physiology associations (26). It may be particularly important to examine the consequences of neighborhood attributes on physiological outcomes in childhood that can potentiate the development of chronic or acute physical health problems. However, extant research has primarily been conducted among older samples and has yielded somewhat inconsistent results. For example, adolescents living in disadvantaged neighborhoods have been found to exhibit either lower (18) or higher basal cortisol (27, 28) compared to adolescents living in more economically resourced communities. Among adults, neighborhood poverty and physical disorder have been associated in some studies with elevated diurnal cortisol and flatter cortisol slopes (26, 29).

Although family-level socioeconomic characteristics may be correlated with the conditions of the surrounding neighborhood, they are not synonymous (30), and each may influence health outcomes via different pathways (31). For example, low family SES may impact children's well-being through greater risk of parental mental health problems and lower quality parenting (32). The challenges of low SES family environments have been shown to impose a substantial "cognitive load" (33) and may create difficulty as parents' aim to be engaged and attentive to children's needs amid other stressors (34). Conversely, lower quality neighborhoods may influence children's health via pathways of institutional resource availability and collective efficacy (35), as well as decay in the physical environment, safety, availability of healthy foods, and social cohesion that precludes the establishment of positive daily routines and healthy lifestyle practices (36, 37).

Interactive influences of family SES and neighborhood conditions on children's physiological and physical health

Children's development does not unfold in isolation of the community, nor is it fully governed by qualities of the neighborhood. Empirical investigation of synergistic effects between family-level socioeconomic factors and neighborhood-level conditions is limited. In

a review of research on neighborhood deprivation and children's health, the 19 identified studies controlled for family-level socioeconomic factors but did not examine interactive effects (38), leaving open the question of individual variability. Different models have been proposed to describe interactions between family- and neighborhood-level factors on broad indices of children's well-being (39). For example, *risk models* suggest additive or multiplicative relations between poorer quality neighborhood contexts and lower family SES in the prediction of children's poor outcomes. *Protective models* highlight the role higher neighborhood quality) in attenuating the negative influence exerted by lower family SES. Consistent with protective models, research has shown more economically advantaged neighborhoods may attenuate the negative influence of low family SES on children's behavioral and academic outcomes (40). Among adults, residing in a more socioeconomically advantaged neighborhood reduced the negative impact of childhood adversity on allostatic load (41) and fewer current negative life events (including financial stressors) attenuated the influence of lower childhood SES on inflammation (42). Less is known about cross-level interactive effects of socioeconomic conditions on physiological and physical health in early childhood, particularly when youth begin to spend greater time outside the home. In one of the only known studies to address this question in early developmental periods, low maternal SES was a risk factor for low birth weight associated in economically disadvantaged neighborhoods, but not in more resourced neighborhoods (43).

A new approach to measuring neighborhood conditions

Most existing indices of neighborhood quality rely on broad economic characteristics of a community (e.g., overall poverty level) and fail to consider other environmental factors that may have health effects (e.g., pollution level, access to recreational spaces, incidence of crime; (44)). Moreover, research that has examined relations between neighborhood deprivation and children's health has often included measures of community attributes without clear grounding in theory or prior research (38). To address these limitations, the Child Opportunity Index (COI) was developed as a multidimensional, population-level surveillance tool that assesses structural, economic, and environmental conditions (see Table 1) (44). The COI provides a comprehensive assessment of varied neighborhood qualities and is uniquely focused on empirically-supported neighborhood attributes that influence children's health and development, including factors not included in previously constructed community indices (44).

As previously reported in this journal, a study with this cohort found significant associations between family SES and children's health based on the degree of negativity in the parent-child relationship and children's level of physiological reactivity (20). The present study sought to extend that investigation and address a significant gap in prior research by examining the moderating influence of a broad variety of neighborhood conditions, assessed by the newly developed COI, on the concurrent and prospective relations between family SES and children's daily total salivary cortisol secretion and physical health. We evaluated children in fall and spring of the kindergarten year to examine short-term associations (in the fall), as well as potential changes over time (from fall to spring) during an important developmental transition when increasing exposures to contextual conditions outside the home may exert salient effects on health. We hypothesized that higher levels of

neighborhood opportunity would serve as a buffer, attenuating the negative consequences associated with lower family SES on cortisol levels and physical health problems.

Methods

Participants

Participants were drawn from a larger longitudinal research project that evaluated children's biological responses to adversity, physical health, social status, and socioemotional outcomes across the kindergarten year. The sample of 338 children was balanced in terms of gender (48% female), and at entry into kindergarten, the mean age of children was 5.32 years (SD = 0.32, Range = 4.75–6.28). Representative of the geographic area from which children were sampled, participants were ethnically diverse: 19% African American, 11% Asian, 43% European or White, 4% Latino, 22% Multiethnic, and 2% Other. Biological mothers were the majority (87%) of caregivers who provided information on family and child characteristics, with biological fathers (9%), adoptive mothers (2.5%), biological grandmothers (0.6%), and individuals with other relationships with the child (0.9%) comprising the remainder of the sample (all caregivers will be hereafter referred to as parents).

Procedures

Families were recruited in three cohorts during the fall of the kindergarten year (2003, 2004, 2005) from 29 kindergarten classrooms taught by 17 teachers (several teachers participated in successive years of data collection) in six public schools in the San Francisco Bay Area (Oakland, Albany, and Piedmont Unified School Districts). Data were collected from September 2003 through June 2005. Schools were systematically selected to ensure representation of the sociodemographic characteristics of the larger metropolitan region and received $20 per child enrolled in the study. All families fluent in English or Spanish with a child who was a member of a participating classroom were invited to take part in the study.

Data for the current study were collected in the fall and spring of the kindergarten year. Parents' and teachers' informed consent and children's assent to participate were obtained prior to data collection. Parents rated their socioeconomic status in the fall and children's physical health in the fall and spring via home mailings and received $50 for each completed time point. Teacher-completed measures of children's physical health paralleled those completed by parents, and teachers were given $30 for each completed child assessment. This study was approved by the Committee for the Protection of Human Subjects of the University of California, Berkeley, and the Committee on Human Subjects of the University of California, San Francisco. Data on opportunity level for neighborhoods in the San Francisco metropolitan area was accessed through a publicly available, online database (www.diversitydatakids.org; see below for more information).

Measures

Socioeconomic status (SES)

Parent income and education were used to evaluate family-level SES. In the fall, parents reported the total household income from all economic resources on an 11-point scale ranging from *less than $10,000* to *over $200,000* (*M* = $60,000–$70,000, *Mdn* = $80,000–$99,0000). Parents were also asked the level of educational attainment for the primary caregiver and partner/secondary caregiver in the household on a 6-point scale that ranged from *less than a high school degree* to *professional/graduate degree* and highest level of education of either caregiver was used for the present analyses. Reflective of educational attainment in the San Francisco Bay area, 75% of parents had earned a college degree or more. In the current study, the total household income and highest educational level (whether from the primary caregiver or partner/secondary caregiver) were standardized and then averaged to measure family SES.

Neighborhood opportunity

Neighborhood opportunity was assessed using the Child Opportunity Index (COI), a measure developed by researchers at Brandeis University and Ohio State University to evaluate risks and resources in a given neighborhood (identified by census tract) within a metropolitan area (44). Census tracts are geographic regions approximately equivalent to the size of a neighborhood that are defined by the United States Census Bureau for the purpose of gathering information about the members of a population (45). The COI yields a relative measure, indicating the level of opportunity for a given neighborhood compared to other neighborhoods within the metropolitan area. The overall neighborhood opportunity score is a composite of 19 indicators (Cronbach's alpha in this sample = 0.91) across three domains relevant to children's health and development: educational opportunity, health and environmental opportunity, and social and economic opportunity (see Table 1; also described in more detail below). Each of the indicators was constructed using data collected from large-scale, nationally representative surveys (e.g., U.S. Census Bureau American Community Survey, U.S. Environmental Protection Agency Toxic Release Inventory). Complete information about the raw data source from which each indicator was constructed and the methods for indicator derivation are available at www.diversitydatakids.org.

Given that many of the components comprising the COI were measured in different units (e.g., distance in miles to a particular resource, percentage of households with a specific risk factor), each indicator was converted into a standardized score (z-score) in order to create each composite. The standardized scores were calculated at the level of the census tract such that all families residing within a specific tract received the same score on a given indicator. Higher standardized scores reflect greater levels of opportunity (i.e., a census tract with a z-score of +1.0 on a given indicator is one standard deviation above the mean on that indicator relative to all other census tracts in the San Francisco metropolitan area). Neighborhood opportunity data were obtained on 321 of the 338 children in the sample; home addresses were not available for 5% of the sample.

As noted above, the COI is composed of three broad domains, each with multiple indicators assessed by census tract within the San Francisco metropolitan area. The domain of *educational opportunity* includes the following eight indicators: Adult educational attainment rate (college and above), school poverty rate, reading proficiency rate, math proficiency rate, preschool/nursery school attendance rate, high school graduation rate, proximity to accredited early education centers, and proximity to early childhood education centers of any type (Cronbach's alpha in this sample = 0.86). The domain of *health and environmental opportunity* was evaluated with the following five indicators: Proximity to healthy food retailers, proximity to toxic release waste sites, volume of toxic release in nearby areas, proximity to parks and open spaces, and housing vacancy rates (Cronbach's alpha in this sample = 0.60). Finally, *social and economic opportunity* domain was measured using the following five indicators: neighborhood foreclosure rate, poverty rate, unemployment rate, public assistance rate, and proximity to employment (Cronbach's alpha in this sample = 0.82).

Daily salivary cortisol secretion

In fall and spring of the kindergarten year, cortisol was sampled from children during the first and last 20 minutes of the school day during morning or afternoon kindergarten classes on three consecutive school days, yielding a total of six collections per time point. Children did not eat or drink during the half hour period prior to sampling and were then provided with cotton rolls to chew until they became saturated. The cotton rolls were deposited in Salivette tubes (Sarstedt, Nümberg, Germany) and frozen at −7°C until they were shipped to the University of Dresden for assay using a commercial immunoassay with chemiluminescence detection (Cortisol Luminescence Immunoassay; IBL-Hamburg, Hamburg, Germany). The detection limit of the assay was 0.41 nmol/l with mean inter- and intrassay variations of 8.5% and 6.1%, respectively. Values over 55 nmol/l were considered unreliable and were discarded (less than 1% of sample met this criteria). Ten children in the fall and seven children in the spring were excluded from analyses due to use of prescription medications with known effects on salivary cortisol levels (e.g., human growth hormone, exogenous glucocorticoids). See Bush et al. (14) for additional details.

Cortisol values were $\log_{10}$-transformed to correct for deviations from normality. The average cortisol values and times of collection were computed across the six samples and using the method of Pruessner and colleagues (46), area under the curve with respect to ground (AUCg) was calculated for each school day and then averaged across the three days to create a single AUCg score that reflects total cortisol output (46). Multiple days of cortisol measurement are recommended over a single day in order to ascertain a more reliable measure of daily cortisol (47, 48). This approach has been previously used in studies with this cohort (14) and other cohorts of children (49). As measured in the present study, AUCg provides a measure of children's chronic HPA arousal during the school day averaged over three school days in fall and spring of the kindergarten year.

In the fall, unadjusted daily and average (days 1 through 3) AUCg values (nmol/l) were as follows: day 1: 1444.63, day 2: 1441.29, day 3: 1458.56, average (days 1 through 3):

1424.76. In the spring, unadjusted daily and average (days 1 through 3) AUCg values (nmol/l) were as follows: day 1: 1413.45, day 2: 1470.31, day 3: 1306.47, average: 1342.58.

Physical health outcomes

Children's physical health was assessed using parallel parent (HBQ-P) and teacher reports (HBQ-T) on the 5-item Global Physical Health subscale of the MacArthur Health and Behavior Questionnaire (50). This includes measures of children's general physical health rated on a scale of 1 (*excellent*) to 4 (*poor*) and physical-health related impairment and distress rated on a scale of 1 (*not at all/none at all*) to 5 (*a great deal*). The HBQ subscales demonstrate good test-retest reliability, discriminant validity, and agreement across informants (51, 52). Previous research has also observed relations between the HBQ physical health subscales and objective measures of health (53) and in the current study, poorer physical health as measured on the HBQ was positively associated with children's school absences due to illness ($r = .42$, $p < .01$). In the fall, Cronbach's alpha was 0.68 on the parent report and 0.84 on the teacher report. In the spring, Cronbach's alpha was 0.73 on the parent report and 0.91 on the teacher report.

A multi-informant index of physical health was created using Principal Component Analyses (PCA) of parent and teacher reported data on the HBQ, as recommended by Kraemer and colleagues (54). The results of the PCA yielded three dimensions: trait (individual differences), informant (reporter characteristics that influence the evaluation), and environment (contextual qualities that shape trait expression). Analyses for the current study used factor scores based on the first (trait) component of the PCA. Thus, children's physical health was measured by a standardized score reflecting common variance shared by parents and teachers, without the potential biases of reporter or environmental influences. Higher scores indicated poorer physical health and health-related functioning.

Statistical Analysis

Participant residential addresses were geocoded in ArcMap 10.3 using the 2010 TIGER/Line street network from the US Census Bureau (https://www.census.gov/geo/maps-data/data/tiger-line.html). Ninety-eight percent (n=313) of addresses were matched to a street segment. For the remaining unmatched addresses (n=8), random number offsets were applied to the street numbers to protect personal information (55) and then entered individually into Google Maps. Resulting locations were manually reviewed to derive the latitude and longitude of appropriate proximity (same census block group) as the original participant address. Latitude and longitude values for all participants were then joined to census tract-level COI data using the spatial join tool in ArcMap 10.3. Within the sample, families were clustered in 92 census tracts that ranged in size from 1 to 60 children.

To account for the clustering of children's family residences at the census tract level, all analyses were conducted in a multilevel modeling framework using SPSS MIXED. Two multilevel models examined the moderating influence of overall neighborhood opportunity on the association between family SES and children's cortisol secretion and between family SES and children's physical health outcomes in fall of the kindergarten year, controlling for gender and ethnicity. Models predicting spring outcomes paralleled those models conducted

for fall outcomes, with the addition of children's fall cortisol or fall physical health outcomes as covariates in order to evaluate the unique prospective effects of contextual resources on our dependent variables of interest. All models that examined cortisol as the dependent variable also controlled for kindergarten class time given relevant influences on the diurnal pattern of cortisol activity. Significant interactions were probed by plotting the association across the range of family SES and child health at 1 standard deviation (SD) above and below the mean for neighborhood opportunity, using coefficients derived from the full model with the full sample and testing for the significance of those slopes (56).

Results

Descriptives of neighborhood risks and resources

Although the primary models evaluated neighborhood opportunity as a continuous variable, overall neighborhood opportunity and domain-specific opportunity scores are also made publicly available as quintiles for San Francisco Bay area census tracts, ranging from very low to very high. As shown in Table 2, the distribution of neighborhood quality level was generally similar across the overall and subdomain-specific opportunity areas in the San Francisco Bay Area, with the exception of the social and economic opportunity area in which fewer participants lived in the highest census tracts. Across the overall and subdomain-specific COI, a large percentage of participants resided in the highest and second-highest quality neighborhoods, however there was good variability in the sample with approximately 20–30% of the sample residing in the lowest and second-lowest quality neighborhoods. Correlations among the overall and subdomains of the COI ranged from $r = .67$ to $r = .94$ (all p's $< .001$). Family SES and the overall COI were correlated $r = .51$ ($p < .001$) and correlations with the COI subdomains were as follows: Educational Opportunity $r = .60$, Health and Environmental Opportunity $r = .40$, and Social and Economic Opportunity $r = .49$ (all p's $< .001$).

Prediction of fall outcomes

Daily salivary cortisol—Family SES interacted with overall neighborhood opportunity to predict children's cortisol in fall of the kindergarten year ($b = .071$, SE = .029, $p = .016$; see Table 3). As shown in Figure 1, lower family SES was associated with higher daily cortisol output only at lower levels neighborhood opportunity ($b = -.097$, SE = .023, $p < .001$). At higher levels of neighborhood opportunity, family SES was not associated with children's daily cortisol output ($b = -.023$, SE = .025, $p = .36$).

Physical health—There was no significant interaction between family SES and the overall measure of neighborhood attributes on children's physical health problems in fall of the school year. Across all cross-sectional models, there was a significant main of effect of family SES on physical health at average levels of neighborhood opportunity whereby lower socioeconomic resources were associated with greater physical health problems (p's ranging from $< .001$ to .003; see Table 3).

Prediction of spring outcomes

Daily salivary cortisol—In contrast to the beginning of the school year, family SES did not interact with overall neighborhood opportunity in the prediction of children's daily cortisol in the spring, controlling for fall. There was a main effect of family SES on children's daily cortisol in the spring, such that lower family SES predicted greater daily cortisol output on average ($p = .030$; see Table 4).

Physical health—Children's physical health in the spring of the kindergarten year was prospectively predicted by an interaction of overall neighborhood opportunity and family SES, controlling for physical health problems in the fall ($b = .279$, SE = .134, $p = .039$; see Table 4). As graphically depicted in Figure 2, lower family SES was associated with poorer spring health only in the context of lower opportunity neighborhoods ($b = -.250$, SE = .105, $p = .018$). There was no association between family SES and children's physical health in neighborhoods characterized by higher levels of opportunity ($b = .042$, SE = .110, $p = .70$).

Discussion

The determinants of health reside not only within the individual, but also within the families and neighborhoods in which individuals live. A significant literature has identified family SES and neighborhood conditions as contextual determinants of the social and economic patterning of health inequalities. Despite the potential for dynamic cross-level associations (10), empirical investigations have generally approached the study of SES-health relations by focusing on the independent contribution of *either* family SES or neighborhood poverty. The current study makes a unique contribution to the extant research by examining the moderating influence of neighborhood-level attributes on the prospective relation between family SES and children's cortisol and physical health during an important maturational stage when children are increasingly exposed to developmental contexts beyond the household environment. Consistent with hypotheses, results indicated that the effect of family SES on children's daily cortisol output and physical health during the transition to kindergarten varied by the qualities of the neighborhood in which families lived. Higher opportunity neighborhoods operated in a protective manner, buffering against the negative consequences of lower family SES on children's daily cortisol in the fall and changes in their physical health problems in the spring.

The potential for neighborhood-level resources to mitigate the negative effects of family-level economic adversity on children's concurrent and prospective health outcomes extends previous research showing main effects of community and family-level SES on mortality and health (31, 57–59). Our findings also complement a recent population-based study in the United States (60) and provide additional support for the potential moderating role of neighborhood attributes. Although not specifically testing an interaction, Chetty et al. found that life expectancy varied more among low-income individuals across metropolitan areas as compared to high-income individuals and suggested that higher neighborhood affluence and education levels may be particularly beneficial for lower income individuals (60). Empirical studies of neighborhood effects on physiological functioning are particularly limited in young children and have primarily been conducted among adolescents and adults using

small samples with limited racial and ethnic heterogeneity (28). Using the unique features of a diverse community sample of children, the present findings suggest that the influence of neighborhood attributes on physiological indicators begins early, and such effects may influence physical and mental health outcomes later in life.

The interactive effects of family SES and neighborhood opportunity on children's cortisol and physical health were examined both cross-sectionally and longitudinally, and the pattern of findings differed across the school year. In models predicting children's daily cortisol and physical health in the fall, family SES interacted with neighborhood opportunity in the prediction of daily cortisol but not physical health. Specifically, lower family SES was associated with higher cortisol when children resided in lower opportunity neighborhoods, and there was no association between family SES and fall cortisol for children who resided in higher opportunity areas. Although there was not a significant interaction between family SES and neighborhood attributes in the prediction of fall physical health, there was a main effect such that lower SES at the level of the household was associated with poorer health, as expected given a previous investigation using this sample of children (14).

In spring of the kindergarten year, children reared in low SES family environments evidenced greater increases in cortisol (controlling for fall levels), however neighborhood opportunity did not moderate this association as it had earlier in the year. Such results are aligned with prior research among adults that failed to find consistent associations between neighborhood attributes and changes in cortisol over time (26), as well as research suggesting that the environmental influences on children's cortisol activity may vary across the course of the school year (61). However, there was a significant interaction between family SES and neighborhood opportunity in the prediction of spring physical health. Higher opportunity neighborhoods attenuated the prospective negative influence of family SES on changes in children's physical health problems, mirroring the pattern observed for cortisol in the fall. Lower family SES was associated with decreases in health quality for children who resided in lower opportunity neighborhoods, but there was no association between family SES and changes in children's physical health problems among children who lived in neighborhoods with higher levels of opportunity. In sum, the moderating influence of neighborhood attributes was evident on children's cortisol output in the shorter-term and changes in physical health in the longer-term.

The investigation of longitudinal socioeconomic influences on young children's health is important for several reasons. Research on family economic disadvantage suggests its effects may be particularly deleterious during the early years of life, contributing to SES-driven differences in lifespan health outcomes that actually widen over time (19). Dysregulated HPA axis functioning has been associated with a range of negative physical health outcomes (62, 63), and, in the current study, the pattern of significant interactions on children's concurrent cortisol and prospective changes in physical health outcomes across the course of the kindergarten year is suggestive of a physiological pathway through which neighborhood disadvantage may exert its health effects. Exposure to the stress and adversity that is associated with low socioeconomic contexts may induce dysregulation of the cortisol response, which in turn, elevates risk for later physical health problems. Although examination of cortisol as an explanatory variable (i.e., a multilevel mediated moderation

model) is beyond the scope of the current study, the pattern of correlations between children's daily cortisol in the fall and greater health problems in the spring ($r = .19$, $p = .002$; partial correlation $r = .13$, $p = .067$ when adjusting for fall health) suggests a potential pathway to be examined within future research of more complex models. Results of the current study may also reflect differences in the timing through which early adverse exposures exert their influence on physiological and physical health. Stress effects on the HPA axis may be more immediate, while stress-related physical health problems may take longer to emerge (5).

The current study is notable for its developmental focus and the use of a comprehensive indicator of neighborhood opportunity. We specifically examined changes in physiological and physical health among children's across the kindergarten year, which is important because entry into the new physical setting of school may bring exposures that increases risk for sickness (64). As poorer physical health may negatively affect children's social and academic functioning during the elementary years (65), identification of factors that heighten or diminish risk for early life health problems can support a healthier course across multiple developmental outcomes of interest. The breadth of COI neighborhood quality indicators across educational, health, environmental, and socioeconomic domains broadens previous neighborhood deprivation research that has been disproportionately focused upon community poverty levels. Our findings highlight a potential protective role for other physical and material characteristics of communities. Results suggest that infusing a neighborhood with resources across various domains could influence the negative effect of a family's economic status on offspring health. Illustratively, new efforts are being put forth to embed supportive social services, increase neighborhood safety, improve the housing quality, and redesign parks and open spaces within rehabilitated housing communities (e.g., hope-sf.org), and the present results suggest that such activities stand to offer physiological and physical health benefits to the youngest residents. We primarily interpreted our findings in the context of a protective model given the emphasis of the COI on beneficial neighborhood attributes (indicators of *opportunity*). However, the nature of the index is such that lower levels of neighborhood resources may confer heightened risk. Within our sample, the highest cortisol levels and greatest physical health problems were observed among children reared in lower SES families *and* lower opportunity neighborhoods. The interaction of low resources across family and neighborhood contexts may create a "double jeopardy" effect that significantly increases the likelihood of poor health outcomes as compared to when risk is limited to one environment (66).

It is important to consider the mechanisms by which family SES interacts with neighborhood opportunity levels to influence multiple indicators of children's health. More disadvantaged communities with fewer neighborhood resources may be associated with lower levels of perceived safety (67) and more health-compromising behaviors (68), factors that have been associated with greater physiological risk, allostatic load, and poorer health among adults (4, 69, 70). Conversely, higher quality communities may provide greater access to health-promoting resources and encourage health-promoting behaviors (e.g., exercise, fruit and vegetable consumption, participation in organized social and recreational activities), attenuating the negative consequences associated with diminished socioeconomic resources within the household. Research has also identified the positive health influence of

neighborhood collective efficacy (71, 72), described as a type of social capital that leverages cohesion among community members and a shared willingness to intervene for the greater good of the neighborhood (73). Though it is not dependent upon it, neighborhood collective efficacy has been associated with neighborhood affluence (73) and may be greater among higher opportunity areas as identified by the COI. To the degree that lower SES parents who reside in higher opportunity neighborhoods derive social support and benefit from the collective, cooperative efforts of community members to promote a healthy environment, the negative relation between parental SES and children's physiological and physical health may be attenuated. Future research may benefit from examining the role of collective efficacy as a potential "active ingredient" in the moderating influence of neighborhood resources on the family SES-children's health association.

There are several limitations to consider in regards to the present study. In the San Francisco Bay Area, there is a unique distribution of wealth at the individual and neighborhood levels. For example, growth of the technology sector in recent decades has led to significant increases in the affluence of various neighborhoods in the Bay Area, and many low-income homeowners in once disadvantaged communities have witnessed rapid improvements in the quality of their neighborhood. Moreover, the multitude of high-wage earners in the region has impacted the housing market and shifted neighborhood affordability for individuals across the SES gradient. Importantly, the COI takes this into account, as values are calculated *relative* to the larger San Francisco metropolitan area, rather than relying on national norms. Although we interpret the specificity to the study's geographic region as a unique contribution of the current study, results may not generalize to other geographic areas in the United States.

This study was originally designed to test relations among family environment factors, school conditions, and children's physical and psychological health. The resulting design presented some limitations for the study of neighborhood effects, including uneven distribution of families across census tracts. The number of families who resided in a given census tract ranged from 1 to 60, and approximately half of the census tracts only had one family from the sample residing within its boundaries. Future research that includes a more rigorous neighborhood sampling strategy is warranted. Our measure of children's cortisol activity across multiple school days rather than a single day strengthened our assessment, and differences in the interactive effects of family SES and neighborhood quality on children's cortisol in fall and spring may reflect true changes across the course of the school year. However, there is some research to suggest that daily cortisol output is fairly state-like in nature, with substantial day-to-day variability that requires highly intensive, repeated annual assessments to capture its trait-like features (74). Future research may wish to employ an even more frequent sampling strategy to examine longer-term trends between neighborhood exposures and cortisol. We conducted separate models to evaluate the interactive effects of family SES and neighborhood resources on four independent outcomes, which increased the possibility of Type I error. However, the consistent pattern of an attenuating effect of neighborhood resources lends credence to the validity of our findings.

Finally, it is possible that the processes modeled in the present study may be attributed to selection biases (i.e., personal preferences and structural or economic external limitations

that lead individuals to select or be sorted into specific neighborhoods) rather than to the influence of neighborhood conditions, particularly since data collection and analysis were not specifically designed for a study of neighborhood effects (75). However, post-hoc analyses (results not presented here) did not reveal differences between lower SES families residing in higher and lower opportunity areas in terms of number of hours offspring spent in childcare, enrollment of children in preschool, exposure to parental depression, rates of home ownership, and other factors that may be relevant to children's health. Moreover, by controlling for children's physical health status in fall of the kindergarten year, our models may have also captured the effects of many of these selection factors. Thus, selection processes do not appear to explain the moderating influence of neighborhood quality observed in the present study.

Exposure to conditions of economic disadvantage may compromise children's physiological and physical health, with effects that persist across the lifespan. Research directed towards understanding modifiable factors that can attenuate this negative relation offers targets of intervention to promote health and well-being among at-risk populations. Using a population-level measure of neighborhood *opportunity* (the COI), the current study revealed the moderating role of community attributes on the relation between family SES and children's cortisol and physical health in kindergarten. During the kindergarten year, lower family SES was associated with higher daily cortisol in fall and decreases in health in spring only among children residing in lower quality neighborhoods; there was no relation of family SES to children's cortisol and physical health in the context of more resource-rich communities. The buffering role of better quality neighborhoods was observed across an overall composite of neighborhood opportunity that reflected educational, health/environmental, and social/economic resources, extending prior research that has predominantly focused more narrowly upon the influence exerted by a community's socioeconomic resources. Results of the present study offer support for neighborhood-level interventions in improving population health, and suggest that bolstering the quality of a variety of different physical, social, and educational community attributes may positively influence the physiological functioning and health among children reared in low SES family environments

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Abbreviations

SES	socioeconomic status
COI	Childhood Opportunity Index

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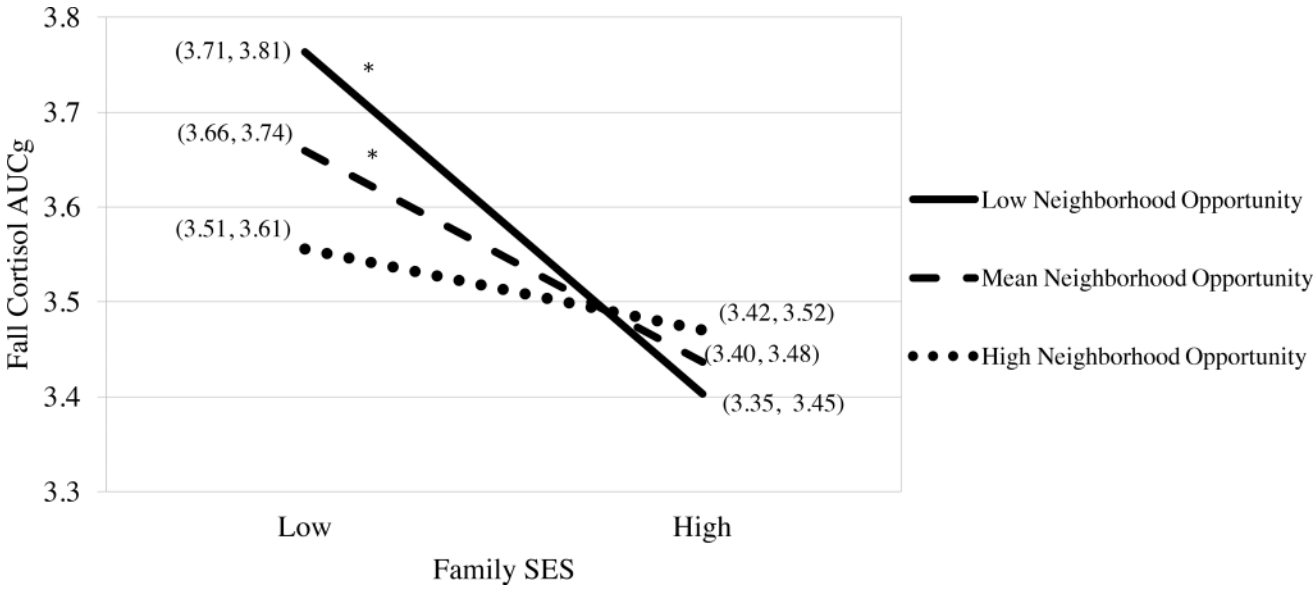

Figure 1.

Association between family SES and children's cortisol expression in the fall at low (−1 SD), mean, and high (+1 SD) levels of neighborhood opportunity.

Note. 95% CI in parentheses. *p < .05

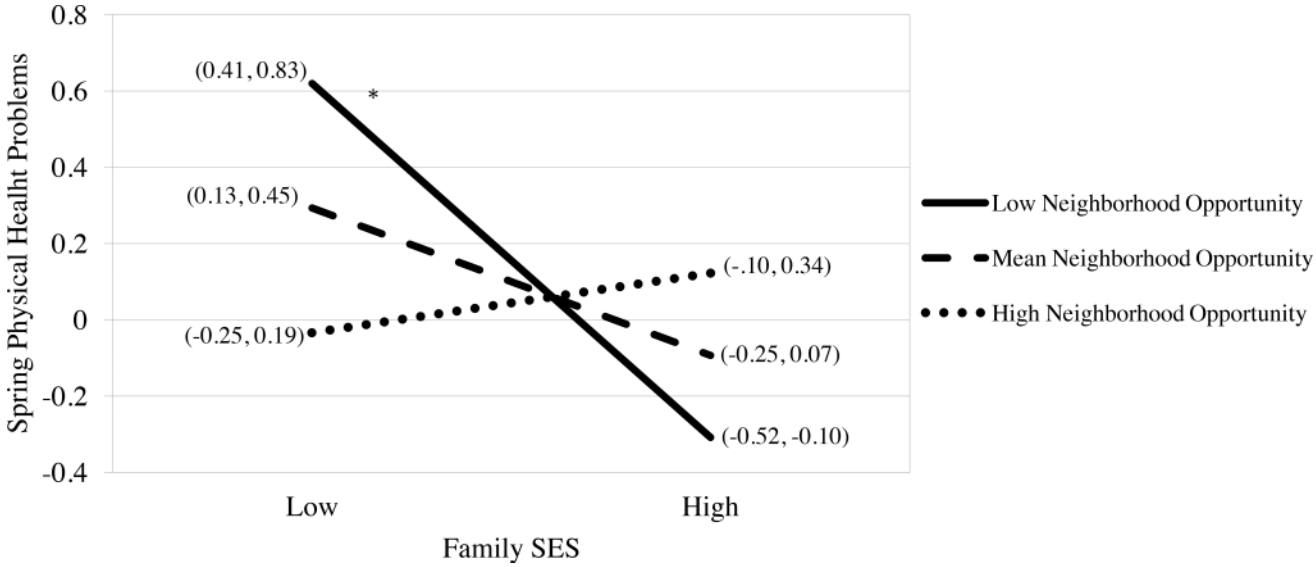

Figure 2.

Prospective association between family SES and children's physical health in the spring at low (−1 SD), mean, and high (+1 SD) levels of neighborhood opportunity, controlling for physical health in the fall

Note. 95% CI in parentheses. *p < .05

Table 1

Opportunity indicators in the Child Opportunity Index

Domain	Indicators
Educational Opportunity	School poverty rate (eligible for free or reduced-price lunch)
	Student math proficiency level
	Student reading proficiency level
	Proximity to licensed early childhood education centers
	Proximity to high-quality early childhood education centers
	Early childhood education participation
	High school graduation rate
	Adult educational attainment
Health and Environmental Opportunity	Retail healthy food environment
	Proximity toxic waste release sites
	Volume of nearby toxic waste release
	Proximity to parks and open spaces
	Housing vacancy rate
	Proximity to health care facilities *
Social and Economic Opportunity	Foreclosure rate
	Poverty rate
	Unemployment rate
	Public assistance rate
	Proximity to employment

* Removed from domain-specific analyses due to lack of congruency with other measures Adapted from: Acevedo-Garcia, McArdle (44)

Table 2

Childhood Opportunity Index distribution of neighborhoods in the current study (n = 321)

	Overall (%)	Educational (%)	Health/Environment (%)	Social/Economic (%)
Very low[a]	18.7	20.9	15.9	16.2
Low	9.7	10.9	7.8	10.0
Moderate	10.0	5.6	12.5	15.9
High	15.3	12.5	16.2	37.4
Very high	46.4	50.2	47.7	20.6

[a]Categories based on quintiles (e.g., very low = lowest 20% relative to other neighborhoods, very high = highest 20% relative to other neighborhoods)

Table 3

Multilevel modeling of children's cortisol and physical health in the fall as a function of parental SES, neighborhood opportunity, and their interaction, adjusting for relevant covariates (n = 321)

	Fall Cortisol			Fall Physical Health		
Fixed effects	**Coefficient**	**SE**	***p***	**Coefficient**	**SE**	***p***
Gender	.035	.024	.13	−.178	.110	.11
Ethnicity	.086	.027	.002	.156	.123	.21
Class time	−.009	.018	.64		--	
Parent SES	−.069	.032	< .001	−.247	.082	.003
Neighborhood Opportunity	−.019	.033	.58	.174	.137	.20
Parent SES x Neighborhood Opportunity	.071	.029	.016	.105	.126	.40

Note. Gender coded as 0 = Male, 1 = Female; Ethnicity coded as 0 = Caucasian, 1 = Non-Caucasian; SES = Socioeconomic status

Table 4

Multilevel modeling of children's cortisol and physical health in the spring as a function of parental SES, neighborhood opportunity, and their interaction, adjusting for relevant covariates (n = 321)

	Spring Cortisol			Spring Physical Health		
Fixed effects	**Coefficient**	**SE**	***p***	**Coefficient**	**SE**	***p***
Fall Baseline	.610	.054	< .001	.556	.049	< .001
Gender	−.016	.020	.43	.036	.098	.71
Ethnicity	−.009	.024	.72	−.178	.106	.098
Class time	−.056	.016	.001		--	
Parent SES	−.037	.017	.030	−.140	.083	.094
Neighborhood Opportunity	−.036	.028	.23	.083	.206	.69
Parent SES x Neighborhood Opportunity	.023	.028	.42	.279	.134	.039

Note. Gender coded as 0 = Male, 1 = Female; Ethnicity coded as 0 = Caucasian, 1 = Non-Caucasian; SES = Socioeconomic status