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School design and physical activity among middle school girls

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INTRODUCTION

The design of streets, sidewalks, and buildings play a role in how much we walk (1). In cities with high levels of sprawl, people walk less than those living in more compact, less sprawling cities (2, 3). Theoretically, designs that require more walking result in a population that is more physically active and may have other benefits related to health and well being. Places in which people spend a large part of their day have the potential to make a significant impact on total physical activity. For most adults, the workplace may be important, but for children and adolescents, schools are likely to be a critical contributor to physical activity

While physical activity accrued at school is estimated to account for only 20–40% of children's total activity (4–6), one study found that girls spent a higher percentage of their time engaged in moderate-to-vigorous physical activity (MVPA) on weekdays during school hours (morning and early afternoon) than in the late afternoon or evening (7). Thus, with attendance being compulsory and school sites almost always having some recreational facilities, schools may be particularly important sites for the promotion of girls' physical activity (8). Elementary school children tend to stay in one classroom; so common areas, like gymnasiums and outdoor playgrounds and fields are likely to contribute most to physical activity. In contrast, middle school students generally have teachers for different subjects and must travel from classroom to classroom throughout the day. Consequently, large schools with more sprawling grounds may encourage more physical activity than those that are smaller or more compact.

Further, schools that have a lot of space for PE classes and a variety of facilities (e.g., tracks, fields, courts) may stimulate more physical activity than schools with fewer amenities. Not all middle schools have indoor gymnasiums and weight rooms, but most have outdoor facilities for sports, play, and exercise that typically include a playing field, a multi-use paved area, and an area with climbing/exercise apparatus (9). Although not a nationally representative study, the School Health Policies and Programs Study 2000 found that 83% of middle/junior high schools had a general use field and 66% had playground equipment (9).

There is limited information on facilities and physical activity. One study, however, found that the average student in smaller high schools participated in over twice as many sports as students in larger schools (10), and another found no correlation between the total recreational space available to students and the percentage of the school population visiting play areas before or after school and during lunchtime (11). For promoting physical activity, the number of programs and facilities available per student may be more important than the absolute number. To further study the relationship between school design and light physical activity and moderate to vigorous physical activity (MVPA) during school hours, we examined 36 middle schools that participated in the Trial of Activity for Adolescent Girls (TAAG), and determined whether their physical features were associated with these two measures of physical activity among adolescent girls.

METHODS

The Trial of Activity for Adolescent Girls (TAAG). TAAG) is a multi-center group-randomized controlled trial designed to test the effectiveness of an intervention to reduce the decline in physical activity among middle-school girls (12). The TAAG field sites represent diverse geographical areas and populations, with field centers at San Diego State University (California), Tulane University (Louisiana), and the Universities of Arizona, Maryland, Minnesota, and South Carolina. The Coordinating Center was at the University of North Carolina, Chapel Hill and the National Heart Lunch and Blood Institute of NIH funded the study as well as participated in its planning and analysis. All methods were approved by the IRBs of all institutions.

Eligible schools were selected by field sites participating in TAAG based upon their location, and if they had at least 90 girls in each school that could be followed over the course of the study, based upon at least at least an annual 80% retention rate. First, we obtained data on the number of students at each school from the Common Core Data Set (www.nces.gov) and acquired high-resolution aerial photographs of all 36 schools. Using GIS techniques we measured the school footprint as well as the size of the fields and school grounds, excluding parking areas. This allowed us to calculate the number of building square feet considering only the first floor as well as the number of field acres.

Next, trained staff visited all 36 middle schools, one of which was closed on the day of the visit and thus was excluded from our analyses. During the site visit, staff documented all outdoor facilities and amenities, including fields, basketball courts, water fountains and lighting; later, they verified the presence or absence of gymnasiums. With this information, we created variables for the presence or absence of each type of facility as well as a variable for the total number of active amenities. Active amenities are those that are used to perform physical activity. Schools also provided information on the percent of students receiving free or reduced price lunches.

The girls wore Actigraph accelerometers (Manufacturing Technologies Inc. Health Systems, Model 7164, Shalimar, FL) and data on physical activity was collected for six consecutive days, four weekdays and two weekend days, during the Winter and Spring of 2003. Accelerometer readings were processed using methods similar to those reported by Puyau et al. (13). Readings above 1500 counts per half minute were treated as MVPA, while readings below that, but above 51 counts per half minute, were considered light physical activity (LPA). We reported previously that this threshold had the optimal sensitivity and specificity for discriminating brisk walking from less vigorous activities in eighth grade girls (14). Half-minute counts were used instead of full-minute counts based on the expectation that they would be more sensitive to fluctuations in activity levels. Occasional missing accelerometry data within a girl's 6-day record were replaced via imputation based on the Expectation Maximization (EM) algorithm (15).

For calculation of MW-MVPA counts above 1500 per half minute were converted into METs using a regression equation developed from a second pilot study for TAAG (16); the METs were summed over the 6 am-midnight day to provide MET-minutes per day of MVPA, where one MET-minute represents the metabolic equivalent of energy expended sitting at rest for one minute. Counts less than 1500 per half minute but greater than 51 per half minute were not used to calculate MW-MVPA.

In addition, we downloaded the locations of all the National Oceanic and Atmospheric Administration's (NOAA) Weather Data Management (WDM) stations and selected the ones nearest to the TAAG schools. We matched data on maximum temperature and precipitation for those stations during the days each girl recorded her accelerometry measurements. Then, we determined the average maximum temperature and average daily precipitation during a girl's school-week of activity.

Analyses

We used accelerometer data measured on the 4 school days between the hours of 9am and 2 pm. While the start and end times varied among the schools, all schools were in session between these hours. In order to explain our analyses in terms of total school activity per week, we then weighted the total in-school minutes of MW-MVPA and LPA recorded on each weekday by 5/4 before summing all the school days together. First, using Chi-square and analysis of variance (ANOVA) statistics, we examined how school characteristics differed by site and how they were correlated with each other.

Second, we investigated whether school design and school features were associated with MW-MWPA and LPA. The TAAG data itself has a hierarchical structure in which girls (level 1 units) are nested within schools, and schools (level 2 units) are nested within study sites. Consequently, for these analyses we treated school and site as random effects in a hierarchical linear model(17). At the girl-level, we modeled race as a fixed effect and, at the school-level, we modeled all the school characteristics also as fixed effects. To make the value of the intercept more interpretable, we centered all continuous covariates around their means. Because the first-level residuals were not normally distributed, we used a log-transformed version of MW-MVPA to run our final analyses with Proc Mixed in SAS 9.0. Thus, the resulting parameter estimates are interpreted as percent changes in our dependent variables per unit change in our covariates. To make our results more easily interpretable, we also calculated the magnitude of this change for the "average girl" by multiplying the estimate by the intercept, or the number of minutes of non-school MW-MVPA when all of the continuous predictors are at their means. LPA did not need to be log-transformed. We also examined the association between maximum temperature and MW-MVPA using the same hierarchical regression methods.

Because school building size and field size were significantly and highly correlated (r= 0.66) and because we suspected that outdoor activity would tend to be more vigorous than indoor activity, we decided to employ separate indoor and outdoor models. All models were run with and without weather-related variables for the days of measurement and controlled for total number of students, the percent of students receiving free or reduced-price lunch, each girl's race/ethnicity. The outdoor models tested the relationship between physical activity and the number of active amenities and the acres of fields available. To reduce correlation among field acres, total active facilities, and total student population (Cronbach's alpha=0.58), we broke the field acres variable into quartiles and created a new categorical variable for use in the outdoor models. Indoor models explored the relationship between physical activity and both the square footage of each school's first floor and the number of yards between school buildings.

RESULTS

Characteristics of student participants are listed in Table 1. The mean age of girls was 11.8 years and 43% of the population were non-Hispanic white. There was a wide variety of building designs and footprints across the 36 schools. The average school had 3.9 acres (169,884 sq feet) of building space as a footprint (range 1.2–17.4 acres) and 9.7 acres of fields around the buildings (range 0–33.7 acres). The average number of students enrolled per school was 1,031 (Table 2). By TAAG field site, the schools were similar in size for both the number of students and the building footprint and field acres. Schools in the warm, dryer western climates, San Diego and Tucson, had the most outdoor activity facilities and amenities, while the schools in the south, New Orleans and Columbia, had the least. The most physically active girls were in San Diego and Tucson as well.

The most common activity facility was a baseball field, with 83% of all TAAG schools having one. This was followed by multi-purpose fields (77%), outdoor basketball courts (74%) and gymnasiums (69%). Tennis courts were observed at 43% of schools and designated running places (i.e., walking paths, multi-use paths, or running tracks) were at 26% of schools. Some schools had more than one of these amenities. As far as passive amenities, less than 31% had outdoor drinking fountains and only 28% had an accessible restroom from the outside. Floodlights were available in 28% of the schools, and shaded areas were found in sites with warmer weather. (Table 3).

Table 4 shows two models to assess whether an association between outdoor facilities and school MW-MVPA existed. The number of active facilities was significant at the .02 level. However, once we include measure of temperature and precipitation, the magnitude of association was attenuated from an average of 4.8 minutes to 3.9 minutes per active facility and the significance was reduced to 0.06, suggesting a trend for weather to confound the relationship between active facilities and moderate to vigorous physical activity. We found no interactions between the weather variables and the school facilities. Since the average number of facilities per school was 15, an average of 58.5 additional minutes of MW-MVPA per week (29% of total MW-MVPA) is potentially attributable to active facilities.

Table 5 shows two models of indoor physical activity. Here the association of the number of square feet (in thousands) of the building foot prints with light physical activity and MW-MVPA was not quite statistically significant, with p=.07 and p=.06, respectively. However, when translating these estimates to total minutes, the average building square feet could potentially account for 18.9 minutes of light PA and 25.7 minutes MW-MVPA per week. This represents 4% of all LPA and 16% of all MW-MVPA during school. The difference between the largest and smallest buildings in association with light PA was 5.6 minutes vs. 83.2 minutes, and for MW-MVPA it is 7.6 minutes vs. 113.5 minutes per week. Although the maximum temperature was also associated with MW-MVPA, its inclusion in the indoor models had no effect on the magnitude of its association with building square feet.

When regression models were run with temperature alone predicting MW-MVPA, each degree (Fahrenheit) increase was associated with an average of 1 minute increase in weekly MW-MVPA (p=.05). However, when the number of active facilities was added into the model the effect of temperature was slightly reduced to 0.95 minutes more MW-MVPA per degree increase (See Table 4).

DISCUSSION

Our study shows small but significant associations between the number of active outdoor facilities and physical activity among middle school girls during school hours. The facilities and amenities available to adolescents in middle schools vary considerably, even among schools that serve relatively similar numbers of students. Some schools had virtually no fields, while in others the total building footprint was several times larger than those of the smallest schools. As well, the number of activity facilities was associated with MW-MVPA but field size was not.

Our study had several limitations, the first being statistical power. With only 35 schools it is not surprising that several significance tests showed associations that were bordering the p=.05 level, but may still be considered clinically significant (18) . We were also limited to a measure of the footprint (first floor) of the school and cannot account for the effects of different stories (floors) or the type of space (e.g., hallways, rooms) within a school. In addition, we would not be able to capture the benefit of stair climbing that may be associated with a multi-story building.

Temperature appears to confound the association between the number of active facilities and MW-MVPA; and because they were so closely associated it is not possible to determine which is more important. Localities with the most outdoor active amenities also had the highest temperatures, and it is possible that girls were more active outdoors because of temperature rather than the amenities. The increase in MW-MVPA associated with 1 additional activity facility is about the same as that seen with an increase in temperature of 4 degrees Fahrenheit. Temperature was associated with more MW-MVPA but not with LPA in the indoor model.

Although we did not measure social factors and school programming in this study, it is likely that they play a much larger role in influencing MVPA than the size of the building footprint and field acreage. Physical activity is possible in small as well as large areas, and its intensity often depends on the activities provided in the space. Aerobics and calisthenics can be accommodated in small spaces, but competitive intramural and interscholastic sports typically require larger and more standardized field and court sizes. Nonetheless, adolescent girls' participation in exercise and sports during school hours is likely to depend upon how well they are promoted. In addition, girls may be more likely to participate in competitive sports after school and on weekends, time periods not captured in our study.

In many localities schools are being built on the town edges where land is more affordable and allows for schools to be larger and include variety of physical activity facilities. In a previous study with the same cohort of girls we found that school proximity to girls' homes was associated with increased physical activity (19). Since field size did not appear to be associated with physical activity, it may better to consider building schools that don't require so much land and have smaller fields, but are closer to population centers. The extra physical activity gained by students from walking to and from school may outweigh the benefits of schools with large fields and buildings.

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Table 1

Study population

Mean Age of Girls	11.8 (0.5)
Race/ethnicity	
% Hispanic	20.3
% White (Non- Hispanic)	43.1
% African American	21.6
% Other Race/ethnicity	15.1
Site, (% of total)	
Minnesota	17.4
Columbia	17.8
Baltimore/DC	14.8
San Diego	18.9
Tucson	12.5
New Orleans	18.6
Mean (Std Dev) Age of Girls (years)	11.8 (0.5)
Mean (Std Dev) MW-MVPA (minutes) per	226.6 (175.0)
Mean (Std Dev) Light PA (minutes)	517.6 (132.0)
Mean (Std Dev) BMI (kg/m^2)	20.9 (4.9)

Table 2

Means

	All TAAG Schools	Maryland	South Carolina	Minnesota	Louisiana	California	Arizona
Based upon # of girls	**(n=1566 girls)**	**(n=232)**	**(n=279)**	**(n=273)**	**(n=291)**	**(n=296)**	**(n=195)**
	Mean (Min-Max)	***Mean (Min-Max)***	***Mean (Min-Max)***	***Mean (Min-Max)***	***Mean (Min-Max)***	***Mean (Min-Max)***	***Mean (Min-Max)***
5-day total LPA in minutes/week	518 (0–1037)	514 (237–860)	433 (0–794)	554 (254–886)	488 (0–1037)	557 (2623–860)	576 (281–930)
5-day total MW-MVPA in minutes/week	227 (0–1849)	197 (6–1157)	139 (0–902)	214 (15–772)	165 (0–1098)	338 (17–1031)	328 (16–1849)
Maximum temp on measurement days (° Fahrenheit)	55 (11–85)	48.1 (29–77)	57.3 (43–76)	23.9 (11–50)	68.4 (55–84)	66.1 (60–75)	68.4 (60–85)
Average daily Precipitation (inches)	.12 (0–.82)	.09 (0–.43)	.15 (0–.81)	.02 (0–.06)	.25. (0–.82)	.14 (0–.53)	.02 (0–.06)
Based upon # of schools	**All TAAG Schools (n=35)**	**Maryland (n=6)**	**South Carolina (n=6)**	**Minnesota (n=6)**	**Louisiana (n=6)**	**California (n=6)**	**Arizona (n=5)**
Number of students	1,031 (606–1703)	998 (835–1480)	968 (859–1198)	1141 (858–1703)	950 (745–1244)	1173 (750–1669)	939 (606–1497)
Active facilities	15 ***(2–44)	12.17 (3–19)	6.5 (2–13)	11.67 (7–17)	7.5 (3–11)	32 (17–44)	20 (10–31)
Building footprint square feet	171,624 (50,851–756,670)	123,750 (41,018– 80,746)	234,308 (52,986–756,670)	189,555 (105,072– 394,163)	123,719 (50,851–204,872)	170,592 (93,213–240,956)	191,062 (140,076– 248,409)
Field acres	9.7 (0–33.7)	8.62 (3.9–14.0)	10.97 (2.8–22.5)	12.76 (3.4–33.7)	4.9 (0–7.4)	8.94 (3.3–16.3)	12.18 (6.5–21.9)
Percent Free Lunch	35.6 ***(0–91.0)	29.83 (11–49)	32.67 (22–48)	14.5 (4–29)	80 (61–91)	35 (15919)	18.6 (0–75)

Significance testing comparing means a cross sites using ANOVA

*** p < .001

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Table 3

Percent of schools with Physical activity facilities and amenities

	All TAAG Schools	Maryland	South Carolina	Minnesota	Louisiana	California	Arizona
	(n=35)	(n=6)	(n=6)	(n=6)	(n=6)	(n=6)	(n=5)
Amenities							
Parking lot	86	83	83	83	83	83	100
Streetlights	80***	83	83	100	100	83	20
Drinking fountain	31***	17	0	0	0	83	100
Floodlights	29	17	17	0	67	33	40
Restroom	29***	17	0	83	0	50	20
Shaded area	26***	0	0	0	50	33	80
Activity Facilities							
Multi-purpose field	77*	67	33	100	83	100	80
Basketball court	74**	83	33	50	83	100	100
Gymnasium	69***	100	100	100	83	0	20
Blacktop	51***	50	0	0	100	100	60
Tennis court	43***	83	0	83	17	33	40
Running track	26***	0	50	0	0	33	80
Handball court	23***	0	0	33	17	83	0
Multi-use path	23**	17	0	0	33	17	80
Tetherball	20***	0	0	0	0	50	80
Volleyball court	11**	0	0	17	0	50	0
Baseball field	83	83	83	100	67	83	80
Football field	37	33	83	17	33	33	20
Gymnastics	23	0	0	0	0	67	80
Play equipment	20	17	17	17	33	17	20
Soccer field	17	33	17	33	0	17	0

	All TAAG Schools	Maryland	South Carolina	Minnesota	Louisiana	California	Arizona
	(n=35)	**(n=6)**	**(n=6)**	**(n=6)**	**(n=6)**	**(n=6)**	**(n=5)**
Outdoor circuit	6	0	0	0	17	17	0
Paddle tennis court	3	0	0	0	0	17	0
Ice rink	3	0	0	17	0	0	0

* $p < .05$;

** $p < .01$;

*** $p < .001$

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Table 4

Models of Outdoor Activity predicting MW-MVPA: (Model 1 without weather, Model 2 with weather)

	Model 1 β-estimate[ii.]	Average magnitude of association[iii.]	p-value	Model 2 β-estimate[ii.]	Average magnitude of association[iii.]	p-value
Intercept[i.]	198.80		0.00	199.19		0.00
# active facilities	**0.02**[*]	**4.76**	**0.02**[*]	**0.02**	**3.88**	**0.06**[†]
Field size (0–5.52)	0	--	--	0	--	--
Field size (5.53–8.92 acres)	−0.24	−47.73	0.16	−0.25	−49.00	0.15
Field size (8.93–11.3 acres)	−0.21	−42.70	0.22	−0.21	−42.16	0.23
Field size (>11.3 acres)	−0.21	−40.76	0.25	−0.20	−40.56	0.25
Number of students/school	0.00	−0.07	0.19	0.00	−0.06	0.28
% of students on free or reduced lunch program	0.00	−0.30	0.68	0.00	−0.44	0.56
Hispanic ethnicity of students	−0.05	−10.32	0.39	−0.06	−11.40	0.34
African American	0.19	37.25	0.01[*]	0.18	36.38	0.02[*]
Non-Hispanic Other	−0.01	−1.09	0.93	0.00	−0.49	0.97
Non-Hispanic White	0.00	0.00		0.00	0.00	
Maximum temperature °F				**0.00**	**0.95**	**0.08**[†]
Precipitation (hundredths of inches)				0.00	−0.43	0.15

[*] $p < .05$;

[†] $p<.10$.

[i.] Since all continuous covariates are centered around their means, the intercept in the value of the dependent variable for white students when all the covariates are at their means.

[ii.] Because the residuals in the MW-MVPA were not normally distributed, we chose to use a log-transformation of this dependent variable, making our estimates a percent change in MW-MVPA per unit change in the covariate.

[iii.] In order to express this in terms of MW-MVPA minutes, we multiplied this estimate by the intercept or the number of MW-MVPA minutes clocked by a girl with average values on all of the other covariates

Table 5

Models of Indoor-related variables, predicting Light Physical Activity (LPA) and MET-weighted Moderate to Vigorous Physical Activity (MW-MVPA)

	Model Predicting LPA		Model Predicting MW-MVPA		
	β-estimate (minutes of light PA)	**p-value**	**β-estimate**[v.]	**Average magnitude of association**[vi.]	**p-value**
Intercept[iv.]	518.64	0.00	164.31		0.00
Building sq feet	**0.11**	**0.07**†	**0.00**	**0.15**	**0.06**†
Yards between buildings	−0.02	0.62	0.00	0.09	0.12
% on free or reduced lunch program	0.26	0.56	0.00	−0.06	0.12
# students per school	0.00	0.92	0.00	0.01	0.99
Hispanic ethnicity of students	−2.97	0.75	−0.06	−9.74	0.32
African American	17.38	0.09†	0.19	30.60	0.02*
Non-Hispanic Other	−2.94	0.76	0.00	−0.11	0.99
Non-Hispanic White	0.00	(REF)	0.00	0.00	(REF)
Maximum temperature °F	−0.32	0.44	**0.01**	**0.91**	**0.04***
Precipitation (hundredths of inches)	0.00	1.00	0.00	−0.32	0.18

* p < .05;

† p<.10.

[iv.] Since all continuous covariates are centered around their means, the intercept in the value of the dependent variable for white students when all the covariates are at their means.

[v.] Because the residuals in the MW-MVPA were not normally distributed, we chose to use a log-transformation of this dependent variable, making our estimates a percent change in MW-MVPA per unit change in the covariate.

[vi.] In order to express this in terms of MW-MVPA minutes, we multiplied this estimate by the intercept or the number of MW-MVPA minutes clocked by a girl with average values on all of the other covariates.