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Neighborhood socioeconomic status predictors of physical activity through young to middle adulthood: The CARDIA study

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ABSTRACT

Neighborhood socioeconomic status (SES) is related to a wide range of health outcomes, but existing research is dominated by cross-sectional study designs, which are particularly vulnerable to bias by unmeasured characteristics related to both residential location decisions and health-related outcomes. Further, little is known about the mechanisms by which neighborhood SES might influence health. Therefore, we estimated longitudinal relationships between neighborhood SES and physical activity (PA), a theorized mediator of the neighborhood SES-health association. We used data from four years of the Coronary Artery Risk Development in Young Adults (CARDIA) study ($n = 5115$, 18–30 years at baseline, 1985–1986), a cohort of U.S. young adults followed over 15 years, and a time-varying geographic information system. Using two longitudinal modeling strategies, this is the first study to explicitly examine how the estimated association between neighborhood SES (deprivation) and PA is biased by (a) measured characteristics theorized to influence residential decisions (e.g., controlling for individual SES, marriage, and children in random effects models), and (b) time-invariant, unmeasured characteristics (e.g., controlling for unmeasured motivation to exercise that is constant over time using repeated measures regression modeling, conditioned on the individual). After controlling for sociodemographics (age, sex, race) and individual SES, associations between higher neighborhood deprivation and lower PA were strong and incremental in blacks, but less consistent in whites. Furthermore, adjustment for *measured* characteristics beyond sociodemographics and individual SES had little influence on the estimated associations; adjustment for *unmeasured* characteristics attenuated negative associations more strongly in whites than in blacks.

Introduction

Neighborhood socioeconomic status (SES) such as census-tract level poverty or composite measures are consistently associated with numerous health outcomes, including mortality (Subramanian, Chen, Rehkopf, Waterman, & Krieger, 2005), general health (Do, 2009), and cardiovascular disease (Diez Roux, Merkin, et al., 2001). Theorized mechanisms by which neighborhood SES influences health (Diez Roux, 2007; R.J. Sampson, Morenoff, & Gannon-Rowley, 2002) include mediation by health behaviors through inequitable access to physical activity (PA) opportunities, healthy foods, or health care (structural perspective) or through establishment of social norms (contagion perspective) (Ross, 2000), or direct, cumulative biological effects of chronic stress (Cox, Boyle, Davey, Feng, & Morris, 2007; Merkin, Basurto-Davila, Karlamangla, Bird, Lurie, Escarce et al., 2009). While there is an international literature on this topic (e.g., (Boyle, Norman, & Rees, 2002; Curtis, Setia, & Quesnel-Vallee, 2009)), we focus on the U.S., given our study population and the nature of the research question in a U.S. context.

Existing research largely focuses on the influence of neighborhood exposures on broader health outcomes (e.g., neighborhood poverty as a predictor of mortality), rather than on health behaviors (e.g., neighborhood poverty as a predictor of physical activity [PA]). Physical inactivity and obesity are key outcomes related to neighborhood SES (Do et al., 2007; Lee, Cubbin, & Winkleby, 2007; Wen &

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Zhang, 2009) and in countries like the U.S. exhibit dramatic racial and socioeconomic disparities (Gordon-Larsen, McMurray, & Popkin, 1999; Ogden et al., 2006) which may result in part from differences in structural (e.g., built environment) (Gordon-Larsen, Nelson, Page, & Popkin, 2006; Moore, Diez Roux, Evenson, McGinn, & Brines, 2008), contagion, or stress-related factors. While neighborhood SES and physical fitness at a single time point has been examined using the U.S.-based Coronary Artery Risk Development in Young Adults (CARDIA) Study (Shishehbor, Gordon-Larsen, Kiefe, & Litaker, 2008), PA is a modifiable behavior that is amenable to intervention, whereas fitness is influenced by physiological factors.

Additionally, a major limitation of existing research examining neighborhood influences on health and related behaviors is potential bias resulting from self-selection into neighborhoods (Boone-Heinonen, Gordon-Larsen, Guilkey, Jacobs, & Popkin, 2011; Diez Roux, 2004; Oakes, 2004; van Lenthe, Martikainen, & Mackenbach, 2007). Briefly, factors such as financial resources and household structure (e.g., marital status, children) influence not only where people are able (through affordability or other constraints) or prefer to live (Clark & Ledwith, 2007; Geist & McManus, 2008; Lund, 2006), but also health behaviors (Bell & Lee, 2005; Yannakoulia, Panagiotakos, Pitsavos, Skoumas, & Stafanadis, 2008) and outcomes (Gordon-Larsen, Adair, & Popkin, 2003; Sobal, Rauschenbach, & Frongillo, 2003). Without accounting for factors which influence residential mobility or location decisions, neighborhood SES-health associations could be biased and incorrectly interpreted as neighborhood influence on health. Yet, studies investigating neighborhood influences on PA – which generally stem from the built environment literature (Papas et al., 2007), as opposed to demographic and geographic studies (e.g., (Curtis et al., 2009)) – generally control for individual SES but not other observed characteristics related to residential selection such as marriage and children.

Furthermore, key drivers of residential self-selection may be difficult or impossible to measure. For example, unmeasured characteristics of individuals who are more likely to select a neighborhood with high quality schools (in the U.S., generally in high SES areas) may also influence adoption of physically active lifestyles. Therefore, unmeasured characteristics may bias traditional, covariate-adjusted estimates of how neighborhood SES influences healthy behaviors. In contrast, with longitudinal data, unmeasured characteristics that are stable over time (time-invariant) can be addressed with within-person estimators (e.g., first difference and fixed effects models), which condition on the individual, thereby exploiting variation observed within person, over time (Boone-Heinonen et al., 2011; Do & Finch, 2008; Eid, Overman, Puga, & Turner, 2008). While within-person estimators do not address dynamic feedback processes in which health may influence subsequent residential selection (Boyle et al., 2002; Curtis et al., 2009), they are uniquely suited to control for unmeasured confounders.

However, few neighborhood health studies have the longitudinal exposure and outcome data necessary to estimate within-person effects. The vast majority of neighborhood health research in the U.S. and elsewhere is cross-sectional, and the few existing longitudinal studies examine general health measures (Do & Finch, 2008) rather than behaviors that might mediate general health, such as PA. In addition, they do not always take advantage of the potentialities of a repeated measures design for addressing unmeasured confounders. Controlling for measured confounders related to residential self-selection and within-person estimation can provide insights into possible causal processes linking neighborhoods and health and into the sensitivity of studies to omission of these unmeasured confounders.

Therefore, we capitalized on longitudinal neighborhood and behavior data from four CARDIA study examinations to investigate how the estimated association between neighborhood SES and PA is influenced by controlling for the confounding effects of (a) measured characteristics related to residential selection in a large body of mobility research (e.g., individual SES, marriage, and children), and (b) unmeasured characteristics which are constant over time.

Methods

Study population and data sources

The CARDIA Study is a population-based prospective epidemiologic study of the determinants and evolution of cardiovascular risk factors among black and white young adults. At baseline (1985–6), 5115 eligible subjects, aged 18–30 years, were enrolled with balance according to race (black, white), gender, education ($\leq$ and $>$high school) and age (18–24 and 25–30 years) from four U.S. communities: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California. Specific recruitment procedures were described elsewhere (Hughes, Cutter, Donahue, Friedman, Hulley, Hunkeler et al., 1987). Study data were collected under protocols approved by Institutional Review Boards at each study center and the University of North Carolina at Chapel Hill. Follow-up examinations conducted in 1987–1998 (Year 2), 1990–1991 (Year 5), 1992–1993 (year 7), 1995–1996 (year 10), and 2000–2001 (year 15) had retention rates of 90%, 86%, 81%, 79%, and 74% of the surviving cohort, respectively.

Using a Geographic Information System, we linked time-varying, community-level, U.S. census data to CARDIA respondent residential locations in exam years 0, 7, 10, and 15 from geocoded home addresses. 48.2, 68.8, and 33.0% of participants moved residential locations between years 0 and 7, 7 and 10, and 10 and 15, respectively.

Of the possible 20,460 observations for 5115 participants at baseline across 4 examinations, 4400 observations were missing due to loss to follow-up (including mortality): 80, 77, and 72% of the initial participants were observed at years 7, 10, and 15, respectively. Of remaining observations, we excluded observations for women who were pregnant at the time of examination ($n = 114$ observations), and with missing PA ($n = 126$ observations), neighborhood SES variables ($n = 86$ observations) or covariate data ($n = 274$ additional observations). Those lost to follow-up or missing data were generally more likely black, male, younger, and of lower baseline education ($p < 0.05$); however, attrition (except for year 7, $p = 0.02$) and missing data were unrelated to baseline PA and, to the extent that attrition and missing data are related to unobserved fixed characteristics of the individuals, our fixed effects models may mitigate selection bias. The final analytical sample totaled 15,460 observations for 4179 individuals.

Neighborhood socioeconomic measures

Several commonly used neighborhood socioeconomic measures were approximately time-matched to each examination period (CARDIA year, Census: Year 0, 1980; Years 7 and 10, 1990; Year 15, 2000). Census tracts were used to define neighborhoods because they are consistent with prior research, block groups were not universally implemented until the 1990 census, and we theorized counties as too large to capture the neighborhood environment.

Measures of socioeconomic disadvantage included percent of persons with income less than 150% of federal poverty level [1.5 times federal poverty level (Krieger, Zierler, Hogan, Waterman, Chen, Lemieux et al., 2003; U.S. Census Bureau, 2009)] and