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Research paper

The right space at the right time: The relationship between children's physical activity and land use/land cover

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HIGHLIGHTS

- Long-term paired GPS and accelerometry data collected from schoolchildren.
- Physical activity significantly correlated with parks and residential land use.
- Most observations of physical activity exhibit significant geographic clustering.

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ABSTRACT

Research increasingly suggests that moderate to vigorous physical activity (MVPA) is essential to children's health. However, little is known about the extent to which and when different urban environments influence the extent to which children engage in MVPA. To this end, this study explores the relationship between children's MVPA and urban land use and land cover (LULC) for several temporal subdivisions of children's weekly routines (before school, after school and weekends). In particular, the location and corresponding level of physical activity of 4th grade students (n = 134) was recorded using paired global positioning system (GPS) receivers and accelerometers over 33 days for each student. GPS locations were temporally related to accelerometry records and then geographically related to 13 categories of LULC. Mixed linear models were fitted to evaluate the extent to which duration spent in each LULC category can explain individuals' time in MVPA before school, after school, and during the weekends. Geographic cluster analysis was also applied to assess whether any significant spatial relationships between observations of MVPA may exist. Duration of exposure to vegetated parks/open spaces, built residential, and built institutional LULC was found to significantly increase children's time spent in MVPA. Further, most observations of MVPA were found to exhibit significant geographic clustering and were predominately associated with built residential areas (particularly those near schools), indicating the importance of neighborhoods and areas in close proximity to children's households on their level of physical activity.

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1. Introduction

It is widely acknowledged that physical activity is central to an individual's health, for both youth and adults (CDC, 2011). However, much less is known about where and when different individuals are active and the influence of geographic and temporal dimensions on physical activity (Jackson, 2003; McCrorie, Fenton, & Ellaway, 2014; Sugiyama & Thompson, 2007). A key problem underlying this issue is that the spatial and temporal dynamics of individu-

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als' can be very complex, making collection and analysis of such behaviors extremely challenging. Efforts to collect such individual level data have often relied upon voluntary self-report and direct observation methods (Davison & Lawson, 2006; Ding, Sallis, Kerr, Lee, & Rosenberg, 2011; Mackett, Lucas, Paskins, & Turbin, 2005), but inconsistencies in the geographic and temporal detail of the data reported can present problems in its analysis. Automated data collection devices such as global positioning systems (GPS), heart rate monitors, and accelerometers now offer a more consistent mechanism for collecting information about individual's physical activity and can record a greater amount of geographic and temporal detail about the locations at which it takes place (Dunton, Almanza, Jerrett, Wolch, & Pentz, 2014; Eyre, Duncan, Birch, Cox, & Blackett, 2015; Evenson, Wen, Hillier, & Cohen, 2013).

While GPS and accelerometry can be jointly collected from individuals and used to learn more about the types of environments within which physical activity occurs, little is known about how schoolchildren use space and how their temporal budgets over different portions of the day or week can affect physical activity levels. In order to analyze patterns of physical activity, one must account for both the geographic location of the activity (i.e. via self-reported activity diaries and global positioning systems) as well as the level of physical activity occurring at that location (i.e. via accelerometers) (Jones, Coombes, Griffin, & van Sluijs, 2009; Mackett et al., 2005). Many protocols for the frequency at which locations are recorded (GPS records location at discrete intervals) and level of physical activity (accelerometers record activity over epochs) have been suggested. For example, some collection efforts have used 1.0 min intervals/1.0 min epochs (Oliver, Badland, Mavoa, Duncan, & Duncan, 2010; Quigg, Gray, Reeder, Holt, & Waters, 2010), 30.0 s intervals/30.0 s epochs (Almanza, Jerrett, Dunton, Seto, & Pentz, 2012; Dunton et al., 2013), 10.0 s intervals/10.0 s epochs (Cooper, Page, & Wheeler, 2010), 5.0 s intervals/1.0 min epochs (Troped, Wilson, Matthews, Cromley, & Melly, 2010), 15.0 s intervals/15.0 s epochs (Klinker et al., 2014). Given the variation in collection efforts, comparison among study results is cumbersome at best. For any reliable relationship between physical activity and location to be evaluated, collection efforts should ideally be structured to minimize temporal deviation among the measurement devices and maximize the frequency at which observations are recorded. That is, a finer temporal resolution in data collection can provide a more detailed record of an individual's behavior. Also, finer resolution data can easily be aggregated to coarser analysis units if desired. Likely the diversity of collection protocols that have been explored are largely due to attempts to tradeoff collection device limitations (i.e., battery power, storage capability, etc.), data processing capabilities, and the ability to adequately capture individuals' behavior. Research on the relationship between physical activity and location has also utilized a broad range of protocols for sampling periods. For instance, studies have considered observations of individuals' physical activity and location over a period of two days (Cooper et al., 2010), four days (Eyre et al., 2015; Jones et al., 2009; Troped et al., 2010), or seven days (Dunton et al., 2013, 2014; Jerrett et al., 2013; Klinker et al., 2014; Oliver et al., 2010; Quigg et al., 2010. Since no studies have involved collection efforts over seven days, there is really no proof that these short-term collection periods are adequate for accounting for individuals' physical activity and locational patterns though. Further, the number of individuals observed over the course of the sampling periods has also varied, from 100 to 367 individuals, with Klinker et al. (2014) being the only study to consider over 300 participants. Likewise, studies have differed in the geographic extent of the study site from which observations of physical activity and location were sampled. For instance, Cooper et al. (2010) and Oliver et al. (2010) focus on physical activity that occurs during transportation between locations such as home and school, Jones et al. (2009), Troped et al. (2010); Almanza et al. (2012), Dunton et al. (2014) consider activity occurring within some distance of home and work/school, Quigg et al. (2010), Evenson et al. (2013), and Wolf and Wohlfart (2014) assess individuals' activity within parks, Klinker et al. (2014) and Andersen, Klinker, Toftager, Pawlowski, and Schipperijn, (2015) confine observations of activity to schoolyards and other specific types of 'domains', while Jones et al. (2009) and Dunton et al. (2013) associate activity with the broader type of land use within which it was observed. This latter approach is important given that more records of physical activity are retained within a study region instead of limiting analysis to those occurring within a specific type of environment. The types of land use that are considered in the analysis of physical activity as well as the way in which portions of the study site are associated with a particular land use category have differed though. For example, Jones et al. (2009) use a variety of sources of land use data to group areas into nine different land use categories (buildings, other built land, gardens, parks, roads and pavements, beaches, woodland, grassland, and farmland). Dunton et al. (2013) rely upon a local land use database classification scheme and associate areas of their study site with one of six land use types (residential, commercial, open space, educational, public facilities, and other uses).

Continuous recording of observations of activity over space and time may provide a way to better understand the complex relationship between physical activity and land use across a short period of time. However, measuring the location of physical activity at the frequency and over the duration needed to capture the behavior for children necessitates a tremendous amount of data recording and storage for just a single individual, let alone a set of individuals. Longer-term, higher resolution data collection and evaluations are likely needed to capture the geographic and temporal dynamics of younger individuals. Shorter accelerometer epoch length is likely more suitable for estimating the time spent in sporadic, short bursts of MVPA (Edwardson & Gorley, 2010). Additionally, the analysis of the land uses and land covers that may influence physical activity levels necessitates an in-depth collection effort to better account for changes in LULC and physical activity over a larger period of time. To better understand these issues, a longer-term, multi-period data collection effort was conducted to capture the location and activity levels of schoolchildren to provide further insight on the relationship between their level of physical activity and the urban land uses and land covers (LULC) to which they are exposed. To this end, a cohort of schoolchildren were enrolled in a longitudinal study to capture detailed observations of their physical activity and location using paired GPS and accelerometry. The relationship between MVPA and LULC throughout the study region as well as over different temporal regimes (i.e. times of day, days of week) were then statistically analyzed.

2. Methods

To better understand the relationship between MVPA, LULC, and children's physical activity, 4th grade students ($n = 134$ with those of 12 years ($n = 1$), 11 years ($n = 11$), 10 years ($n = 105$), and 9 years ($n = 17$)) from four elementary schools in Columbia, Missouri (Fig. 1) were recruited. Children of this age were selected because their cognitive maturation is sufficient for them to responsibly participate in the data collection (with support from parents/caregivers) by following basic protocols for wearing and caring for the measurement instrumentations. Both written consent from parent/guardian and assent from the child were obtained as part of the institutional review board approval of this study. Students were provided a GPS receiver (QStarz BT-1300) and an accelerometer (ActiGraph) so that the location and intensity of physical activity could be jointly measured. The students were instructed to

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