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Community Design and Access to Recreational Facilities as Correlates of Adolescent Physical Activity and Body-Mass Index

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Background: Neighborhood-level environmental features have been associated with adult physical activity and weight status, but this link has not been established for adolescents. *Methods:* Community design and access to recreational facilities variables were derived using geographic information systems (GIS) for 799 adolescents (age 11 to 15 y, mean = 12.8 y, 53% girls, 43% ethnic minority). Environment variables were calculated for a 1-mile buffer around each participant's residence. Accelerometers measured min/d of physical activity. *Results:* Number of nearby recreation facilities and number of nearby parks correlated positively with girls' physical activity, and intersection density inversely related to girls' physical activity. Retail floor area ratio correlated positively with boys' physical activity. No community design or access to recreation variables were related to BMI-percentile. *Conclusions:* There was limited evidence that both community design and access to recreation facilities variables were associated with adolescent physical activity, but additional built environment variables need to be studied that have particular relevance for youth.

Key Words: children, exercise, obesity, built environment, policy

Several studies have identified aspects of the built environment that are related to adult physical activity.[1-2] These built environment features typically reflect distance between places (proximity) and ease of travel between places (connectivity).[1] Factors such as the distance between a residence and a shopping center can influence the decision of whether to walk, bicycle, or drive to a destination. Numerous studies show that people who live in more walkable communities (i.e., communities offering relatively greater proximity to numerous destinations, as well as high levels of connectivity between those destinations) are more physically active and less overweight than people in less walkable communities.[1, 3-7]

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Another dimension of the built environment that has been shown to correlate with adult physical activity is access to recreation facilities such as parks, trails, swimming pools, and gyms.[8] The proximity and availability of recreation facilities has been shown to be positively related to adult physical activity levels.[9-15]

Few studies have investigated the relationship between built environment factors and adolescent's physical activity and weight status. The more time preschool children spend outdoors, the more they tend to be physically active.[16-18] The number of play spaces near children's homes, and the amount of time children used those play spaces were positively associated with activity levels.[18] Access to physical activity equipment was associated with youth physical activity for rural youth[19] and in public middle schools.[20]

Only one study has examined objectively measured built environment variables for their association with adolescent physical activity and weight status.[21] Kligerman and colleagues found overall community walkability was significantly related to physical activity, but proximity of recreational facilities was not related. The study demonstrated the relevance of neighborhood environment variables for adolescents, but it was limited by a small sample size (n = 97).[21]

Studies from the urban planning literature have documented relatively higher levels of non-motorized and transit trip-making among adolescents without driver's licenses.[22] Because adolescents younger than 16 y tend to rely upon travel options other than driving, they may be particularly sensitive to the built environment near their homes. The present study investigated whether community design features and access to recreation facilities, which have been shown to be correlates of adult physical activity and weight status, were related to these markers of adolescent health in a large diverse sample.

Methods

Participants

Adolescents between the ages of 11 and 15 were recruited through their primary care providers as part of a health promotion intervention trial. A total of 45 primary care providers from six clinic sites in San Diego County participated. The selected clinics were dispersed across several mainly suburban San Diego communities and serviced a wide geographic area. Adolescents were not eligible to participate in the study if they were not able to read English at or above a sixth-grade reading level, or had any disability that would make exercise or nutrition counseling contraindicated. Over a 13-month period trained recruiters attempted to contact 3366 households by telephone (including wrong numbers, those not eligible, and refusals) to determine eligibility and obtain initial verbal consent and child assent to participate in the study. A total of 878 adolescents (64% of eligible contacts) were enrolled into the study after parents signed consent forms and adolescents signed assent forms. Adolescents received $10 for completing all measurements and were entered into a lottery drawing for one of 10 cash prizes ranging between $10 and $50. All study procedures were approved by university and clinic institutional review boards.

Of the 878, there were 799 adolescents (425 girls, 374 boys) for whom valid addresses were available for geocoding. Table 1 presents the sample characteristics for girls and boys. The sample was ethnically diverse with approximately 42% of participants from minority backgrounds. Forty-seven percent of girls and 44% of boys were ≥ 85th percentile for BMI-for-age indicating that nearly half the sample was at risk of being overweight or already overweight to obese.[23]

Table 1 Sample Demographic Characteristics and Physical Activity Levels for Adolescent Girls (*N* = 425) and Boys (*N* = 374) with Geocoded Addresses

Variable	Girls	Boys
Age (years)		
11	87 (20.5%)	87 (23.3%)
12	106 (24.9%)	86 (23.0%)
13	97 (22.8%)	84 (22.5%)
14	86 (20.2%)	72 (19.3%)
15	49 (11.5%)	45 (12.0%)
Ethnicity		
Asian/Pacific Islander	11 (2.6%)	18 (4.8%)
African American	23 (5.4%)	28 (7.5%)
Native American Indian	4 (0.9%)	2 (0.5%)
Hispanic	59 (13.9%)	46 (12.3%)
White	243 (57.2%)	211 (56.4%)
Multi-ethnic/Other	85 (20.0%)	69 (18.4%)
Highest adult household education		
Some college or less	155 (37.2%)	105 (29.0%)
Bachelor's degree	114 (27.2%)	120 (33.1%)
Graduate degree	148 (35.5%)	137 (37.8%)
BMI-for-age percentile	0.74 (0.26)	0.69 (0.29)
Physical activity (min/d)	50.9 (24.8)	69.9 (31.6)

Measures

Physical Activity (PA). PA was measured with the Computer Science and Applications accelerometer (WAM 7164; now available through Actigraph; www.mtiactigraph.com). Actigraphs have been validated for measuring physical activity of children and adolescents.[24-27] This uni-axial accelerometer is a small (5.1 × 3.8 × 1.5 cm) and lightweight (45 g) device worn on the waist. The accelerometers stored data as 1-min averages for a 7-d period. Acceleration counts were processed using age-specific cutpoints for youth to estimate physical activity.[22] Estimates of moderate (3 to 5.9 METs) and vigorous (> 6 METs) activity levels were summed and averaged across valid days of monitoring for each participant. A participant's data was included if the monitor was worn for at least 3 d and had daily acceleration counts greater than 5000. Accelerometer data were available for 413 girls and 357 boys.

Body-Mass Index (BMI). An Accu-Hite wall stadiometer model 216 measured standing height. Weight was measured with the digital Body Comp Scale (American

Weights & Measures, Rancho Santa Fe, CA). Each measure was taken twice by trained technicians at the research office and the average of the two readings calculated. BMI was calculated as kilograms per square meters. BMI-for-age percentile was determined from CDC national norms using age to the nearest month and sex-specific median, standard deviation, and power of the Box-Cox transformation.[23]

Built Environment Measures. Community design and access to recreation facilities measures were created using geographic information systems (GIS). GIS allows digital geo-referenced data to be processed and displayed. The process involves three steps: 1) geocoding participant residential addresses on a street network; 2) creating "buffers," bounded areas of a specific dimension, around each residence location in which built environment features will be quantified; and 3) linking built environment data sources (e.g., location and size of neighborhood parks) to geocoded participants' buffers to measure the built environment near the participant's residence (e.g., number of parks). Arcview 3.2 (ESRI, Redlands, CA) software was used to geocode participant addresses and create 1-mile buffers, with distances based on the street network. Computed built environment variables were of two types, community design features and access to recreational facilities.

Access to recreational facilities has been previously shown to be associated with physical activity.[9,28] Measures of recreational facilities consisted of the number of private and public facilities within the 1-mile network buffer where adolescents can engage in physical activity. Private recreational facilities (fitness clubs, dance studios, skating rinks, etc.) were geocoded using address locations obtained from the five yellow page phone books for San Diego County. A total of 980 facilities were found. Attempts were made to obtain missing or incomplete addresses by calling the phone numbers listed and checking Internet websites. GIS database files with locations of public schools and parks were obtained from San Diego Association of Governments (SANDAG), which maintains one of the most complete and updated GIS databases in the US.

Community design variables consisted of aspects of the built environment that have been previously found to be correlated with active transportation and included residential density, intersection density, land use mix, retail floor area ratio, and an index of neighborhood walkability.[1,29] Variables were calculated for the 1-mile network buffer around each participant's residence using SANDAG and other proprietary data (SanGIS and DataQuick). Residential density was calculated as the number of residential units per residential acre using 2000 Census data and SANDAG land cover data. Intersection density, which provides a measure of street connectivity, was calculated as the number of street intersections per square acre of the network buffer. The retail floor area ratio (retail-FAR) was defined as the ratio of retail building square footage to parcel square footage. The average retail-FAR was computed for commercial land parcels within the buffer. A high ratio indicates that most or all of a parcel is devoted to building structure rather than parking lot or landscaping, buildings are close to the sidewalk, and the arrangement is assumed to be pedestrian-oriented. A low retail-FAR indicates buildings take up a fraction of the land, the remainder of parcels is likely used for parking, and the arrangements is assumed to be automobile oriented.

Land use mix was calculated for each buffer as the geometric mean of residential, institutional, entertainment, retail and office acreage. The higher the land use mix score, the more diverse the land use within a buffer. Buffers that more closely approximate an equal distribution of the five land use types within a physical space have the highest land use mix scores. Mixed land use provides nearby destinations that can stimulate walking and cycling for transportation. Geographic files describing locations of approximately 120 different land use types within the San Diego region were obtained from SANDAG.

An overall walkability index was derived by taking the sum of the *z*-scores for all four community design variables, as described in greater detail elsewhere.[30] Higher scores indicated greater ability to walk to a variety of locations in participant's neighborhood, and this index has been associated with physical activity[6,21] and weight status.[4]

Results

Table 1 shows descriptive statistics for demographics and the outcome variables moderate-to-vigorous physical activity min/d and BMI percentile. Both variables demonstrated fairly normal distributions with skewness and kurtosis moments not exceeding an absolute value of 1.0. Table 2 presents the descriptive characteristics of the built environment variables for the total sample based on the 1-mile network buffer. Extreme values were truncated for number of parks (> 15), residential density (> 100), and retail-FAR (> 2). Analyses were conducted separately for girls and boys to determine if different built environment variables were associated with girls' and boys' physical activity levels and weight status.

Table 2 Recreation Facilities and Community Design Variables Calculated for a 1 Mile Buffer Around Participants' Homes (*n* = 799)

Variable	Minimum	Maximum	Mean	*SD*
Recreation variables				
Number of private recreation facilities	0	16	2.1	2.4
Number of schools	0	9	2.4	1.8
Number of parks[a]	0	15	2.1	2.5
Community design variables				
Residential density[a] (households per residential acre)	0.01	100	7.3	10.2
Intersection density (intersections per buffer acre)	0.02	0.59	0.23	0.08
Retail floor area ratio[a] (retail building square footage/parcel square footage)	0.0	2.0	0.39	0.26
Land use mix factor (entropy) (residential, retail, institutional, office and entertainment uses)	0.03	0.71	0.38	0.13
Walkability index (composite of residential density, intersection density, land use mix, and retail FAR)	–9.2	24.7	0.83	3.7

Note. Variable truncated to maximum value displayed in table.

For girls, statistically significant bivariate correlations were found for total min/d of moderate-to-vigorous physical activity with number of recreation facilities ($r = 0.11$, $P < 0.05$), number of parks ($r = 0.14$, $P < 0.01$), and intersection density ($r = -0.14$, $P < 0.01$). For boys, total min/d of physical activity was correlated only with retail FAR ($r = 0.12$, $P < 0.05$). No statistically significant correlations were found between environmental variables and BMI percentile for girls or boys. BMI percentile was marginally correlated with number of recreation facilities for boys ($r = 0.08$, $P < 0.11$).

Hierarchical multiple linear regression models were specified to explain total min/d of physical activity. In step 1, demographic variables (age in months, ethnicity [white, non-white], and highest household education level [some college or less, BA degree, graduate degree]) were entered. Step 2 included built environment variables that had statistically significant bivariate relationships. Complete data were available for 375 girls and 324 boys. Table 3 presents standardized regression coefficients explaining total min/d of physical activity for girls and boys. For girls, the number of recreation facilities and intersection density remained significant in the model but number of parks became not significant. Age and ethnicity were also significant contributors to the model. The adjusted R^2 for the model was 0.25 with the built environment variables explaining about 3% of the total variance. For boys, retail-FAR and age were significant contributors to the model. The adjusted R^2 for the model was 0.23 with the retail-FAR explaining about 2% of the total variance.

Table 3 Multiple Linear Regression Analyses for Moderate-to-Vigorous Minutes/Day of Physical Activity for Girls and Boys

	Standardized Beta	*P*-value
Girls		
Step 1		
age	–0.456	< 0.001
ethnicity (non-white)	–0.096	0.041
highest household education level	–0.039	0.405
R^2 change = 0.23		
Step 2		
number of private recreation facilities	0.110	0.016
number of parks	0.009	0.842
intersection density	–0.127	0.006
R^2 change = 0.03		
Final model adjusted R^2 = 0.25		
Boys		
Step 1		
age	–0.455	< 0.001
ethnicity (non-white)	0.069	0.171
highest household education level	0.045	0.368
R^2 change = 0.23		
Step 2		
retail floor area ratio	0.135	0.007
R^2 change = 0.02		
Final model adjusted R^2 = 0.23		

Note. 699 participants with complete data (375 girls, 324 boys).

Discussion

Results of the present study provide limited evidence that both community design and access to recreation facilities variables are significantly associated with moderate to vigorous physical activity in a diverse sample of adolescents. The associations were independent of sociodemographic variables, but built environment variables explained small amounts of variance in physical activity, and significant variables were not consistent across girls and boys.

The finding that boys living near retail stores with a high floor area ratio were more physically active was consistent with principles of walkability.[29] A high floor area ratio usually means the building was designed to be easily accessible to pedestrians by being close to the sidewalk, rather than being automobile-oriented by using much of the parcel for parking. A higher retail floor area ratio within the 1-mile network buffer provides destinations within walking and biking distance. The association suggests that boys may walk to pedestrian-oriented shops when they are nearby, contributing to overall physical activity. No other built environment variables were significantly related to boys' physical activity, so overall support of environmental correlates was weak.

The number of private recreational facilities within 1 mile explained a small but significant amount of variance in girls' physical activity. This is consistent with other studies showing that access to recreational facilities is related to physical activity.[31] The present study was somewhat unique in examining private recreational facilities. It is notable that proximity of private recreational facilities was significant only for girls, because in another study of San Diego adolescents, girls were somewhat more likely to report doing physical activity at commercial facilities.[32] Intersection density was another significant correlate of girls' physical activity, but unexpectedly, the correlation was negative. Several studies of adults[1] supported the principle that highly connected streets create direct routes for pedestrians and stimulate more walking and cycling.[30] However, it has been suggested that in low-connectivity areas with many cul-de-sacs, young people could play on these low-traffic streets.[33] Present findings suggest girls may use disconnected, low-traffic streets for physical activity. Because street connectivity may have different associations with adult and youth physical activity, more detailed studies are needed that assess the places where people do their physical activity. The findings for girls provide weak support for built environmental correlates of physical activity.

The findings are somewhat different from a study of adolescents conducted in San Diego County using very similar measures.[21] In the previous study, the walkability index was significantly associated with overall physical activity based on accelerometer measures, accounting for about 7% of the variance. Access to recreational facilities was not significant. The previous study was smaller, with $n = 97$, so results of a few individuals could unduly influence the results. The inconsistencies need to be resolved by further studies of adolescents using high-quality measures in multiple geographic locations.

Given the weak associations with physical activity, it is not surprising that built environment variables were not significantly related to BMI. This finding is consistent with the Kligerman et al.[21] study of adolescents but inconsistent with several studies of adults.[4,5,7,33] Additional studies on this topic are needed, because the two studies of adolescents were not definitive.

There are several potential explanations for the weak and inconsistent results in the current study. Community design and access to recreation facilities variables are expected to be associated with physical activity for transportation and leisure purposes, respectively.[1] Despite the strengths of using the objective physical activity measure, the overall measure may have obscured associations between specific subsets of variables.[34] Separate estimates of physical activity pertaining to transportation, recreation, and sports participation may have helped to delineate which types of physical activity were related to different built environment variables. Accelerometers may underestimate common adolescent activities such as bicycling and swimming, which would be expected to be related to features of the built environment.

Though the age range of 11 to 15 y seems small, this is an age of rapid development. Increasing freedom of mobility across this age range could mean that built environment variables' associations with physical activity could vary by age. However, the greatest change in mobility for youth was found for older teens once they get a driver's license and use the automobile as their primary mode of transportation.[22] We did not report analyses by age because of the reduced statistical power of tests within age subgroups. Additional studies are needed to fully examine how relationships between the built environment and activity vary by age.

Measures of access to recreation facilities were limited, assessing only proximity. Giles-Corti and colleagues[15] found that access, distance, attractiveness, and size of public open spaces were all related to their use by adults. There are many hypothesized built environment correlates that were not measured in the present study, such as sidewalks, trees, traffic speed and volume, and intersection design.[29] There are likely other built environment variables that are particularly important for youth physical activity that have yet to be hypothesized. Further studies are needed to evaluate associations between physical activity and a greater range of built environment variables. For example, a recent study by Boarnet and colleagues[35] found that sidewalk improvements and intersection signalization in the vicinity of schools increased the frequency of school walk trips.

The present study was not designed to maximize variation in built environment variables, and few areas in San Diego County appear to meet the definition of walkable neighborhoods.[1, 29] Thus, restricted variability in walkability may have obscured associations, though it is difficult to determine what a wide range of walkability is because experience with the measures is limited. A better test of current hypotheses would select regions and neighborhoods to produce the widest possible variability in walkability, would use a wider range of built environment variables, and would have an even larger sample to support examination of subgroup-specific associations.

These inferences about the results highlight several of the study's limitations related to the nature and type of variables assessed. These limitations can potentially be addressed in future studies. First, rather than only using accelerometers to collect physical activity data, including self-reported activity in a log or recall can help to distinguish whether activity recorded on an accelerometer is for recreation, transportation, or other purposes. Second, determining the optimal buffer size for measuring environmental characteristics pertinent to adolescents needs further consideration. While we presented results using a 1 mile buffer, we also conducted initial analyses with a 0.5 mile buffer but found even fewer associations with physical activity. The larger buffer size demonstrated somewhat more land use mix and variation in the number of facilities in the buffer. However, even the 1 mile buffer produced environmental variables with limited sample variation, which may have attenuated the findings. Other aspects of the buffers such as whether access to recreational facilities in the buffers varied based on obstacles (e.g., a freeway) or restrictions (e.g., for adults only, fees) could also be considered. Assessing other buffer sizes and characteristics may help to better delineate the relationship between the environment and adolescent physical activity and weight status. Third, the generalizability of the findings is limited to communities similar to those found in San Diego County, which are predominantly suburban communities with low walkability and few areas with high land use mix. The hypothesized relationships will need to be further tested in other geographic areas.

Built environment variables in the present study explained only 2% to 3% of the variance in physical activity. However, this amount of variance could have public health significance, because environmental variables affect all people exposed, and the exposure occurs over a long period of time. More studies of built environment correlates of physical activity in youth are needed to define the most important variables for youth. When consistent correlates are identified, it will be useful to estimate the number of youth exposed to "risky" environments and to devise strategies to ensure that young people grow up in environments that make it easy and safe for them to be physically active. The present study is an early investigation of a complex phenomenon that requires continued examination.

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