The neighborhood and home environments: Disparate relationships with physical activity and sedentary behaviors in youth

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James N Roemmich
United States Department of Agriculture

Leonard H Epstein
University at Buffalo, The State University of New York

Samina Raja
University at Buffalo, The State University of New York

Li Yin
University at Buffalo, The State University of New York

The Neighborhood and Home Environments: Disparate Relationships With Physical Activity and Sedentary Behaviors in Youth

James N. Roemmich, Ph.D.
Department of Pediatrics and Department of Exercise and Nutrition Sciences
University at Buffalo

Leonard H. Epstein, Ph.D.
Department of Pediatrics and Department of Social and Preventive Medicine
University at Buffalo

Samina Raja, Ph.D. and Li Yin, Ph.D.
Department of Urban and Regional Planning
University at Buffalo

ABSTRACT

Background: *To increase participation in physical activity, it is important to understand the factors associated with a child's choice to be physically active or sedentary. The neighborhood and home environments may be related to this choice.* ***Purpose:*** *To determine whether the neighborhood environment or number of televisions in the home environment are independently associated with child physical activity and television time.* ***Methods:*** *The associations of the neighborhood and home environments on active and sedentary behaviors were studied in 44 boys and 44 girls who wore accelerometers and recorded their television watching behaviors. Neighborhood environment variables were measured using extensive geographic information systems analysis.* ***Results:*** *Hierarchical regression analyses were used to predict physical activity after controlling for individual differences in age, socioeconomic status, percentage overweight, and time the accelerometer was worn in Step 1. Sex of the child was added in Step 2. A neighborhood design variable, street connectivity, accounted for an additional 6% ($p \leq .01$) of the variability in physical activity in Step 3. A block of variables including a measure of neighborhood land use diversity, percentage park area, and the interaction of Percentage Park Area × Sex then accounted for a further 9% ($p \leq .01$) of the variability in physical activity in Step 4. Increased access to parks was related to increased physical activity in boys but not in girls. The number of televisions in the home accounted for 6% ($p \leq .05$) of the variability in television watching behavior. Neighborhood environment variables did not predict television watching that occurs in the home.* ***Conclusion:*** *The neighborhood environment is more strongly associated with physical activity of boys than girls. Sedentary behaviors are associated with access to television in the home environment. To promote physical activity in children, planners need to design environments that support active living and parents should limit access to television viewing in the home.*

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Reprint Address: J. N. Roemmich, Ph.D., Department of Pediatrics, School of Medicine and Biomedical Sciences, State University of New York at Buffalo, Farber Hall, Room G56, 3435 Main Street, Building 26, Buffalo, NY 14214-3000. E-mail: roemmich@acsu.buffalo.edu

INTRODUCTION

Each day children are presented with multiple choices between being sedentary and physically active. The home and neighborhood environments likely differentially influence these choices. Behavioral economic theory suggests that children's choice to be sedentary or active depends in part on the ease of access to sedentary activities in the home and physical activity in the neighborhood environment and the reinforcing (i.e., motivating) value of the available sedentary and active alternatives (1,2). Research has shown that increased access to reinforcing sedentary behaviors within the home increases time youth spend watching television (3,4). Thus, youth may be more likely to stay home and be sedentary than be active in the neighborhood environment because watching television is both easily accessible and a more reinforcing behavior than physical activity (5–7).

In designing an "active living" neighborhood environment that successfully competes with sedentary behaviors inside the home environment, planners must consider what aspects of the built form optimize youths' access to physical activities that youth are motivated to engage in. In adults, the concepts of the "3 Ds" (i.e., design, density, diversity) have been used to describe neighborhood environment correlates of physical activity for the purpose of shopping and going to work (8). The current urban planning literature on promoting active living through design suggests that for adults housing density, street connectivity, and pedestrian amenities correlate with physical activity (9,10). However, the neighborhood environment amenities that promote physical activity in children have not yet been widely studied. For example, a neighborhood environment that reduces the walking distance to a friend's house due to a greater housing density may increase youth physical activity. Likewise, a greater street network connectivity that increases access between a child's home and neighborhood parks and recreation areas or friends' homes may be more successful at competing with home environments that promote sedentary behavior.

If the neighborhood environment does not possess amenities—such as parks—that provide physical activities children are motivated to participate in, children may be less likely to go outdoors. This could result in increased television watching within the home environment and perhaps reduce physical activity. If a child watches more television, they are less likely to spend time in the neighborhood environment—even if the neighborhood environment possesses amenities such as parks and recreation centers that promote physical activity. In this case neighborhood environment variables would be hypothesized to not have a strong influence on children's physical activity and sedentary behaviors. Rather home environment variables, such as increased access to television through a greater number of televisions in the home, may exert a greater influence on sedentary behaviors (3,4).

The purpose of this article is to test our hypothesis of possible disparate associations of the neighborhood and home environments on physical activity and television watching of youth. This was accomplished by determining whether the 3 Ds of the neighborhood environment or number of televisions in the home were independently associated with child physical activity and television time.

This study contributes to the limited literature on youth physical activity and neighborhood environment in two ways. First, the study relies on objective measures for both physical activity and the neighborhood environment. Accelerometers were used to provide objective measures of the amount and intensity of physical activity. Neighborhood environment variables such as housing density and street connectivity were measured using extensive geographic information systems (GIS) analysis, rather than relying on the perception of the participants (11–13). Second, the GIS analysis was conducted at a neighborhood level, rather than the usual county or metropolitan level. The neighborhood level is the geographic scale within which an individual child lives, recreates, and makes choices between being physically active outdoors and watching television indoors.

METHOD

Study Participants

This article is based on a cross-sectional analysis of the screening data from a longitudinal study to increase the physical activity of youth. Four cohorts were recruited over a 2-year period with similar recruitment efforts made for each cohort. Two cohorts were completed during the spring season, and two cohorts were completed during the fall season. Participants were recruited through newspaper advertisements and targeted mailings. In addition, addresses of households with at least one child between the ages of 8 and 12 years were identified by InfoUSA (Omaha, NE). A list of approximately 22,000 households within Erie County, New York was purchased. Three thousand addresses were randomly selected for each cohort recruitment period. The selected households received a letter that provided information about the intervention study and our contact information. Phone calls were received from 382 families. Interested families were screened by telephone to determine if they met the criteria of having a child who had a body mass index (BMI) of less than the 90th percentile based on parent report of child height and weight. Child BMI was limited to less than the 90th percentile (14) to reduce participant variability in response to the treatments because the physical activity levels of overweight and lean children are different. To increase accuracy of the parent reporting, the targeted mailings instructed families to have measured their child's height and weight prior to calling. The parents' self-reported measurements were based on recent pediatricians' records or parents' own measurements of their child's height and weight. At the study orientation meeting, the children's heights and weights were measured by trained staff. Other entry criteria included no conditions that would limit physical activity, and children had to watch 15 or more hr of television per week including VCR use and video game playing. An average child participates in 23.7 hr per week of targeted sedentary behaviors including 15.4 hr of television, 5.1 hr of VCR use, and 3.2 hr of computer games (15,16). Thus, the criterion allowed for the inclusion of children who participated in a wide range of sedentary behaviors in that they had to be at least moderately sedentary with no upper limit on sedentary behavior time. A total of 152 families did not meet BMI percentile, television watching, or physical activity entry criteria after an initial phone interview. We invited 230 families to study orientation meetings, 152 families attended the orientation, 122 children met BMI percentile criteria when measured at the laboratory, and 110 enrolled in the study and started the screening process of wearing an accelerometer and keeping a habit book for 6 days. Of these 110 children, 44 boys and 44 girls successfully completed the screening process by wearing the monitor the required time for at least 4 of the 6 days and lived in Erie county for which we had GIS data sets. A parent gave written informed consent, and children gave their assent for participation in the study. The University at Buffalo Health Sciences Institutional Review Board approved the study. Participants were reimbursed $10 total for their participation. Participant characteristics are shown in Table 1.

Research Procedures

Youth participants were asked to report to the research laboratory and were measured for height and weight. Youth were taught how to wear a Biotrainer-Pro accelerometer activity monitor (Individual Monitoring Systems, Baltimore, MD). The display on the accelerometer was turned off so youth (or their parents) did not receive any feedback about physical activity although the monitor was recording data. Youth were also instructed how to record times the accelerometer was worn and the duration of sedentary behaviors in a habit book. Parents completed questionnaires to determine family socioeconomic status and child ethnicity. All participants were studied during the school year. On returning to the laboratory, the habit books were collected and thoroughly reviewed with the child and parent by a

TABLE 1
Physical Characteristics

	Boys[a]	*Girls*[b]
Race		
White	38	40
Black	5	3
Other	1	1
Age (years)	10.3 ± 1.4	10.6 ± 1.4
Height (cm)	140.0 ± 11.3	143.0 ± 10.4
Weight (kg)	78.7 ± 20.5	83.4 ± 17.2
BMI (kg/m^2)	17.9 ± 2.5	18.3 ± 2.0
Percentage overweight	6.5 ± 12.7	6.4 ± 11.7
Socioeconomic status	47.3 ± 10.1	45.9 ± 10.0
Television sets in the home (count)	2.9 ± 1.4	2.5 ± 1.1
Physical activity (counts/day)[c]	578.3 ± 254.9	431.2 ± 175.9
MVPA (minutes/day)[c]	186.2 ± 53.5	155.5 ± 41.3
Time activity monitor was worn (minutes/day)	464 ± 115	479 ± 117
Television watching (minutes/day)[c]	137.3 ± 32.1	110.2 ± 59.4

Note. Data are $M \pm SD$. Percentage overweight = (subject BMI – BMI at 50th percentile)/BMI at 50th percentile × 100. Socioeconomic status of 46 through 48 is equivalent to medium-size business owners, minor professionals, and technical jobs, such as computer programmers, real estate agents, sales managers, social workers, and teachers. BMI = body mass index; MVPA = moderate to vigorous physical activity (≥ 3 METS).
[a]$n = 44$. [b]$n = 44$. [c]Boys greater than girls ($p \leq .05$).

research assistant. Characteristics of the children's neighborhood environment were determined using GIS, after geocoding each child's primary residence.

Measurement

Demographics. Race and ethnic background as well as socioeconomic status were obtained using a standardized questionnaire (17).

Height and weight. Child weight was assessed to the nearest 0.1 kg using a calibrated scale. Height was assessed using a SECA stadiometer (SECA Corporation, Hanover, MD) to the nearest 1.0 mm. Body mass index was calculated according to the following formula: (BMI = kg/m^2). Percentage overweight, (BMI – BMI at 50th percentile)/BMI at 50th percentile × 100, was calculated in relation to the 50th BMI percentile for children based on their sex and age using the *CDC Growth Charts for the United States* (14, pp. 178–186).

Objective daily physical activity. Participants wore a biaxial BioTrainer-Pro accelerometer. Data were collected at a sample rate of 10 Hz with an epoch of 1 min. When downloaded to a computer each epoch is presented on an intensity (g) by time data display screen. The accelerometer can be initialized at sensitivity levels of 1 to 40, representing the sensitivity of the monitor in relation to the data display. The sensitivity is set at a lower setting if vigorous activity is anticipated to be measured. Each accelerometer was initialized at a sensitivity of 4 because the study population consisted of children, who are naturally active in frequent bouts of intense activity (18). This allowed viewing of a full range of activity intensities on the data display screen.

Each child was fitted with an appropriate sized belt and wore the monitor at the hip and snug against the body. Parents were instructed to ensure that their child wore the monitor in the appropriate fashion each day. Children were instructed to wear the activity monitor for the next 6 days with at least 4 hr on weekdays before or after school hours and at least 6 hr on weekends. Wearing the monitor was limited to before or after school on weekdays because we wanted to measure spontaneous or planned activity of the child's choice and not activity that was part of a school curriculum. Children who did not go home directly after school took the monitor with them in their backpack and put it on after school hours. With the help of a parent, children recorded the time each occasion they put the monitor on and took it off each day. Most children (n = 65 of 88 total) wore the monitor the required time all 6 days, and others wore the monitor 5 days (n = 16) or 4 days (n = 7).

The downloaded activity data are viewed in a display screen on a computer monitor. A window is placed over the region of interest and the total activity counts and time spent in moderate to vigorous physical activity (MVPA, defined as > 3 METs) are displayed. The amount of time spent in MVPA was determined by placing a cutpoint line along the y axis at 1.0 g. The cutpoint for MVPA was determined by having 31 boys and 31 girls wear a Biotrainer-Pro accelerometer and walk on a treadmill at 56.4 m·min^{-1}, 69.6 m·min^{-1}, and 85.8 m·min^{-1} for 3 min at each speed while oxygen consumption (mL·kg^{-1}·min^{-1}, Vmax 29 metabolic cart, Sensormedics, Yorba Linda, CA) was measured by indirect calorimetry and averaged over the last 30 sec of each walking speed. Linear regression was used to determine the g value at 3 METs (10.5 mL·kg^{-1}·min^{-1}) for each child, and this averaged 0.86 g. The MVPA cutpoint was rounded-up to 1.0 g because the software increments the cutpoint in 0.25 g units. Physical activity data were adjusted for the number of days the monitor was worn by dividing the total activity counts and the time spent in MVPA by the number of days the monitor was worn. During the analyses, activity counts per day were covaried for the total time the accelerometer was worn to adjust for individual differences in time spent wearing the accelerometer.

The treadmill test was also used to perform a validation of the Biotrainer-Pro in the same set of 62 boys and girls. The average Biotrainer-Pro g value across the 3 min of each exercise stage and the average oxygen consumption across the last 30 sec of each stage were regressed for each participant. The average r of the 62 regressions was .96 ± .07.

Habit book. Each child completed a habit book for 6 days with the help of a parent. Each day was divided by half-hour increments. Children were instructed to record start/end times next to the reported activities. Children and parents were instructed to record times when the child watched television, including movies on videos and DVDs; played video games, including handheld games; or read or used the computer for nonschool work-related purposes. Children drew an X through times they performed activities other than the activities of interest. When families met with a research assistant the child's habit book was carefully reviewed for completeness. Discrepancies between the self-reported times and the accelerometer file were probed. For example, if activity counts were displayed during times the monitor was not reported to be worn, a research assistant would confirm with the family that the monitor was not worn during the time in question. If activity counts were not displayed during times when the monitor was reported to be worn, the assistant would first determine from the habit book if the child was engaged in a form of sedentary behavior that does not produce counts, such as watching TV, and then confirm with the child if the monitor was actually worn during the time period of interest. With the aid of a parent, the assistant would have the child recollect what they did during any unaccounted times. A habit book recording was considered complete when every half-hour was accounted for. Validity of television viewing diaries has been previously reported (19). When diary uncertainty is interpreted as the child was watching television, parental diaries overestimate a child's television viewing by 3.2 hours/week when compared with video observation and are highly correlated with video observation ($r = .86$, $p < .001$). When times of diary uncertainty are not included in the analyses, diaries overestimate television viewing by 0.8 hr per week and remain highly correlated with video observation ($r = .84$, $p < .001$) (19).

Neighborhood environment characteristics. A spatial database was built using GIS to measure the attributes of each child's neighborhood environment. The neighborhood environment data were measured in 2004. The parcel data layer was obtained from New York State GIS Clearinghouse, which is based on assessors' databases for counties in New York State. The street GIS layer was obtained from GDT technologies, now Tele Atlas (Boston, MA). The activity data were collected over a 2 year period between 2003 and 2005. The discrepancy between the years that activity data were collected and neighborhood environment data were collected is not a major issue because Erie County, the site of the study, is not a fast growth county. The slow pace of growth is evident from the fact that a mere 1.6% of all land parcels in the county were developed between 2000 and 2004 as detailed in the Erie County Assessor's databases for 2000 and 2004. Family residences were geocoded to a unique parcel of land within the GIS database. The attribute table accompanying the data layer in the GIS was used to identify the type of housing, assessed as the number of housing units in the residence of the child. Neighborhood environments were defined as the area within a 0.5 mile radius around each child's residence based on a straight-line distance (20). Variables were carefully chosen to reflect the density, design, and diversity of the neighborhood environment (8).

Residential housing density in this study is measured as total housing units per residential acre within a 0.5 mile neighborhood around a participant's house. Residential area (the denominator in the variable) was computed using land use classification codes provided by parcel data. Computing the total number of housing units (the numerator of the variable) within a participant's 0.5-mile neighborhoods involved estimating the number of housing units for each parcel within the neighborhoods and a process of summing them up for the neighborhoods using GIS. This measure was chosen because neighborhoods with a greater density of destinations are associated with greater physical activity in adults (8,21). Likewise, greater housing density increases proximity between houses in the neighborhood and may influence children's willingness to walk and play with their friends living in the neighborhood.

Two measures of design were selected. The first was street connectivity, computed as the number of street intersections per mile of street length network. This measure was chosen because an increased connectivity among streets may facilitate access to destinations within the neighborhood by walking, bicycling, or rollerblading and, therefore, influence physical activity among youth (22–24) . The second measure to reflect design of the neighborhood was street width, not including sidewalk width. Width of streets in the neighborhood is likely to affect the volume of traffic and incidents of accidents (25–27). The safety of the street network, or the perception thereof, may then influence parents' decision to allow their children to be active physically in the neighborhood.

Previous measures of land use diversity have focused on the mix of businesses and residences available in a neighborhood (8). Although these may influence walking trips by adults to retail or work destinations in the neighborhood, the amount of playing space, such as parks and recreation centers, is more likely to influence children's physical activity. Therefore, measures for land use diversity in this study included the percentage of park area (ft^2)/total area (ft^2) of residential land use in a neighborhood (percentage park area) and the percentage of total area of park plus nonpark recreation land (ft^2)/total area (ft^2) of residential land use in a neighborhood (percentage park + recreation area). Park area included nature trails, bike paths, playgrounds, athletic fields, and state, county, and municipally owned parks within 0.5 mile of the participant's home. Recreational area was defined as the area of land used for ice or rolling skating rinks, swimming pools, health clubs, tennis courts, and camping facilities. Both ratios were expressed as percentages by multiplying by 100. Park and recreation areas did not have to be completely inclusive in the 0.5-mile radius. If a park or recreation area straddled the 0.5-mile boundary, the portion that lay within the child's 0.5 mile was considered accessible to the child. School grounds were not included in park area. Although people use school playgrounds for physical activity, the lack of data on schools made this computation impossible. All areas classified as recreation by land use codes that had the possibility of being used by children were included recreation area measure. Recreation area did not include golf courses because they are unlikely to be used by children. Private recreation facilities in the neighborhood were included in the measurement. However, private gardens were not included. The GIS computations for these variables were completed using ArcGIS 8 and ArcView 3.3 and their extensions such as Network Analyst (28).

Analytic Plan

Separate one-way analyses of variance tested differences in participant physical characteristics and of the neighborhood form of boys and girls with sex as a between variable. Physical activity was correlated with the time the activity monitor was worn ($r = .35$, $p < .001$) so total physical activity and MVPA were analyzed with separate one-way analyses of variance with sex as a between variable and the amount of time the activity monitor was worn as a covariate. Univariate neighborhood environment predictors of sedentary and active behaviors were identified using Pearson product–moment correlations. Hierarchical regression was used to determine whether addition of information regarding the neighborhood environment improved prediction of total physical activity, MVPA, and television watching while controlling for differences in demographic variables. All three hierarchical models included demographic variables of age, family socioeconomic status, and percentage overweight in Step 1. Models to predict total physical activity and MVPA also included the amount of time the activity monitor was worn in Step 1 to adjust for individual differences in time the activity monitor was worn. The second step for each model was the sequential addition of sex of the child (male = 0, female = 1) to test for the independent effect of sex on the dependent variables. These first two steps were followed by sequential addition of neighborhood or home environment predictors to the models. Significant Sex × Neighborhood Environment variable interactions were also added in the final step. Two efforts were taken to develop parsimonious models. First, only the univariate neighborhood and home environment predictors that were significantly ($p \leq .05$) correlated with active and sedentary behaviors based on Pearson product–moment correlations were included in the hierarchical regressions. Second, after the first step, only significant ($p \leq .05$) predictors were maintained in the model. Careful attention was paid to multicollinearity between variables and detected by examining the correlation matrix of regression coefficients assuring that no values were greater than .80. Entry criteria limited children's BMI to less than the 90th percentile and no neighborhood or home variables were independently correlated to adiposity, likely due to the limited range of the BMI data.

RESULTS

The boys and girls were relatively homogenous in terms of their age, height, and weight characteristics. The characteristics of the children are shown in Table 1. The boys and girls did not differ for age ($p = .31$), height ($p = .16$), weight ($p = .25$), BMI ($p = .47$), percentage overweight ($p = .97$), socioeconomic status ($p = .53$), the time the activity monitor was worn each day ($p = .50$), or number of televisions in the home ($p = .10$). The boys had greater total accelerometer counts ($p \leq .001$), spent more time in MVPA ($p \leq .05$), and spent greater time watching television ($p = .04$). Nine children lived in single-parent homes. The remaining participants lived in households with two adults. The children primarily lived in single-family homes ($n = 76$) with smaller numbers living in two- ($n = 9$) and three-family homes ($n = 1$) and suburban apartment complexes ($n = 2$). Other characteristics of the participants' neighborhood environment are shown in Table 2. There were no significant differences in housing den-

TABLE 2

Neighborhood Built Environment Characteristics Within a Half-Mile Radius of the Participant's Home

	Boys[a]	*Girls*[b]
Neighborhood density		
Density (housing units/acre)	7.5 ± 6.7	6.4 ± 4.6
Neighborhood design		
Street connectivity (intersections/network mile)	5.6 ± 1.6	5.5 ± 1.5
Street width (ft)[c]	24.5 ± 12.1	30.2 ± 7.7
Neighborhood diversity		
Park area ($ft^2 \times 10^6$)	0.66 ± 1.18	0.50 ± 0.90
Recreation area ($ft^2 \times 10^6$)	0.12 ± 0.36	0.22 ± 0.96
Residential area ($ft^2 \times 10^6$)	9.36 ± 3.21	10.37 ± 3.05
Park area/residential area (%)	9.3 ± 17.3	5.9 ± 11.6
(Park area + recreation area)/residential area (%)	10.6 ± 18.1	8.3 ± 14.8

Note. Data are $M \pm SD$.
[a]$n = 44$. [b]$n = 44$. [c]Girls greater than boys ($p \leq .05$).

TABLE 3
Univariate Correlations Between Neighborhood Built Environment Characteristics or Number of Televisions in the Home and Physical Activity and Television Watching

	Physical Activity (Counts/Day)		*MVPA (Minutes/Day)*		*Television Watching (Minutes/Day)*	
	Boys	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
Density (housing units/acre)	0.23	0.06	0.18	0.17	–0.03	0.15
Street connectivity (intersections/network mile)	**0.30***	0.18	**0.34***	0.15	–0.11	–0.01
Street width (ft)	0.06	–0.14	–0.05	–0.02	–0.08	–0.07
Park area (ft^2 × 10^6)	0.25	–0.11	0.11	–0.07	–0.26	0.08
Recreation area (ft^2 × 10^6)	–0.08	0.09	–0.18	0.09	–0.10	–0.09
Residential land (ft^2 × 10^6)	–0.11	0.06	–0.15	0.03	0.19	0.02
Park area/residential area (%)	**0.34***	–0.14	0.21	–0.06	–0.27	0.08
(Park area + recreation area)/residential area (%)	**0.32***	–0.03	0.16	0.02	**–0.29***	–0.01
Television sets in the home (count)	0.06	–0.11	0.05	0.03	0.26	**0.29***

Note. MVPA = moderate to vigorous physical activity (≥ 3 METS).
*$p \leq .05$.

sity (p = .38), street connectivity (p = .79), park land area (p = .46), recreation area (p = .49), residential land area (p = .13), percentage park area (p = .27), or percentage park + recreation area (p = .51), but street width ($p \leq .01$) was greater in girls' neighborhoods than boys.

As shown in Table 3, correlations of neighborhood environment variables and home environment variables with physical activity and television watching were different by sex. Neighborhood street connectivity, percentage park area, and percentage park + recreation area were positively correlated to total physical activity; street connectivity was positively correlated with MVPA; and percentage park area + recreation area was inversely correlated with television watching in boys but not in girls. The number of televisions in the home was positively correlated with the television watching time in girls but not in boys. When combining the boys and girls into a single group (data not shown) total physical activity was correlated to street connectivity (r = .25, $p \leq .05$) and percentage park area (r = .22, $p \leq .04$). Total physical activity was positively but not significantly correlated with density of housing (r = .19, p = .07) and percentage park + recreation area (r = .20, p = .06). Street connectivity was correlated with MVPA (r = .26, $p \leq .05$). Home environment, rather than neighborhood environment, variables were correlated with sedentary behaviors in that the number of televisions in the home was related to television watching time (r = .31, $p \leq .01$).

Hierarchical regression analyses were performed and the incremental R^2, total model R^2 and final multiple R are shown in Tables 4 and 5. Participant differences in age, socioeconomic status, and percentage overweight were controlled for in the hierarchical models predicting total physical activity, MVPA, and television watching by adding these variables as a block in the first step. Models to predict physical activity also included the amount of time the activity monitor was worn in Step 1. The block of variables in Step 1 accounted for 19% ($p \leq .01$) of the variability in total physical activity. Addition of sex of the child as a predictor in Step 2 explained an additional 8% ($p \leq .01$) of the variability in total physical activity. Street connectivity then accounted for an additional 6% (p ≤ .01) of the variability in Step 3. A block of variables including a measure of neighborhood land use diversity, percentage park area, and the interaction of Percentage Park Area × Sex then explained a further 9% ($p \leq .01$) of the variability in total physical activity in Step 4. For MVPA the variables in Step 1 accounted for 20% ($p \leq .01$) of the variability. Addition of sex in Step 2 explained an additional 2% (p = .12) of the variability in MVPA. Adding street connectivity and the interaction of Street Connectivity × Sex in Step 3 explained an additional 8% ($p \leq .05$) of the variability in MVPA.

For the prediction of television watching behavior (Table 5) the demographic variables accounted for 4% (p = .40), and addition of sex to the model in Step 2 explained an additional 5% ($p \leq .05$), of the variability. Addition of the number of televisions in the home in Step 3 accounted for a still further 6% ($p \leq .05$) of the variability in television watching behavior. Entering percentage park + recreation area in Step 3 instead of the number of televisions accounted for 3% of the variability in television watching behavior, but this was not a significant improvement in the ability to predict television watching (p = .12). The interaction of Sex × Number of Televisions in the home did not improve (p = .84) the prediction of television watching.

DISCUSSION

We applied the concept of the 3 Ds (i.e., design, density, diversity) to describe the environment at the neighborhood level (8) and utilized hierarchical regression models to examine whether the 3 D factors were related to the physical activity and television watching of children. The design and diversity of the neighborhood environment as measured by greater street network connectivity and a greater percentage of park area independently predicted greater total physical activity of children. The association of percentage park area on total physical activ-

TABLE 4
Hierarchical Regression Models Predicting Total Physical Activity and Moderate to Vigorous Physical Activity

	B	β	R^2 *(Unique)*
Total physical activity[a]			
Step 1			.19*
Age (years)	–42.61*	–0.26	
Socioeconomic status	1.72	0.08	
Percentage overweight	–0.23	–0.01	
Time activity monitor was worn (minutes/day)	0.11*	0.30	
Step 2			.08*
Gender	–55.40	–0.12	
Step 3			.06*
Street connectivity (intersections/network mile)	36.69*	0.24	
Step 4			.09*
Park area/residential area (%)	519.23*	0.34	
Park Area/Residential Area (%) × Gender	–840.10*	–0.32	
Moderate to vigorous physical activity[b]			
Step 1			.20*
Age (years)	–	–0.24	
Socioeconomic status	0.39	0.05	
Percentage overweight	0.21	0.03	
Time activity monitor was worn (minutes/day)	0.04*	0.35	
Step 2			.02
Gender	92.83	0.60	
Step 3			.08*
Street connectivity (intersections/network mile)	20.70*	0.40	
Street Connectivity × Gender	–	–0.78	

Note. Gender: boys = 0, girls = 1. Percentage overweight is (participant BMI – BMI at 50th percentile)/BMI at 50th percentile × 100. BMI = body mass index.
[a]Model R^2 = .42, final multiple R = .65, $p < .001$. [b]Model R^2 = .30, final multiple R = .55, $p \leq .001$.
*$p \leq .05$.

TABLE 5
Hierarchical Regression Model Predicting Television Watching

	B	β	R^2 *(Unique)*
Television watching			
Step 1			.04
Age (years)	5.65	0.02	
Socioeconomic status	–6.26	–0.15	
Percentage overweight	–3.12	–0.09	
Step 2			.05*
Gender	–150.83	–0.17	
Step 3			.06*
Television sets in the home (count)	87.41*	0.26	

Note. Gender: boys = 0, girls = 1. Percentage overweight is (participant BMI – BMI at 50th percentile)/BMI at 50th percentile × 100. Model R^2 = .15, final multiple R = .39, $p \leq .02$.
*$p \leq .05$.

ity was different between boys and girls: The greater percentage park area in the neighborhoods of boys, the greater their total physical activity, but the percentage park area was not associated with the physical activity of girls. Greater street connectivity also predicted greater MVPA in boys but not MVPA of girls. As hypothesized, the number of televisions in the home environment rather than neighborhood environment variables was correlated to sedentary activities.

Strengths of this study include the focus on children, accelerometers as objective measures of physical activity, and objective GIS measures of the built form at the neighborhood level. Studies on the link between the neighborhood environment and health outcomes have typically focused on adults although there is a probable differential impact of the built environment on youth behaviors (29). Given that obesity (30) and physical activity behaviors (31,32) are established during childhood and track into adulthood it is important that efforts to promote active living focus on the impact of the built environment on youth as well as adults. Use of accelerometers as objective measures of physical activity strengthens the validity of the relations reported between the built environment and physical activity because youth may not accurately recall their physical activity (33,34).

Previous studies have used large geographic areas, such as a county or metropolitan level as their scale of analysis (29). Although this yields interesting insight at a macro geographic level, the neighborhood form varies within a metropolitan or a county area, and it is at the neighborhood level that youth make choices to watch TV and be sedentary or go outside to be active. Obtaining data at a neighborhood level is only possible with GIS analysis.

We based our hypotheses on behavioral economic theory, which suggests that choices to engage in sedentary or physically active behaviors depend on access to these alternative behaviors and the reinforcing- or motivating-value of the alternatives (1,2). Our findings are consistent with our hypotheses in that two measures of access to parks in the neighborhood environment (street connectivity and the percentage park area) predicted children's physical activity. Access to televisions in the home environment, not the neighborhood environment, predicted television viewing time.

Previous work supports the importance of environmental access for promoting youth physical activity. Urban environments are generally considered to provide greater access through increased street network connectivity (29) and have been positively correlated to physical activity in some (22–24) but not all (35) studies of youth. Boys and girls who perceive that there are no parks in their neighborhood and whose parents perceive reduced access to play areas are less likely to walk or bicycle in their neighborhood (36). In addition, increased perceived access to physical activity (37–39), readily available opportunities to exercise (40), and time spent outdoors (38,41,42) are positive correlates of youth physical activity. Thus, children may be more likely to play in their neighborhood if it provides easy access to parks or friends' homes through increased street connectivity.

Parks are an important resource for providing opportunities for physical activity (43). Access to larger parks with more amenities may promote more physical activity (44). Neighborhood parks may increase youth physical activity by encouraging walking or bicycling to parks and providing facilities and a meeting area for active play. A limitation of this and previous studies is the lack of concurrent measures of where the activity occurred or the purpose of the physical activity. At this time there are no published data regarding how much of the additional physical activity that occurs in neighborhoods with parks is a function of walking to or playing at the parks.

The association of access to parks with youth physical activity may differ according to the sex of the child. Boys who lived in neighborhoods with a greater percentage park area were more physically active, but the percentage park area was not correlated to the physical activity of girls. To the best of our knowledge this is the first study to demonstrate that the neighborhood environment has differential associations with the health behaviors of boys and girls. This result agrees with our work on substitution of physically active for sedentary behaviors in youth. When access to sedentary behaviors such as television is decreased, boys increase their physical activity whereas girls do not (45).

This hypothesis may also be applied to treatment studies designed to increase physical activity of sedentary children by reducing access to reinforcing sedentary behaviors. Prior to treatment there are few restrictions on television viewing so the television may act to "pull" or draw the child into the home. The neighborhood environment has less influence on their behavior. When access to television is reduced and television time is decreased, children are left with a choice of how to allocate their free time. Access to fewer reinforcing sedentary activities in the home may act as a "push" into the neighborhood environment to promote children to engage in physically active play in their neighborhood. However, parental rules may impinge on these relations. Decreasing television may not result in children spending more time and being physically active in their neighborhood environment if parents do not allow their child to play outside or if the child chooses another sedentary activity to replace television.

The results of this study are based on a highly selected group of children. Only 88 children were included from a mailing targeting 3,000 households. This careful participant selection may impose limits to inferences for a larger population of children in that selection bias may influence the external validity of this study's results.

In conclusion, the results of this study demonstrate disparate associations of the neighborhood environment and home environment on youth health behaviors. To promote physical activity in children, planners need to design neighborhood environments that support active living, and parents should limit access to reinforcing sedentary behaviors such as television viewing and video games in the home environment. The neighborhood environment factors that promote an active lifestyle may differ between boys and girls.

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