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Examining the cross-sectional and longitudinal association between diurnal cortisol and neighborhood characteristics: Evidence from the multi-ethnic study of atherosclerosis

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ABSTRACT

We examined cross-sectional and longitudinal associations between neighborhood socioeconomic status, social cohesion and safety and features of the diurnal cortisol curve including: area under the curve (AUC), wake-to-bed slope, wake-up, cortisol awakening response (CAR, wake-up to 30 min post-awakening), early decline (30 min to 2 h post-awakening) and late decline (2 h post-awakening to bed time). In cross-sectional analyses, higher neighborhood poverty was associated with a flatter early decline and a flatter wake-to-bed slope. Higher social cohesion and safety were associated with higher wake-up cortisol, steeper early decline and steeper wake-to-bed slope. Over 5 years, wake-up cortisol increased, CAR, early decline, late decline and wake-to-bed slope became flatter and AUC became larger. Higher poverty was associated with less pronounced increases in wake-up and AUC, while higher social cohesion was associated with greater increases in wake-up and AUC. Adverse neighborhood environments were cross-sectionally associated with flatter cortisol profiles, but associations with changes in cortisol were weak and not in the expected direction.

1. Introduction

Research has found that residents of more deprived neighborhoods have poorer health on multiple domains, including mental health and a range of chronic diseases (Diez Roux and Mair, 2010).

The stress pathway is one mechanism that may partly explain these findings. Psychosocial (violence, poor social cohesion) and physical environment (poor quality housing, lack of green space) stressors may be more frequently experienced by residents of deprived neighborhoods. Individuals who experience stress may adopt unhealthy behaviors, such as increased alcohol or tobacco consumption, unhealthy diets, or sedentary lifestyles, all of which have health consequences. In addition, neighborhood stressors may activate the hypothalamic–pituitary–adrenal axis (HPA), as well as other biological systems, with a range of physiological consequences.

Although a number of studies have examined how neighborhoods are related to behaviors (Diez Roux and Mair, 2010) fewer have directly examined the stress pathway. To date, most observational studies on neighborhoods and cortisol have employed a cross-sectional study design (Brenner et al., 2013; Chen and Paterson, 2006; Do et al., 2011; Karb et al., 2012; Roe et al., 2013; Rudolph et al., 2014) and have examined neighborhood socioeconomic status (NSES) as the main characteristic of interest (Brenner et al., 2013; Chen and Paterson, 2006; Dulin-Keita et al., 2012; Rudolph et al., 2014). To our knowledge, few studies have looked beyond NSES at other neighborhood social and physical characteristics like violence, social support and green space (Do et al., 2011; Karb et al., 2012; Roe et al., 2013) and only one has

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used a longitudinal approach (Dulin-Keita et al., 2012).

We used unique longitudinal data on daily cortisol profiles from a population sample to examine how neighborhood factors were related both to levels of cortisol and to longitudinal changes in cortisol. It is thought that the process of aging itself impacts cortisol rhythms, an indication of the natural wear and tear on the HPA (Karlamangla et al., 2013; Wang et al., 2014). Evaluating how additional chronic stressors, such as neighborhood factors, impact HPA functioning over time will contribute to our understanding of the relationship between stress and health. The neighborhood characteristics of interest in our study were measures of neighborhood socioeconomic status as well as safety and social cohesion. We investigated the following research questions: (1) Are stressful neighborhoods cross-sectionally associated with daily cortisol profiles? (2) Are neighborhood characteristics associated with changes in cortisol profiles over a five year period?

Daily cortisol patterns experience a sharp rise during the first 30–45 min after awakening, called the cortisol awakening response (CAR), followed by a gradual decline over the remainder of the day reaching the lowest point before bedtime (eFigure 2). Given this distinct pattern, we examine four pieces of the cortisol curve: wake up cortisol, CAR, early decline (slope between 30 min and 120 min after wake up) and late decline (slope between 120 min and bed time). We also examine two summary measures: the wake to bed slope and the area under the curve (AUC). As supported by existing evidence, we hypothesized neighborhood disadvantage, measured by higher poverty, less social cohesion and less safety, would be associated with lower wake up cortisol, steeper CAR, flatter early decline, late decline and wake to bed slope, and larger AUC (Do et al., 2011; Karb et al., 2012). We also hypothesized that changes associated with aging would be exacerbated in adverse neighborhood environments.

2. Methods

We used data from the Multi-Ethnic Study of Atherosclerosis (MESA). MESA, a longitudinal cohort study of cardiovascular disease (CVD), sampled 6814 CVD-free men and women age 44–84 years from six US sites. A baseline examination was held from 2000–2002 and four follow up exams from 2002–2012 (Bild et al., 2002).

The MESA Stress Study is an ancillary study that collected detailed measures of stress hormones at two time periods. MESA Stress Study I collected data over the third and fourth examination of the MESA parent study (2004–2006) from participants in the New York and Los Angeles study sites, ($n=$ 1002). Six salivary cortisol samples were collected per day over three weekdays, resulting in 18 samples per participant. Cortisol was measured immediately after waking but before getting out of bed, 30 min later, around 1000 h (h), around 1200 h, around 1800 h and before bed.

A follow up to Stress Study I was conducted from 2010–2012, in conjunction with MESA exam 5. Stress Study II recruited participants from Stress Study I, new participants at each of the two Stress I sites and participants from the Baltimore study site ($n=1082$). Stress Study II collected eight saliva samples over two days (16 samples): upon awakening but before getting out of bed, 30 min later, 1 hour after breakfast, around 1000 h, at noon, around 1600 h, around 1800 h and before bed. There were 514 participants who contributed to both Stress studies, with a maximum of 34 samples over 5 days available for analysis. Institutional review board approval was granted at each study site and written informed consent was obtained from participants.

2.1. Cortisol

Saliva samples were collected using Salivette collection tubes and stored at −20 °C until analysis. Before biochemical analysis, samples were thawed and centrifuged at 3000 rpm for three minutes to obtain clear saliva with low viscosity. Salivary cortisol levels were determined by employing a commercially available chemi-luminescence assay (CLIA) with a high sensitivity of 0.16 ng/mL (IBL-Hamburg; Germany). Intra- and inter-assay coefficients of variation were below eight percent. All samples were assayed at a central laboratory in Dresden, Germany. Cortisol was measured in nmol per liter and log transformed for analysis.

2.2. Neighborhood features

Various features of neighborhoods were obtained by another ancillary study, the MESA Neighborhood Study. During 2003–2005, a total of 6191 MESA participants were enrolled in the Neighborhood ancillary study (91% of baseline sample).Socioeconomic indicators from the US Census and survey-based assessments of the social environment were assigned to each participant. Participant's home addresses at time of Stress Studies I and II were geocoded using the TeleAtlas geocoding software (TeleAtlas Lebanon, NH) which assigned each address to a census tract (Census 2000 boundaries), a proxy for neighborhood of residence.

2.2.1. Neighborhood socioeconomic status

Neighborhood socioeconomic status was accessed using data from the American Community Survey (ACS) 2005–2009 (Stress I) and ACS 2007–2011 (Stress II). Measures utilized were percent of persons below poverty level, median household income, percent of unemployed persons 16 years and older and median value of housing units. In addition, a summary measure of socioeconomic status (SES) was derived from principal components analysis (PCA); 16 census variables were included in the PCA and results yielded a summary index that included 6 indicators of household income, wealth, poverty, employment and housing. More information on the NSES index can be found elsewhere (Hajat et al., 2013; Moore et al., 2013). All NSES indicators were measured at the census tract level.

2.2.2. Social cohesion and safety

Questionnaires on neighborhood characteristics were administered to a random sample of residents living in selected census tracts where MESA Stress I participants resided in New York and Los Angeles in 2006–2008, referred to as Community Survey II. Responses from Community Survey II were used to create the social cohesion and safety measures corresponding to Stress I. A similar survey was administered to another random sample of residents living in selected census tracts where MESA participants lived from all six MESA study sites in 2011–2012, referred to as Community Survey III. In addition, the same survey was administered to the MESA participants at Exam 5 in 2010–2012. The responses from Community Survey III and MESA Exam 5 were combined to increase sample size in creating the survey based measures for Stress II.

On the basis of a conceptual model (Diez Roux, 2003) and prior work (Echeverria et al., 2004), safety and social cohesion were selected as the relevant survey based measures (see eAppendix for questions). Safety was derived from a 3 item scale and social cohesion from a 4 item scale and responses for each item of the scale ranged from 1 (strongly agree) to 5 (strongly disagree). Scales were based on previous work (Mujahid et al., 2007) and have acceptable internal consistency (Cronbach alpha 0.64–0.82). Conditional empirical Bayes (CEB) estimates were derived for each census tract