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The association between cortisol and neighborhood disadvantage in a U.S. population-based sample of adolescents ☆

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ABSTRACT

The association between neighborhood conditions and cortisol is rarely studied in children or adolescents and has been hampered by small sample size and racial/ethnic and geographic homogeneity. Our objective was to estimate the association between neighborhood disadvantage and salivary cortisol levels in a large, geographically and racially/ethnically diverse sample of adolescents from the National Comorbidity Survey Replication Adolescent Supplement. Salivary cortisol was collected before and after an interview administered in the adolescent's home. We used a propensity score approach to match adolescents living in disadvantaged neighborhoods with those in non-disadvantaged neighborhoods to create two similar groups based on the time and day of cortisol collection as well as demographic characteristics. Adolescents living in disadvantaged neighborhoods had higher pre-interview cortisol levels and steeper rates of decline in cortisol levels over the course of the interview than similar adolescents in non-disadvantaged neighborhoods. This bolsters the evidence base suggesting that place may influence the stress response system.

1. Introduction

Place may influence health through several pathways; stress is one potential mediator that is frequently invoked (Diez Roux and Mair, 2010, Anisman and Zacharko, 1992). For example, living in a blighted urban neighborhood may increase exposure to stressors such as violence, noise, and crowding. These exposures may elicit repeated activations of the stress response system, which in turn may lead to eventual dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, a primary stress regulatory system. HPA axis dysregulation has been associated with a range of mental, cardiovascular, immunologic, and metabolic disorders (Anisman and Zacharko, 1992, Seeman et al., 2004). Although recent studies have found associations between neighborhood conditions and stress biomarkers (Bird et al., 2010; Chen and Paterson, 2006; Do et al., 2011; Nazmi et al., 2010), there has been limited research on links between neighborhood conditions and stress biomarkers in children or adolescents.

Cortisol is a hormone involved in the HPA axis (McEwen, 2007) that has been used in several contexts. Adverse conditions in neighborhood and family environments have been linked to both cortisol levels and cortisol reactivity, although the evidence is mixed. In adults, some studies have yielded associations between neighborhood- and individual-level low socioeconomic status (SES) and cortisol diurnal levels—specifically lower waking levels (Hajat et al., 2010), higher average levels (Cohen et al., 2006b, 2006a), and less steep declines over the course of the day (Do et al., 2011; Hajat et al., 2010; Agbedia et al., 2011; Karb et al., 2012), though others have found null or opposite results (Agbedia et al., 2011; Cohen et al., 2006a; Hajat et al., 2010). Do et al. also found that neighborhood violence was associated with lower cortisol levels at awakening and less steep initial declines

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(Do et al., 2011). In children, studies have reported associations between individual-level disadvantage (including low SES, exposure to stressful life events, and family adversity) and lower morning cortisol levels (Bevans et al., 2008; Repetti et al., 2002), higher average cortisol levels (Bevans et al., 2008; Fernald and Gunnar, 2009; Kelly et al., 2008; Repetti et al., 2002), and less steep declines (Kelly et al., 2008; Gustafsson et al., 2010; Martin et al., 2012). In addition, some have suggested a curvilinear (upside-down u-shaped) association; children and adolescents exposed to the most stressful conditions have cortisol levels that resemble those of non-disadvantaged individuals (Bevans et al., 2008; Gustafsson et al., 2010).

The link between individual- and neighborhood-level adverse conditions and cortisol reactivity is likely complex. Some studies have shown that adverse conditions in childhood are associated with greater cortisol reactivity in adulthood (Goldman-Mellor et al., 2012; Pesonen et al., 2010; Mangold et al., 2010), but lifetime adversity is associated with blunted reactivity (Goldman-Mellor et al., 2012; Lovallo et al., 2012). Others have found no association (Steptoe et al., 2005). Relatedly, moderate adversity has been associated with heighted reactivity in children and adolescents (Gutteling et al., 2005; Repetti et al., 2002), whereas more severe forms of adversity, such as prolonged child maltreatment, has been associated with blunted reactivity (MacMillan et al., 2009). The timing and duration of exposure to adverse conditions may also be influential (Bosch et al., 2012; Steptoe et al., 2005).

The evidence for an independent association between adverse neighborhood conditions and salivary cortisol in adolescents is extremely limited. Studies conducted to date provide preliminary evidence that neighborhood disadvantage is associated with higher average resting cortisol levels (Brenner et al., 2012; Chen and Paterson, 2006) and greater cortisol reactivity (Hackman et al., 2012). However, the studies have been based on small, racially homogeneous samples in single urban areas (Chen and Paterson, 2006; Brenner et al., 2012; Hackman et al., 2012). The present study was motivated to address this gap in the literature. We used the National Comorbidity Survey Replication Adolescent Supplement (NCS-A) to estimate the association between neighborhood disadvantage and salivary cortisol levels in adolescents. The NCS-A consists of a nationally representative, ethnically diverse sample of adolescents in the United States. Cortisol measurements are available for 2490 of the adolescents, making it the largest sample of cortisol in U.S. children or adolescents. Our analyses of these data utilize a propensity score approach coupled with regression adjustment designed to address a key threat to internal validity—non-random neighborhood assignment and consequent imbalance of confounding variables, including those particularly influential to cortisol measurement.

2. Methods

2.1. Study sample

The NCS-A is a nationally representative, cross-sectional survey of U.S. adolescent mental health. The background, design, sampling, and field procedures are presented elsewhere (Kessler et al., 2009b, 2009a, 2009c; Merikangas et al., 2009). Participants aged 13–17 were recruited from a dual-frame sample consisting of household and school subsamples. Face-to-face, computer-assisted interviews (which included a modified Composite International Diagnostic Interview) were conducted in the adolescent's home by professional interviewers from the Survey Research Center at the Institute for Social Research at the University of Michigan. The interviews took place between February 2001 and January 2004. While the adolescent was interviewed, his/her parent or parent surrogate was given a self-administered questionnaire. A short-form version of the questionnaire was administered to parents who did not complete the long-form version. Each participating adolescent and his/her parent or guardian provided informed assent and consent. Recruitment and consent procedures were approved by the Human Subjects Committees of Harvard Medical School and the University of Michigan.

2.2. Contextual measures

2.2.1. Neighborhood disadvantage

The Survey Research Center at the Institute for Social Research at the University of Michigan geocoded residential addresses to U. S. Census tracts. Neighborhood SES, defined at the Census tract level, is a summary measure created by Diez-Roux et al. (2001) that has been used previously (Diez Roux et al., 2004; Henderson et al., 2005; Borrell et al., 2006; Nordstrom et al., 2007). We defined neighborhoods in the lowest SES tertile as disadvantaged, and those in the middle and upper tertiles as non-disadvantaged.

Neighborhood SES is made up of six indicators from the U.S. Census Short Form 3 (SF3): log median household income; % households with interest, dividend, or rental income; log median value of housing units; % persons over age 25 with high school degree; % persons over age 25 with college degree; % persons in executive, managerial, or professional specialty occupations (Diez-Roux et al., 2001). The normally distributed summary score results from summing the z-score of each indicator. In the NCS-A sample, the summary score has a median value of -0.36 (range: -13.6, 17.8) and a Cronbach's α of 0.83.

2.3. Individual measures

2.3.1. Outcome measures

Cortisol levels in ng/mL were measured using saliva samples. Saliva samples were collected in a salivette by passive drool after the participant chewed on a piece of sugarless gum immediately before and after the interview, while the interviewer was present. The interviewer's laptop automatically recorded the time and date of each sample collection, and interviews lasted an average of 146 min (standard deviation: 32 min, range: 28–237 min, interquartile range: 124–169 min). Salivettes were treated with sodium azide at Harvard University, centrifuged, and pre-labeled with subject identification numbers and study information prior to sample collection. After collection, samples were mailed to NIH where they were stored at $-80\,^{\circ}$C until testing. Quantification of cortisol levels was done by a radioimmunoassay (Siemens Diagnostic). The sensitivity of the assay was 0.0165 ng/mL. Intra- and inter-assay coefficients of variation were 5.4% and 26.0%, respectively. Similar coefficients of variation for this method have been reported previously (Wirth et al., 2006).

We examined three outcomes in the present study: (1) point-in-time pre-interview cortisol level, (2) point-in-time post-interview cortisol level, and (3) cortisol rate of change (slope) over the course of the interview, calculated as the difference in post versus pre-interview levels divided by the length of the interview in hours. These outcomes do not directly map onto specific HPA axis dimensions. For example, a Trier stress test (Kirschbaum et al., 1993) measures stress reactivity, but such a test was deemed inappropriate for children by the NCS-A investigators. Instead, pre- and post-interview samples measure cortisol in slightly different naturalistic settings. In the case of the pre-interview sample, the adolescent is interrupted from his/her normal routine for the interview (the adolescent may have been active—not sitting quietly), and the adolescent is anticipating the new experience of being interviewed by a stranger as part of a survey of mental health. In the case of the post-interview sample,