Preventive Medicine 93 (2016) 21–26

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

The context of context: Examining the associations between healthy and unhealthy measures of neighborhood food, physical activity, and social environments

Candice A. Myers, Ph.D. [a,*], Kara D. Denstel, M.P.H. [a], Stephanie T. Broyles, Ph.D. [a]

[a] Pennington Biomedical Research Center, Baton Rouge, LA 70808, USA

ARTICLE INFO

Article history:
Received 29 April 2016
Received in revised form 26 July 2016
Accepted 5 September 2016
Available online 6 September 2016

Keywords:
Neighborhood
Place
Co-location
Spatial analysis
Cluster analysis

ABSTRACT

Multilevel health research often focuses on a singular dimension of the neighborhood environment in relation to individual-level health behaviors (e.g., diet, physical activity) and outcomes (e.g., obesity). This study examined associations between healthy and unhealthy neighborhood features across food, physical activity, and social environments. We used neighborhood-level (i.e., census block group) access (0/1) measures of the 1) food (grocery store, convenience store, fast food restaurant), 2) physical activity (fitness/recreation facility, park), and 3) social (crime, renter occupancy) environments to capture both healthy and unhealthy neighborhood features for a sample of neighborhoods ($n = 126$) in East Baton Rouge Parish, Louisiana, United States. We employed a) bivariate correlations, or spatial regression where necessary, to identify significant associations between neighborhood access measures; and b) two-step cluster analysis to identify neighborhood typologies based upon neighborhood access measures. Results demonstrated multiple significant associations between healthy and unhealthy access measures across the three neighborhood environments. Cluster analysis further confirmed that neighborhoods are not completely healthy or unhealthy, but rather can be characterized by neighborhood features that are both health-promoting and health-constraining. This study elucidates a 'context of context' whereby no singular aspect of a neighborhood completely explains health in individuals. Rather, in order to effectively model the association between neighborhood and individual-level health, it may be necessary to account for the inter-related nature of neighborhood features.

1. Introduction

There is a substantial body of international research examining place effects on health, and obesity in particular. This research explicitly acknowledges that where people live influences their health and often utilizes multilevel frameworks to examine how neighborhood of residence impacts overall health (Diez-Roux, 2000; Diez Roux, 2001, 2008; Matthews and Tse-Chuan, 2010; Yang and Matthews, 2010) and obesity-related health outcomes in particular (Black and Macinko, 2008; Harrington and Elliott, 2009; Sundquist et al., 1999). Such analyses often adjust for multiple characteristics at the individual-level (e.g., age, sex, race/ethnicity, socioeconomic indicators), while focusing on a single context of the neighborhood environment (e.g., physical activity resources, food access, social indicators) at the place-level (Hattori et al., 2013; Morland et al., 2006; Sturm and Datar, 2005; Veitch et al., 2012; Wolch et al., 2011). However, research has shown that neighborhood features are inter-related (Black and Macinko, 2008; Diez Roux, 2001; Leal et al., 2012; Matthews and Yang, 2013) and demonstrate patterns of association (Boone-Heinonen et al., 2010).

Further, this research often defines neighborhoods as 'healthy' or 'unhealthy' given the presence or absence of certain features that facilitate or inhibit healthy behaviors (Swinburn et al., 1999). Healthy neighborhoods are often classified as such based upon the availability of resources that encourage or enable healthy behaviors, such as healthy eating habits and physical activity. Conversely, unhealthy neighborhoods prohibit healthy behaviors due to a lack of resources and encourage unhealthy behaviors, such as poor dietary choices and sedentary behaviors. Yet, most neighborhoods do not contain only healthy or unhealthy resources. Neighborhoods can have a variety of contextual features, some of which may be 'positive' and others 'negative' for the health of residents. With respect to the food environment, for example, a United States (U.S.)-based study found that while neighborhoods can have access to grocery stores or supermarkets that provide healthy food options, such as fresh fruits and vegetables, fast food restaurants, which provide access to calorie-dense food options with poor nutritional value (e.g., burgers, French fries), are often also present and potentially co-

* Corresponding author at: Pennington Biomedical Research Center, 6400 Perkins Road, Baton Rouge, LA 70808, USA.
E-mail address: candice.myers@pbrc.edu (C.A. Myers).

http://dx.doi.org/10.1016/j.ypmed.2016.09.009
0091-7435/

located with grocery stores (Lamichhane et al., 2013). Research in Sweden also found similar patterns, in that neighborhoods were found to have access to both grocery stores and fast food restaurants that offer competing healthy and unhealthy food resources, respectively (Kawakami et al., 2011).

Given these issues, the purpose of this study was to examine how healthy and unhealthy aspects of neighborhood environments were related. This approach has been undertaken in other studies examining the neighborhood food environment in the U.S.(Lamichhane et al., 2013). We extended this approach to also include healthy and unhealthy dimensions of the physical activity (PA) and social environments in order to encapsulate the neighborhood aspects most often examined in the extant multilevel obesity literature. The conceptual framework guiding our study is outlined in Fig. 1. We focused on those relationships indicated by solid arrows.

2. Methods

2.1. Study area

Census block groups were used to define neighborhoods for a sample of white and African American children and adolescents (5–18 years) from households located in East Baton Rouge Parish (EBR), Louisiana, U.S., who participated in a cross-sectional study of factors related to abdominal obesity. This spatial scale was selected given the use of census block groups in area-based health research in the U.S. (Krieger et al., 2002; Lamichhane et al., 2013; Sharkey et al., 2009) Census block groups are administrative units for which U.S. census data are collected and are the smallest geographic unit for which census socioeconomic data are available. Census block groups typically contain between 600 and 3000 people (U.S. Census Bureau, n.d). In 2010, there were 303 census block groups comprising EBR. One of these census block groups was completely non-residential with zero population or housing units. Our study sample included 126 of those 302 census block groups in EBR. Utilizing a number of socioeconomic measures (Lamichhane et al., 2013), we analyzed census socioeconomic data to compare our sample of neighborhoods to the entirety of EBR (Table 1). The mean population in 2010 for our sample of neighborhoods was 1674 (standard deviation = 824) and our study sample captured almost half (48%) of the total population in EBR. While our neighborhoods were not purposefully sampled from different socioeconomic areas, our analysis indicates that our study neighborhoods a) are representative of the wider city and b) capture both advantaged and disadvantaged areas.

Table 1
Neighborhood socioeconomic characteristics.
Source: American Community Survey 2013 5-Year Estimates.

	EBR	Study
No. of neighborhoods (census block groups)	302	126
Total population	440,171	210,978
Population density (total population/mile^2)	3233 (2484) [36; 24,049]	2997 (1954) [40; 9461]
Median household income ($)	51,590 (29,794) [11,912; 225,057]	53,077 (30,389) [15,000; 225,087] High = 44 (35%) Low = 40 (32%)
Median housing value ($)[a]	161,737 (91,978) [12,500; 668,900]	162,867 (90,593) [53,000; 668,900] High = 40 (32%) Low = 41 (33%)
Population below poverty (%)	15.0 (16.3) [0.0; 65.91]	15.5 (16.7) [0.0; 65.4]
Poor (≥20%), n (%)	88 (29%)	33 (26%)
Population with a high school degree and above (%)	86.7 (11.8) 53.16, 100.0	86.9 (11.3) 53.16; 100 High = 42 (33%) Low = 39 (31%)

Mean (S.D.) [range], unless otherwise noted.
High and low categories, which indicate less disadvantaged (High) and more disadvantaged (Low) areas, were created from tertiles of each characteristic for all EBR neighborhoods.
[a] East Baton Rouge Parish, Louisiana, United States (EBR) $n = 289$, study $n = 124$ due to missing data for this measure.

2.2. Neighborhood measures

Our study focused on three neighborhood contexts: 1) food environment; 2) physical activity (PA) environment; and 3) social environment. For the food environment, we included three measures of healthy and unhealthy food access, including grocery stores, conveniences stores, and fast food restaurants. Grocery stores served as proxies for healthy food access because these outlets provide access to a wide variety of produce and lean meats, while convenience stores and fast food restaurants served as proxies for unhealthy food access given these establishments often provide an abundance of less healthier food options (Jones-Smith et al., 2013; Lamichhane et al., 2013). Using the North American Industry Classification System (NAICS) codes 445110 (supermarkets and other grocery stores), 452910 (warehouse clubs and supercenters), and 452111 (department stores), we captured large corporate-owned franchised food outlets selling groceries

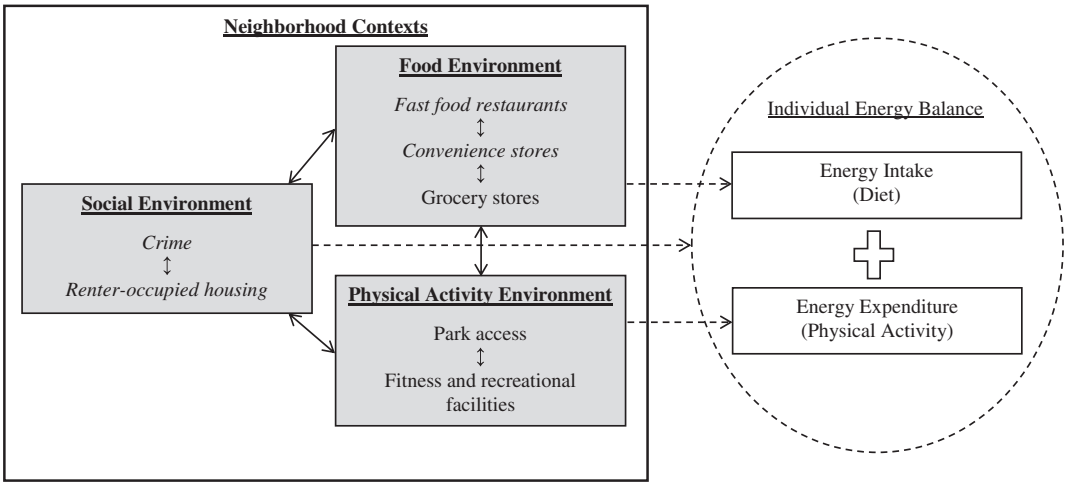

Fig. 1. Conceptual framework outlining the inter- and intra-relationships between neighborhood environments and corresponding measures. Non-italicized neighborhood measures are conceptualized as healthy, while italicized neighborhood measures are considered unhealthy.

(i.e., Target; Walmart, Sam's Club), as well as smaller non-corporate-owned food stores, to measure the presence of a grocery store (Morland et al., 2006). Convenience stores were measured as outlets with and without gas (NAICS 445120, 447110) and other gasoline stations that also provide food services (NAICS 447910) (Morland et al., 2002). Fast food restaurants were defined using NAICS 722211 (limited-service restaurants, which includes carryout restaurants and take out eating places) and 722213 (snack and nonalcoholic beverage bars) (Morland et al., 2002), as well as quick serve restaurants (i.e., McDonald's, Burger King) that are typically excluded from the aforementioned NAICS codes (Forsyth et al., 2012).

The PA environment was characterized by the presence of a fitness/recreation facility (NAICS 713490: establishments engaged in operating fitness and recreational sports facilities, including fitness centers, gyms, and health clubs) and park access. Both fitness/recreation facilities and parks are categorized a healthy because they are resources that promote or make space available for physical activity. Data for food environment measures and fitness/recreation facilities were obtained from an InfoUSA business data file, which is a comprehensive list of businesses in the U.S. and is widely utilized in area-based and multi-level health research to capture retail establishments that characterize food and physical activity environments (Hurvitz and Moudon, 2012; Lamichhane et al., 2013; Moore and Diez Roux, 2006). Completeness and validity of the InfoUSA business data file has been a point of investigation for other researchers (Boone et al., 2008; Liese et al., 2013; Liese et al., 2010; Powell et al., 2011). These investigations concluded moderate sensitivity for InfoUSA in correctly capturing food and physical activity outlets and that the database most often under-counted food outlets and exhibited small error in physical activity facility counts. Parks were obtained from a proprietary geodatabase enumerating the park system for EBR.

The social environment was operationalized using total crime, which was derived from the Federal Bureau of Investigation's Uniform Crime Report data (CrimeRisk, Applied Geographic Solutions, 2010) and includes personal crime, murder, rape, robbery, assault, property crime, burglary, larceny, and motor vehicle theft. We also included a measure of renter-occupied housing (2010 Census Summary File 1). A greater presence of both crime and renter-occupied housing signals an unhealthy social environment (Boone-Heinonen et al., 2010; Harrington and Elliott, 2009). Each neighborhood measure was dichotomized as an access variable indicating whether or not a neighborhood contained at least one establishment for that measure (1 = yes/0 = no). Crime and renter occupancy were dichotomized on the median (high crime = 224; high renter occupancy = 36) of each variable's distribution across neighborhoods and coded as 'high' if above the median and 'low' if below the median (1 = high/0 = low). All neighborhood data were from 2010.

ArcMap 10.2 was used to geographically link and enumerate locations for the food environment measures and fitness/recreation facilities to census block groups. The parks geodatabase was then overlaid to identify if any geographic area of a park was contained in a census block group. These data were then linked to aggregate crime and renter occupancy data.

2.3. Statistical analysis

We first explored potential spatial autocorrelation in our dataset. Because we used CBGs as our units of analysis, there was risk for geographic proximity to influence statistical results given Tobler's first law of geography that "near things are more related than distant things."(Hill et al., 2012; Schuurman et al., 2009; Tobler, 1970) Global Moran's I identified that significant spatial autocorrelation was an issue in one of our neighborhood environment measures: total crime (data not shown) (Anselin et al., 2006). To examine associations between neighborhood measures we first conducted bivariate correlations using Spearman's rho (ρ), or univariate spatial regression where appropriate for neighborhood crime. Beta (b) coefficients derived from spatial regression were converted into bivariate correlation coefficients using this equation: $\rho = \frac{(b * standard\ \ deviation_x)}{standard\ \ deviation_y}$. We next examined how neighborhoods clustered together according to neighborhood features utilizing two-step cluster analysis, which is appropriate for binary data. We used IBM© SPSS© Statistics Version 20 for calculation of descriptive statistics, bivariate correlations, and cluster analysis. GeoDa 1.4.6 was used to assess spatial autocorrelation and carry out spatial regression models.

3. Results

As shown in Table 2, on average, 34% of neighborhoods had access to a grocery store, and 25% and 41% had access to a convenience store and fast food restaurant, respectively; 44% had access to a fitness/recreation facility and over half of neighborhoods, 52%, had access to a park.

3.1. Co-location of neighborhood measures

Table 3 presents significant ($p < 0.05$) associations between neighborhood measures. Neighborhood access to a grocery store was significantly co-located with access to a convenience store and high renter occupancy. This indicates that in those neighborhoods with access to a healthy food outlet – grocery store – neighborhood residents also have access to an unhealthy food outlet – convenience store. Further, access to a grocery store was significantly co-located with high renter occupancy, which is generally considered an unhealthy social environment indicator. Neighborhood access to a fitness/recreation facility was positively correlated with the presence of a fast food restaurant and park access and negatively correlated with both high crime and high renter occupancy. High crime was positively correlated with high renter occupancy, but high crime neighborhoods significantly lacked access to a fast food restaurant.

3.2. Clustering of neighborhood measures

Table 4 shows results from the cluster analysis. Three distinct neighborhood typologies were identified with 24% of neighborhoods belonging to Cluster 1 and 43% and 33% belonging to Clusters 2 and 3, respectively. Cluster 1 contained a high proportion of neighborhoods with grocery store access and a smaller proportion with availability of fast food restaurants, as well as access to PA resources. Cluster 2 contained a greater number of neighborhoods with access to a park and a fitness and recreation facility. Cluster 3 contained neighborhoods with higher percentages of the social environment measures, high crime and high renter. While results from the cluster analysis reveal a three-cluster neighborhood typology that generally groups neighborhoods according to the three neighborhood contexts we focus on here

Table 2
Neighborhood environments and corresponding measures.

	Mean (SD), n (%)
Food Environment	
Grocery store	0.52 (0.92), 43 (34%)
Convenience store	0.34 (0.70), 32 (25%)
Fast food restaurant	1.08 (1.90), 51 (41%)
Physical Activity Environment	
Fitness/recreation facility	0.63 (0.87), 55 (44%)
Park	0.68 (0.78), 65 (52%)
Social Environment	
Total crime index[a]	210.5 (103.5), 63 (50%)
Percent renter-occupied housing[a]	36.9 (22.4), 63 (50%)

n = 126.
Non-italicized neighborhood measures are conceptualized as healthy, while italicized neighborhood measures are considered unhealthy.
[a] Median used to dichotomize as high versus low for analyses: high crime = 224; high renter occupancy = 36.

Table 3
Significant associations between healthy and unhealthy neighborhood measures across multiple neighborhood environments.

	Food environment			Physical activity environment		Social environment	
	Grocery store	Convenience store	Fast food restaurant	Fitness/recreation facility	Park	High crime[b]	High renter occupancy
Food environment							
Grocery store	–					0.029	
Convenience store	0.195*	–				0.022	
Fast food restaurant	0.123	0.150	–			−0.049*	
Physical activity environment							
Fitness/recreation facility	0.075	0.038	0.187*	–		−0.113*	
Park	−0.006	0.054	−0.042	0.308*	–	−0.092	
Social environment							
High crime[a]	0.114	0.084	−0.661†	−0.310*	−0.217	–	0.340*
High renter occupancy	0.218*	0.109	0.049	−0.240*	0.016	0.334*	–

n = 126.
[a] High crime treated as dependent variable (y).
[b] High crime treated as independent variable (x).
* $p < 0.05$.
† $p = 0.05$.

(food, PA, social), results largely suggest a varied pattern of neighborhood contexts across our sample. For example, neighborhoods in Cluster 1 largely have access to a grocery store, but also have access to a fast food restaurant and some are also high crime and high renter neighborhoods.

4. Discussion

This study examined associations between multiple neighborhood contexts by assessing both the co-location and clustering of healthy and unhealthy neighborhood features. Multiple associations and clustering were shown between access to healthy and unhealthy neighborhood measures within and across food, PA, and social environments. This coincides with a body of research that has shown the inter-related nature and co-location of neighborhood features across international settings (Boone-Heinonen et al., 2010; Diez Roux, 2001; Leal et al., 2012; Matthews and Yang, 2013). Findings also suggest that both healthy and unhealthy features spanning different neighborhood contexts were significantly linked. This demonstrates that neighborhoods may not be wholly 'healthy' or 'unhealthy', but rather can contain a varied distribution of both healthy and unhealthy features. Thus, people can face a range of healthy and unhealthy features within their neighborhoods that can affect their personal obesity-related behaviors and body weight outcomes. For example, a neighborhood can have access to a healthy feature, such as a grocery store that provides access to fresh fruits and vegetables, and an unhealthy feature, such as high crime that may operate in a prohibitive way in relation to healthy behaviors and activities.

Our study fits within a larger body of research that has demonstrated the correlated nature of neighborhood features both within and across different neighborhood environments. Research from New Zealand found that access to fast food outlets was strongly associated with neighborhood deprivation (i.e., high unemployment, low income, single-parent families) (Pearce et al., 2007). Moreover, this study also found a similar correlation between neighborhood deprivation and access to supermarkets, further indicating that healthy (supermarkets) and unhealthy (socioeconomic deprivation) neighborhood features can co-occur. In a major U.S. city, a study shown that obesogenic (unhealthy) neighborhoods, characterized by the presence of fast food restaurants and convenience stores, were more likely to have poorer social environments, indicated by lower residential property values (Drewnowski et al., 2014). Further, U.S-based studies examining the geographic relationship between crime and the retail environment have established a positive relationship between alcohol outlet density within neighborhoods and crime within neighborhoods (Jennings et al., 2014; Lipton et al., 2013). Similar associations were also found between neighborhood wealth (i.e., median housing value) and alcohol outlets, with low wealth neighborhoods experiencing a greater presence of places to consume alcoholic beverages (i.e., bar and taverns) (Morland et al., 2002).

In addition to the extant literature, our study also relates to a number of public health efforts in the U.S. that have been undertaken to characterize neighborhood food environments based upon healthy and unhealthy food access. Specifically, food deserts were defined to capture areas (census tracts) of the U.S. lacking supermarkets or large grocery stores (Ver Ploeg et al., 2012). Further, the modified Retail Food Environment Index (mRFEI) is an area (census tract)-based index that measures the number of healthy and less healthy food retails in a neighborhood (Centers for Disease Control and Prevention, 2011). These efforts demonstrate the importance of characterizing neighborhoods to understand how the health of residents will be impacted, as well as for the purpose of identifying areas that should be targeted for

Table 4
Two step cluster analysis: neighborhood typologies.

	Cluster 1		Cluster 2		Cluster 3	
	30 (23.8)		54 (42.9)		42 (33.3)	
Neighborhood measures	Yes	No	Yes	No	Yes	No
Food environment						
Grocery store	30 (100.0)	0 (0.0)	0 (0.0)	54 (100.0)	13 (31.0)	29 (69.0)
Convenience store	11 (36.7)	19 (63.3)	9 (16.7)	45 (83.3)	12 (28.6)	30 (71.4)
Fast food restaurant	15 (50.0)	15 (50.0)	18 (33.3)	36 (66.7)	18 (42.9)	24 (57.1)
Physical activity environment						
Fitness/recreation facility	21 (70.0)	9 (30.0)	28 (51.9)	26 (48.1)	6 (14.3)	36 (85.7)
Park	19 (63.3)	11 (36.7)	29 (53.7)	25 (46.3)	17 (40.5)	25 (59.5)
Social environment						
High crime	10 (33.3)	20 (66.7)	16 (29.6)	38 (70.4)	37 (88.1)	5 (11.9)
High renter occupancy	15 (50.0)	15 (50.0)	6 (11.1)	48 (88.9)	42 (100.0)	0 (0.0)

Cell entries are n (%).

health promotion interventions or policy efforts to improve neighborhood health resources.

To explain the potential mechanisms underlying our findings, it is necessary to acknowledge that the co-location or clustering of food, PA, and social features within and across neighborhoods is not random. Rather, these contextual resources are often placed in areas with regard to a number of considerations and influences. Retail establishments in particular may be placed in areas that have the population density or socioeconomic capacity to support and sustain their economic success; that is, demand and infrastructure for the placement of certain establishments must exist in order for it to be deemed advantageous to locate a business in a particular neighborhood (Gordon-Larsen, 2014). For example, in the U.S. it has been shown that supermarkets are more likely to be located in wealthier communities (Morland et al., 2002). This may be due to a desire on the part of supermarkets to locate in economically vital areas. Yet, international evidence indicates that socioeconomically deprived areas can also be home to supermarkets, as well as a range of healthy and unhealthy neighborhood food and PA resources (Kawakami et al., 2011; Pearce et al., 2007). The placement of such retail establishments in lower socioeconomic areas could be the result of lower building rental and land costs (Pearce et al., 2007), as well as land-use and zoning laws that dictate the placement of certain retail and commercial establishments in less wealthier neighborhoods (Kawakami et al., 2011). Nonetheless, these mechanisms further highlight the complex nature of how neighborhoods are developed and organized and, in turn, influence the health of residents.

Although there is much multilevel research showing associations with neighborhood food and physical activity resources and obesity-related outcomes, reviews often highlight the existence of many null findings or ambiguous relationships (Black and Macinko, 2008). The colocation of both healthy and unhealthy environmental features affecting energy balance means that it is difficult for studies to disentangle these relationships, which could be potentially competing with one another. The omission of relevant neighborhood features that have been shown to influence individual-level obesity could lead to erroneous or unexpected results, while studies that examine multiple contexts allow for comparisons of each environmental dimension's contribution (Boone-Heinonen et al., 2013).

4.1. Study limitations and strengths

Strengths of this study are the analysis of both healthy and unhealthy neighborhood measures, as well as measures across multiple neighborhood contexts including the food, PA, and social environments. Our analysis also accounted for spatial autocorrelation where appropriate. Limitations of this study include, first, a cross-sectional study design which negates the ability to ascertain causality; the significant associations suggested by our analysis are most likely bi-directional. Second, the neighborhood measures assessed in this study were not perceived or directly observed, but rather drawn from publicly available secondary data sources. Third, our findings are vulnerable to both the modifiable areal unit problem (MAUP) and the uncertain geographic context problem (UGCoP), which are problems intrinsic in most ecological analyses in that temporal considerations are not addressed, geographic proxies of 'neighborhood' were created for purposes other than that under study (e.g., CBGs are government administrative units), and ultimately there is no correct spatial scale to measure neighborhood.(Kwan, 2012; Matthews and Yang, 2013; Saib et al., 2014) Last, we acknowledge the potential error associated with using the InfoUSA business data file to capture food outlets and fitness/recreation facilities in our neighborhoods given documented evidence of under counting food and physical activity outlets. The reliance on commercial business lists has been cited as a limitation of research examining neighborhood environments (Gordon-Larsen, 2014). However, the nature of our analysis, which focused on the binary presence or absence of specified neighborhood features to analyze patterns of spatial co-location and clustering, potentially diminishes bias associated with using this business database.

5. Conclusions

In summary, our work demonstrates the complexity of multiple pathways linking neighborhood to individual-level obesity and highlights a need to disentangle these pathways by addressing both healthy and unhealthy dimensions across neighborhood contexts in order to better specify and estimate relationships between neighborhood resources and individual obesity-related behaviors and outcomes. Analogous to the energy balance equation proposed for understanding health in individuals, our work fits with current research demonstrating an energy balance equation external to the human body.(Boone-Heinonen et al., 2013; Boone-Heinonen et al., 2010) In addition to the usual energy suspects, energy expenditure (i.e., PA) and energy intake (i.e., food consumption), there is another component important in the contextual energy balance equation: the social environment, which is increasingly recognized as an important contextual influence when considering health outcomes (Suglia et al., 2016). Taken together, the food, PA, and social contexts of places are inter-related and thereby concurrently influence energy balance in individuals (see Fig. 1). This work suggests a 'context of context' wherein it is necessary to understand and account for linkages between neighborhood characteristics in order to comprehensively model how neighborhoods shape health. Future studies should jointly examine multiple neighborhood contexts to allow for parsing out the singular impact of a neighborhood dimension.

Competing interests

The authors have no financial or other conflicts of interest to disclose.

Acknowledgments

Funding: This research was supported by the American Heart Association (11GRNT7750027; Broyles) and the National Institutes of Health (F32 HL123242; Myers). Funding sources had no involvement in the design of this study; collection, analysis and interpretation of the data; and preparation, review, or approval of manuscript.

We would like to thank Samaah Sullivan for valuable feedback on previous drafts of this manuscript.

References

Anselin, L., Syabri, I., Kho, Y., 2006. GeoDa: an introduction to spatial data analysis. Geogr. Anal. 38, 5–22.

Black, J.L., Macinko, J., 2008. Neighborhoods and obesity. Nutr. Rev. 66, 2–20.

Boone, J.E., Gordon-Larsen, P., Stewart, J.D., Popkin, B.M., 2008. Validation of a GIS facilities database: quantification and implications of error. Ann. Epidemiol. 18, 371–377.

Boone-Heinonen, J., Evenson, K.R., Song, Y., Gordon-Larsen, P., 2010. Built and socioeconomic environments: patterning and associations with physical activity in U.S. adolescents. Int. J. Behav. Nutr. Phys. Act. 7, 45.

Boone-Heinonen, J., Diez-Roux, A.V., Goff, D.C., Loria, C.M., Kiefe, C.I., Popkin, B.M., Gordon-Larsen, P., 2013. The neighborhood energy balance equation: does neighborhood food retail environment + physical activity environment = obesity? The CARDIA study. PLoS One 8, e85141.

Centers for Disease Control and Prevention, 2011. Children's food environment state indicator report, 2011. (Accessed July 11, 2016 at:) http://www.cdc.gov/obesity/downloads/childrensfoodenvironment.pdf.

Diez Roux, A.V., 2001. Investigating neighborhood and area effects on health. Am. J. Public Health 91, 1783–1789.

Diez Roux, A.V., 2008. Next steps in understanding the multilevel determinants of health. J. Epidemiol. Community Health 62, 957–959.

Diez-Roux, A.V., 2000. Multilevel analysis in public health research. Annu. Rev. Public Health 21, 171.

Drewnowski, A., Aggarwal, A., Rehm, C.D., Cohen-Cline, H., Hurvitz, P.M., Moudon, A.V., 2014. Environments perceived as obesogenic have lower residential property values. Am. J. Prev. Med. 47, 260–274.

Forsyth, A., Larson, N., Lytle, L., Mishra, N., Neumark-Sztainer, D., Noble, P., Riper, D.V., 2012. In: Forsyth, A. (Ed.), LEAN-GIS Protocols (Local Environment for Activity and Nutrition–Geographic Information Systems).

Gordon-Larsen, P., 2014. Food availability/convenience and obesity. Adv. Nutr. 5, 809–817.
Harrington, D.W., Elliott, S.J., 2009. Weighing the importance of neighbourhood: a multilevel exploration of the determinants of overweight and obesity. Soc. Sci. Med. 68, 593–600.
Hattori, A., An, R., Sturm, R., 2013. Neighborhood food outlets, diet, and obesity among California adults, 2007 and 2009. Prev. Chronic Dis. 10, E35.
Hill, J.L., Chau, C., Luebbering, C.R., Kolivras, K.K., Zoellner, J., 2012. Does availability of physical activity and food outlets differ by race and income? Findings from an enumeration study in a health disparate region. Int. J. Behav. Nutr. Phys. Act. 9, 105.
Hurvitz, P.M., Moudon, A.V., 2012. Home versus nonhome neighborhood: quantifying differences in exposure to the built environment. Am. J. Prev. Med. 42, 411–417.
Jennings, J.M., Milam, A.J., Greiner, A., Furr-Holden, C.D., Curriero, F.C., Thornton, R.J., 2014. Neighborhood alcohol outlets and the association with violent crime in one mid-Atlantic City: the implications for zoning policy. J. Urban Health 91, 62–71.
Jones-Smith, J.C., Karter, A.J., Warton, E.M., Kelly, M., Kersten, E., Moffet, H.H., Adler, N., Schillinger, D., Laraia, B.A., 2013. Obesity and the food environment: income and ethnicity differences among people with diabetes: the diabetes study of northern California (DISTANCE). Diabetes Care 36, 2697–2705.
Kawakami, N., Winkleby, M., Skog, L., Szulkin, R., Sundquist, K., 2011. Differences in neighborhood accessibility to health-related resources: a nationwide comparison between deprived and affluent neighborhoods in Sweden. Health Place 17, 132–139.
Krieger, N., Chen, J.T., Waterman, P.D., Soobader, M.J., Subramanian, S.V., Carson, R., 2002. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter?: the public health disparities geocoding project. Am. J. Epidemiol. 156, 471–482.
Kwan, M.-P., 2012. The uncertain geographic context problem. Ann. Assoc. Am. Assoc. Am. Geogr. 102, 958–968.
Lamichhane, A.P., Warren, J., Puett, R., Porter, D.E., Bottai, M., Mayer-Davis, E.J., Liese, A.D., 2013. Spatial patterning of supermarkets and fast food outlets with respect to neighborhood characteristics. Health Place 23, 157–164.
Leal, C., Bean, K., Thomas, F., Chaix, B., 2012. Multicollinearity in associations between multiple environmental features and body weight and abdominal fat: using matching techniques to assess whether the associations are separable. Am. J. Epidemiol. 175, 1152–1162.
Liese, A.D., Colabianchi, N., Lamichhane, A.P., Barnes, T.L., Hibbert, J.D., Porter, D.E., Nichols, M.D., Lawson, A.B., 2010. Validation of 3 food outlet databases: completeness and geospatial accuracy in rural and urban food environments. Am. J. Epidemiol. 172, 1324–1333.
Liese, A.D., Barnes, T.L., Lamichhane, A.P., Hibbert, J.D., Colabianchi, N., Lawson, A.B., 2013. Characterizing the food retail environment: impact of count, type, and geospatial error in 2 secondary data sources. J. Nutr. Educ. Behav. 45, 435–442.
Lipton, R., Yang, X., Braga, A.A., Goldstick, J., Newton, M., Rura, M., 2013. The geography of violence, alcohol outlets, and drug arrests in Boston. Am. J. Public Health 103, 657–664.
Matthews, S.A., Tse-Chuan, Y., 2010. Exploring the role of the built and social neighborhood environment in moderating stress and health. Ann. Behav. Med. 39, 170–183.
Matthews, S.A., Yang, T.C., 2013. Spatial polygamy and contextual exposures (SPACEs): promoting activity space approaches in research on place and health. Am. Behav. Sci. 57, 1057–1081.
Moore, L.V., Diez Roux, A.V., 2006. Associations of neighborhood characteristics with the location and type of food stores. Am. J. Public Health 96, 325–331.
Morland, K., Wing, S., Diez Roux, A., Poole, C., 2002. Neighborhood characteristics associated with the location of food stores and food service places. Am. J. Prev. Med. 22, 23–29.
Morland, K., Diez Roux, A.V., Wing, S., 2006. Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. Am. J. Prev. Med. 30, 333–339.
Pearce, J., Blakely, T., Witten, K., Bartie, P., 2007. Neighborhood deprivation and access to fast-food retailing: a national study. Am. J. Prev. Med. 32, 375–382.
Powell, L.M., Han, E., Zenk, S.N., Khan, T., Quinn, C.M., Gibbs, K.P., Pugach, O., Barker, D.C., Resnick, E.A., et al., 2011. Field validation of secondary commercial data sources on the retail food outlet environment in the U.S. Health Place 17, 1122–1131.
Saib, M.-S., Caudeville, J., Carre, F., Ganry, O., Trugeon, A., Cicolella, A., 2014. Spatial relationship quantification between environmental, socioeconomic and health data at different geographic levels. Int. J. Environ. Res. Public Health 11, 3765–3786.
Schuurman, N., Peters, P.A., Oliver, L.N., 2009. Are obesity and physical activity clustered? A spatial analysis linked to residential density. Obesity 17, 2202–2209.
Sharkey, J.R., Horel, S., Han, D., Huber Jr., J.C., 2009. Association between neighborhood need and spatial access to food stores and fast food restaurants in neighborhoods of colonias. Int. J. Health Geogr. 8, 9.
Sturm, R., Datar, A., 2005. Body mass index in elementary school children, metropolitan area food prices and food outlet density. Public Health 119, 1059–1068.
Suglia, S.F., Shelton, R.C., Hsiao, A., Wang, Y.C., Rundle, A., Link, B.G., 2016. Why the neighborhood social environment is critical in obesity prevention. J. Urban Health 93, 206–212.
Sundquist, J., Malmstrom, M., Johansson, S.E., 1999. Cardiovascular risk factors and the neighbourhood environment: a multilevel analysis. Int. J. Epidemiol. 28, 841–845.
Swinburn, B., Egger, G., Raza, F., 1999. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. Prev. Med. 29, 563–570.
Tobler, W.R., 1970. A computer movie simulating urban growth in the Detroit region. Econ. Geogr. 46, 234–240.
United States Census Bureau, (n.d). Geographic terms and concepts — block groups (Accessed July 11, 2016 at:) https://www.census.gov/geo/reference/gtc/gtc_bg.html.
Veitch, J., van Stralen, M.M., Chinapaw, M.J., te Velde, S.J., Crawford, D., Salmon, J., Timperio, A., 2012. The neighborhood social environment and body mass index among youth: a mediation analysis. Int. J. Behav. Nutr. Phys. Act. 9, 31.
Ver Ploeg, M., Breneman, V., Dutko, P., Williams, R., Snyder, S., Dicken, C., Kaufman, P., 2012. Access to affordable and nutritious food: updated estimates of distance to supermarkets using 2010 data. In: E.R.S. (Ed.), United States Department of Agriculture. Economic Research Report.
Wolch, J., Jerrett, M., Reynolds, K., McConnell, R., Chang, R., Dahmann, N., Brady, K., Gilliland, F., Su, J.G., et al., 2011. Childhood obesity and proximity to urban parks and recreational resources: a longitudinal cohort study. Health Place 17, 207–214.
Yang, T.C., Matthews, S.A., 2010. The role of social and built environments in predicting self-rated stress: a multilevel analysis in Philadelphia. Health Place 16, 803–810.