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Proximity to School and Physical Activity Among Middle School Girls: The Trial of Activity for Adolescent Girls Study

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Abstract

Background— Proximity to routine destinations is an important correlate of physical activity. We examined the association between distance from school and physical activity in adolescent girls.

Methods— We mapped the addresses of 1554 sixth-grade girls who participated in the Trial of Activity for Adolescent Girls (TAAG) Study and calculated the shortest distance from home to school along the street network. Using a hierarchical design we examined the association between MET-weighted moderate to vigorous physical activity (MW- MVPA) and distance to school, while controlling for potential confounders.

Results— Distance to school was inversely associated with weekday MW- MVPA for middle school girls. For every mile the girls lived from their schools, they engaged in an average of 13 fewer MET- weighted minutes per week.

Conclusions— Distance to school is inversely associated with MW-MVPA. The most adversely affected girls lived more than 5 miles from school. Time spent commuting could explain reduced time for physical activity.

Keywords

GIS; accelerometers; school location; urban design; street connectivity

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Over the past several decades, the trend in school siting has been to build bigger schools on the outskirts of a community where land is less expensive.[1] As a consequence, schools draw students from a larger area, with children living so far from school that it is not often feasible for them to walk or bicycle to school on their own. Indeed, there has been a significant decline in the proportion of children who walk or bike to school over the past several decades, from 48% in 1969 to less than 16% in 2001.[2] Theoretically, the decline in walking and biking to school, coupled with longer bus/car commuting time, is likely to impact the amount of physical activity youth engage in daily.[3,4] There have been mixed findings in the literature, making this relationship unclear. However, one objective study of physical activity of 5-y old children wearing accelerometers indicated a negligible difference in total physical activity between children who walked and those who were driven to school.[5] In contrast, a study in Norway compared fitness among high school students who rode the bus to school with those who walked or biked and found that distance by school bus was negatively associated with measured components of fitness, including hip abduction, hip flexion, hip extension, and hamstring flexibility.[6] Another study, also using accelerometers, demonstrated increased moderate physical activity among primary school boys who walked to school compared to those who did not, but this difference was not seen among girls.[7] A study of Filipino adolescents showed that youth who actively commuted to school expended more energy than those who took motorized transport; the difference was estimated to account for a weight reduction of 2 to 3 pounds per year.[8]

With population growth, migration, deterioration of physical structures over time, changes in building codes, and efforts to reduce exposures to toxic substances in older buildings, localities all over the country will need to continue to build and/or rebuild schools. The influence of school location on the physical activity, and thus the health of the student population should be considered when schools are sited and when parents decide where to live. The purpose of our study was to investigate the relationship between school location and physical activity among sixth-grade girls. We hypothesized girls who lived closer to school would have higher levels of physical activity. We analyzed baseline data collected by the Trial of Activity for Adolescent Girls (TAAG) Study, a national school-based randomized controlled intervention trial designed to reduce the decline in physical activity among adolescent girls.[9]

Methods

The TAAG study is a group-randomized trial supported by the National Heart, Lung, and Blood Institute (NHLBI) that recruited sixth-grade adolescent girls from 36 schools in the environs of six sites, including the University of South Carolina, Columbia SC, University of Maryland, Baltimore, MD/Washington, DC area. San Diego State University, San Diego, CA, University of Arizona, Tucson, AZ, University of Minnesota, Minneapolis, MN. and Tulane University School of Public Health and Tropical Medicine, New Orleans, LA. Our project was an ancillary study to TAAG, and all methods were approved by the IRBs of all participating institutions. We had valid addresses from 1554 of the 1603 participating girls (97%), geocoded them using Arc View software developed by the Environmental Systems Research Institute [ESRI (www.esri.com)], and calculated the distance from their residences to their schools along the shortest street network distance.

Physical Activity Measurement

The girls wore Actigraph accelerometers (model 7164, Manufacturing Technologies Inc. Health Systems, Shalimar. FL) for 7 d during the winter and spring of 2003. The monitors were attached to a belt worn around the waist, and activity counts were stored in 30-s time intervals. Using an equation developed from a calibration study of 74 eighth-grade girls, physical activity at least moderate-to-vigorous (MVPA) was defined at a cut-point of 1500 counts per 30 s, corresponding to a 4.8 MET value.[10] MW-MVPA was calculated by multiplying the intensity of the activity (in METS, based on the accelerometer reading) for each minute that was greater than or equal to the 1500 count cut-point. This provided more weight to more vigorous activities. For example, an activity count corresponding to 6 METS for 10 min received a value of 60 MW-MVPA min.

We examined physical activity in discrete time periods separating weekdays from weekend days. Accelerometer data were coded as MW-MVPA, which accounted for activity equivalent to a brisk walk or higher and weighted by duration in minutes and by the intensity of exercise. We ran models for overall weekly MW-MVPA, weekday MW-MVPA, and weekend MW-MVPA. We also looked at MW-MVPA for weekdays after 3 pm. Each of these measures is skewed towards zero. For each model, we log transformed MW-MVPA so that we would have a normally distributed outcome variable. This means that the covariates will have exponentiated coefficients, representing a constant percent effect rather than a constant absolute effect.

Other Variables

We considered several neighborhood measures as potential confounders. Because previous studies indicate that more people walk in neighborhoods with shorter blocks and greater number of intersections,[11, 12] we used two indices of street design in the models at the individual level. The first index assessed the connectivity of streets (called a "connectivity index") and was defined as a combination of alpha, beta, and gamma indices, which are measures of the ratio of intersections (also called nodes) to street segments (also called links). The alpha index is the ratio of the number of actual circuits or loops in the tract to the maximum possible number of circuits and is equal to: [(# links − # nodes + 1) / 2(# nodes) − 5], The alpha index ranges between 0 and 1 and higher value indicates greater connectivity. Beta is the ratio of streets to intersections, and higher values indicate greater connectivity. The gamma index is a ratio of the number of links in the tract to the maximum possible number of links between nodes, and uses the formula: [# links / (3 * (# nodes − 2)]. Gamma is a number between 0 and 1, and a higher value indicates more connectivity. These three measures are highly correlated with one another, but do not always agree. Rather than select a single measure and lose the additional variability from the remaining two, we combined all of three in a single factor (Cronbach's alpha = 0.99).

The second summary measure assessed block size (called "street segment index"), and was defined by combining the average street length in feet, the average block size in acres, and the average block perimeter in miles. Again, these individual measures are highly correlated but differ from one another. We also combined them into a single factor (Cronbach's alpha = 0.95). All of our street network measures were based on the US Census Bureau's TIGER/Line street centerline data[13].

Neighborhood was defined as the area within a ½-mile circle centered on the girl's place of residence. We created each of the following demographic measures specific to each individual girl: The percentage of the population in the neighborhood that was African American and Hispanic was included in the models, and a standardized neighborhood index to indicate socioeconomic status was created using the US Census.[14] This SES index consisted of percent of households in poverty, percent of individuals over 18 y of age with less than a high school education, and percent unemployed (Cronbach's alpha = 0.88). To create these measures, we combined the 2000 US Census population data for each census block group that intersected the ½-mile buffers around the girls' addresses. For block groups that were partially within the buffer, we added the proportion of population in the block group, commensurate with the proportion that fell within the buffer. Table 1 describes these measures. We also examined different configurations of neighborhoods, including the census block group and the census tract.

We used the same covariates (percent ethnic/racial distribution, SES index) but applied the appropriate respective data to match the various geographies from the US census. We calculated the street design indices for census block group and census tract lo use in the respective models. In this way we could determine how much geographic unit matters in the relationship between physical activity and place.

Statistical Analyses

To determine whether distance from school was associated with measures of physical activity, we used a 3-level hierarchical linear model to adjust for group clustering and correlations at each level. We assumed that girls were nested within schools, which were in turn nested within sites. The first level is the individual girls in the study. We controlled for individual self-reported race/ethnicity as well as the neighborhood measures described above. Since neighborhoods were defined specifically for each girl, we considered these measures to be girl level (or level 1) covariates. The second level was for schools, and we controlled for the percentage of students in the school who were on the free lunch program, as a proxy for school-level SES. Generally, students whose families earned less than 200% of poverty were eligible for this program. The third level of the hierarchy was the site, and we did not include any site level covariates for the six participating sites.

While the trend between MW-MVPA and distance from school appeared to be linear and negative, we used both linear and nonlinear specifications for distance to school to explore the data. Rather than assume that the relationship between distance to school and MW-MVPA was the same at 1 mile from school as at 10 miles from school, we grouped distance to school into four ranges and used dummy variables for each range or category. We refer to these models with the dummy variables for distance categories as our non-linear models. We analyzed the data examining MW-MVPA for all times during the weekday, the weekend, and during the weekday time after 3 PM.

Results

The sample consisted of 1554 girls, including 4% Asian, 21 % African American, 22% Hispanic, 45% white, and 8% mixed race or Native American. Figure 1 shows the number of girls by distance category from school. Only 15.5% lived within 1 mile of the school; 28% lived 1 to 2 miles from school, 23% lived 2 to 3 miles from school, 24% lived 3 to 5 miles from school, and 9% lived more than 5 miles away. The farthest distance from school varied considerably by site ranging from 7.4 miles in Minneapolis, MN to approximately 20 miles in Tucson, AZ. Overall, only 4% of the girls lived within a half-mile of school, although in New Orleans 20% lived within this radius.

Figure 2 shows the unadjusted minutes of MW-MVPA by distance categories from school. In each category, minutes of MW-MVPA are shown for total time not in school, after school time on weekdays, and weekend time. The patterns indicate an inverse relationship such that total and weekday non-school MW-MVPA declined as girls lived further away. In contrast, a 1-way ANOVA test for differences in the average value by distance showed that MW-MVPA on the weekends was similar across all the distances ($P = 0.96$). Considering only the time after 3 PM on weekdays, girls living 5 to 6 miles from school had 58 fewer MW-MVPA minutes per week than girls living within a ½ mile of the school.

Because time after 3 PM did not include minutes that may have been spent in physical activity before school, we used total weekday MW-MVPA for our non-linear model. Here we collapsed distance to school into four categories based upon the observed differences in MET-weighted MVPA: 0 to less than ½ mile from school, ½ to less than 5 miles, 5 miles to less than 10 miles, more than 10 miles. Table 2 shows the results of the adjusted non-linear model. In addition to exponentiated coefficient estimates, the table presents the effect size of the coefficient at the average MW-MVPA for girls living within ½ mile of school. For example, girls living ½ mile to 5 miles from school have, on average, 11.8% less total MW-MVPA for the week than girls living within ½ mile of school. The average girl living within ½ mile had 852 MW-MVPA minutes per week. In contrast, the average girl living ½ to 5 miles from school, had 101 fewer MW-MVPA for the week (11.8% of 852). Minutes of MW-MVPA did not differ significantly among girls within this range. Girls living 5 to 10 miles from school had 19.7% fewer MW-MVPA minutes per week (a difference of 168 MET-min per week) than girls living within ½ mile, and girls living more than 10 miles away had 54.2% fewer (a difference of 462 MET-rnin per week).

The results are even more striking for MW-MVPA during the school week (Table 3). Girls ½ to 5 miles from school had 14% fewer MW-MVPA minutes per week of physical activity than girls within ½ mile, while girls 5 to 10 miles had 21% fewer and those more than 10 miles away had 62% fewer.

Table 4 shows the coefficient estimates for a model predicting MW-MVPA during weekdays at three different units of geography with a linear specification for distance. In these models we assume a constant effect of distance from school. The findings are similar across all three models, and show consistent associations between MW-MVPA and distance to school as well as large associations between MW-MVPA and race/ethnicity. The effect sizes for MW-MVPA are very similar for all geographic units and range from 12.8 to 14.6 MW-MVPA minutes per week per mile away from school.

Discussion

We found a significant inverse relationship between physical activity and distance from school for sixth-grade girls, and it is not fully explained by time spent walking to school. Most girls in the sample lived too far from school to walk, yet those living more than 5 miles from school still had lower levels of MW-MVPA than those living 3 miles from school. Our findings suggest that girls living further from school may spend more time commuting, have less time to be physically active, and do not compensate in other ways. Also, girls depending on buses or cars for transportation home may be less likely to be able to stay late for after-school activities. The lack of significant differences in MW-MVPA by distance on weekends also supports the possibility that reduced physical activity during weekdays is due to commuting in cars or buses.

An important strength of this study is that the data are from a variety of sites and there is a large variability in distance from school. The populations included are representative of the increasing trend to build large schools in growing suburban areas, usually on the edge of development. Other studies of physical activity and distance to school may not have had this degree of variability, so their findings may be comparatively attenuated. Another strength of the current study is that the finding persists even when examining several types of neighborhood configurations.

While the magnitude of the effect is substantial, the effect is strongest for the 9% of girls living more than 5 miles from school. The impact of the “lost opportunity” for physical activity, especially for girls living more than 5 miles from school, cannot be underestimated, as this amount translates to an average of 165 fewer minutes per week of MW-MVPA. Families wanting their children to maximize physical activity should consider this in their choice of whether to locate close to schools or promote transportation for after-school activities.

The study is limited by its cross-sectional nature, so it is not possible to determine whether distance and physical activity are causally associated. For example, active families may choose to live closer to schools. Because people select where they live, longitudinal data including those who relocate are needed to pinpoint a causal effect. Furthermore, our data are limited to a single age and gender group, making it difficult to generalize findings to other populations.

Future decisions on school sitings should consider locating schools centrally in residential areas. This would reduce distances to school for the majority of students, and perhaps increase walking and bicycling to school while reducing the costs of inactive transport (cars, buses). It is not likely that it will be possible to build enough schools so that all youth do not have to commute long distances to schools. Thus it is all the more important for schools to provide ample opportunities for physical activity for students during the school day as well as provide additional bus runs to facilitate their participation in after-school programs.

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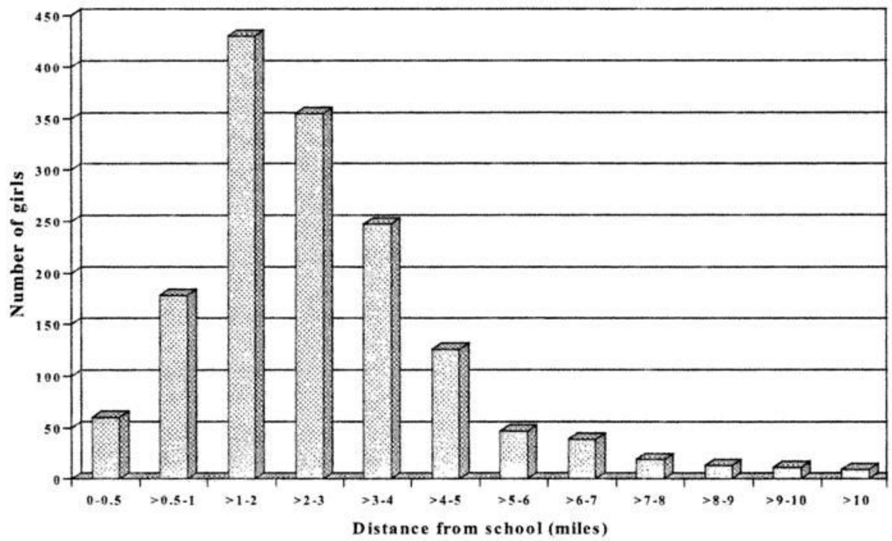

Figure 1.
Number of girls by category of distance from school

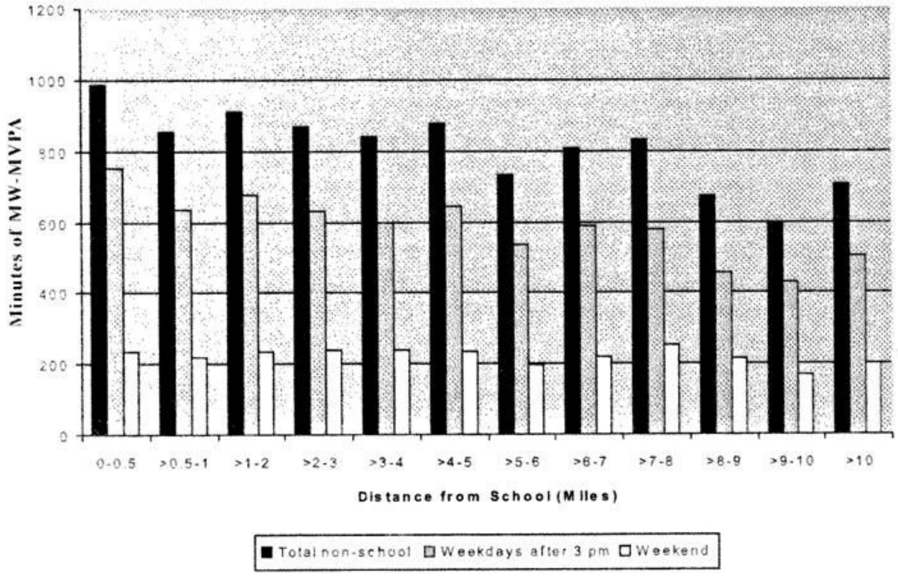

Figure 2.
Minutes of MET-weighted MVPA by distance from school

Table 1

Study Variable Values

Variable	Mean	*SD*	Minimum	Maximum
MW-MVPA	868	490	77	4917
Distance to school (miles)	2.7	2.0	0.0654624	19.81
Alpha	0.2	0.1	0	0.6
Beta	1.4	0.2	0.8	2.0
Gamma	0.5	0.1	0.3	0.8
Block length (feet)	1651	970	399	11910
Block size (sq acres)	45.3	82.2	2.3	1111.4
Block perimeter (miles)	1.0	0.6	0.2	7.7
% African American	19.6	26.4	0	99.4
% Hispanic White	5.8	8.1	0	50.1
% households in poverty	10.1	9.2	0	42.9
% Less than HS	10.8	7.2	5.9	29.0
% Unemployed	2.5	1.3	0	9.8

Table 2

Non-Linear Model Predicting Total MET-Weighted MVPA for the Entire Week

Distance to school	Coefficient estimate (%)	Average minutes of MET-weighted MVPA (95% CI)
0 to < 1/2 mile	reference	852
1/2 to<5 miles	−11.8*	757 (669, 858)
5 to < 10 miles	−19.7**	700 (607, 807)
≥ 10 miles	−54.2**	495 (419, 585)

*Note. $P < 0.10$;

** $P < 0.05$. Models control for site, school % free lunch, girls' race/ethnicity, neighborhood SES, neighborhood % Hispanic and % African American, street connectivity, and the street segment index at the 1/2-mile radius.

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Table 3

Non-Linear Model Predicting Total MET-Weighted MVPA for Weekdays

Distance to school	Coefficient estimate (%)	Average minutes of MET-weighted MVPA (95% CI)
0 to < 1/2 mile	reference	633
1/2 to < 5 miles	−14.0**	550 (480, 631)
5 to < 10 miles	−21.2**	512 (441, 594)
> 10 miles	−61.5**	342 (248, 470)

** *Note.* $P < 0.05$, Models control for site, school % free lunch, girls' race/ethnicity, neighborhood SES. neighborhood % Hispanic and % African American, street connectivity and the street segment index at the 1/2-mile radius.

Table 4

Full Model Predicting Weekday MET-Weighted MVPA by Block Group, Census Tract, and 1/2-Mile Radius Neighborhoods

	Block group		Tract		1/2 mile	
Variable	**Coefficient**	**Effect**	**Coefficient**	**Effect**	**Coefficient**	**Effect**
Intercept	643.23**		645.83**		629.74**	
Distance to school (miles)	−2.04**	−13.02	−2.29**	−14.62	−2.02**	−12.81
Street Network Factor 1 (GAMMA)	0.14	0.89	−0.21	−1.34	−0.15	−0.97
Street Network Factor 2 (Block size)	0.11	0.69	0.55	3.49	0.03	0.21
Girl’s race = Asian	−23.64**	−150.60	−23.51**	−149.77	−23.64**	−149.86
Girl’s race = African American	2.81	17.91	2.30	14.68	3.07	19.45
Girl’s race = Hispanic	−4.59**	−29.27	−4.34**	−27.63	−4.55**	−28.86
Girl’s race = Multi-racial	−3.81	−24.29	−4.16	−26.53	−4.01	−25.40
Girl’s race = Native American	28.61*	182.28	30.15*	192.10	29.40*	186.42
Neighborhood % Af. Am.	−12.36**	−78.76	−10.77**	−68.62	−13.94*	−88.40
Neighborhood %Hispanic	−41.18**	−262.33	−43.48**	−276.98	−42.03*	−266.46
School % on free lunch	−0.05	−0.30	−0.03	−0.18	−0.02	−41.15
Neighborhood SES (standardized)	5.78**	36.81	6.59**	41.97	4.30	27.26

* Note. $P < 0.10$;

** $P < 0.05$.