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Healthy and unhealthy food environments are linked with neighbourhood socio-economic disadvantage: an innovative geospatial approach to understanding food access inequities

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Abstract

Objective: This study examined the separate relationships between socio-economic disadvantage and the density of multiple types of food outlets, and relationships between socio-economic disadvantage and composite food environment indices.

Design: Cross-sectional data were analysed using geospatial kernel density techniques. Food outlet data included convenience stores, discount stores, fast-food and fast casual restaurants, and grocery stores. Controlling for urbanicity and race/ethnicity, multivariate linear regression was used to examine the relationships between socio-economic disadvantage and density of food outlets.

Setting: This study occurred in a large Southeastern US county containing 255 census block groups with a total population of 474 266, of which 77·1 % was Non-Hispanic White, the median household income was $48 886 and 15·0 % of residents lived below 125 % of the federal poverty line.

Participants: The unit of analysis was block groups; all data about neighbourhood socio-economic disadvantage and food outlets were publicly available.

Results: As block group socio-economic disadvantage increased, so too did access to all types of food outlets. The total food environment index, calculated as the ratio of unhealthy food outlets to all food outlets, decreased as block group disadvantage increased.

Conclusions: Those who reside in more disadvantaged block groups have greater access to both healthy and unhealthy food outlets. The density of unhealthy establishments was greater in more disadvantaged areas; however, because of having greater access to grocery stores, disadvantaged populations have less obesogenic total food environments. Structural changes are needed to reduce access to unhealthy food outlets to ensure environmental injustice and reduce obesity risk.

Keywords
Food environment
Food inequities
Geospatial analysis
Social disadvantage

Neighbourhoods play a key role in health[1–3]. Living within socio-economically advantaged neighbourhoods is linked with greater self-rated health[4], decreased rates of obesity[5,6] and lower overall mortality[7]. In contrast, people living within socio-economically disadvantaged neighbourhoods, such as those with high rates of poverty and lower educational attainment, are more likely to experience negative health outcomes[8–10], even after accounting for individual socio-economic characteristics (e.g. income and education)[11]. Although neighbourhood disadvantage has persistent negative effects on health, the structures by which neighbourhood disadvantage operates to affect health outcomes are less clear[12].

The food environment may be one avenue through which neighbourhood disadvantage impacts individual and community health[2,13]. Neighbourhood food environments have been repeatedly linked with fruit and vegetable consumption as well as consumption of unhealthy foods (e.g. foods containing excessive fat and sodium)[14]. Additionally, childhood exposures may influence food

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quality and eating behaviours throughout the life course[15]. People who consume inferior quality foods have higher rates of obesity[16], hypertension[17], heart disease[18], diabetes[19] and cancer[20]. Further, certain populations are at greater risk for diet-related conditions than others; disparities by socio-economic status are well documented across the USA[21–23]. The combination of limited access to supermarkets, increased reliance on convenience stores, and the difference in price between healthy and unhealthy foods has the potential to perpetuate health disparities. Ultimately, unhealthy food environments may exacerbate health inequities for socially disadvantaged groups[22,24].

Although density of healthy and unhealthy food establishments can impact food choice[15,25], research has produced mixed findings on the relationship between neighbourhood disadvantage and the quality of available foods[26,27]. Some research suggests that disadvantaged neighbourhoods may have fewer high-quality supermarkets[28], whilst other studies found no association between area deprivation and supermarket access[29]. In one study, while high-density urban-disadvantaged neighbourhoods had greater access to all food outlets, low-density urban-disadvantaged neighbourhoods had greater access to only fast-food establishments[26]. In another study, low-income neighbourhoods had fewer chain supermarkets, which typically stock healthier foods[30,31], and more non-chain supermarkets and grocery stores, which stock lower quality foods[32].

Considerable research has examined food deserts, areas that lack access to affordable healthy foods[33,34], whereas other research has studied food swamps, areas with a greater density of food outlets selling unhealthy foods[35]. However, few studies have addressed both food deserts and swamps[36–38] or utilised a composite measure to characterise the relative density of unhealthy food to healthier food options[39–41]. In contrast, many studies have used simple counts to enumerate the number of distinct types of establishments or have confined such measures to a given administrative neighbourhood, thereby ignoring proximal food outlets outside this boundary[36,37].

Healthy food outlets are those that increase availability of and access to fresh fruits and vegetables, whilst unhealthy food outlets include those that carry a disproportionate number of items with low nutritional value[40]. Little research has applied advanced spatial methods, such as kernel density, to understand the distributions of healthy and unhealthy food outlets, and none has applied these methods to understand the relationship between the food environment and socio-economic disadvantage (SED)[42,43]. Kernel density methods can be used to quantify the impact of a particular food outlet over a given distance, thereby operationalising the assumption that its influence will be stronger on more proximal areas with decaying influence as distance increases[42]. This method can be used to study how neighbourhood disadvantage relates to the relative densities of healthy and less healthy food outlets across a geographic landscape to understand their composite relationship with SED[44]. A comprehensive look at socio-economic status and area demographics is important for gaining an understanding of a neighbourhood; however, when labelling neighbourhoods as disadvantaged or advantaged, often only one neighbourhood indicator has been assessed, such as the percentage of the population below the poverty line[26]. Few studies have created an index for both SED and the neighbourhood food environment[29,45].

Given these gaps in the literature, the purposes of this study were to examine (1) the separate relationships between SED and the density of multiple types of food outlets, and (2) relationships between SED and composite unhealthy and healthy food environment indices. It was hypothesised that higher levels of block group disadvantage would be associated with a higher density of unhealthy food establishments, a lower density of grocery stores and a more negative overall food environment.

Methods

Study setting

This study occurred in a large Southeastern US county with an area of 795 square miles (2060 km^2). As seen in Table 1, in 2013, the county had a total population of 474 266, of which 77·1 % was non-Hispanic white, 18·5 % was African American and 8·5 % was Hispanic or Latino. The median household income was $48 886 and approximately 15·0 % of residents lived below the federal poverty line[46]. The county contained 255 census block groups which served as the units of analysis for this study. Block groups are permanent subdivisions of a county, are the second-smallest geographical unit recognised by the US Census Bureau (usually 600–3000 people with varying area depending on population density) and have been used to approximate neighbourhoods in previous studies[47–49].

Food outlet enumeration and categorisation

As described elsewhere[45], food outlet data were obtained, enumerated and classified from two secondary sources, the State Department of Health and Environmental Control and Info USA, both of which have been used frequently for research[50,51]. Duplicate entries were removed, and all food outlets were geocoded at the point address level using ArcGIS and a US street network data set. As outlined and defined in Table 1, outlets were classified as grocery stores/supermarkets (*n* 80), convenience stores (*n* 248), discount or drug stores (*n* 67), fast-food restaurants (*n* 368) or fast casual restaurants (*n* 349). Grocery stores and supermarkets usually contain diverse options for fruits and vegetables and other healthy options and have been positively associated with healthy eating and healthy weight status in youth[14,32,52]. Convenience and discount

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Table 1 Food environment categories and definitions

Food outlet types	Definitions
Food stores[50]	
Grocery	Retail food store that primarily sells food (e.g. Bi-Lo, Publix)
Convenience	Retail food store with extended opening hours and convenience location, stocked with a limited range of household goods and food products (e.g. QuikTrip).
Discount and drug stores	Establishments that sell a limited variety of food products (e.g. Dollar Tree, CVS)
Restaurants[51]	
Fast food	Restaurants that are characterised by minimal service and by food that is supplied quickly after ordering where food is commonly cooked in bulk in advance and kept hot, or reheated to order (e.g. Arby's, Taco Bell)
Fast casual	Restaurant that is similar to fast food in that it does not offer table service, but promises somewhat higher quality of food and atmosphere where customers often order and pay at a counter and food is brought to the table (e.g. Atlanta Bread Company, Moe's Southwest Grill)

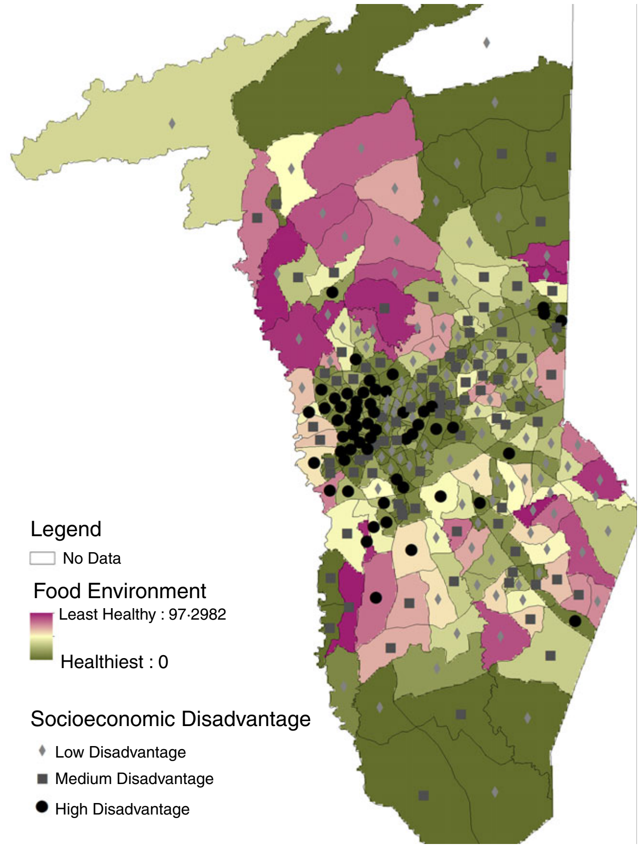

Fig. 1 (colour online) Food environment by socio-economic disadvantage

or drug stores are usually characterised as stocking high-fat, sugary, take-away or snack food, and other unhealthy food options and are open longer hours compared with other food outlets[53]. Fast food and fast casual outlets are characterised as supplying energy-dense and nutrient-poor food options that are cheap and highly convenient[54,55].

Measures

Block group characteristics

All block groups in the study setting were categorised as either rural, mixed or urban. To accomplish this, using GIS, we overlaid all study block groups with US Census Bureau data for urbanised areas (50 000 or more people) and urban clusters (2500–50 000 people)[56]. Urban block groups were those located entirely within areas of 50 000 or more people. Mixed block groups were those that were entirely within areas of 2500–50 000 people or overlapping areas of both 2500–50 000 people and 50 000 or more people. Finally, rural block groups were all others not classified as urban or mixed[57,58].

To characterise the racial/ethnic composition of each block group, the percentage of population that was non-White was calculated from American Community Survey 5-year estimates (2009–2013).

Finally, data from American Community Survey 5-year estimates (2008–2012) were used to construct a composite SED index for each block group that served as the independent variable[46]. Four key economic and education variables were selected based on prior research, including the percentage of the population that was unemployed, percentage with less than a high school education, percentage of renter occupied housing and percentage of the population under 125 % of the federal poverty threshold[48]. These variables were subjected to a principal components analysis with oblique rotation and all loaded strongly (>0·50) on a single factor[45]. Each variable was then standardised to ensure a similar scale and equal weighting prior to summing them together to create the SED index value for each block group[48,59]. Figure 1 provides an illustration of the study area by SED and food environment.

Food outlet density surfaces

A kernel density analysis was conducted for convenience stores, discount and drug stores, fast casual restaurants, fast-food restaurants and grocery stores using ArcGIS. Kernel density diffuses the impact of an environmental feature across a specified distance and creates a raster surface representing 100 m × 100 m cells with varying weights[57]. For the four types of less healthy food outlets, a standard 1-mile (1·6 km) buffer was applied around each establishment[60,61], while for grocery stores, a 3-mile (4·8 km) buffer was applied because these outlets have greater population reach and a recent study demonstrated that the average distance to a grocery store for youth in our study area was 2·9 miles[57,60]. A separate surface was created for each type of food outlet by aggregating the scores for each cell (e.g. a cell might be impacted by multiple fast food restaurants

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at varying distances). Each food outlet surface was then normalised such that 0 represented a cell with no access to the food outlet and 1 represented the cell with the greatest access to the food outlet[57]. To match the unit of analysis, a block group score for each type of food outlet was created by calculating the average density score for all cells within the block group.

The four unhealthy food environment layers – convenience stores, discount and drug stores, fast-food restaurants and fast casual restaurants – were aggregated using ArcGIS to create a composite unhealthy food environment index. The healthy food environment was represented by the grocery store layer.

It has been shown that the relative density of food outlet types is a better predictor of fruit and vegetable intake than counts of healthy and less healthy food outlets.[41,62]. Thus, a variation of the Modified Retail Food Environment Index, which accounts for relative densities of food establishments, was used to create a total food environment index[63]. The Modified Retail Food Environment Index produces a ratio of unhealthy food outlets to the total number of food outlets, per area[63]. For this study, the raster calculator was used to divide the kernel density of unhealthy food outlets by the total density of food outlets (kernel density of unhealthy outlets plus the kernel density of grocery stores), all times one hundred. A greater score on the total food environment index indicates that a larger proportion of food outlets are unhealthy. All three indices – healthy, unhealthy and total – were calculated at the block group level by finding the mean value for all cells within the block group using the Zonal Statistics tool in ArcGIS.

Analysis

Multivariate linear regression was used to examine differences in food environments according to level of SED. Separate models were conducted to test the relationship between SED and the density of each type of food outlet. To examine the relationship between SED and the composite food environment, three separate models explored the association between SED and the unhealthy food environment index, healthy food environment index and total food environment index. All analyses were conducted in SPSS 25.0 and adjusted for urbanicity and the percentage of the population considered a racial/ethnic minority.

Results

Block group characteristics are displayed in Table 2. Table 3 reports relationships between SED and the four unhealthy food outlet layers. There was a positive association between neighbourhood SED and all types of unhealthy food outlets, such that higher block group disadvantage was associated with greater convenience store density

Table 2 Block group descriptive statistics (*n* 255)

Variable	Mean	SD	Range
Population	1776·2	864·8	297·0–4566·0
Size (sq. miles)	3·1	6·9	0·2–68·5
Less than high school education (%)	16·9	12·9	0–63·2
Racial/ethnic minority composition (%)	31·5	23·3	0–98·6
Unemployment (%)	6·4	4·4	0–23·0
Population below 125 % poverty (%)	23·0	16·7	0–76·1
Renter occupied housing (%)	34·0	23·2	0–100·0
Socio-economic disadvantage	0·0	2·9	–5·5–9·9

Table 3 Relationships between neighbourhood socio-economic disadvantage and food outlet density (*n* 255)

Dependent variable	β	SE	R^2	*P*-value
Convenience stores	0·02	0·00	0·34	<0·01
Discount stores	0·01	0·00	0·07	0·02
Fast casual restaurants	0·01	0·00	0·05	0·04
Fast-food restaurants	0·01	0·00	0·05	0·02
Healthy food environment (grocery stores)	0·04	0·01	0·22	<0·01
Unhealthy food environment	0·01	0·00	0·15	<0·01
Total food environment	–1·74	0·00	0·04	0·02

($R^2 = 0{\cdot}34$, $\beta = 0{\cdot}02$, $P < 0{\cdot}01$), discount store density ($R^2 = 0{\cdot}07$, $\beta = 0{\cdot}01$, $P = 0{\cdot}02$), density of fast casual restaurants ($R^2 = 0{\cdot}05$, $\beta = 0{\cdot}01$, $P = 0{\cdot}04$) and density of fast food restaurants ($R^2 = 0{\cdot}05$, $\beta = 0{\cdot}01$, $P = 0{\cdot}02$).

Table 3 also reports relationships between SED and the composite unhealthy, healthy and total food environment indices. There was a positive association between SED and the density of unhealthy food outlets ($R^2 = 0{\cdot}15$, $\beta = 0{\cdot}01$, $P < 0{\cdot}01$); as block group disadvantage increased, so too did the overall density of unhealthy establishments. Likewise, there was a positive association ($R^2 = 0{\cdot}22$, $\beta = 0{\cdot}04$, $P < 0{\cdot}01$) between SED and the density of healthy food outlets (i.e. grocery stores); as block group disadvantage increased, so too did the density of grocery stores. Finally, there was a negative association between SED and the total food environment ($R^2 = 0{\cdot}04$, $\beta = -1{\cdot}74$, $P = 0{\cdot}02$); as block group SED increased, the total food environment index (as a ratio of unhealthy to total food outlets) decreased.

Discussion

This study examined neighbourhood variations in the food environment by SED. It was hypothesised that as block group SED increased, there would be a higher density of unhealthy food establishments, a lower density of grocery stores and a more unhealthy overall food environment.

Block group SED was positively related to the density of unhealthy food outlets as predicted. However, the relationship between SED and the healthy and total food environment indices did not follow the hypothesised relationship. As neighbourhood disadvantage increased, there were more grocery stores per block group and the overall food environment scores, where higher scores indicate worse total environments, decreased (with grocery stores balancing out the impacts of unhealthy food outlets).

In this context, people who reside in more disadvantaged block groups have greater access to all food outlets. This includes unhealthy food outlets such as convenience stores and fast-food restaurants, which is consistent with past research reporting that lower income areas had greater access to these types of outlets[64]. This is important since research shows that higher density of unhealthy food outlets has a detrimental effect on health concerns that are frequently observed in less affluent populations[7].

Another important finding from this study was that disadvantaged block groups also have significantly greater availability of grocery stores compared with advantaged block groups. While some past research has reported lesser access to healthy foods in low-income, minority and rural neighbourhoods[65], this study showed contrasting results. One explanation for this might be the study setting, wherein there was overall high access to all types of food outlets across the block groups and over 80 % of the population resided in an urban area[46]. Even with adequate access to grocery stores, certain residents may not have the financial ability to purchase healthy, higher quality and more expensive food options, meaning that even proximal, healthy outlets may remain inaccessible to low-socioeconomic status individuals[66]. Future research using these methods may also account for variables such as cost and quality of basic food items.

When examining the composite food environment, more disadvantaged block groups had comparatively healthier total food environment scores compared with advantaged block groups. In this study setting, disadvantaged areas may have greater population density and be home to more proximal grocery stores (which also have greater geographic influence). And while some past research has shown, contrary to our findings, that healthy food outlets are often lacking in low-income areas, it is also true that a higher density of unhealthy food outlets may predict obesity more than the availability of healthy food outlets[36,67]. Overall, additional research is needed on the synergistic effect of healthy and unhealthy food outlets on outcomes, such as obesity, to understand which ratio of healthy and unhealthy outlets is optimal for maintaining good health[41,62].

Strengths and limitations

This study has several strengths, including that it occurred in the Southeastern US, which has some of the highest rates of obesity in the world, and disparities in access to food resources are particularly salient[68]. Additionally, the use of multiple types of outlets, examined individually and as part of composite food indices, allowed for a more thorough understanding of the relationship between SED and the food environment. Lastly, this study used innovative kernel density methods to quantify the impact of food outlets over the study area, thereby facilitating a better understanding of spatial relationships between the food environment and SED.

Despite the strengths of this study, important limitations should be noted. First, we did not test these composite measures against a health outcome, such as obesity, to understand the impact and differing effects of healthy and unhealthy outlets. Future research could examine the total relationship between SED, food environment and health. Second, the sample of block groups was from a single county with less variation in terms of rurality and SED which was not representative of the entire state or country, though these methods could be replicated elsewhere. Third, we did not account for additional barriers to accessing healthy food outlets in local settings, such as safety travelling to the outlet without a car and prices of basic food items for the healthy and unhealthy outlets under study. While this information was not available for this study, future research on socio-economic disparities for food environments may adjust for crime safety, walkability and food costs since low-income residents may experience these barriers more than barriers related to geographic access. Finally, due to the cross-sectional nature of this study, we were unable to assess the role residential selection may play in disparities.

Conclusion

As area disadvantage increased, so too did access to both healthy and unhealthy food outlets. Although disadvantaged populations have greater access to all types of food outlets, the density of unhealthy establishments was lower than the density of grocery stores in these areas. These results highlight the importance of examining a composite food environment indices *v.* considering only access to healthy or unhealthy food outlets individually. Contrary to expected results, this study found that healthy outlets were actually more prevalent in disadvantaged areas, highlighting that food outlet availability can differ significantly by geographic location[37,65]. Unhealthy outlets were also more prevalent in more disadvantaged areas, and this could partially be the cause of higher rates of chronic conditions in more disadvantaged neighbourhoods. Structural interventions and policies, such as zoning ordinances and retailer incentives, are needed to decrease access to obesogenic food outlets and ultimately address environmental injustice related to obesity risk.

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