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Comparing residence-based to actual path-based methods for defining adolescents' environmental exposures using granular spatial data

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ABSTRACT

This paper uses data from a population-based case control study of daily activities and assault injury to examine residence-based versus actual path-based approaches to measuring environmental exposures that pose risks for violence among adolescents. Defining environmental exposures based on participant home address resulted in significant misclassification compared to gold standard daily travel path measures. Dividing participant daily travel paths into origin-destination segments, we explore a method for defining spatial counterfactuals by comparing actual trip path exposures to shortest potential trip path exposures. Spatial methods explored herein can be utilized in future research to more accurately quantify environmental exposures and associations with health outcomes.

1. Introduction

A growing body of research suggests that where people live and the places in which people spend time may have important impacts on a broad range of health outcomes. In contrast to health predictors such as blood pressure or cholesterol, for which there are clear and objective measurement guidelines, no consensus exists for how best to measure environmental exposures O'Campo (2003). Failure to appropriately define and measure environmental exposures may lead to misclassification bias, which can impact on the ability to detect meaningful associations between the environment and heath, and can also result in spurious findings (Gilliland et al., 2005; Lam et al., 2013; Flowerdew et al., 2008; Geronimus, 2006; Holt et al., 1996; Chaix et al., 2017). Due to budgetary and feasibility limitations, investigators often define environmental exposures based on participant home address (Duncan et al., 2013, 2014). Other more nuanced analyses use spatial modeling techniques to study environmental exposures on trips between home and pre-specified destinations (Lam et al., 201). These complex spatial models have been applied predominantly among adult populations to study associations between environmental pollutants and traffic infrastructure on health outcomes (Lam et al., 2013; Yao et al., 2015; Xue et al., 2009)

Many exposure modeling techniques rely on the assumption that participants will select the shortest potential travel route between a given origin and destination, or that participants are equally likely to select from among available routes based on distance and time constraints (Lam et al., 2013; Yao et al., 2015; Xue et al., 2009). However, other work suggests that pedestrians select walking paths based on a complex constellation of individual, social and environmental factors, including aesthetic appeal, proximity to retail, traffic patterns, and safety, which ultimately affect their actual walking paths (Millward et al., 2013; Guo and Loo, 2013; Giles-Corti and Donovan, 2003; Brown et al., 2007). Current modeling techniques are unable to fully account for these complex decision-making inputs, and thus

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remain vulnerable to misclassification (Xue et al., 2009; Duncan and Mummery, 2007)

Even less is known about how travel decision-making may operate specifically among adolescents. Adolescence is a time of tremendous neurocognitive development that directly impacts on risk assessment and decision-making across myriad health behaviors (Piaget, 1972; Millstein and Halpern-Felsher, 2002; Halpern-Felsher et al., 2002; Gerrard et al., 2008; Keating and Halpern-Felsher, 2008; Morrell et al., 2010; Institute of Medicine, 2011). Through cognitive maturation, adolescents develop improved abstract reasoning (Piaget, 1972) and refinement of cognitive processing, (Gerrard et al., 2008) both of which are important for risk assessment Millstein and Halpern-Felsher (2002). Most research to understand salient factors in adolescent route choice decision-making has narrowly centered on decisions to walk or bike to school (Panter et al., 2008). Perceived safety emerges as a frequent factor of interest, but studies in the general adolescent population demonstrate mixed findings regarding associations between perceptions of safety and walking among adolescents (Panter et al., 2008; Carver et al., 2005; Kerr et al., 2006). Qualitative research in a sample of Philadelphia youth residing in low resource neighborhoods highlights adolescents' hypervigilance to their immediate surroundings and their focus on strategies to promote safety during daily activities (Teitelman et al., 2010). Further quantitative research that assesses adolescent route choice decision-making in the context of daily activities is needed to inform spatial analysis methods.

Most research that examines the impact of the environment on health relies on observational data because randomized experiments often prove unfeasible or unethical. While statistical methods can account for measured confounding in observational research, techniques to manage unmeasured confounding are limited. This hinders our ability to draw causal inference from observational environmental research, as findings may be due to unmeasured confounding from factors that were either too challenging to measure, or not thought to be important to the associations under study. Researchers have historically employed propensity scores and sensitivity analyses as "proxy counterfactuals" to combat these methodological weaknesses, but these remain vulnerable to unmeasured confounding (Harding and Xa, 2003). Methods for assessing spatial counterfactuals using observational data are urgently needed.

The current study uses data from a population-based case control study of daily activities and assault injury to examine the implications related to using residence-based approaches versus actual travel path-based approaches to measuring environmental exposures that pose risks for violence among adolescents. In doing so, the current study examines the extent to which commonly employed metrics, including home address and shortest potential trip paths, can be used as proxies for a broad range of environmental exposures that adolescents actually encounter during their daily activities, and what factors may influence the accuracy of these predictions. It additionally introduces a method for defining spatial counterfactuals by comparing environmental exposures along actual trip paths selected by youth to exposures that would have accrued had participants chosen to travel the shortest routes to their destinations.

2. Methods

2.1. Overview of data source

This study utilized data from control participants in the Space-Time Adolescent Risk Study (STARS), a population-based case control study of daily activities and assault in Philadelphia, PA. That study recruited as cases 10–24 year-old males who presented to the Emergency Departments of adjacent pediatric and adult trauma centers with assault-related injuries from 2007 to 2011. Control participants were recruited using random digit dial in the 12 zip codes that account for the hospitals' catchment area to achieve population-based sampling and matched on age group strata (10– 14, 15– 17, 18– 24), race, and sex (Waksberg, 1978; Hartge et al., 1984; Perneger et al., 1993). The racial composition of the study sample reflects the fact that in Philadelphia, as in many other urban centers, African American male youth bear a disproportionate burden or violent injury, (Centers for Disease Control and Prevention, 2017) and therefore represent the majority of cases and matched controls in the larger study, in keeping with demographic trends at the study sites (Nance et al., 1996). Because the sample of control participants was recruited to reflect the source population that gave rise to the assault-injured cases in the larger case control study, the control participant neighborhoods represent relatively under-resourced neighborhoods compared to all of Philadelphia.

Participants completed structured in-person interviews during which the trained interviewer collected a detailed record of each participant's daily activities. For control participants, this involved recounting details for a recent day (within 3 days of the interview, randomly assigned). Using a customized version of ArcEngine software, the participants "walked the interviewer through" their entire day from awakening until going to sleep. With a stylus, the interviewer placed points on the interactive map to draw the participant's path, which were automatically coded with latitude and longitude coordinates. After processing, the data record consisted of many rows per participant with each row being a 1 min interval that denoted where the participant was, what they were doing, their mode of transit, and who they were with. Additional details related to study design and daily travel path data collection have been previously reported (Wiebe et al., 2016). The study was approved by the Institutional Review Boards of the University of Pennsylvania and The Children's Hospital of Philadelphia.

Utilizing data from control participants in the STARS afforded a unique opportunity to examine multiple methods for quantifying environmental exposures for violence encountered in the context of daily activity among a population-based sample of Philadelphia youth. The study enrolled 283 adolescent male control participants, of whom 274 provided detailed daily path data. The participant daily paths traversed a median distance of 4.8 miles and included a total of 1590 self-powered trips.

2.2. Measuring environmental exposures

We gathered data on 19 environmental variables of interest from 2010 Census data (median household income, per capita income, unemployment, college education, racial and ethnic composition, population density, adolescent population density, household alcohol expenditures; census block group (BG)), the City of Philadelphia (fire stations, police stations, recreation department facilities; point location), the Pennsylvania Liquor Board (alcohol outlets; point location), the Department of Education (truancy rate; BG), and the University of Pennsylvania Cartographic Modeling Lab (CML) (vacant properties, crimes (vandalism, disorderly conduct, public drunkenness, narcotics arrests), and murals; point location).

We additionally included 5 items measuring neighborhood resident cohesion (belonging, improvement, help, trust, participation; census tract (CT)) and 3 items measuring neighborhood stress and violence exposure (stress, violence victimization, firearm access; CT) from the 2010 Philadelphia Health Management Corporation's Southeastern Pennsylvania Household Survey (PHMC), a bi-annual survey of 10,000 households in the region (Philadelphia Health Management Corporation). Questions that used ordinal response scales were re-coded into dichotomous outcomes and summarized as the proportion coded 1 per census tract (Supplementary Table 1).

We ascribed participant exposure to environmental risk factors for violence using three methods: residence-based measurement, daily travel path-based measurement, and trip path-based measurement (origin-destination segments of the full path). Next, we compared