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Hiwot Y. Zewdie, MSc[1]*, Amy Y. Zhao, BSc[2*], S. Scott Ogletree, PhD[3,12], Sarah E. Messiah, PhD[4,5], Sarah C. Armstrong, MD[6,7,10,11], Asheley C. Skinner, PhD[7,11] , Cody D. Neshteruk, PhD[7], J. Aaron Hipp, PhD[3,8],Sophia E. Day, MA[9], Kevin J. Konty, PhD[9], Emily M. D'Agostino, DPH[7,10]

[1] Department of Epidemiology, University of Washington, Seattle, WA
[2] Trinity College of Arts & Sciences, Duke University, Durham, NC
[3] Center for Geospatial Analytics, NC State University, Raleigh, NC
[4] Department of Epidemiology, Human Genetics and Environmental Sciences, University *of Texas Health Science Center School of Public Health, Dallas Campus, Dallas, TX*
[5] *Center for Pediatric Population Health, Children's Health System of Texas and UTHealth School of Public Health, Dallas, TX*
[6] Department of Pediatrics, Duke University School of Medicine, Durham, NC
[7] Department of Population Health Sciences, Duke University School of Medicine, Durham, NC
[8] Department of Parks, Recreation, and Tourism Management, NC State University, Raleigh, NC
[9] NYC Department of Health and Mental Hygiene, Office of School Health, New York, NY
[10] Department of Family Medicine & Community Health, Duke University School of Medicine, Durham, NC
[11] Duke Clinical Research Institute, Durham, NC
[12]OPENSpace Research Centre, University of Edinburgh, Edinburgh, UK

*Co-first authors

Corresponding Author

Hiwot Y. Zewdie, MS
PhD Student, Epidemiology
University of Washington
Hans Rosling Center
3980 15th Ave NE Seattle, WA 98195
941-822-9930
hzewdie@uw.edu

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Introduction: Neighborhood environments can support fitness-promoting behavior; yet, little is known about their influence on youth physical fitness outcomes over time. We examined longitudinal associations between neighborhood opportunity and youth physical fitness among NYC public school youth.

Methods: The Child Opportunity Index (COI), a composite index of 29 indicators measuring neighborhood opportunity at the census tract-level, along with scores on four selected COI indicators were linked to NYC FITNESSGRAM youth at baseline. Fitness outcomes (measured annually, 2011 – 2018) included BMI, curl-ups, push-ups, and PACER laps. Unstratified and age-stratified adjusted three-level generalized liner mixed models, nested by census tract and time, estimated the association between COI and fitness outcomes.

Results: The analytic sample (n=204,939) lived in very low (41%) or low (30%) opportunity neighborhoods. Unstratified models indicate that overall COI is modestly associated with improved youth physical fitness outcomes. The strongest opportunity-fitness associations were observed for PACER. Stratified models show differences in associations across younger vs. older youth.

Conclusion: We find that neighborhood factors are associated with youth fitness outcomes over time, with the strength of the associations dependent on age. Future implications include better informed place-based interventions tailored to specific life stages to promote youth health.

Introduction

Physical fitness is an integrated measure of body functions involved in the performance of daily physical activity that is related to both present and future health.[1,2] Physical fitness is considered an important indicator of health, as low fitness is strongly associated with cardiovascular disease risk in childhood, as well as cardiometabolic disease, some cancers, and all-cause mortality in adulthood.[3] However, the percentage of youth who meet performance standards on physical fitness assessments remains low: nationally, 21-35% of boys and 20-32% of girls from 4th-12th grades met performance standards in 2010-2014.[4] This is particularly evident in New York City (NYC), where only 23% of 4th-12th grade public school youth met performance standards in the 2016/17 academic year.[5] Furthermore, disparities persist in youth fitness attainment across sex and age.[4,6,7] In NYC, girls had the lowest prevalence of meeting performance standards on physical fitness assessments during the 2006/7 to 2016/17 school years, and improved less in fitness attainment compared with boys (11.2% to 18.5% vs. 19.7% to 27.9%).[5] Additionally, 9th-12th graders had lower improvements during this time in meeting fitness standards as compared to 4th-8th graders (5.3% vs. 9.9%).[5] These fitness disparities observed during youth may contribute to persistent cardiovascular health inequities across the lifecourse.[3]

While physical fitness is partially genetically determined, it can also be greatly influenced by environmental factors.[1] In particular, the neighborhood physical environment has been proposed to be an important determinant of youth fitness and related cardiovascular health outcomes. Prior studies have found positive associations between neighborhood walkability and youth fitness outcomes,[8] as well as positive associations between walkability, sidewalk access, greenspace, mixed land-use and youth body mass index (BMI), and negative associations between fast food

proximity and crime and (BMI).[9,10,11,12,13] Additionally, youth living in built environments that do no promote physical activity (PA), such as unsafe surroundings, poor housing, and lack of access to sidewalks/parks/recreation centers, are more likely to be physically inactive, which corresponds to reduced fitness.[14] These associations also vary with age and sex.[15] For instance, in NYC, low density of street trees and lower levels of neighborhood safety have been associated with higher prevalence of obesity among preschool youth.[16] Furthermore, neighborhood crime has been associated with lower PA duration among boys, while park access has been associated with higher frequency of PA among girls.[17]

However, these and other studies examining neighborhood-youth fitness associations have predominantly focused on body composition or physical activity as outcome measures, which are less accurate proxies for youth cardiovascular health compared to physical fitness.[3] Additionally, prior studies on neighborhood-youth BMI and PA associations have primarily been cross-sectional. Longitudinal studies can support causal inference by addressing the temporality of exposure and outcome.[18] Finally, these studies mainly stratify by sex and not by age,[18] despite steep drops in PA participation during adolescence (42.5%, 7.5%, and only 5.1% of 6-to 11-year-olds, 12-to 15-year-olds, and 16-to 19-year-olds, respectively, meet PA guidelines to engage in at least 60 minutes of daily PA).[2] Given that the influence of neighborhood factors may shift from childhood to adolescence, examining the neighborhood-fitness association across age subgroups can provide insight into effective approaches for tailoring place-based interventions.

Furthermore, among the studies on the neighborhood-BMI or PA relationship, individual area-level features are examined without considering the combined influence of multiple

neighborhood factors together.[18,19] Youth are exposed to numerous neighborhood-level factors at once, rather than in isolation. To fill this gap, the Child Opportunity Index (COI) was created as a population-level surveillance system of child neighborhood opportunity across the United States.[20] It is a multidimensional index incorporating 29 individual-level neighborhood-based conditions and resources that affect healthy child development.[21] This index is unique in that it describes neighborhood factors that specifically matter for children.[20] Furthermore, the COI's multidimensionality is more characteristic of the wide range of resources and risks present in children's neighborhood environments.[20] The COI and its indicators allow for considering both the individual and combined effect of multiple neighborhood factors, which can provide a more representative assessment of the exposures that youth experience.

To address the limitations of prior research, the present analysis uses the Child Opportunity Index (COI) and data from the NYC FITNESSGRAM to examine longitudinal associations between NYC neighborhood factors and multiple standardized, criterion-referenced youth physical fitness outcomes (i.e. standards that determine if a student is at a health risk). We aim to assess how overall COI and specific COI indicators are related to changes in youth physical fitness over time, and across age subgroups. Findings from this work can inform targeted place-based interventions to improve youth physical fitness and cardiovascular health in diverse metropolitan settings.

Methods

Data sources and study population

This longitudinal analysis used data from the COI and the NYC FITNESSGRAM, described in detail below, to assess associations between multiple neighborhood factors and repeated measures of individual-level youth physical fitness outcomes. The COI is managed by the Heller School of Brandeis University and offers a population-level measure of neighborhood-based conditions conducive to healthy child development.[21] The NYC FITNESSGRAM is managed by the NYC Department of Education and Department of Health and Mental Hygiene (DOHMH) and comprises individual-level annual fitness tests and demographic data from approximately 860,000 youth (grades 4 – 12) enrolled in NYC public schools. The NYC FITNESSGRAM is a surveillance tool; all youth (K-12) enrolled in the NYC public school system are meant to be included in this dataset, although some youth receive exemptions and not all youth are present on days the tests are administered. Despite these exemptions, response rates are consistently high, ranging from 87-94% over the last decade.

Youth were included in our analytic dataset if they had complete data for academic years 2011/12 – 2017/18 and were in grades 4-8 at baseline in the 2011/12 academic year to maximize total number of observations for youth over time. Youth with missing data for any of the fitness outcomes, census tract, student ID, and who had physiologically implausible values for curl-ups, push-ups, BMI, or PACER were excluded. This study was classified as public health surveillance by the NYC Department of Education and Department of Health and Mental Hygiene Institutional Review Board and thus exempt from written informed consent.

Exposure

Neighborhood opportunity, as measured by the COI, was the primary exposure. The COI is a comprehensive index of 29 census tract-level indicators across domains of education, health and

environment, and social and economic. Education domain indicators include variables such as school poverty, third grade reading proficiency, and teaching experience. Health and environment domain variables include indicators like extreme heat exposure, health insurance coverage, and housing vacancy rate. Finally, social and economic domain indicators include variables such as homeownership rate and public assistance rate. A z-score standardization method was used to standardize each indicator across the surrounding metropolitan area.[21] The standardized variables were given varying weights based on the predictive strength of the indicator to predict health and economic outcomes.[21] Resulting standardized and weighted indicators were summed to calculate domain scores that were subsequently aggregated to derive an overall COI score (0-100) for each census tract. The continuous overall COI scores were divided into quintiles, corresponding to very low (overall COI scores of 0-20), low (20-40), moderate (40-60), high (60-80), and very high (80-100) neighborhood opportunity.[21] Predictive validity tests demonstrate that overall COI is predictive of adult health outcomes including, life expectancy, asthma, obesity, coronary heart disease, and physical inactivity.[21]

Four individual COI indicators (i.e., greenspace, walkability, access to healthy foods, and commute duration) were investigated as a secondary aim to explore longitudinal associations between select environment variables and youth fitness outcomes. Greenspace and walkability were chosen as measures of the built and natural environment, access to healthy foods as a measure of the social environment, and commute duration as a proxy for transportation vulnerability. This subset of COI indicators was selected to build on prior work exploring cross-sectional associations of these indicators with youth fitness in another urban context.[8]

Greenspace was measured as the inverse percent of impervious surface areas, such as roads or parking lots, defined using satellite imagery from the 2011 National Land Cover Database. Walkability was measured using 2010-2012 Environmental Protection walkability index, a weighted average of area-level features that predict walking trips: street intersection density, population center distance to nearest transit stop, and mix of employment types and occupied housing across an area. Access to healthy foods was measured as the percent of households without a car located further than a half-mile from the nearest supermarket. This was derived using 5-year estimates from 2006-2010 American Community Survey and the USDA Food Access Research Atlas. Commute duration was measured as the percentage of workers older than 16 with a one-way commute time of greater than one hour, derived using 5-year estimates from the American Community Survey (2008-2012).[21] Raw scores for each indicator were standardized prior to modeling.

The COI is available for both 2010 and 2015. This analysis only used data from 2010 to ensure measurement of exposures preceded the outcomes.

Outcome

Youth physical fitness outcomes included body composition and performance on a series of fitness tests assessing aerobic capacity and muscular strength and endurance. These measures were taken by NYC physical education staff, who have completed extensive training to ensure consistency and accuracy of fitness measurement.

To assess body composition, annual height and weight measurements were converted to BMI percentiles relative to the 95th percentile using age and sex-specific growth charts from the US Centers for Disease Control and Prevention, to better characterize children with severe or

extreme obesity,.[22] Fitness performance was measured using a battery of fitness tests from Cooper Institute's FitnessGram™, an evidence-based measure for youth physical fitness metrics demonstrating strong reliability and validity.[23] Tests included measures of muscular strength and endurance (i.e., push-up and curl-up assessments) and aerobic capacity (i.e., Progressive Aerobic Cardiovascular Endurance Run (PACER)). Push-ups are performed at a 90° elbow angle, and sit-ups are conducted with knees flexed and feet free; both scored as the number completed. Both are completed without rest and set to a specified pace. The PACER is a multistage shuttle run where participants run back and forth (i.e., lap) across a 20-meter course to a pace that increases incrementally after each minute. It was scored as the number of laps completed.

Covariates

Grade level (continuous) was included in our analysis as a time-varying covariate. Sex (binary: male/female) and youth race/ethnicity (categorical: Hispanic, non-Hispanic Black, non-Hispanic white, Asian/Pacific Islander, and other/multiple races) were included as fixed covariates. Household poverty status based on eligibility for free/reduced price school meals (binary: yes/no) was additionally included as fixed covariate because eligibility was determined only once (at enrollment into NYC public school system).

Statistical Analysis

Descriptive statistics were derived to summarize demographic and socioeconomic characteristics of the analytic population. Mean (standard deviation) youth physical fitness outcomes across quintiles of overall COI were generated.

Three-level generalized linear mixed models, nested by census tract and time, were fit to examine longitudinal associations between continuous overall COI scores and repeated measures of youth physical fitness outcomes across all participants. Outcome variables included BMI percentiles, curl up counts, push up counts, and PACER laps measured from 2011/2012 – 2017/2018 academic years. Models were also fit to examine longitudinal associations between continuous z-scores of selected neighborhood indicators of the COI (i.e., greenspace, walkability, access to healthy foods, and commute duration) and the aforementioned youth fitness outcomes for all participants.

Age-stratified models were also fit to explore COI-youth physical fitness associations by grade level (i.e., younger age: 4-5th grades, older age: 6th-12th grades). This grade-level cut-off was chosen based on prior literature indicating significant declines in fitness for youth following elementary school.[2]

Models were adjusted for individual grade level (unstratified models only), sex, race/ethnicity, and poverty status. Beta coefficients can be interpreted as the average linear change in continuous youth cardiovascular outcomes per year for every one-point increase in COI scores. The beta coefficients allow us to interpret longitudinal changes across fitness measures. Uncertainty was reported using 95% confidence intervals. All statistical analyses were conducted in SAS 9.4 (SAS Institute, Inc., Cary, NC).

Results

Baseline demographic and socioeconomic characteristics are presented in **Table 1.** The final analytic sample included 204,939 youth and 752,486 observations. Fifty-two percent of the sample was male, 40% identified as Hispanic, and 28% identified as non-Hispanic Black. Forty-three percent of the sample was enrolled in elementary school at baseline and 73% of the sample was eligible for free/reduced price school meals. Most youth lived in neighborhoods with very low (41%) or low (30%) overall COI scores.

Mean (SD) youth physical fitness outcomes across quintiles of overall COI are presented in **Table 2**. Across all outcomes, we observed poorer mean health outcomes for those living in lower scoring overall COI neighborhoods compared to higher scoring overall COI neighborhoods. BMI percentiles for those living in very low neighborhoods was 84.09 (15.33) compared to a mean BMI percentile of 79.21 (14.21) among those living in very high COI neighborhoods. Similarly, lower mean muscular endurance performance was observed among those living in very low COI neighborhoods (curl ups: 24.35 (15.26); push-ups: 10.14 (7.46)), compared to those living very high overall COI neighborhoods (curl ups: 30.00 (16.28); push-ups: 12.78 (7.79)). Mean PACER lap counts were also observed to be lower among very low COI neighborhoods, 26.64 (15.79), compared to very high COI neighborhoods, 33.34 (16.36).

Unstratified models (**Table 3)** indicate overall COI is modestly associated with youth physical fitness over time, with the greatest magnitude observed for PACER laps (β_{PACER}: 0.06, 95% CI 0.06, 0.07). Across the selected indicators of the COI, greenspace, walkability, and commute duration were largely associated with lower BMI and improved fitness performance. The strongest associations were observed between the selected neighborhood indicators and PACER

performance. Specifically, greenspace was associated with a 0.72 (95% CI 0.49, 0.95) increase per year in number of PACER laps, walkability with a 0.72 (95% CI 0.49, 0.94) increase per year in laps, and commute duration with an almost full lap increase per year ($\beta_{\text{commute duration}}$: 0.92, 95% CI 0.82, 1.01). Less consistent results were observed for access to healthy foods; higher access to healthy foods was associated with higher BMI and lower fitness performance (β_{BMI}: 0.01, 95% CI -0.11, 0.13, $\beta_{\text{curl-ups}}$: -0.07, 95% CI -0.25, 0.11, $\beta_{\text{curl-ups}}$: -0.07, 95% CI -0.25, 0.11, $\beta_{\text{push-ups}}$: -0.25, 95% CI -0.34, -0.17, β_{PACER}: -0.22, 95% CI -0.42, -0.01), though associations between access to healthy foods and BMI and curl-ups were not statistically significant.

Similar findings from the unstratified models, in terms of direction of effects, were found in age-stratified models, with the magnitude of associations differing across age groups and fitness outcomes (**Figure 1)**. For BMI, stronger neighborhood opportunity-fitness associations were observed for younger youth compared to older youth, except for access to healthy foods. A similar pattern was observed for PACER laps, with younger youth demonstrating higher fitness performance with higher neighborhood opportunity, overall and across specific indicators, compared to older youth. For both BMI and PACER specifically, we observe the greatest magnitude of difference between younger and older youth for commute duration (younger: β_{BMI}: -0.40, 95% CI 0.-0.49, -0.30; older: β_{BMI}: -0.13, 95% CI -0.19, -0.07; younger: β_{PACER}: 1.02, 95% CI 0.87, 1.17; older: β_{PACER}: 0.82, 95% CI 0.72, 0.92).

Muscular endurance measures (i.e., curl-ups and push-ups) revealed less consistent patterns by age group. For curl-ups, we observe higher performance among younger youth living in tracts with high commute duration ($\beta_{\text{commute duration}}$: 1.05, 95% CI 0.88,1.22), whereas stronger

associations were estimated for older youth living in tracts with high greenspace and walkability ($\beta_{greenspace}$: 0.47, 95% CI 0.27, 0.68; $\beta_{walkability}$: 0.84, 95% CI 0.65,1.04). Similarly, stronger associations were observed between commute duration and push-ups for younger youth (β: 0.22, 95% CI 0.15, 0.30) compared to older youth (β: 0.04, 95% CI -0.01, 0.08). However, we did not observe significant differences across age groups for greenspace ($\beta_{younger}$: 0.44, 95% CI 0.27, 0.61; β_{older}: 0.48, 95% CI 0.39, 0.57). Associations between walkability and push-ups, and access to healthy foods and push-ups were not statistically significant for younger youth.

Discussion

This study examined the longitudinal effects of multiple neighborhood-level factors, using the Child Opportunity Index (COI), on changes in youth physical fitness among a large, diverse population of NYC public school youth. Overall COI was associated with improved performance across all youth fitness outcomes. Associations between selected neighborhood indicators (greenspace, walkability, and commute duration) and improved performance on multiple fitness outcomes were also observed. Finally, age-stratified models showed differences in the magnitude of associations between younger vs. older age. Study findings support further research investigating neighborhood-youth fitness relationships, particularly as they change across age. This research can ultimately inform tailored population-level initiatives targeting the neighborhood environment to reduce youth cardiovascular health disparities.

The association between neighborhood greenspace with decreases in BMI is supported by previous studies.[19,24,25] We further show that greenness is associated with improved aerobic capacity and muscular strength/endurance in addition to body composition. Higher greenness may indicate spaces for recreational activity and proximity to parks, playgrounds, or other open

spaces that promote PA, leading to improved fitness.[26] Greenness has also been associated with lower air pollution, less heat, and lower crime, which may impact fitness directly or through increasing time spent in outdoor physical activity.[26] A previous longitudinal study also demonstrated that more walkable built environments are associated with reduced youth BMI.[27] We show that neighborhood walkability is additionally associated with improved aerobic capacity and muscular strength/endurance. More walkable neighborhoods have more sidewalks, greater street intersection density, and greater land use mix, which may promote physical activity or active transportation.[28] Notably, for aerobic fitness, a one-unit increase in both greenspace and walkability corresponded to a difference of moving from the Needs Improvement-Health Risk Zone to the Healthy Fitness Zone over the duration of the study period.[29]

Longitudinal associations between neighborhood food environments and youth BMI have been previously explored; however, results have been inconsistent. For instance, higher access to supermarkets has been associated with smaller BMI increases in some studies, but other studies found no associations or slightly greater BMI increases.[18,19] Also, higher access to fast food restaurants has been associated with subsequent increases in BMI in some studies, while others found no associations with weight trajectories.[18] Null associations between access to healthy foods and BMI/curl-ups and negative associations with push-ups/PACER suggest that proximity to healthy food outlets may be insufficient to influence youth physical fitness. Interestingly, greater access to healthy foods was associated with decreased performance on push-ups and PACER for older youth only. This may be because proximity to these resources does not necessarily indicate access, or even electing to take advantage of healthy food options given their increased autonomy compared to younger youth.[30]

The finding that commute duration was associated with improvements across all youth fitness outcomes was surprising. Prior research has shown that increased neighborhood adult commute time is associated with decreased early child development.[31] Additionally, long commute times are associated with decreased fitness and increased BMI, obesity, and hypertension in adults,[32,33] which may predict youth outcomes as there is a well-documented correlation between parents' and children's weight status.[34] Our finding, however, suggests that there are other factors associated with long adult commute times that impact youth fitness behaviors. For instance, youth may need to be more independently mobile and increase their participation in active transportation and after-school programs/recreational activities, which increase youth PA. Additionally, in the context of NYC, those commuting to work likely live away from densely populated areas, in neighborhoods that may be more conducive to physical activity (i.e. less polluted and less crowded). Finally, if commuting is largely done through public transportation, then increased commute time may mean increased time using public transportation. This may impact youth fitness because neighborhood adult public transportation usage has been shown to be associated with youth PA.[35]

Overall, stronger COI-fitness associations were observed among younger youth with respect to decreased BMI and improved aerobic capacity. For instance, for a one-unit increase in walkability, younger youth experienced an increase in aerobic capacity double that of older youth across the duration of the study period. However, COI indicators (i.e. greenspace, walkability) appeared to be more strongly associated with muscular strength/endurance performance among older youth. This could result from differences in the types of physical

activity that youth of different age groups are engaged in. Additionally, commute duration was associated with greater improvements across all fitness outcomes for younger vs. older youth, while walkability was generally associated with greater improvements in more outcomes for older vs. younger youth. This may be because older children have increasing independence from parents and have more agency to leave their neighborhoods, walk, drive, etc. and so are less affected by parental commuting time. Considering these nuances may result in more effective place-based interventions for specific age groups and particular fitness outcomes. For instance, incorporating active transportation strategies in improving fitness outcomes for elementary/middle school youth may result in greater fitness improvements over time as youth age, supporting improved health in later adolescence. Furthermore, addressing neighborhood walkability for high school youth may help to reduce current disparities in fitness outcomes.

Strengths and Limitations

Strengths of this study include the longitudinal analysis, large and diverse sample, and utilization of a standardized, evidence-based measure of youth health-related fitness. Including multiple dimensions of physical fitness as outcome measures, in addition to BMI, provides more evidence for a link between neighborhood factors and health-related fitness. Additionally, utilizing the COI allows for the consideration of several objectively measured neighborhood features together. Our findings are consistent with a prior study demonstrating that COI at mid-childhood is associated with cardiometabolic outcomes from mid-childhood to adolescence. Furthermore, as neighborhood factors that impact youth fitness may change as youth age, examining effect modification by age, which is lacking in the literature, helps provide a more nuanced understanding of neighborhood-health associations to inform targeted place-based initiatives

across childhood and adolescence. Finally, our sample draws from one of the largest and most diverse school districts in the nation and consisted of a majority racialized minority population with low or very low COI scores, highlighting the importance of modifiable neighborhood built environment features in impacting youth fitness for populations traditionally experiencing cardiovascular health disparities.

This study has several limitations. First, the COI indicators do not reflect utilization of neighborhood resources, nor account for their quality, both of which may impact the relevance of neighborhood factors to youth fitness. Second, youth commute time to school would more accurately measure youth transportation vulnerability compared to adult commute time to work, but this indicator was not part of the COI. Third, neighborhood factors specifically relevant to NYC, such as land use mix, bus and subway stop density, and cleanliness, were also not included in the analysis because the COI was limited to nationally representative data.[37] In regards to policy-relevance of the COI, the multidimensionality of the index may obscure information about any one specific indicator; however, the single indicators used in the COI can offer more detailed data to inform policy by highlighting the individual factors that may have greater influence on a particular outcome.[20] Additionally, despite presenting stratified findings by age, we did not statistically assess for effect measure modification. Associations appear to descriptively differ across strata of age suggestive of effect modification, however readers should interpret these findings with caution. Furthermore, we did not analyze changes in exposure along with changes in outcome, which would have strengthened conclusions as neighborhood environment factors may change over time. Finally, we could not account for residential move

and changes in household poverty status; however, prior studies suggest that accounting for moving results in similar results.[18]

Conclusion

We found that a more favorable neighborhood environment is associated with improved physical fitness among NYC youth from diverse backgrounds. Overall neighborhood opportunity and commute duration had stronger associations among younger youth compared to older youth. Our results suggest that neighborhood environments have the potential to be a powerful influence on youth physical health development, with the strength of neighborhood environment-youth fitness associations dependent on age. Future studies should examine pathways accounting for these relationships, which has potential to better inform place-based interventions tailored to particular life stages to maximize fitness and support better health.

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Table 1. Baseline descriptive characteristics of the analytic sample (n = 204,939), NYC FITNESSGRAM, 2011

	No	%
Gender		
Male	106,673	52.05
Female	98,266	47.95
Race/Ethnicity		
Hispanic	82,849	40.43
Non-Hispanic, Black	56,543	27.59
Asian, Pacific Islander	33, 956	16.57
Non-Hispanic White	30,158	14.72
Other	1,433	0.70
Eligible for free/reduced school meals	No	**%**
Yes	148,872	72.59
No	56,167	27.41
Grade Level	No	**%**
Elementary (Grades 4-5)	87,249	42.57
Middle School (Grades 6-8)	117,690	57.42
Overall Child Opportunity		
Very High	5,819	2.84
High	13,528	6.60
Moderate	40,056	19.55
Low	60,739	29.64
Very Low	84,797	41.38
Subset of COI Indicator[a]		
Greenspace,	-2.12 (0.62)	
Walkability	1.08 (0.64)	
Healthy Foods	0.69 (0.63)	
Commute Duration	-3.00 (1.24)	

COI = Child opportunity index
[a] Values are expressed as mean (standard deviation)

Table 2. Results from descriptive analyses estimating mean (SD) fitness outcomes across levels of overall COI (n= 752,486 observations)

Physical Fitness Outcomes	Mean (SD)				
	Very Low (n_{obs} = 308,679)	Low (n_{obs} =227,942)	Moderate (n_{obs} = 151,065)	High (n_{obs} = 47,132)	Very High (n_{obs} = 17,668)
BMI (percentile)	84.09 (15.33)	83.30 (15.38)	82.45 (15.27)	81.48 (14.91)	79.21 (14.21)
Curl-ups (count)	24.35 (15.26)	25.60 (15.92)	26.79 (15.80)	29.04 (15.92)	30.00 (16.28)
Push-ups (count)	10.14 (7.46)	10.67 (7.53)	11.34 (7.72)	12.42 (7.76)	12.78 (7.79)
PACER (laps)	26.64 (15.79)	27.34 (15.68)	28.09 (15.49)	29.58 (15.63)	33.34 (16.36)

BMI = Body Mass Index

Table 3. Overall and age-stratified adjusted modeled estimates for the longitudinal association between metro-normed child opportunity youth cardiovascular fitness outcomes

Physical Fitness Outcomes	Overall COI		Greenspace		Walkability		Healthy Foods		Commute Duration	
	β[a]	95% CI	β[a]	95% CI	β[a]	95% CI	β[a]	95% CI	β[a]	95% CI
BMI (percentile)										
Overall	-0.03	-0.03, -0.02	-0.26	-0.39, -0.13	-0.20	-0.31, -0.07	0.01	-0.11, 0.13	-0.24	-0.30, -0.18
Younger age[b]	-0.03	-0.04, -0.03	-0.31	-0.52, -0.10	-0.11	-0.32, 0.09	-0.02	-0.21, 0.17	-0.40	-0.49, -0.30
Older age[b]	-0.02	-0.03, -0.02	-0.29	-0.41, -0.16	-0.14	-0.26, -0.01	0.04	-0.08, 0.16	-0.13	-0.19, -0.07
Curl-ups (count)										
Overall	0.06	0.05, 0.06	0.43	0.23, 0.65	0.82	0.62, 1.01	-0.07	-0.25, 0.11	0.58	0.50, 0.66
Younger age	0.05	0.03, 0.06	0.32	-0.08, 0.72	0.62	0.33, 1.01	-0.01	-0.37, 0.35	1.05	0.88, 1.22
Older age	0.05	0.05, 0.06	0.47	0.27, 0.68	0.84	0.65, 1.04	-0.13	-0.31, 0.05	0.41	0.32, 0.50
Push-ups (count)										
Overall	0.03	0.02, 0.03	0.47	0.39, 0.56	-0.13	-0.21, -0.04	-0.25	-0.34, -0.17	0.09	0.06, 0.14
Younger age	0.03	0.02, 0.03	0.44	0.27, 0.61	-0.06	-0.23, 0.10	-0.08	-0.24, 0.07	0.22	0.15, 0.30
Older age	0.03	0.02,0.03	0.48	0.39, 0.57	-0.18	-0.27, -0.09	-0.30	-0.38, -0.22	0.04	-0.01, 0.08
Pacer (laps)										
Overall	0.06	0.06, 0.07	0.72	0.49, 0.95	0.72	0.49, 0.94	-0.22	-0.42, -0.01	0.92	0.82, 1.01
Younger age	0.08	0.07, 0.08	0.85	0.49, 1.20	0.99	0.64,1.33	-0.20	-0.51, 0.12	1.02	0.87, 1.17
Older age	0.06	0.05, 0.07	0.64	0.40, 0.88	0.59	0.36, 0.82	-0.21	-0.42, 0.00	0.82	0.72, 0.92

BMI = Body Mass Index; COI = Child Opportunity Index

[a] Overall models adjusted for individual age, sex, race and ethnicity, and poverty status; age-stratified models adjusted for individual sex, race and ethnicity, and poverty status

[b] Younger age defined as observations at or below 5th grade; Older age defined as observations above 5th grade