Objective Assessment of Obesogenic Environments in Youth

Geographic Information System Methods and Spatial Findings from the Neighborhood Impact on Kids Study

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Background: GIS-based walkability measures designed to explain active travel fail to capture "playability" and proximity to healthy food. These constructs should be considered when measuring potential child obesogenic environments.

Purpose: The aim of this study was to describe the development of GIS-based multicomponent physical activity and nutrition environment indicators of child obesogenic environments in the San Diego and Seattle regions.

Methods: Block group–level walkability (street connectivity, residential density, land-use mix, and retail floor area ratio) measures were constructed in each region. Multiple sources were used to enumerate parks (~900–1600 per region) and food establishments (~10,000 per region). Physical activity environments were evaluated on the basis of walkability and presence and quality of parks. Nutrition environments were evaluated based on presence and density of fast-food restaurants and distance to supermarkets. Four neighborhood types were defined using high/low cut points for physical activity and nutrition environments defined through an iterative process dependent on regional counts of fast-food outlets and overall distance to parks and grocery stores from census block groups where youth live.

Results: To identify sufficient numbers of children aged 6–11 years, high physical activity environment block groups had at least one high-quality park within 0.25 miles and were above median walkability, whereas low physical activity environment groups had no parks and were below median walkability. High nutrition environment block groups had a supermarket within 0.5 miles, and fewer than 16 (Seattle) and 31 (San Diego) fast-food restaurants within 0.5 miles. Low nutrition environments had either no supermarket, or a supermarket and more than 16 (Seattle) and 31 (San Diego) fast-food restaurants within 0.5 miles. Income, educational attainment, and ethnicity varied across physical activity and nutrition environments.

Conclusions: These approaches to defining neighborhood environments can be used to study physical activity, nutrition, and obesity outcomes. Findings presented in a companion paper validate these GIS methods for measuring obesogenic environments.

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Background

The IOM[1] and National Research Council[2] have recommended changes to "obesogenic environments" as strategies to prevent childhood obesity. However, obesogenic environments have not been defined operationally. Logically, obesogenic environments would relate to both energy intake and expenditure.[3]

An extensive literature exists on how walkability measures relate to youth travel to school.[4–9] Correlates of active school trips include land-use mix,[10,11] street connectivity,[11,12] population density,[11,12] and distance to school.[11,13] Research on youth activity patterns[14–16] highlights the importance of access to recreational opportunities such as parks. Proximity to recreation facilities has been related to both walking for transportation[17,18] and leisure-time physical activity.[19,20] A review[21] confirmed that land-use mix and access to recreation facilities were among the most consistent correlates of youth physical activity.

Access to food may influence youth health outcomes; however, studies show mixed results. Powell et al.[22] and Liu et al.[23] found supermarket access related to lower obesity prevalence in youth, whereas Sturm and Datar[24] did not find this connection. Results for fast-food access are similarly inconclusive.[22,24–26] However, access to sources of many healthy foods such as supermarkets, and unhealthy food sources such as fast-food restaurants, are logical components of obesogenic environments and have at least limited empirical support.[27] Prior methods using census geography to examine environmental factors do not typically account for effects of adjacent areas such as block groups. GIS-based spatial sampling methods have seldom captured food and recreational amenities and have seldom systematically identified environments with adequate variability in built form.

A critical study design consideration for testing hypotheses about obesogenic environments is to maximize variation in both physical activity and nutrition environments to ensure statistical power. Random selection is unlikely to achieve these goals, but definitions of obesogenic environments must be constructed to produce a sufficient recruitment pool. An innovative targeted spatial sampling method using GIS was developed and applied to identify block groups that had households with children aged 6–11 years and contrasting physical activity and nutrition environment attributes in San Diego County CA and King County (Seattle) WA. This paper describes the method and its application to the recruitment of youth for the Neighborhood Impact on Kids (NIK) study. Results showing differences in obesity across physical activity– and nutrition-environment neighborhood types based on the application of this method are presented in a companion paper[28] in this theme issue.

Methods

Procedures to develop a series of geographically based physical activity and nutrition environment measures are described, along with the process to establish cut points to target census block groups falling into four quadrants formed by high and low combinations of physical activity and nutrition environments. Each neighborhood type needed to have 1000 potential recruits of children aged 6–11 years. A 10% recruitment rate was assumed, based on previous experience. Variables used for block group selection included walkability, park proximity, park quality, fast-food proximity/concentration, and supermarket proximity. An iterative process was required to balance sample size requirements, fast-food outlet concentrations, and distance to grocery stores and parks. A resulting 2×2 matrix of high/low physical activity environments and high/low nutrition environments was defined through specific numeric thresholds for the high and low categories for each region. Applying evidence about how far people travel for recreation and food, a similar process for defining high/low thresholds in each region yielded different values that reflected distributions that varied by region.

Using objective built environment data and GIS software (ArcGIS v. 9.3), census block groups were categorized into quadrants of high and low physical activity environment and high and low nutrition environment. The physical activity environment was defined here to include validated measures of neighborhood walkability[4] shown to predict active transportation[29] and the recreation environment or "playability."[14] The nutrition environment was defined to include the type and distance of food outlets including supermarkets and fast-food restaurants.[30–32]

Sampling for an age-specific subgroup (children aged 6–11 years) presented challenges because of low numbers of potential participants in any one location. A marketing firm provided address-specific identifiers and, with informed consent, provided the ability to contact families with children in the target age range. The requirement to define physical activity and food environments in all four quadrants further constrained the pool of potential participants.

Utilitarian Walkability Index

Walkability methods were based on previously developed procedures.[4] A walkability index was created for each region using 2000 U.S. Census block group geography. Built environment measures were calculated for each block group plus a 0.25-mile "shadow-buffer" around it, to compensate for households near the boundary that were likely to be influenced by an adjacent block group. Parcel, census, and road network data were used to calculate the following variables: >net residential density; intersection density; an entropy-based land-use mix measure of five land uses (civic and educational, entertainment, retail under 300,000 sq ft, multi- and single-family, office); and retail floor area ratio (FAR) variables. Region-specific composite walkability indices were created for each block group by summing the normalized *z*-score values of each variable.

Playability Index

A block group–level playability index was created based on public park proximity and availability and quality features within them

Table 1. Environmental Assessment of Public Recreation Spaces park scores by region

Region	Parks, *n*	Min	Max	Median	M (SD)
King County WA	527	0	1091	294	308 (208)
San Diego County CA	290	14	1102	343	340 (201)

Max, maximum; Min, minimum

presumed to be most related to physical activity among children aged 6–11 years. Comprehensive lists of public parks in the study regions were compiled from a variety of digital and print sources, including government-supplied park lists (e.g., name, address, amenities) from each municipality within each county; government- and ESRI, Inc.–supplied GIS shapefiles showing park boundaries; parcel data (indicating land uses including parks, open spaces, fields, and other land-use designations that suggested public recreation space); commercial maps and listings (e.g., Thomas Brothers Guide); various websites; and aerial photography. No single source encompassed all parks meeting criteria for this study. Considerable differences were noted across these sources of data, including variation in the number of parks listed.

In San Diego (Seattle, King County), these sources yielded more than 2600 (2800) parks, of which approximately 900 (1600) were unique. Duplicate park records were identified using name, address, and spatial location. All sources contributed unique records. Park-quality measures were created from in-field park audits using portions of the Environmental Assessment of Public Recreational Spaces (EAPRS) tool,[33] including assessments of trails and paths; activity-related water areas (e.g., pool, beach); playground equipment; athletic fields/courts; and the surrounding neighborhood (e.g., sidewalk access to parks, safety). Spaces containing no usable features (i.e., wooded areas with no trails), fenced off or not accessible, or restricted to private access were not rated.

Defining Physical Activity Environments

Thresholds of walkability, park proximity, and park quality were chosen to enable the inclusion of participants from across the spectrum of physical activity environment levels while gaining a large-enough potential recruitment pool (assuming a 10% completion rate) to measure 700–800 children across the two regions. A block group was defined as having high walkability if its region-specific walkability index was above the median score and having low walkability if below. Block groups with low physical activity environments were defined as having less than median walkability and no park in or within a 0.25-mile "shadow buffer" around their periphery. A block group with a high physical activity environment was required to have a nearby park. Different score thresholds for playability (park quality) were tested for effect on the potential recruitment pool. Table 1 shows the scoring that was done on 527 parks in King County and 290 in San Diego County and provides descriptives of park scores in or near the high-walkability block groups.

Overall EAPRS scores ranged from 0 to 1102 (assessment algorithm available on request). A high physical activity environment block group had an above-median walkability index and a park in or within 0.25 miles, with an EAPRS score of >200. More parks (527 vs 290) were in the eligible set of high-walkability block groups in King County, yet overall ratings of the parks in San Diego County were higher.

Food Environment Enumeration and Selection Criteria

A GIS shapefile of current food outlets (address points) was created from addresses in county food license lists, Dun & Bradstreet business listings, city business permits, and phone book listings. Outlets that were not primarily for institutional food service were excluded. Considerable overlap across sources existed; however, each source excluded valid establishments found by another source, or listed establishments no longer in existence. For example, for King County (San Diego), Dun & Bradstreet showed 5131 (7427) listings as compared to 6923 (10,045) County Food Licenses, with 3263 (5368) of the Dun & Bradstreet listings also in the County Food License list.

Outlets were categorized into convenience stores; markets/produce stores; supermarket/grocery; fast-food restaurants; sit-down restaurants; specialty food stores (e.g., bakery); and multipurpose stores (e.g., pharmacies) according to North American Industry Classification System or Standard Industrial Classification codes, name of establishment, and Internet searches including lists of local and regional chains with telephone calls to the locations. The existence, location, and purpose of all food locations in participant block groups were verified also through phone calls.

Defining Nutrition Environments

A block group's nutrition environment was defined using a combination of fast-food concentration and supermarket proximity within and immediately surrounding the block group, again coupled with the need to have a sufficiently high potential recruitment pool in both high and low nutrition and physical activity environments. An iterative process similar to that used to define the physical activity environment threshold was used to define nutrition environment thresholds for each region. Final definitions for high and low cut points were created after reviewing the effect on the potential recruitment pool and distribution across nutrition environments. Consistent definitions of high/low nutrition environment were desired for both regions; however, major differences in fast-food outlet availability were discovered.

There were 3474 enumerated fast-food locations in San Diego County, as compared to 1660 in King County. On a county-level block group average basis, San Diego had 2.0 fast-food locations per block group, and King County had 1.1. Thresholds of 31 and 16 fast-food outlets within 0.5 miles of a block group for San Diego and King County, respectively, were established by iterating between quadrant-level recruitment targets for 1000 households for both regions and the presence of fast-food outlets. A San Diego threshold of 31 fast-food locations within 0.5 miles was established first based on reaching a sufficient number of potential recruits (>1000). When this target was used in King County (with half the number of enumerated fast-food outlets), it resulted in too few potential households (540) in the quadrant with high physical activity environments and low nutrition environments. A final target of 16 fast-food outlets was set for King County, which corresponded with more than 1000 potential households.

Rationale for Park and Food Outlet Distance Thresholds

A distance threshold to parks was set at 0.25 miles and to food outlets at 0.5 miles, supported by the finding that the average trip distance was 35% and 15% longer for meal-related trips compared with exercise and visiting public places trips in San Diego and King County, respectively, based on recent household travel data in both regions (LDF & JC, unpublished observations, January 2012). Distances of 0.25 and 0.5 miles were used for parks and food outlets, respectively, to reflect both greater observed distances traveled for food and consistency with design standards commonly seen in the planning literature.

Results

Using the high/low physical activity environment/nutrition environment (PAE/NE) designations, a 2 × 2 sampling plan resulted. Table 2 provides counts of block groups, the number of potential recruits, and the number of completed measurement visits by these quadrants. The spatial distribution of block groups in each of the four quadrants is provided in Figure 1 for San Diego County (left) and King County (right).

Block groups that were high on both measures were located in the most-central areas where densities are moderately higher in both counties but which also correspond with generally higher income levels. High PAE/low NE block groups tended to be farther from retail districts. Low PAE/high NE block groups tended to be less central and farther east in less densely populated areas. The block groups that were low on both measures were in the most remote locations. Block groups not in one of the four quadrant categories, and therefore not eligible to be recruited from, were spread throughout both regions, with large contiguous groupings in rural sections to the east (both regions) and north (San Diego).

Table 3 presents descriptive statistics on the built environment measures for King and San Diego Counties for the four quadrants. As expected, because of the sampling criteria, differences across the quadrant exist, within and among the regions. Comparing built environment measures across the quadrants shows that King County is more compact, more interconnected, with a higher land-use mix, but a lower retail FAR than San Diego County. The biggest differences in residential and intersection density were across the quadrants that were either high on both measures or low on both. King County block groups had a higher proportion with a supermarket within 0.5 miles and a lower number of fast-food outlets overall and more fast-food outlets by quadrant than San Diego. However, a higher proportion of San Diego block groups were within 0.5 miles of a supermarket.

Table 4 presents information on key demographic variables for each of the eligible block groups for each quadrant

Table 2. Eligible block groups and completed measurements across four neighborhood types

			Physical activity environment/nutrition environment (all eligible BGs)							
	County totals		High/high		High/low		Low/high		Low/low	
Counts	King	San Diego	King	San Diego	King	San Diego	King	San Diego	King	San Diego
No. of eligible BGs (county total BGs)	496 (1580)	619 (1762)	153	177	117	175	79	120	147	147
No. of potential recruits in eligible BGs (no. of completed measurements)	4028 (366)	4639 (364)	1039 (92)	1241 (102)	950 (91)	1051 (88)	789 (71)	1131 (97)	1250 (112)	1216 (77)

Note: Data are for King County WA and San Diego County CA.
BG, block group

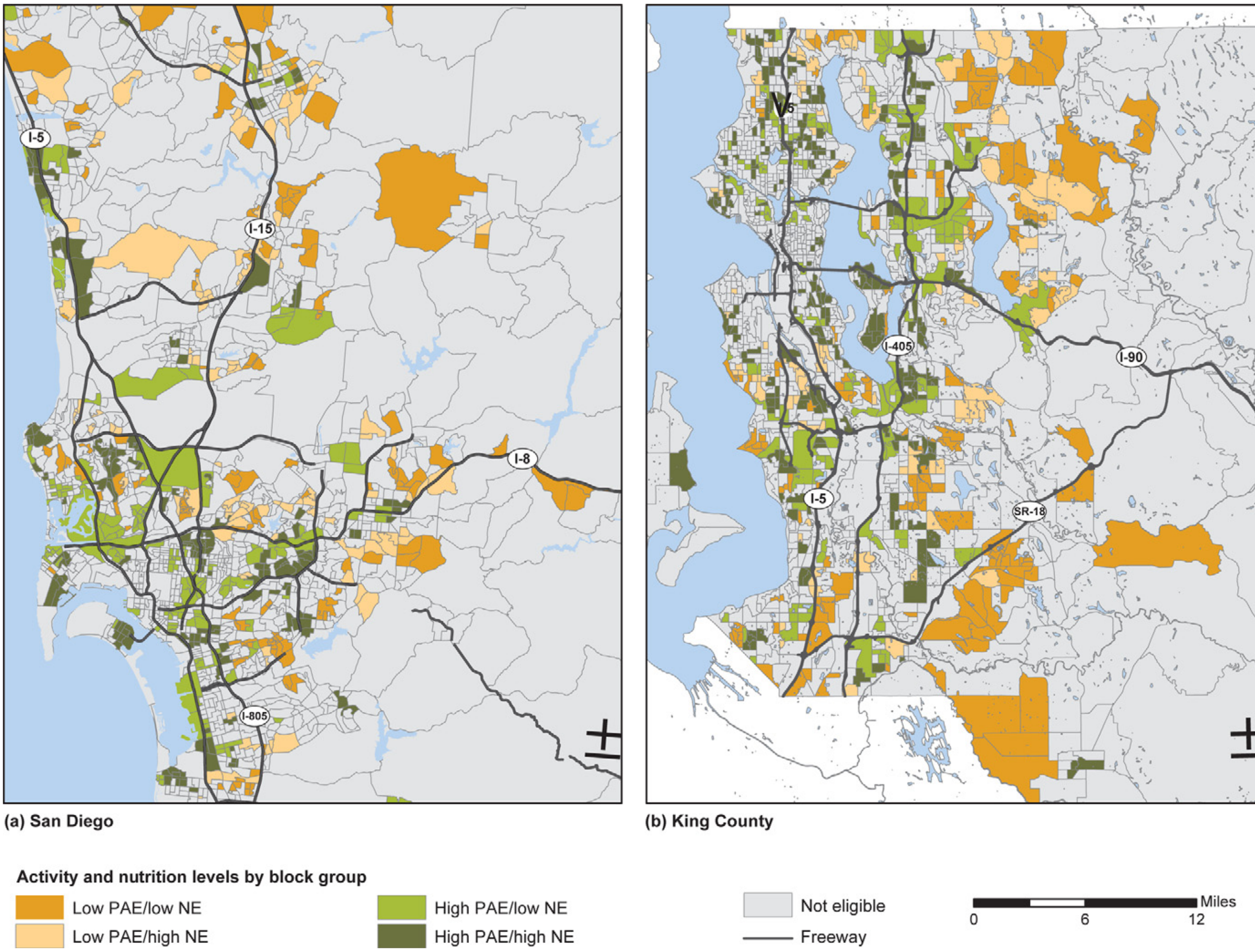

Figure 1. Physical activity and nutrition environments—eligible block groups for San Diego County CA and King County WA

Note: To see these maps with additional corresponding data, view the online versions at www.calit2.net/ajpm/0312/san-diego.html and www.calit2.net/ajpm/0312/kings.html.

NE, nutrition environment; PAE, physical activity environment

and provides a comparison to the respective county average. The largest percentage white in both regions was in the low quadrant on both measures. There was, however, considerable contrast between the two regions with respect to income distribution across the quadrants; those low on both measures had the highest income for both regions. However, only 5.8% of the households in this quadrant earned more than \$100,000 per year compared with nearly 63% earning <\$50,000 per year in the high PAE/low NE quadrant in San Diego County. This sharply contrasts King County, where 18.8% earned >\$100,000, and 36.6% earned <\$50,000 in the high PAE/low NE quadrant.

King County had a higher proportion of households with children aged 6–11 years in both low physical activity environment quadrants, whereas little difference was found in San Diego County across quadrants. Both quadrants with low physical activity environments in San Diego were younger than their high counterparts, yet no difference across median age was found in King County across any of the quadrants. Both high physical activity environment quadrants had lower educational attainment than their low counterparts in San Diego County, whereas the opposite was found in King County. Other studies have shown that educational attainment is among the strongest predictors of obesity.[34] Information on participant demographics for each quadrant is reported in a companion paper[28] in this theme issue.

Table 5 presents the median age of development for each of the four quadrants and conveys that neighborhoods with environments high on both measures were the oldest in both regions (1967 vs 1959) for San Diego and King County, respectively. The quadrants that were low on both environment measures were the newest in both regions (1976 vs 1978) for San Diego and King County. Higher levels of both types of environments were

Table 3. Built environment measures by physical activity and nutrition environment quadrant, block group median values, unless otherwise noted

			Physical activity environment/nutrition environment categories							
			High/high		High/low		Low/high		Low/low	
Variable	San Diego	King	San Diego	King	San Diego	King	San Diego	King	San Diego	King
Net residential density (housing units/acre)	2.5	5.63	5.17	8.32	5.15	7.54	1.33	4.11	0.95	2.81
Intersection density (per sq. km)	41.75	54.62	53.24	70.64	58.72	56.76	36.3	43.21	33.09	43.14
Retail floor area ratio	0.24	0.18	0.28	0.22	0.3	0.22	0.2	0.11	0.12	0
Land-use mix	0.18	0.25	0.28	0.31	0.3	0.47	0.12	0.17	0.03	0.1
Walk index[a]	−0.51	−0.35	1.42	0.69	1.55	1.27	−1.67	−1.79	−2.75	−2.78
No. of fast-food outlets	13	6	17	8	24	19	11	3	3	0
% with supermarket within 0.5 miles[b]	61.41	69.24	100	100	100	74.36	100	100	8.84	0.68

Note: Data are for San Diego County CA and King County WA.
[a]Walk index variables across regions are not comparable. They are normalized on values of variables within the regions.
[b]Not a median value

found in the older more central areas of both regions. However, greater difference across quadrants for age of development was observed in King County.

Discussion

Obesity is a function of physical activity and dietary patterns, and it is therefore important to evaluate how the built environment may collectively affect both behaviors.[35] This paper documents the development of an innovative method to sample age-specific populations (in this case children) from contrasting physical activity and nutrition environments using a wide variety of highly detailed spatial data. The measures used to evaluate obesogenic environments are objectively measured, replicable, and generalizable to other studies.

The methods used to set region-specific cut points for each of the measures, including fast-food outlet count, distances to parks and grocery stores, and walkability can be used by other researchers with similar study objectives. This method used an iterative process to spatially target census block groups by assessing various cut points for measures defining contrasting physical activity and nutrition environment quadrants until the identified block groups provide a desired number of potential recruits. This empirical methodology was necessary because criteria for "optimal" environments of these two types have not been established in the literature, and adopted cut points must be realistic within each region.

No previous method has integrated physical activity and nutrition environment concepts to define environments that were high and low in obesogenicity. This new measure of obesogenic environments reflects many of the dimensions that have been proposed and studied.[1–3,36] Creating measures for the sampling strategy required using both archival and newly collected data and integrating them in GIS. Employing a highly detailed sampling strategy to maximize variation across the environment factors is cost effective and reduces sample sizes needed to test associations of environments with health outcomes. Failure to employ a targeted sampling strategy and relying on random recruitment would likely result in a lack of variation in built environments that in turn would reduce the ability to detect effects of physical activity environments and nutrition environments on youth obesity that may exist.

Ensuring environmental variability is essential for testing environmental hypotheses. Results shown in a companion paper[28] in this theme issue confirm that the method presented in the paper was validated by significant relationships between obesogenic environments and obesity of children aged 6–11 years. Developing the GIS-based environmental assessment method in two regions suggests it could be applied in multiple study areas. San Diego County and King County are different on multiple dimensions, and resulting cut points used reflected these differences. King County was more walkable whereas

Table 4. San Diego County CA and King County WA block group demographics, % unless otherwise noted

	County	Eligible block group physical activity environment/nutrition environment			
		High/high	High/low	Low/high	Low/low
SAN DIEGO COUNTY CA					
% families with children aged 6–11 years	35.60	36.00	35.60	35.20	35.60
% white[a]	74.10	72.20	63.10	81.50	83.70
Median age (years)[a]	34.7	33.9	31.7	36.45	37.9
Family size: average no. of people	3.2	3.2	3.2	3.1	3.2
Annual income ($), % families[b]					
<50,000	45.66	52.94	62.95	31.47	21.58
50,000–99,9999	35.16	32.52	29.44	41.27	46.83
≥100,000	12.63	9.29	5.81	20.18	29.17
Completed college or higher	25.35	23.43	18.57	28.71	30.42
KING COUNTY WA					
% families with children aged 6−11 years	34.40	33.40	33.50	36.10	36.10
% white[a]	82.20	78.10	79.30	80.00	86.50
Median age (years)[a]	36.6	36.9	36.2	36.8	37.1
Family size: average no. of people	3	2.9	2.9	3.2	3.2
Annual income ($), % families[b]					
<50,000	31.89	34.11	36.59	21.58	21.58
50,000–99,9999	40.90	42.22	39.92	41.27	46.83
≥100,000	20.82	17.53	18.82	20.18	29.17
Completed college or higher	38.97	41.05	44.14	36.51	35.05

[a]Source: Year 2000 U.S. Census, where population includes all ages
[b]Source: Year 2000 U.S. Census, family annual income for 1999

fast-food outlet density was greater in San Diego. San Diego County had about twice as many fast-food outlets as King County yet had approximately 50% more people (2.9 million vs 1.9 million people in 2010), respectively. There was a fast-food outlet for every 834 people in San Diego County compared with one for every 1145 people in King County.

Distance to grocery stores differed across regions (shorter in San Diego County). Park scores were higher in San Diego County. However, the geographic distribution of block groups in each quadrant were generally similar across regions, which was likely related to both regions being bounded by water on the west and mountains to the east. Just as the walkability scores are standardized for each region to reflect that region's characteristics, it was necessary to use different cut points for each region's fast-food concentration. The issue of whether obesogenic environments should have absolute optimal values or whether they need to be relative to the distribution within each region should be the subject of future research. Such research is needed to inform recommendations for environments that will support healthy physical activity– and nutrition-related behaviors.

Eligible block groups differed considerably across demographic factors by quadrant. Those low on both environment measures were the wealthiest and the whitest in both regions. However, equitable access to healthy food choices differed considerably across regions by income. Nearly 63% of those living in high PAE/low NE quadrants in San Diego earned <$50,000 in San Diego County compared with 33.5% in King County, a striking difference. Given that these are also high physical activity environments, there is considerable potential to yield substantial health benefits for lower-income youth through healthier food policies by targeting these block groups.

Educational attainment was greater in the low physical activity environment block groups in San Diego and in the high physical activity environment block groups in

Table 5. Age of development by physical activity and nutrition environment

	Median year structure built (block group level through 2009)				
		Physical activity environment/nutrition environment (block group)			
County	Year	High/ high	High/ low	Low/ high	Low/ low
San Diego	1973	1967	1967.5	1976	1976
King	1970	1959	1973	1972	1978

Source: American Community Survey, 2005–2009

King County. At least one study found that educational attainment was the most important factor across demographic and built environment features in predicting obesity in the general population.[34] Higher educational attainment of parents in the low physical activity environment quadrants in San Diego County may be protecting against the effects of an obesogenic built environment on youth obesity in these areas.

The combined effect of increased educational attainment and a built environment supportive of physical activity was found in King County. Low physical activity environments in King County also had lower educational attainment and may be a worst-case scenario. There is an interesting split between income and educational attainment in King County. Typically the two factors track together. Income was highest in the peripheral quadrant that was low on both measures, whereas educational attainment was higher in more-central high physical activity environment quadrants. More of the well-educated and wealthier families chose central and walkable areas in King County; but they trade off local access to healthy food for these features, noting that affluent families were the highest proportion in the high PAE/low NE quadrant.

Study limitations included the lack of sidewalk data to measure where youth can safely walk, lack of measures of the quality of the food establishments, and reliance on outdated census information. Physical activity environments and nutrition environments only reflected the home environment, and subsequent applications could include schools. The current framework was a compromise approach driven by theoretic and practical considerations. Although the specific variables used may not be optimal, the general approach can be adapted to other circumstances and as other relevant built environment variables are identified. The environmental measures employed objectively assessed GIS data to create an novel study design and recruitment scheme that allowed examination of the separate and interactive effects of both physical activity and nutrition measures of built environment, which are believed to represent the most important dimensions of obesogenic environments for youth. It is alarming to note that the newest areas perform the worst and the oldest, the best across both sides of the energy balance equation.

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Supplementary data

A pubcast created by the authors of this paper can be viewed at www.ajpmonline.org/content/video_pubcasts_collection.