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Relationship between Recreational Resources in the School Neighborhood and Changes in Fitness in New York City Public School Students

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Abstract Physical fitness in children has many beneficial effects, including the maintenance of a healthy weight. The built environment may influence youths' physical fitness by encouraging physical activity. This paper assessed whether higher density of parks, playgrounds, and sports facilities around a school is related to improvements in fitness in middle school boys and girls. Fitness scores and other student covariates collected as part of NYC FITNESSGRAM between the 2006–2007 and 2010–2011 school years were linked with school neighborhood data on characteristics of the built environment for NYC public school students in grades 6–8. Data were analyzed in 2015. Medium, but not high, density of recreational resources in the area surrounding a school was associated with greater annual improvements in fitness for both boys and girls. This association appeared to be driven mainly by the presence of parks. Findings for sports facilities and playgrounds were inconsistent. Overall, few associations were observed between recreational resources near a school and changes in student fitness. Future studies of school influences on student fitness should consider the influence of school resources and the home neighborhood.

Keywords Fitness · Built environment · School health

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Introduction

Several recent reports have provided evidence that physical fitness in childhood has beneficial effects on childhood obesity [1–4] and prevention of other chronic diseases [5–7], suggesting that improving fitness has important public health implications. Since physical fitness changes in response to physical activity with a dose-response relationship, changes in physical fitness may reflect changes in physical activity over time [1]. Aspects of the environment that influence physical activity may therefore be expected to also influence fitness. A recent meta-analysis suggested a potential small effect of aspects of the built environment on youth's daily physical activity, with stronger results observed in adolescents than children [8]. The studies investigating this association have used heterogenous measures of exposure, generally assigned based on residential or school locations, including proximity to parks or playgrounds, walkability indices, and presence of recreational facilities nearby [9–16]. Fewer studies have investigated the relationship between aspects of the built environment and physical fitness in either youth [17–19] or adults [20, 21].

Studies of the built environment and fitness in youth have found mixed results. A study in Europe found the outdoor space or gymnasiums near a student's home were associated with higher cardiorespiratory fitness and muscular endurance test scores, respectively [19]. Cross-sectional studies of adolescents in both Malaysia [17] and North Carolina [18] found neighborhoods with more walking infrastructure were associated with lower measured fitness. These previous studies of the built environment and fitness have been limited by cross-sectional data, with exposure and outcome measured at a single point in time. There is potential for reverse causation if parents select neighborhoods to support their children's physical activity behavior, and these studies are unable to assess whether changes in fitness are associated with built environment characteristics.

This study, taking advantage of unique longitudinal data from 94,997 public school students collected as a part of the annual New York City (NYC) FITNESSGRAM program in New York City public schools, investigates the relationship between the school's built environment and trends over time in objective measures of physical fitness. Specifically, we investigate whether the density of parks, playgrounds, and recreational sports facilities around the school (individually and as composite measure) are related to changes in student fitness between grades 6 and 8.

Methods

This study linked two datasets using a unique identifier for each school: (1) the NYC FITNESSGRAM dataset from the Department of Education (DOE) and (2) data on recreational resources in each school's neighborhood provided by the Built Environment and Health Research Group at Columbia University. The NYC FITNESSGRAM dataset combines annual student enrollment records with annual student fitness scores based on the FITNESSGRAM curriculum [22], linking years of student data with a unique identifier. The following student measures were available for each year of data: height, weight, and date of measurements and fitness scores; attendance data; and demographic information from a student's enrollment file based on parent's responses to a questionnaire distributed at the start of the year. The surveillance system constructed using the NYC FITNESSGRAM data received an IRB non-research determination based on the Public Health Surveillance exemption.

The study population included 192,679 students in the sixth through the eighth grade, which predominantly includes students ages 11–14. Students had to be enrolled in non-charter and non-special education NYC public schools in consecutive years between 2006–2007 and 2010–2011. Students are likely to remain in the same school throughout these grades and are generally of an age where they can travel independently in and around the school neighborhood. Of these students, 109,536 had complete fitness measurements for all three assessments of interest (described below) in all three grades. The analysis was further limited to the 95,544 students who remained in the same school for grades 6–8. There were 547 students excluded for a lack of data on school recreational resources; thus, the analysis was based on 94,997 students with three repeat annual measures on each student. Data were analyzed in 2015.

The school-based built environment and health dataset includes measures of parks, playgrounds, and other recreational resources that fall within an 800-m network buffer of each school. Data were provided by the NYC Department of Parks and Recreation [23–25]. The primary exposure was the density of recreational resources in the neighborhood of a student's school, specifically the density of parks, playgrounds, and sports facilities within an 800-m network buffer of the school (referred to subsequently as the "school neighborhood"). The network buffer represents recreation resources accessible to pedestrians traveling along the street. All points on the street network that are within 800 m of each school entrance were included in the network buffer, resulting in an irregularly shaped polygon [25]. While there is no standard definition of what represents a school neighborhood, the 800-m network buffer captures all locations within an approximately 10-min walk from school.

Density of parks and playgrounds was calculated as the total land area covered by parks or playgrounds divided by the total land area of the school neighborhood. Location and area of parks and playgrounds were obtained through the NYC Park Inspection Program.

Data were collected between the years 2004 and 2006, prior to measurements of fitness [26]. Density of sports facilities was measured by the number of baseball fields, basketball courts, multipurpose courts, soccer fields, tennis courts, and running tracks per square kilometer in the school neighborhood. Geocoded locations of facilities were taken from the NYC data mine website [27], which includes information provided by the NYC Department of Parks and Recreation.

Tertiles based on a ranking of all schools were created for each of these three measures. A composite recreational score was created by calculating a z-score for each of the three measures (i.e., density of parks, playgrounds, and sports facilities) and summing the three z-scores; the composite variable was also categorized into tertiles for the primary analysis. The tertiles represent schools surrounded by low, medium, and high densities of recreational resources. Park and playground cleanliness data were also obtained from the NYC Parks Inspection Program [26]. Details regarding construction of park and playground neighborhood cleanliness scores can be found in Rundle et al [28]. For this analysis, school neighborhoods were categorized as "high" or "low" park or playground cleanliness relative to the median value for all schools; those schools with no parks or playgrounds in the neighborhood had the cleanliness value set to a missing indicator.

The outcome in this study was fitness during middle school, assessed by tests administered as a part of the FITNESSGRAM curriculum in physical education classes. The NYC FITNESSGRAM is based on FITNESSGRAM/ACTIVITYGRAM™ 8.0, owned by the Cooper Institute, Dallas, TX, and published by Human Kinetics, Champaign, IL. The FITNESSGRAM uses five assessments to measure aerobic capacity, muscular strength and endurance, and flexibility and also includes height and weight measurements to assess body composition [29].

FITNESSGRAM tests designed to measure cardiorespiratory fitness (PACER) and muscular strength and endurance (curlup and pushup) were used to calculate a composite fitness score. The two tests designed to measure flexibility were not used due to limited evidence linking flexibility to health outcomes among children [4], and body mass index was not included because the focus was changes in fitness independent of weight. For each of these three FITNESSGRAM tests, a grade- and sex-specific z-score was calculated; these three z-scores were summed to create a composite measure and z-scores were calculated from this composite score. Thus, each student's z-scores represent a measure of fitness relative to students in New York City public schools of the same grade and sex during the study period.

Additional covariates included individual and school neighborhood demographic characteristics and other attributes of the school neighborhood that may confound the relationship between recreational resources and student fitness. Covariates included at the individual level were gender, race/ethnicity, and student household income level. Gender and race/ethnicity were based on demographic information reported by parents. Household poverty was categorized as "low" or "high" using student status in the National School Lunch Program. Students categorized as "high poverty" received free or reduced-price lunch, indicating they lived in a household where income was ≤185% of the federal poverty level or received benefits from federal assistance programs [30]. Student household poverty was included as a time-varying measure since household economic circumstances may have changed over the study period.

Neighborhood-level confounders included safety and walkability of the school network buffer and poverty of the school zip code tabulation area, a U.S. Census approximation to a postal zip code. School neighborhood poverty was defined using a four-category area-based poverty measure, calculated by using the percentage of households in the school zip code below the federal poverty limit in the 2000 U.S. Census [31]. Categories were low (<10% of households), medium (10–20%), high (20–30%), and very high (≥30%). Safety was measured by the density of homicides per square kilometer within the school network buffer and categorized into tertiles [25]. Walkability for the school neighborhood network buffer was measured using a version of a walkability scale [32] that was adapted for New York City; this scale includes five equally weighted components: residential density, unique intersection density, density of subway stops, land use mix, and ratio of retail building floor area to retail land area [23].

Statistical Analysis

Analyses were performed for all students and, separately, for boys and girls, because there is evidence that physical activity patterns are different in boys and girls during adolescence and could therefore be differentially affected by recreational resources [13]. Bivariate relationships between potential confounders and both starting fitness and rate of change in fitness were examined for all the potential individual- and neighborhood-level confounders. All bivariate analyses adjusted for school and F tests were used to assess whether starting fitness and fitness change scores differed across levels of covariates, after controlling for race and student household poverty.

The multivariable analysis included four sets of models: testing each of the three recreational resources (parks, playgrounds, and sports facilities) separately and the composite recreational score. In each model, individual trajectories of fitness scores from the sixth to the eighth grade were estimated using a multilevel growth model in which repeat measures of fitness scores (level 1) are nested within students (level 2) who are nested within schools (level 3). Repeat measures were modeled as a function of time since baseline (with baseline being the sixth grade), time-varying student characteristics (household income), time-invariant covariates (student race/ethnicity and school area safety, poverty, and walkability), and interactions of selected characteristics with time. The model also included random intercepts and random time slopes for students and random intercepts for schools. The adjusted models included the recreational resource, time, and the interaction of recreational resource and time as well as student ethnicity and household income, school neighborhood safety, poverty, walkability, and interactions of student poverty × time and student ethnicity × time. Models for parks and playgrounds were also adjusted for cleanliness. The primary coefficient of interest was the interaction between the recreational resource tertile and time, indicating the association between the resource and change in fitness over the study period.

Results

The 94,997 students included in the analysis were evenly distributed between boys (49.6%) and girls (50.4%) (Table 1). A majority of both boys (65.0%) and girls (65.7%) received free or reduced-price lunch. Students attending school in high-resource-density areas were more like to be black or Hispanic and more likely to be from high-poverty households.

Mean starting (6th grade) fitness scores and mean fitness change scores for students stratified by potential confounders are presented in Table 2. Non-Hispanic white girls had higher fitness scores in grade 6 than girls of other race/ethnic groups and the greatest improvements in fitness z-scores over the study period. Hispanic girls had the lowest mean scores in the sixth grade, and Hispanic and black girls had substantially lower changes in fitness over time than white or Asian girls. For boys, the highest sixth grade fitness scores were observed in black students and the lowest in boys who identified as Asian/Pacific Islander, but Asian/Pacific Islander boys had the greatest improvements in fitness over the study period. For girls, baseline fitness scores did not differ by student household poverty, but girls from low-poverty households saw greater improvements in fitness over the study period. Conversely for boys, significantly lower baseline fitness scores were observed in boys from high-poverty households, but annual changes in fitness were similar for high- and low-poverty boys.

Table 3 presents the mean starting and fitness change scores by recreational resource tertile, adjusted for race/ethnicity, student household poverty, and school. After adjustment for race/ethnicity and household poverty, mean fitness scores in grade 6 were lowest for students in areas of high recreational resources for both boys and girls. Changes in fitness were significantly associated with overall recreational resources, but the greatest relative improvements in fitness were seen in the middle tertile of the composite measure of recreational resources. A similar pattern was observed for the association between parks and changes in fitness. For girls, neither playgrounds nor counts of sports facilities were associated with changes in fitness.

The results of fully adjusted models are presented in Table 4. Similar to findings from models only adjusted for race and household income, attending a school with medium overall recreational density in the neighborhood was associated with a more positive rate of change in student fitness compared to low or high recreational density [mean difference in annual change = 0.015, 95% CI (0.006, 0.024) for girls and 0.022, 95% CI (0.013, 0.032) for boys]. This finding seems to be driven primarily by the presence of parks, where a similar pattern was observed. Baseline fitness scores did not vary significantly across tertiles of recreational resource density for girls; boys in the middle tertile of recreational resources had higher baseline fitness scores than those in the low or high categories.

Table 1 Demographic characteristics of New York City public school students enrolled in grade 6–8 between 2006 and 2011 in the study sample, stratified by a level of recreational resources in the school neighborhood

	Recreational resource tertile[a]							
	Girls				Boys			
	Total ($N = 47{,}856$), %	Low ($N = 21{,}043$), %	Medium ($N = 15{,}309$), %	High ($N = 11{,}504$), %	Total ($N = 47{,}141$), %	Low ($N = 20{,}466$), %	Medium ($N = 15{,}337$), %	High ($N = 11{,}338$), %
Study population	50.4	44	32	24	49.6	43.4	32.5	24.1
Race/ethnicity								
Non-Hispanic white	17.9	20.3	17	14.7	19.1	21.7	18.5	15.5
Non-Hispanic black	26.8	20.4	32.4	31.2	24.6	19.2	28.4	29.3
Hispanic	36.9	35.3	34.8	42.7	37.1	34.7	36.1	42.8
Asian/Pacific Islander	18.1	23.7	15.5	11.2	18.9	24.2	16.8	12.1
Other	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Student household poverty[b]								
High	65.8	63.3	67.7	67.5	65	62.3	67	67.1
Low	34.2	36.7	32.3	32.5	35	38.7	33	32.9

[a] Empirical percentiles were calculated separately for the density of parks, playgrounds, and sports facilities for all schools in NYC. These percentiles were summed, and a new composite percentile was created, representing the overall relative school rank. Tertiles were created based on the distribution of school composite percentiles

[b] Participation in the National School Lunch Program acts as a proxy for household poverty. Students are considered "high poverty" if they are eligible for reduced-price/free meals, meaning their household income is within federally defined poverty limits [34]. Students are considered "low poverty" if they are not known to be eligible

Table 2 Mean fitness percentile at baseline and mean annual change in fitness z-score by demographic characteristics for NYC public school students enrolled in grades 6–8, 2006–2011

	Girls ($N = 47{,}856$)				Boys ($N = 47{,}141$)			
	Grade 6 score		Annual fitness change		Grade 6 score		Annual fitness change	
	Mean	SE	Mean[a]	SE	Mean	SE	Mean	SE
Overall	−0.044	0.027	0.032	0.002	−0.030	0.023	0.066	0.002
Ethnicity								
White	0.076	0.028	0.063	0.005	0.048	0.026	0.061	0.005
Black	−0.165	0.014	0.015	0.006	0.063	0.015	0.034	0.006
Hispanic	−0.245	0.012	0.019	0.006	−0.087	0.013	0.065	0.006
Asian/Pacific Islander	−0.191	0.068	0.054	0.007	−0.159	0.014	0.118	0.007
Other[b]	−0.150	0.068	−0.048	0.039	−0.058	0.069	0.043	0.037
P value[c]	<0.0001		<0.0001		<0.0001		<0.0001	
Student household poverty[d]								
High	−0.044	0.007	0.018	0.002	−0.036	0.007	0.064	0.003
Low	−0.035	0.027	0.054	0.004	−0.014	0.023	0.069	0.005
P value	0.167		<0.0001		0.001		0.343	
School neighborhood poverty[e]								
Very high	−0.192	0.070	0.009	0.006	−0.126	0.063	0.058	0.006
High	0.114	0.065	0.018	0.006	−0.015	0.063	0.069	0.007
Medium	−0.051	0.066	−0.155	0.006	0.047	0.063	0.040	0.006
Low	0.154	0.057	0.049	0.005	0.071	0.053	0.064	0.005
P value	0.082		<0.0001		0.180		0.043	

SE standard error

[a] Average change in composite fitness percentile between the sixth and eighth grade, adjusted for school

[b] Includes Native American, multiracial, unknown, and other

[c] *P* value calculated using the *F* test

[d] Participation in the National School Lunch Program acts as a proxy for household poverty. Students are considered "high poverty" if they are eligible for reduced-price/free meals, meaning their household income is within federally defined poverty limits [34]. Students are considered "low poverty" if they are not known to be eligible

[e] Within the school postal code area, levels of poverty were classified as low (<10% of residents living below the federal poverty level as defined by the U.S. Census 2000) [31], medium (10 to <20%), high (20 to <30%), and very high (≥30%)

Discussion

This study observed no clear patterns of association between recreational resource density in the area around a school and changes in student fitness. Attending a school in the middle tertile of overall density was associated in greater improvements in fitness than attending school in either a low- or high-density neighborhood. In analyses by a specific type of recreational resources, this finding appears to be mostly driven by an association with parks. The associations between race/ethnicity and student household income and fitness were more consistent than the associations between neighborhood characteristics and fitness.

An unexpected finding was that in boys, neighborhoods with medium or high density of playgrounds were associated with a negative change in fitness, and neighborhoods with medium density of sports facilities were also associated with decreases in fitness. This may represent residual confounding: during the period when the exposure data were collected, the NYC Parks Department was working to add facilities in areas with the most need. It is possible that those boys attending schools with more sports facilities, such as basketball hoops and

Table 3 Mean fitness percentile at baseline and mean change in fitness percentile by school neighborhood recreational resources for NYC public school students enrolled in grades 6–8 and included in the analysis, 2006–2011

	Girls (*N* = 47,856)					Boys (*N* = 47,141)				
	N	Grade 6 score		Annual fitness change[a]		*N*	Grade 6 score		Annual fitness change	
		Mean	SE	Mean	SE		Mean	SE	Mean	SE
Overall recreational density										
High	11,504	−0.092	0.061	0.033	0.005	11,338	−0.100	0.056	0.068	0.005
Middle	15,309	−0.032	0.062	0.040	0.005	15,337	−0.021	0.057	0.079	0.005
Low	21,043	0.056	0.045	0.025	0.003	20,466	0.033	0.041	0.057	0.003
P value[b]		0.075		0.006			0.083		<0.0001	
Parks										
High	12,311	0.010	0.062	0.023	0.005	12,513	0.005	0.056	0.057	0.005
Middle	12,428	−0.085	0.062	0.055	0.005	12,024	−0.088	0.056	0.087	0.005
Low	23,117	−0.003	0.045	0.022	0.003	22,604	−0.012	0.040	0.059	0.003
P value		0.266		<.0001			0.220		<0.0001	
Playgrounds										
High	11,041	−0.060	0.063	0.030	0.005	10,711	−0.078	0.057	0.088	0.006
Middle	17,722	−0.033	0.061	0.030	0.005	18,400	−0.033	0.056	0.000	0.005
Low	19,093	0.023	0.046	0.033	0.003	18,030	0.017	0.042	0.069	0.003
P value		0.408		0.760			0.269		<0.0001	
Sports facilities										
High	11,964	0.004	0.005	0.036	0.005	11,703	−0.140	0.055	0.075	0.005
Middle	15,712	−0.002	0.005	0.031	0.005	16,107	0.076	0.056	0.050	0.005
Low	20,180	−0.003	0.045	0.029	0.003	19,331	−0.020	0.041	0.076	0.003
P value		0.012		0.406			0.002		<0.0001	

SE standard error

[a] The average annual change in composite fitness score between the sixth and eighth grade, adjusted for race/ethnicity and student household poverty

[b] *P* value calculated using the *F* test

tennis courts, are also the ones with the poorest overall fitness trajectories for reasons unrelated to environmental features not fully captured by our adjustment variables.

Few previous studies have considered the relationship between the built environment and fitness; far more have looked at physical activity [11–16] or BMI [13, 17, 18]. A study of adolescents in Europe observed a relationship between outdoor fields and gymnasiums near home and better physical fitness [19], in contrast to the generally null results observed in this cohort. It is possible that home, rather than school, neighborhood represents the most relevant location for recreational resources in this age range. Cross-sectional studies of adults in the USA have observed associations between the measures cardiorespiratory fitness and residential walkability [20] and work and home neighborhood recreational amenities [21]. In schools, interventional studies have shown modest improvements in physical activity with multicomponent interventions; it is possible the school environment influences physical activity and fitness in coordination with other efforts [33, 34].

There were some limitations to this study. Unfortunately, information was not available about physical fitness programs offered through schools, either during physical education class or before and after school. Attributes such as a robust physical education program or a strong and diverse offering of afterschool sports may significantly contribute to changes in student fitness beyond what access to recreational facilities provides. Data also were not available on facilities that may have been available within schools themselves if these

Table 4 Relationship between recreational resource density and changes in student fitness in NYC public school students enrolled in grades 6–8, 2006–2011: results of adjusted models

	Girls ($N=47,856$)		Boys ($N=47,141$)	
	Beta	95% CI	Beta	95% CI
Overall recreational density				
Mean difference at baseline				
High	−0.037	−0.179, 0.104	−0.039	−0.168, 0.09
Medium	−0.009	−0.145, 0.126	0.006	−0.117, 0.129
Low	Reference		Reference	
Mean difference in annual change				
High	0.008	−0.002, 0.019	0.011	0.001, 0.022
Medium	0.015	0.006, 0.024	0.022	0.013, 0.032
Low	Reference		Reference	
Parks				
Mean difference at baseline				
High	0.135	−0.016, 0.286	0.099	−0.034, 0.233
Medium	0.016	−0.121, 0.153	−0.009	−0.131, 0.113
Low	Reference		Reference	
Mean difference in annual change				
High	0.008	−0.004, 0.02	0.014	0.002, 0.026
Medium	0.037	0.027, 0.047	0.036	0.026, 0.046
Low	Reference		Reference	
Playgrounds				
Mean difference at baseline				
High	0.035	−0.11, 0.18	0.006	−0.127, 0.139
Medium	−0.004	−0.139, 0.13	0.003	−0.122, 0.128
Low	Reference		Reference	
Mean difference in annual change				
High	0.001	−0.01, 0.012	0.001	−0.017, 0.019
Medium	0.003	−0.006, 0.013	0.003	−0.021, 0.015
Low	Reference		Reference	
Sports facilities				
Mean difference at baseline				
High	−0.009	−0.153, 0.136	−0.030	−0.161, 0.101
Medium	0.099	−0.031, 0.229	0.123	0.006, 0.24
Low	Reference		Reference	
Mean difference in annual change				
High	0.007	−0.003, 0.017	0.000	−0.011, 0.01
Medium	0.002	−0.008, 0.011	−0.026	−0.035, −0.016
Low	Reference		Low	Reference

Fully adjusted models include fixed effects for recreational density tertile, school neighborhood SES, ethnicity, student SES, walkability, safety, recreational density tertile × time, student poverty × time, and student ethnicity × time. Park and playground models also include cleanliness and cleanliness × time

facilities were not managed by the NYC Parks Department. The use of the school neighborhood does not fully capture the spaces in which NYC students are physically active, particularly for students who commute to schools outside of their neighborhood. During the study period, approximately 55% of all NYC students enrolled in non-alternative public schools in grades 6–8 attended school in a zip code other than their home zip code. Finally, this study used a relative rather than an absolute measure of fitness. Since fitness is expected to increase over time in this age range, a relative measure provides useful information on whether students are improving their fitness more or less than expected relative to the study population as a whole, but we are unable to make inferences about absolute changes in fitness. It is possible that NYC public school students were experiencing declines in fitness overall. However, previously published research on this cohort showed that while the prevalence of obesity remained greater than 20% across all years of data, it did decrease slightly during the study period [35].

This analysis does have several strengths and is among the first to measure neighborhood effects on fitness in youth. Nearly 95,000 students from schools in all neighborhoods of NYC provided a large and diverse sample. We had repeated measures of fitness which allowed us to assess changes over time. Detailed data on individual and neighborhood-level confounders were available. Fitness measures were objective and assessments were administered by trained physical education teachers.

This study provides an initial assessment of the relationship between recreational resources in the area around a school and changes in student fitness and adds to a large body of existing research on the relationship between neighborhood recreational resources and physical activity and health outcomes. Future research should consider combining school and home neighborhood information to more adequately capture the range of areas where students spend their time. In addition, future studies should consider whether school-based multicomponent interventions, for example combining environmental attributes and program offerings, are more effective at improving fitness in the school context than environmental factors alone.

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