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Activity Space Environment and Dietary and Physical Activity Behaviors: A Pilot Study

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Abstract

This study examined relationships among individual demographics, environmental features (e.g., fast food outlet density, park land use) of residential neighborhoods and activity spaces, and obesity-related behaviors (diet, physical activity). Participants' movement was tracked for seven days using global positioning systems (GPS). Two activity space measures (one standard deviation ellipse, daily path area) were derived from the GPS data. Activity spaces were generally larger than residential neighborhoods; environmental features of residential neighborhoods and activity spaces were weakly associated; and some activity space environmental features were related to dietary behaviors. Activity spaces may provide new insights into environmental influences on obesity-related behaviors.

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Keywords

Global positioning system; Activity space; Neighborhood; Diet; Physical activity; Environment

Introduction

Research over the past decade has advanced understanding of geographic environmental features that are associated with dietary and physical activity behaviors and body weight status. Some of this research has shown that living in a neighborhood with more supportive environmental features (e.g., walkability, accessibility of recreational places, pleasing aesthetics) is associated with greater physical activity and lower body weight status (Black and Macinko, 2010; Coogan et al., 2009; Duncan et al., 2010; Frank et al., 2005; Gomez et al., 2010; Kondo et al., 2009; Rodríguez et al., 2009). Other studies have found associations between neighborhood accessibility of (un)healthy foods and dietary behaviors and body weight status (Franco et al., 2009; Li et al., 2009; Moore et al., 2009; Morland et al., 2002; Rose et al., 2009; Paquet et al., 2010). However, overall, findings for many environmental features are inconsistent (Ball et al., 2006; Casagrande et al., 2009; Fleischhacker et al., 2011; Giskes et al., 2011; Lopez and Hynes, 2006; Lovasi et al., 2009; Witten et al., 2008; Pearce et al., 2008).

Two recent reviews indicate that research has concentrated almost exclusively on environmental features of the residential neighborhood, defined as a surrounding administrative unit (e.g., census tract, ZIP code) in most studies (59–73%) and as a ‘buffer’ (e.g., 0.5 mile radius) in the remaining studies (Feng et al., 2010; Leal and Chaix, 2011). Measuring environmental features for non-residential locations in relation to weight-related behavior has been rare (Inagami et al., 2006; Jeffery et al., 2006; Troped et al., 2010). In fact, a review on geographic environments and cardiometabolic risk factors found that 90% of studies measured environmental features in the residential neighborhood only and just 4% in both the residential neighborhood and around a non-residential location (Leal and Chaix, 2011). The very small number of studies that have examined associations between non-residential environmental features and dietary and physical activity behavior or body weight status have been typically limited to one (i.e., work) (Jeffery et al., 2006; Troped et al., 2010) and at most five (Inagami et al., 2006; Vallee et al., 2010) non-residential locations. Even among studies that measure environmental features based on proximity (rather than density) and thus can incorporate features outside the residential neighborhood, measures are still generally constructed in relation to the place of residence (Apparicio et al., 2007; Sharkey and Horel, 2008; Smoyer-Tomic et al., 2006; Burns and Inglis, 2007; Giles-Corti et al., 2005; Kaczynski et al., 2008).

Yet, individuals routinely conduct day-to-day activities (e.g., work, child care, social engagements, shopping) outside their residential neighborhood. For example, the average travel time to work in the United States is 25.3 minutes (United States Census Bureau). In an ethnographic study of low-income families in Boston (n=10), just 6% of day-to-day activities took place in their residential census tract, another 21% in adjacent census tracts, and a startling 73% in other areas of the city (Matthews et al., 2005; Matthews, 2010). Research in the Paris metropolitan area found that 19–47% of individuals engaged in five activities (food shopping, using services, going for a walk, meeting friends, going to a restaurant or café) mainly outside their neighborhood of residence, though 54% reported mainly shopping for food in their residential neighborhood (Vallee et al., 2010). Further, with regard to food shopping, the Los Angeles Family and Neighborhood Study (n=2,144) found that only 22% of participants grocery shopped within their own census tract, 42% in adjacent census tracts, and 37% beyond surrounding census tracts (Inagami et al. 2006).

Studies of predominately African-American and/or Latino samples in Philadelphia (n=1440) and Detroit (n=919) revealed that individuals traveled, on average, 2.2–3.3 miles to shop for food (Matthews, 2008a; Zenk et al., 2008). With regard to physical activity, a Boston study found that, on average, less than one-third of moderate and vigorous physical activity among a convenience sample of 148 adults occurred within one kilometer (0.62 mile) of participants' homes (Troped et al., 2010).

Thus, focusing solely on the residential neighborhood may mischaracterize environmental influences on dietary and physical activity behaviors and body weight status (Inagami et al., 2006; Troped et al., 2010; Morenoff, 2003; Rodriguez et al., 2005; Kestens et al., 2010). Scholars have called for research on non-residential environmental influences on health (Chaix et al., 2009; Cummins et al., 2007; Inagami et al., 2007; Kwan and Weber, 2003; Matthews, 2008b; Rainham et al., 2009; Saarloos et al., 2009). Characterizing the space within which people move or travel during the course of their day-to-day activities (activity space) (Golledge and Stimson, 1997; Horton and Reynolds, 1971), rather than only where they live, may provide a more comprehensive and accurate assessment of the environment to which individuals are exposed and utilize. In turn, this could help to elucidate the mechanisms by which geographic environments affect dietary and physical activity behavior and body weight status. However, little is known about activity space environments and obesity or related behaviors.

Purpose

In this exploratory pilot study, we drew upon data from the Detroit Activity Space Environments Study (DASES), designed to pilot test methodology to measure individuals' activity space using wearable global positioning systems (GPS) and associated environmental exposures in this space that may affect dietary and physical activity behaviors and, ultimately, body weight status. We addressed the following questions:

1. To what extent do activity space characteristics (size and environmental features, specifically fast food outlet density, supermarket availability, park land use) vary across individuals and differ by individual demographics?
2. How similar are environmental characteristics of activity spaces and residential neighborhoods?
3. Are activity space environmental features associated with dietary and physical activity behaviors, controlling for residential neighborhood environmental features?

Methods

Design and Overview

The Detroit Activity Space Environments Study (DASES) was conducted in September 2008-April 2009. It employed an exploratory observational design. Data collection consisted of three phases: baseline interview, 7-day study period (which included wearing a GPS and accelerometer except during bathing or other water activities), and follow-up interview. All materials were available in English and Spanish, and the research team included Spanish-speaking interviewers.

Sample

Participants were recruited from respondents to a 6-year follow-up, two-stage probability sample survey of residents in three areas (eastside, northwest, and southwest) of Detroit, Michigan, United States (Schulz et al., 2005). The "Lean & Green in Motown" survey was implemented by the Detroit Healthy Environments Partnership, a community-based participatory research partnership comprised of representatives from community-based organizations, health services organizations, and academic institutions. After completing the survey, respondents were provided with information about the DASES and asked if they were interested in participating. The DASES staff attempted to contact interested individuals via telephone. We enrolled 28.3% (n=131) of Lean & Green in Motown respondents overall, 40.9% of those who expressed interest, and 85.6% of those we successfully reached by telephone (Figure 1). A significantly lower percentage of male (20.7%) than female (32.7%) Lean & Green in Motown respondents enrolled in the DASES. However, the samples did not differ significantly on age, race/ethnicity, socioeconomic position (SEP), or area of the city (study area) (Zenk et al., Unpublished results).

Measures

Environmental Characteristics

Overview: We measured environmental characteristics of each participant's residential neighborhood (0.5 mile street-network buffer around the census block centroid) and two alternative measures of activity space (one standard deviation ellipse, daily path area), derived from GPS data. Participants were nested within 77 census blocks; the average number of participants per census block was 1.6 (median=1.0). Census block centroids are a reasonable proxy for the participants' home addresses, due to the small size of census blocks in the sample (median=0.009 square miles (mi^2), minimum=0.001, maximum=0.038).

Participants' movement was tracked using the Foretrex 201 (Garmin, Olathe, KS) over the 7-day study period (Zenk et al., Unpublished results). We selected the Foretrex 201 because at the time of the study it had documented reliability (Rodriguez et al., 2005), good battery performance (15 hours), was rechargeable via an electrical outlet, and was a low-cost commercially available model. The GPS was programmed to record position every 30 seconds. During the 7-day study period, participants were also asked to record on a log the daily start and end times of wearing the GPS, when the battery died (as needed), as well as any problems or unusual circumstances. GPS data were downloaded using the DNR Garmin Application 5.3 (Minnesota Department of Human Resources, St. Paul, MN). We had GPS data for 90% of the sample (n=120), with a mean of 5.7 days (Figure 1). Individuals were deemed to have worn the GPS if at least one GPS point was recorded on the assigned day or the participant reported on their log that they were at home indoors all-day (which implied there would be no GPS point). GPS data corresponding with four trips (one each for four participants) outside of the metropolitan area were removed.

The GPS point data were used to calculate two measures of activity space: one standard deviation ellipse and daily path area. These measures are a summary of the spatial patterning of all activity locations collected via the GPS. Ellipses are commonly used measures of activity space (Newsome et al., 1998; Sherman et al., 2005). We used a one standard deviation ellipse, which covers approximately 68 percent of all GPS-recorded points and is centered on the mean center of the point pattern. Its long axis is in the direction of maximum dispersion; its short axis is in the direction of minimum dispersion. This measure was calculated using the Spatial Statistics toolbox in ArcGIS 9.2. The daily path area was adapted from the work of Kwan (Kwan, 1999). Using ArcGIS 9.2., it was calculated by buffering all GPS points at 0.5 mile and dissolving these separate features into a single feature, or space. We selected 0.5 mile to capture the immediate vicinity around activity locations and travel routes. Canada borders the City of Detroit to the south and east, separated only by the Detroit River. Barriers to entry into Canada are real and require a passport. We did not expect Canada to be part of any participant's space where day-to-day activities were conducted, and as it turned out, no participants actually travelled to Canada during the observation period. We "clipped" the activity space measures at the Detroit River

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(the international boundary) for those whose calculated activity space extended beyond, as these were inaccessible areas. Maps illustrating each of these activity space measures based on one participant's GPS data are shown in Figure 2.

Size: Geographic size (area) was calculated in mi^2.

Fast food outlet density: Fast food outlet density was based on the number of chain fast food outlets. To derive the measures, in November 2007-February 2008, we obtained lists of food service places in the metropolitan area from the county departments of agriculture as well as the City of Detroit. Based on the operational definitions of fast food outlets used in prior work (Morland et al., 2002; Powell et al., 2007), we identified chain fast food restaurants that were among the top 50 national quick service restaurants in the United States, excluding coffee shops, ice cream places, and juice bars. Next, using ArcGIS 9.2, we geocoded and counted the number of fast food outlets in each residential neighborhood and activity space. Because a large number of residential neighborhoods (45%) did not have a fast food outlet, we created a 3-level variable: no fast food outlet, 1 outlet, and 32 outlets. To take into account differences in activity space size, for each activity space measure, we divided the number of fast food outlets by the size (in mi^2) of the activity space indicator.

Supermarket availability: Supermarket availability was based on the number of chain full-service grocery stores or supercenters. To derive the measures, in November 2007, we obtained a list of food stores in the metropolitan area from the Michigan Department of Agriculture and identified chain supermarkets based on name recognition. Using ArcGIS 9.2, we geocoded and counted the number of supermarkets in each residential neighborhood and activity space. None of the residential neighborhoods had a supermarket. Because a sizeable proportion of the activity spaces did not include a supermarket, we created a dichotomous indicator for presence or absence of a supermarket.

Park land use: Park land use was measured as the percentage of the total land area in the residential neighborhood and activity space that was municipal park land. Data were from the 2005 Southeast Michigan Recreation and Open Space coverage (Southeast Michigan Council of Governments, Detroit, MI). These were the most current metropolitan-level data available at the time of the study's data analysis.

Individual Demographics—Participant demographic data were collected as part of the Lean & Green in Motown survey. We included several demographics in the analysis: age, gender, race/ethnicity, and four indicators of socioeconomic position (SEP): education, labor force participation, annual household income, and auto ownership.

Physical Activity—Participants were asked to wear the Actigraph GT1M (Actigraph, Pensacola, FL), an accelerometer that measures, records, and stores vertical accelerations as "counts," on an elastic band over their right hip while awake for seven consecutive days. Data were recorded in one-minute epochs. Accelerometer data were analyzed using the Spatial Activity Data Processor (Rodriguez et al., 2005). Valid data were defined as at least 10 hours of data (greater than zero count values for each hour) in a 24-hour period on at least three days (Troiano et al., 2008; Trost et al., 2005). A subset of 97 participants met the criteria for valid accelerometer data. We calculated the mean number of daily minutes of moderate or vigorous intensity physical activity, defined as ≥2,200 activity counts per minute (≥3.0 metabolic equivalents or METS) (Troiano et al., 2008).

Dietary Intake—As part of the follow-up interview, participants completed a 2005 Spanish Block food frequency questionnaire, modified to assess dietary intake over the previous seven days. Available in both English and Spanish, the Spanish 2005 Block expands the food list of the standard 2005 Block to include additional foods typical of diets of Latinos. For each of 110 food items, frequency of intake over the past week and typical portion size were asked, with pictures provided to enhance accuracy of quantification. Twenty-four hour dietary recalls are most commonly used to measure foods and amounts actually consumed on one or more specific days (Willett, 1998). However, because dietary recalls are expensive to collect, we used a 7-day food frequency questionnaire in this pilot study. Most participants (n=116) had complete food frequency questionnaire data. In this analysis, we used three dietary intake measures that are associated with body weight status or chronic disease risk: mean daily saturated fat intake (in grams), servings of fruits and vegetables, and servings of whole grains (Alinia et al., 2009; Hession et al., 2009; Swinburn et al., 2007). We controlled for mean daily energy intake (tertiles) in regression analysis.

Data Analysis—For our first research question, we examined variation in activity space characteristics using descriptive statistics. We used medians and interquartile ranges for geographic size, fast food outlet density, and park land use. Frequencies and percentages were used for supermarket availability. We examined demographic variations in activity space characteristics using ordinary least squares (OLS) regression or binary logistic regression (for supermarket availability). These models controlled for study area to help account for the residential clustering of study participants. To address the second question regarding the degree of similarity of environmental features in the activity space and residential neighborhood, we examined bivariate correlations using Spearman's rho coefficient. Finally, we examined associations between activity space environmental features and dietary and physical activity behaviors using hierarchical OLS regression. Model 1 included demographics and the residential neighborhood environmental measure. Model 2 added the activity space environmental measure. These models were estimated separately for environmental features based on the ellipse and daily path area indicators of activity space. Because they were skewed to the right, all continuous environmental characteristics and outcome measures except daily path area fast food outlet density, daily path area park land use, and saturated fat intake were log transformed [LN (var + 1)] to produce approximate normal distributions.

Results

Sample Characteristics

Table 1 shows characteristics of the 120 study participants with GPS data. The sample was predominately female, African American or Latino, and of lower SEP. The median for daily minutes of moderate or vigorous physical activity was 8.2. The median daily intake was 20.4 grams of saturated fat, 2.8 servings of fruits and vegetables, and 0.8 servings of whole grains.

Variation in Activity Space Environmental Characteristics

Activity spaces varied considerably in size. The median size of participants' one standard deviation ellipse was 7.60 mi^2 [quartile 1 (Q1): 0.71; quartile 3 (Q3) 22.52] and 28.63 mi^2 (Q1: 10.46; Q3: 49.67) for the daily path area (Table 2). Thus, there was more variability in the size of the daily path area than the ellipse [interquartile range (IQR): 39.21 versus 21.81 mi^2, respectively]. Seventy-eight percent of the one standard deviation ellipses and 100% of the daily path areas were larger than the residential neighborhood (results not shown). We also observed considerable variability in fast food outlet density, with the ellipse having greater variability in the number of fast food outlets per mi^2 than the daily path area (IQR: 1.48 and 0.64, respectively). The ellipse also had great variability in the percentage of land that was parks as compared to the daily path area (IQR 2.08 and 1.20, respectively). Thirtyfive percent and 76.7% of participants had a supermarket in their ellipse and daily path area, respectively (results not shown).

Demographic Variation in Activity Space Environmental Characteristics

Table 3 shows multiple regression results for relationships between activity space characteristics and individual demographics. Participants who were employed ($p<0.05$; ellipse measure only) and auto owners ($p<0.001$) had significantly larger activity spaces than those who were not in the labor force and did not own an automobile, respectively. Activity space size did not differ significantly by age, gender, race/ethnicity, income, or education. Overall, we found few statistically significant differences in activity space environmental features by demographics. Fast food outlet density did not differ by age, gender, race/ethnicity, or SEP. Those who were currently employed (versus not in labor force) ($p<0.05$) and auto owners (versus non-owners) ($p<0.01$) were more likely to have a supermarket in their one standard deviation ellipse. Based on the daily path area, auto owners (versus non-owners) were more likely to have a supermarket ($p<0.05$). For the daily path area measure but not the ellipse measure, auto owners had proportionately less park land in their activity space than non-owners ($p<0.05$). Residence in northwest Detroit was significantly related to activity space characteristics in some models.

Comparison of Activity Space and Residential Neighborhood Environmental Characteristics

Bivariate correlations for geographic size between the one standard deviation ellipse and daily path area were strong (rho=0.91; $p<0.001$). However, as shown in Table 4, bivariate correlations between residential neighborhood and activity space environmental features were weak to moderate in strength. For fast food outlet density, these correlations were 0.35 for the ellipse (p<0.001) and 0.03 for the daily path area. For park land use, correlations with the residential neighborhood were 0.05 for the ellipse and −0.03 for the daily path area. Correlations between the daily path area and ellipse were also weak: 0.16 for fast food outlet density and 0.18 for park land use. Thus, the residential neighborhood and activity space at most shared 12% of the variance in the environmental feature. While no participants had a supermarket in their residential neighborhood, a supermarket was present in 35.0% and 76.7% of participants' ellipses and daily path areas, respectively.

Associations Between Activity Space Environmental Features and Obesity-Related Behaviors

Table 5 shows multiple regression results for the three dietary intake measures regressed on fast food outlet density and supermarket availability, controlling for demographics and area of the city. Residential neighborhood fast food outlet density was not associated with saturated fat, fruit and vegetable, or whole grains intake. Fast food outlet density in the daily path area was positively associated with saturated fat intake ($p<0.05$) and negatively associated with whole grain intake ($p<0.05$). Fast food outlet density in the daily path area increased the explained variance in these outcomes by 1.8% and 4.6% respectively. Fast food outlet density in the daily path area was not associated with fruit and vegetable intake. We found no associations between fast food outlet density in the one standard deviation ellipse and any of the three outcomes. Supermarket availability in neither the ellipse nor daily path area was associated with any of the three dietary intake measures.

We also regressed minutes of moderate or vigorous intensity physical activity on park land use in the residential neighborhood and activity space, controlling for demographics and area of the city (results not shown). We found no association between physical activity and park land use in the residential neighborhood, one standard deviation ellipse, or daily path area.

Discussion

Overall, our findings suggest that applying the concept of “activity space” from behavioral geography to public health research may provide new insights into environmental influences on dietary and physical activity behaviors. Most individuals’ activity space was larger than their residential neighborhood, suggesting that most conducted day-to-day activities outside their residential neighborhood. Further, environmental features of the residential neighborhood were generally weakly associated with those in the activity space. This implies that the environmental features of the residential neighborhood are a poor proxy for those to which individuals were exposed through the course of their day-to-day activities. Measuring environmental features in the activity space may offer a more accurate and comprehensive characterization of environmental exposures.

We found some socioeconomic differences in activity space size, with those who did not own an automobile (versus auto owners) and those not in the labor force (versus currently employed) having smaller activity spaces. These findings are consistent with assumptions in the literature that the local environment may be more important to those of lower SEP (Black and Macinko, 2008). Nonetheless, as demonstrated in previous research (Matthews et al., 2005; Vallee et al., 2010), few participants in this study, even those of lower SEP, were confined to commonly-used residential neighborhood boundaries (e.g., 0.5 mile street network buffer). It is possible that activity spaces are constrained among other groups (e.g., children, elderly) or according to other characteristics (e.g., physical disabilities) not tested here. An individual’s activity space is structured in large part by the locations of “fixed” or “obligatory” activities (activities not easily rescheduled or relocated such as work) as well as individual financial (e.g., income), physical (e.g., physical health limitations), and social (e.g., discrimination, social network member locations) resources and constraints (Golledge and Stimson, 1997). While we expected that these factors would translate into poorer quality activity space environments for those of lower SEP and racial/ethnic minorities, we did not find strong support for this thesis in the analyses reported here. This finding is interesting in the context of research showing that urban neighborhoods with proportionately more low-income and African American residents generally have lower accessibility of supermarkets and parks and greater accessibility of fast food outlets than more economically advantaged and White neighborhoods (Fleischhacker et al., 2011; Lopez and Hynes, 2006; Zenk et al., 2005; Beaulac et al., 2009). Our findings may reflect characteristics of the sample, which—in addition to being relatively small—reflects a limited range of SEP and geographic representation. Future research should investigate the extent to which individual SEP or membership in an identified racial or ethnic group is associated with exposure to different environments through the course of daily activities, and the extent to which groups with poorer quality residential environments may travel out of their way to reach specific health resources.

Whereas fast food outlet density in the residential neighborhood or one standard deviation ellipse was not associated with dietary intakes, fast food outlet density in the daily path area was positively associated with saturated fat intake and negatively associated with intake of whole grains. One potential explanation for the discrepant findings for the alternative activity space measures is that the daily path area may better capture fast food outlets that were actually utilized. Nonetheless, the findings highlight the need for research to test multiple definitions of activity space. Further, findings from previous research have been inconsistent with regard to relationships between residential neighborhood fast food outlet accessibility and dietary intakes or body weight status (Fleischhacker et al., 2011). If our findings of a relationship between activity space fast food outlet density and diet are confirmed by future research, failure to consider fast food outlet accessibility in the activity space may lead to erroneous conclusions that fast food outlet accessibility is not an important contributor to dietary behaviors.

While supermarket availability in the activity space was not associated with dietary intake in our pilot study, others have found that greater accessibility of supermarkets in the residential neighborhood is associated with better dietary behaviors (Larson and Story, 2009). This may imply health behavioral benefits of having supermarkets close to home, for example to refresh home supplies of healthy foods such as fresh produce in between major shopping trips. In conjunction with our finding that fast food outlets in the activity space, but not the residential neighborhood, were associated with dietary intakes, these findings raise important questions for future research on whether environmental resources and hazards have greater health impacts in the residential neighborhood or in the broader activity space or non-residential locations.

Limitations

This is the first study of its kind of which we are aware. We applied GPS technology to go beyond the residential neighborhood to more comprehensively characterize the broader environment to which individuals were exposed through day-to-day activities and to examine its relationships with obesity-related behaviors. We learned several important lessons in this pilot study, and the study has several limitations, which are discussed below.

First, as this was a pilot study, the relatively small sample size limited power to detect statistically significant effects, and the restricted geographic and socioeconomic scope of the sample limits the generalizability of the findings. In part due to the clustering of participants within study areas, a second limitation is that there was overlap in residential neighborhoods and activity spaces, which raises concerns about spatial autocorrelation. The presence of spatial autocorrelation introduces redundancy affecting the calculation of confidence intervals and significance tests in regression-based techniques (O'Sullivan and Unwin, 2002). We included dummy variables representing the areas of the city in which participants lived to the regression models to help control for similarity of location, at least with respect to residence. Point data on individual residence locations can be used to define spatial weights and measure spatial autocorrelation, which if present, can be incorporated into exploratory and confirmatory advanced spatial analytical techniques (e.g., geographically weighted regression and spatial econometric approaches). The use of these advanced spatial methods, however, requires larger samples than ours (for an application of GWR to childhood obesity, see Edwards et al., 2009).

We based the activity space measures on recorded GPS points. Discerning whether the absence of recorded points reflects non-wear or poor/no satellite signal (e.g., being indoors, under heavy tree or building cover) is challenging (Oliver et al., 2010). While missing GPS data poses less of a concern for the daily path area measure, it may have consequences for the ellipse measure. That is, because the ellipse measure is based on the number of points, it is possible that the ellipse measure is larger than if we had "weighted" the data to reflect locations with lost satellite signal (e.g., home). New procedures and software, such as the Physical Activity Location Measurement System (PALMS) and the Extended Time-Geographic Framework Tools Extension for ArcGIS 9.3, for GPS post-processing and imputation of missing data can help address this limitation and will be beneficial for future studies (Chung and Shalaby, 2005; Nusser et al., 2006; Patrick et al., 2008; Shaw and Yu, 2009; Stopher et al., 2008; Wiehe et al., 2008).

We removed GPS points corresponding with four trips (one from each of four participants) that led outside the metropolitan area and clipped the activity-space measures at the Detroit River based on the assumption that the international border would present a barrier to

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movement. Because we did not collect environmental data outside the Detroit metropolitan area, we are not able to assess the extent to which results are sensitive to these geoprocessing decisions. Future studies should carefully consider how to handle complexities such as lengthy trips outside the study area and, when of substantive relevance, the implications of international borders.

Another limitation of our activity space approach is possible selection bias. For example, activity space fast food outlet density may be associated with dietary behaviors because individuals who want to consume fast food seek out environments with higher fast food outlet concentrations in order to obtain it. One of our overarching hypotheses is that potential accessibility of environmental resources and hazards in relation to fixed activity locations affects utilization and, in turn, obesity-related behaviors. However, we cannot rule out self-selection. It would be useful in future studies to more explicitly analyze whether utilization of food outlets and physical activity facilities mediates relationships among potential accessibility based on the activity space and obesity-related behaviors.

This study also has limitations with regard to the environmental measures. We relied on food outlet type as a proxy for the accessibility of healthy foods (supermarket) and unhealthy foods (fast food outlet). As this was a pilot study with limited resources, the time (e.g., year) of the individual data collection does not correspond exactly with the time for which the environmental features were measured, especially for park land use (though park land use tends to be fairly stable over time). Food outlet type is a commonly used and reasonable proxy of the relative availability of healthy and unhealthy foods (Farley et al., 2009; Liese et al., 2007), but it is imperfect with variability in food offerings within outlets of the same type (Cummins et al., 2009; Zenk et al., 2006). Furthermore, it is difficult to incorporate measures of “quality” into activity space environmental assessment. Measurement of environmental quality often requires direct observation, which is expensive. With some participants’ activity spaces spanning three counties in a densely populated metropolitan area, the large size of many participants’ activity spaces makes this type of data collection impractical for activity spaces. This would involve visiting thousands of food outlets and hundreds of parks across the metropolitan area. Sampling environmental features to assess each participant’s activity space is challenging because the activity space is not known a priori.

Finally, our findings may reflect seasonality. Our data collection period in this northern setting included months with the coldest weather and fewest hours of daylight. Because these conditions are not particularly conducive to outdoor physical activity, it is possible that we failed to find a relationship a relationship between park land use and physical activity due to these seasonal effects (Tucker and Gilliland, 2007). While much less is known, it is also possible that activity space size and features may vary by season, with individuals, for example, travelling away from home less often. Seasonal effects should be explored in future studies.

Opportunities for Future Research

An activity space approach presents many opportunities for future research. It can be used to learn more about non-residential environmental influences on obesity-related behaviors and outcomes (and other health outcomes as well), about which we currently know very little. As part of this line of research, investigators can investigate the extent to which environmental features of the activity space as a whole (including the residential neighborhood), non-residential spaces only, or specific non-residential spaces (e.g., around work, on routes to and from childcare locations) affect obesity-related behaviors and outcomes. Investigators can also examine relative effects of environmental features in residential and non-residential locations. For example, does park accessibility in the total activity space or the residential neighborhood have a stronger relationship with physical activity behavior? Interactions between environmental features of the activity space and residential neighborhood are also plausible. For example, individuals who have a poor residential neighborhood food environment but more supportive food environment in their broader activity space may have better dietary intakes than those with poor residential and activity space food environments (Inagami et al., 2006; Vallee et al., 2010). Failure to take into account activity space environmental features, therefore, might contribute to some of the inconsistent findings observed in the literature (Fleischhacker et al., 2011; Lopez and Hynes, 2006; Lovasi et al., 2009; Casagrande et al., 2009).

An activity space approach can assist in better understanding the contributions of duration and frequency of exposure, elements that have been largely ignored in previous research. In the measurement of environmental exposures, investigators can incorporate the duration of time individuals spend at activity locations or the frequency with which they visit these locations. It is plausible that environmental features in spaces where individuals spend more time are more consequential for obesity-related behaviors and outcomes. Thus, because substantial time is spent there, work environments, for example, may be particularly important for individuals who are employed. Investigators can use kernel density methods to produce smooth continuous surfaces of ‘intensity’ of environmental features (e.g., fast food outlets) and day-to-day activities (based on GPS point data) and map algebra to combine these surfaces in a way that weights environmental features by activity duration (Gatrell et al., 1996; Guagliardo, 2004; Kloog et al., 2009; Levine, 2010; Tomlin, 1990). Another possibility is that the frequency with which an individual visits or travels to an area is of most importance. For example, while minimal time is spent at childcare locations, trips to and from childcare may expose individuals to influential environmental resources and hazards. This highlights potential health consequences of sequencing and “coupling” of activities as part of multipurpose trips (Golledge and Stimson, 1997; Matthews, 2008b).

As with the residential neighborhood, demographic and psychosocial factors as well as characteristics of nutrition and recreation settings (e.g., amenities, safety, quality), may moderate the effect of activity space environmental features on utilization and obesity-related behaviors (Black and Macinko, 2008; Lytle, 2009). Thus, another direction for future research is to link improved measures of environmental exposures through an activity space approach with measures at other levels of a social ecological model to achieve a better understanding of influences on obesity-related behaviors.

Finally, an activity space approach has implications for interventions. Environmental and policy approaches to promote healthier behaviors and body weights have been based largely on evidence from epidemiologic studies of residential neighborhoods (Giang et al., 2008; Khan et al., 2009; United States Department of Agriculture, 2009). Yet, because residential neighborhoods only partially reflect environmental features to which individuals are exposed through day-to-day activities, this research may lead to less than optimal interventions. For example, limiting fast food outlets near low-income residential areas may not be effective in curbing fast food intake if individuals frequently obtain fast food around other activity hubs. Activity space research could provide more solid evidence upon which to base environmental and policy interventions. Indeed, interventions addressing multiple geographic contexts may be most effective (Cummins et al., 2007). Beyond environmental interventions and policies, an activity space approach can also inform new avenues for individually tailored interventions, such as ‘momentary’ interventions via cellular telephones that point individuals to recreational settings and healthy food sources, depending on the current location using mobile GPS and location-based systems (Drummond, 2007; Heron and Smyth, 2010; Kolodziej and Hjelm, 2006; Patrick et al., 2009; Stone et al., 2007).

Conclusions

Epidemiologic research is valuable for identifying promising targets of environmental and policy interventions to promote health. While our understanding of relationships between geographic environments and health has surged over the past decade, epidemiologic research to date is almost exclusively based on residential neighborhoods. In our pilot study with a diverse urban sample, we found that most individuals spent time in a broader space than their residential neighborhood, and that those activity spaces differ from residential neighborhoods in environmental features. We also found some evidence that environmental features of the activity space, but not the residential neighborhood, were related to obesity-related behaviors. An activity space approach offers important new avenues for research that may provide a more complete understanding of how geographic environments influence obesity-related behaviors and outcomes and, in turn, inform environmental and policy interventions.

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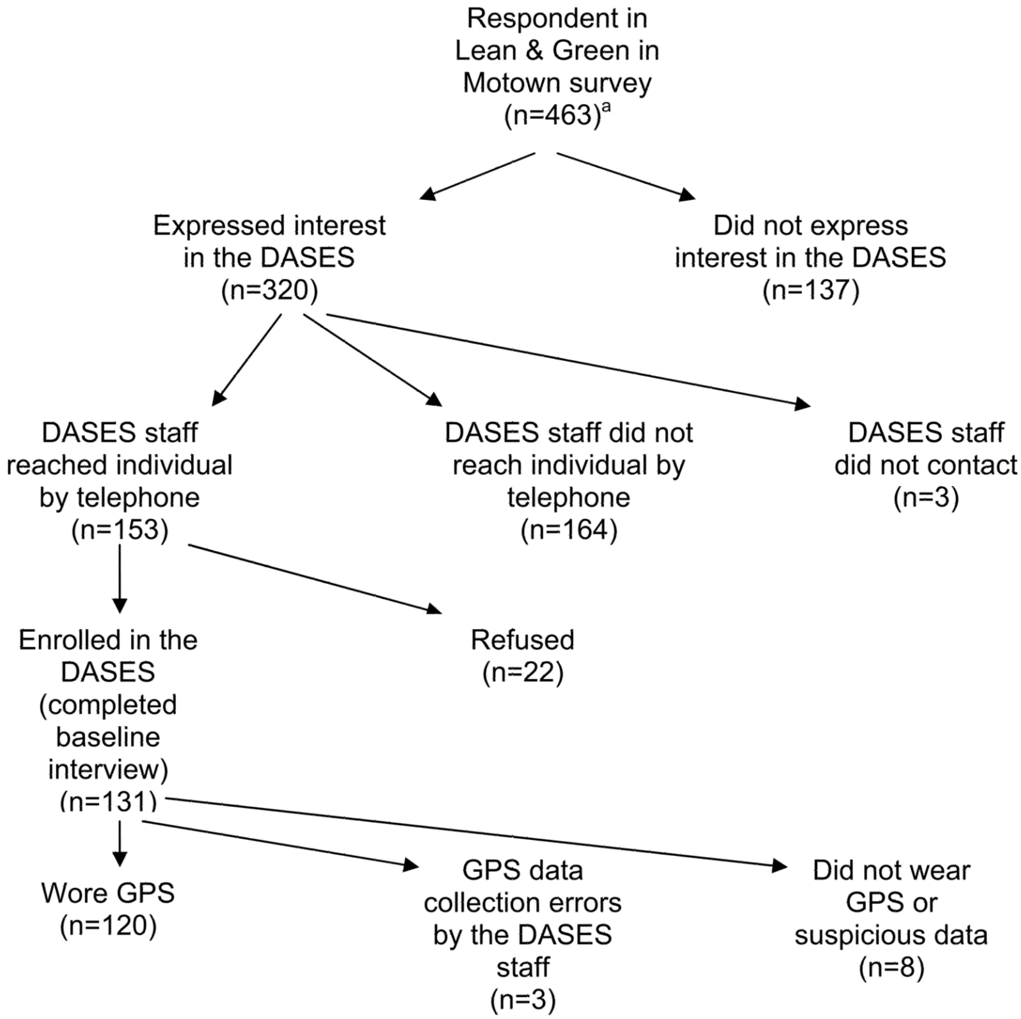

Figure 1.
Depiction of participation by stage for respondents in the parent study, the Healthy Environments Partnership's Lean & Green in Motown survey, and completion of the Detroit Activity Space Environments Study (DASES)
[a]Only 457 Lean & Green in Motown respondents had completed the survey when the DASES stopped all recruitment due to lack of funds.

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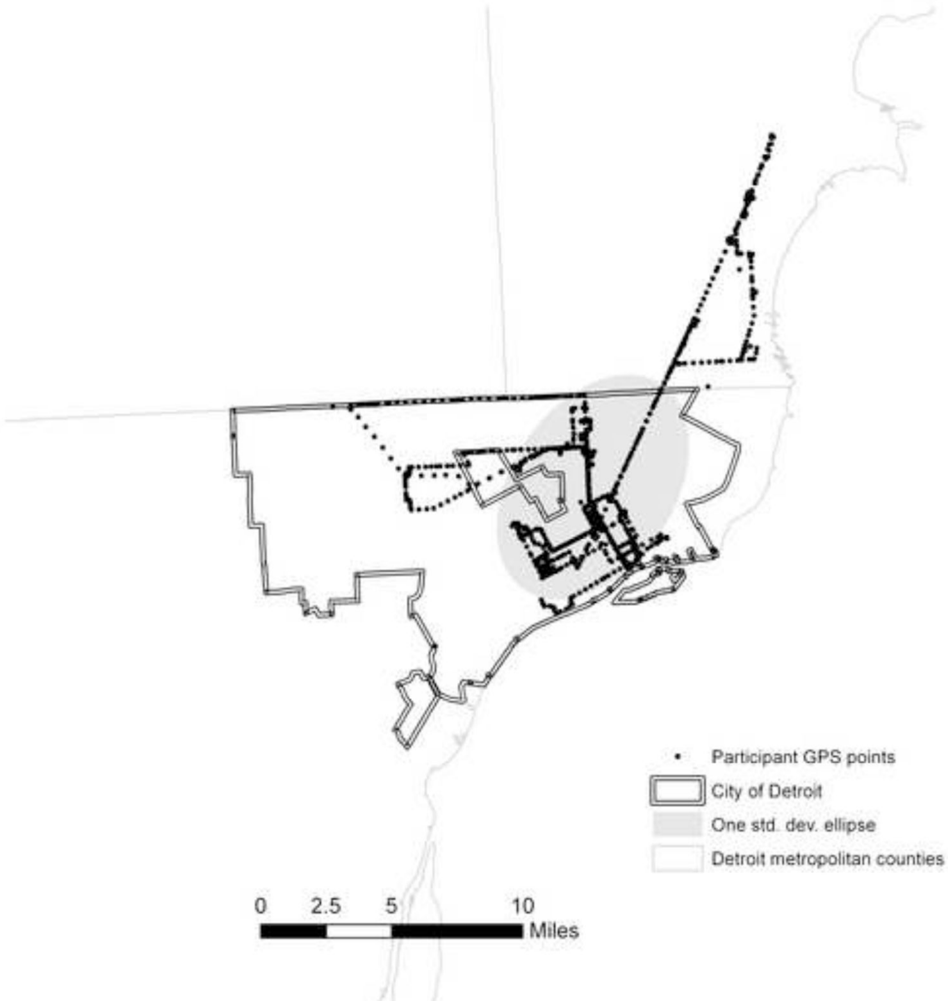

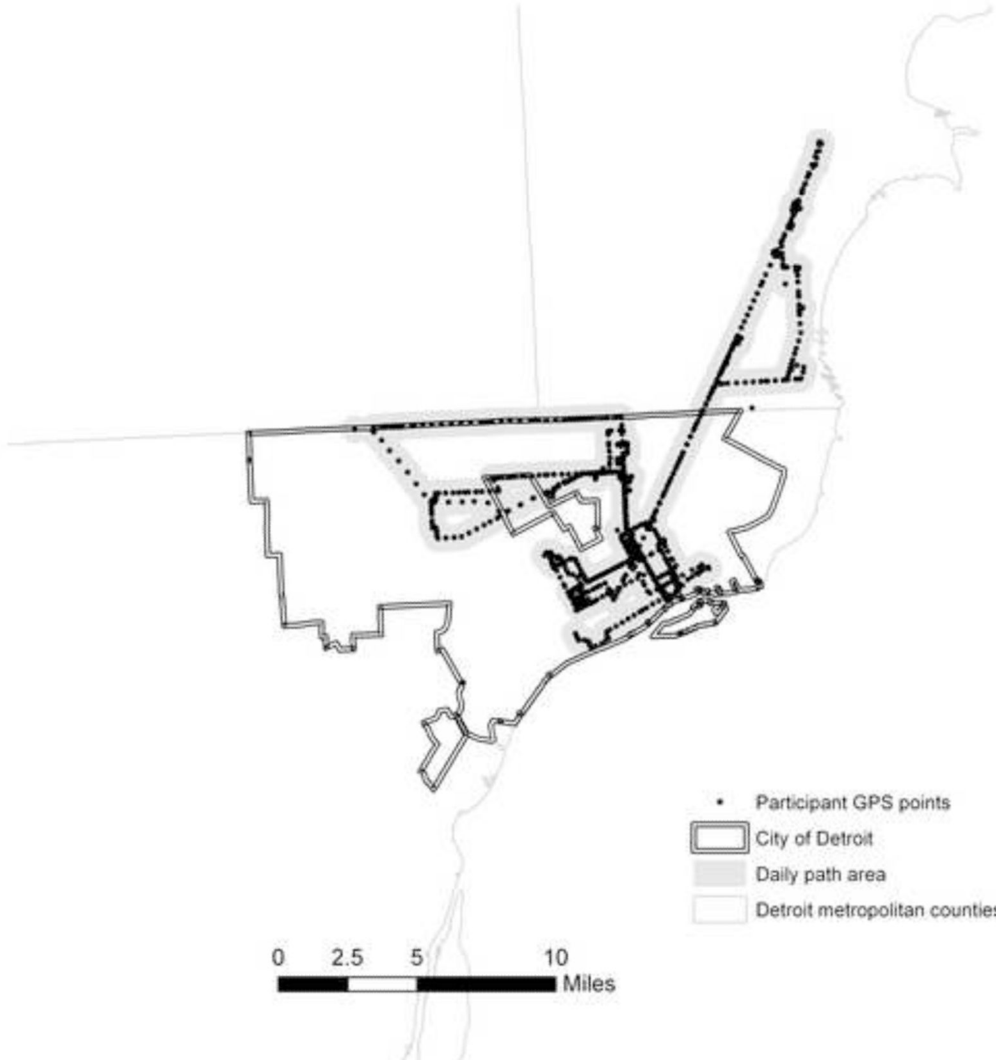

Figure 2.
One standard deviation ellipse and daily path area measures of activity space for one participant in the Detroit Activity Space Environments
Study See attached files

Table 1

Descriptive statistics of sample characteristics, Detroit Activity Space Environments Study (n=120)

	%	n
Age, years		
<45	38.3	46
45–64	51.7	62
>64	10.0	12
Female	75.0	90
Race/ethnicity		
Non-Hispanic African American	55.0	66
Latino	24.2	29[b]
Non-Hispanic White/Other	20.8	25[c]
Education		
Less than high school	35.8	43
High school degree	19.2	23
Some college or technical school	38.3	46
Four-year college degree	6.7	8
Currently employed	35.0	42
Annual household income[a]		
<$10,000	34.2	41
$10,000–$25,000	35.0	42
>$25,000	21.7	26
Owns automobile	64.2	77
Area of the city (study area)		
Eastside Detroit	25.8	31
Southwest Detroit	53.3	64
Northwest Detroit	20.8	25
	Median	**Standard deviation**
Mean daily minutes of moderate or vigorous physical activity [d]	8.2	14.2
Mean daily saturated fat intake, grams [e]	20.4	11.7
Mean daily fruit and vegetable servings [e]	2.8	2.4
Mean daily servings of whole grains [e]	0.8	1.4

[a]Eleven participants were missing data for annual household income

[b]75.0% of the Latino participants were first generation immigrants.

[c]All but one were non-Hispanic White

[d]n=97

[e]n=116

Table 2

Variation in characteristics (size, environmental features) of the activity space (one standard deviation ellipse, daily path area) (n=120) [a, b]

Characteristics	Median	Quartile 1	Quartile 3	Interquartile Range
One standard deviation ellipse				
Geographic size (in mi^2)	7.60	0.71	22.52	21.81
Fast food outlet density (per mi^2)	1.28	0.24	1.72	1.48
Park land use, %	2.37	1.25	3.33	2.08
Daily path area				
Geographic size (in mi^2)	28.63	10.46	49.67	39.21
Fast food outlet density (per mi^2)	1.85	1.48	2.12	0.64
Park land use, %	2.60	2.17	3.37	1.20

[a]Statistics for residential neighborhoods: geographic size (median=0.43 mi^2, Q1=0.38, Q3=0.45, number of fast food outlets (median=0, minimum=0, maximum=3), and percent park land use (median=1.22, Q1=0.10, Q3=3.48)

Table 3

Relationships between characteristics of the activity space (one standard deviation ellipse, daily path area) and individual demographics (n=120)

	Geographic size				Fast food outlet density				Supermarket availability[a]				Park land use			
	One standard deviation ellipse		Daily path area		One standard deviation ellipse		Daily path area		One standard deviation ellipse		Daily path area		One standard deviation ellipse		Daily path area	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	O.R.	C.I.	O.R.	C.I.	Coef.	S.E.	Coef.	S.E.
Intercept	1.67		2.90		0.54				0.38		1.39		1.26		2.91	
Age	<−0.01	0.01	−0.01	0.01	<−0.01	0.01	<−0.01	0.01	0.99	(0.96, 1.03)	0.97	(0.93, 1.01)	−0.01	<0.01	−0.01	0.01
Female	−0.12	0.28	−0.19	0.20	0.26	0.13	0.26	0.13	0.55	(0.20, 1.57)	1.35	(0.39, 4.64)	−0.03	0.13	−0.52	0.32
Race/ethnicity (Ref.: African American)																
Latino	−0.68	0.41	−0.23	0.29	0.05	0.20	0.06	0.15	0.26	(0.05, 1.34)	4.37	(0.73, 26.30)	0.06	0.19	0.69	0.47
White/Other	−0.31	0.39	−0.17	0.27	<−0.01	0.19	0.03	0.15	0.76	(0.18, 3.13)	1.23	(0.27, 5.56)	−0.06	0.18	0.64	0.44
Education (Ref.: <High school degree)																
High school degree	0.11	0.35	0.24	0.25	−0.05	0.17	−0.05	0.17	0.72	(0.19, 2.74)	1.26	(0.28, 5.61)	−0.09	0.16	−0.24	0.40
>High school degree	0.08	0.29	0.14	0.20	−0.01	0.14	<0.01	0.14	0.72	(0.23, 2.21)	1.16	(0.35, 3.83)	−0.13	0.13	0.31	0.33
Currently employed	0.67	0.27*	0.36	0.19	0.09	0.13	0.09	0.13	3.02	(1.12, 8.18) *	3.90	(0.93, 16.42)	0.09	0.13	−0.31	0.31
Annual household income[b] (Ref.: < $10,000)																
$10,000–$25,000	−0.09	0.30	−0.11	0.21	0.04	0.15	0.07	0.14	0.70	(0.22, 2.22)	0.50	(0.13, 1.96)	0.05	0.14	0.54	0.34
>$25,000	0.05	0.34	−0.05	0.24	−0.06	0.17	−0.06	0.17	0.99	(0.27, 3.62)	0.58	(0.12, 2.87)	−0.05	0.16	0.47	0.39
Owns automobile	1.37	0.27 ***	0.99	0.19***	0.13	0.13	0.11	0.13	4.99	(1.62, 15.39) **	7.50	(2.27, 24.84) **	0.24	0.12	−0.79	0.30*
Area of city (Ref: Southwest Detroit)																
Eastside Detroit	−0.63	0.39	−0.19	0.27	−0.11	0.19	0.09	0.14	1.82	(0.45, 7.37)	2.28	(0.47, 11.14)	−0.01	0.18	1.31	0.44*
Northwest Detroit	−0.38	0.39	−0.09	0.26	0.13	0.18	0.28	0.14	1.64	(0.44, 6.20)	6.73	(1.18, 38.45) *	0.37	0.17*	1.94	0.42**
Adjusted R^2	0.25		0.24		−0.03		0.06		--		--		0.04		0.18	

Coef. = coefficient S.E. = standard error O.R. = odds ratio C.I. = confidence interval Ref. = reference category

* $p<0.05$

** $p<0.01$

*** $p<0.001$

[a] Dichotomous measure: Presence or absence of a supermarket in the activity space

[b] A dummy variable was included representing those with missing income data.

Table 4

Bivariate correlations among environmental features (fast food outlet density, park land use) in the residential neighborhood, one standard deviation ellipse, and daily path area (n=120)[a]

	Residential neighborhood	One standard deviation ellipse	Daily path area
Fast food outlet density			
Residential neighborhood	1	0.35[b]	0.03
One standard deviation ellipse		1	0.16
Daily path area			1
Park land use, %			
Residential neighborhood	1	0.05	−0.03
One standard deviation ellipse		1	0.18
Daily path area			1

[a]No participant had a supermarket in their residential neighborhood; 35.0% had a supermarket in their one standard deviation ellipse; 76.7% had a supermarket in their daily path area

[b]$p<0.001$

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Table 5

Relationships between three dietary intake measures and fast food outlet density and supermarket availability in the residential neighborhood and activity space (one standard deviation ellipse, daily path area) (n=116)[a, b, c]

	Saturated Fat Intake				Fruit and vegetable intak				Whole grain intake			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Fast food outlet density												
One standard deviation ellipse												
Neighborhood fast food												
1 outlet	0.34	(2.00)	0.19	(2.00)	0.01	(0.14)	<−0.01	(0.14)	0.12	(0.14)	0.12	(0.14)
2+ outlets	−2.28	(1.71)	−2.91	(1.80)	−0.04	(0.12)	−0.07	(0.13)	−0.05	(0.12)	−0.08	(0.13)
(Reference: no outlet)												
Ellipse fast food outlet density			1.29	(1.18)			0.07	(0.08)			0.04	(0.09)
Adjusted R^2	0.65		0.65		0.16		0.15		0.19		0.18	
R^2 Change			<0.01				0.01				<0.01	
Daily path area												
Neighborhood fast food												
1 outlet			0.29	(1.94)			0.01	(0.14)			0.13	(0.14)
2+ outlets			−2.78	(1.66)			−0.03	(0.12)			−0.02	(0.12)
(Reference: no outlet)												
Daily path area fast food outlet density			3.72	(1.42) *			−0.09	(0.10)			−0.27	(0.10) *
Adjusted R^2			0.67				0.15				0.24	
R^2 Change			0.02	*			0.01				0.05	*
Supermarket availability												
One standard deviation ellipse												
Ellipse supermarket availability			0.24	(1.59)			−0.02	(0.11)			−0.18	(0.11)
Adjusted R^2			0.65				0.16				0.21	
Daily path area												
Daily path area supermarket availability			0.95	(1.80)			−0.04	(0.12)			−0.17	(0.13)

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	Saturated Fat Intake				Fruit and vegetable intak				Whole grain intake			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Adjusted R^2			0.65				0.16				0.20	

Coef. = Coefficient S.E.= Standard error

[*] $p<0.05$

[a] Estimated using ordinary least squares (OLS) regression. Models for each of the activity space measures (one standard deviation ellipse, daily path area) and the two environmental features (fast food outlet density, supermarket accessibility) were estimated separately. Model 1 was not estimated for supermarket accessibility because none of the participants had a supermarket within 0.5 mile of their home.

[b] Covariates: age, gender, race/ethnicity, education, income, employment status, auto ownership, area of the city

[c] A dummy variable was included representing those with missing income data.