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The effects of student, school and neighborhood poverty on the association between fitness and absenteeism in New York City middle school youth

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ABSTRACT

Recent research demonstrates that youth fitness improvements are associated with lower absenteeism. This study assessed whether the effects of poverty on the longitudinal fitness-absenteeism relationship are consistent across poverty measures at the student, school, and neighborhood levels and across sex in New York City (NYC) public school youth individually followed over 4 years. Negative binomial longitudinal mixed models with random-intercepts were developed stratified by five dichotomized student, school and neighborhood poverty measures and sex to test the change in fitness-lagged absenteeism relationship in six cohorts of NYC middle school students (2006/7–2012/13). Models were adjusted for individual-level race/ethnicity, place of birth, change in obesity status, grade, time, and school size. The sample included 360,743 students (51% male, 39% Hispanic, 28% non-Hispanic black, 69% qualifying for free/reduced price school meals). Adjusted estimates showed an inverse dose-response fitness-absenteeism relationship in high poverty youth across all poverty measures, including the student, school and neighborhood levels. For example, in girls exposed to high poverty based on school neighborhood, absenteeism decreased by 11.3% (IRR = -0.12 , 95% CI: -0.20 , -0.04), 10.4% (IRR = -0.11 , 95% CI: -0.21 , -0.02), 6.8% (IRR = -0.07 , 95% CI: -0.14 , 0.00) and 4.9% (IRR = -0.05 , 95% CI: -0.15 , 0.04) for students who had a > 20% increase, 10–20% increase, < 10% change, and 10–20% decrease in fitness from the prior year, respectively, relative to the reference group (> 20% decrease in fitness). Future research should explore the impact of tailored interventions for youth that aim to promote youth physical activity at each of the individual, school and neighborhood levels, and particularly among high poverty subgroups.

1. Background

In New York City (NYC), 19% of 6–8th grade students are chronically absent (i.e. missing 10% or more of the school year; 200,000 students), and 60% of youth aged 6–12 years do not meet physical activity guidelines. (Day et al., 2011; Balfanz and Byrns, 2013) These figures are consistent with national prevalence rates, which show that just 42% of United States (US) children (ages 6–11) and 25% of middle school youth (ages 12–15) obtain the recommended 60 min or more of

daily physical activity. (Troiano et al., n.d.) Similarly, 10–15% (5–7.5 million) of US students are chronically absent. (Balfanz and Byrns, 2012) Recent research demonstrates that health-related fitness improvements, which provide a proxy for health status and risk of chronic conditions, (Janssen and Leblanc, 2010; Plowman and Meredith, 2013) are associated with lower absenteeism, and particularly for students attending schools located in neighborhoods with a high percentage of households living below the federal poverty line. (D'Agostino et al., 2018a) However, poverty at each of the student, school, and

Abbreviations: FRM, free/reduced price school meals eligibility; IQR, interquartile range; NYC, New York City; DOE, New York City Department of Education; Fitnessgram, NYC FITNESSGRAM; DOHMH, New York City Department of Health and Mental Hygiene; % HNP, percent of students living in high/very high poverty neighborhoods; % FRM, percent of students qualifying for free/reduced price school meals; PACER, progressive aerobic cardiovascular endurance run; SD, standard deviation; United States, US

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neighborhood levels can be hypothesized to have unique effects on both physical activity and absenteeism in youth, and across sex.

Consistent with the socioecological model, (Bronfenbrenner, 1994) the interaction of intrapersonal, interpersonal and macro-level factors can influence differences in the fitness and school outcomes association across poverty exposures and sex, including household, school and neighborhood psychosocial factors, the built environment, accessibility of recreation and healthy/affordable foods, and crime/safety related to transportation to and from school and recreational spaces. For example, individual household poverty can play a role in parental expectations or abilities to devote time and resources to their child's fitness and/or school attendance patterns. (Janssen et al., 2006; Bramley and Karley, 2007; Bezold et al., 2014) Similarly, school-level poverty can influence peer and school cultural attitudes pertaining to both physical activity and school absenteeism. (Graham et al., 2011; Caldas and Bankston, 1997; Myers Jr et al., 2004) In addition, neighborhood level poverty can impact access to physical activity resources and/or community norms towards both physical activity participation and school attendance. (Yen and Kaplan, 1998; Bezold et al., 2017; Nauer et al., 2014; Sheldon and Epstein, 2004; Balfanz and Legters, 2004; Vanhelst et al., 2013; Boone-Heinonen et al., 2010) Moreover, sex differences in the fitness-absenteeism relationship across different levels of exposure to poverty may result from differences in psychosocial factors related to self-perception of athletic ability and fitness in more versus less impoverished neighborhoods. (McCullough et al., 2009) Similarly, low school-area recreational resource abundance has been shown to predict reduced physical activity patterns and fitness in middle-school girls versus boys. (Bezold et al., 2017)

Prior research on the effects of poverty measured at different levels on youth fitness has shown mixed findings. No differences were found in the association between socioeconomic status and adolescent fitness when poverty was measured based on a composite score of individual household education level/income/employment status and neighborhood living conditions/access to public utilities. (Sandercock et al., 2017) A second study found that percent of students attending a school who qualified for free/reduced price school meals was the most accurate proxy (vs. student's home- and school- area poverty) with respect to poverty's influence on youth participation in health-promoting behaviors, including physical activity, and when data on individual household poverty is not available. (Day et al., 2016) A third study found that youth exposed to higher neighborhood poverty showed greater fitness improvements after participating in a park-based afterschool program. (D'Agostino et al., 2018b)

Sex differences also have been shown in the literature examining the relationship between fitness and academic outcomes. For example, a study drawing from school area-level poverty showed a greater magnitude of association between fitness changes and individual student-level absenteeism in middle school girls compared with boys attending schools in high poverty neighborhoods. (D'Agostino et al., 2018a) Six additional studies examined whether gender modifies the youth fitness-academics association, four of which found stronger associations in girls. (Bezold et al., 2014; Booth et al., 2013; Torrijos-Nino et al., 2014; Coe et al., 2013; London and Castrechini, 2011; Grissom, 2005) One study found no significant differences by gender, (Coe et al., 2013) and one study found stronger associations for elementary school-aged boys. (Torrijos-Nino et al., 2014) One study, which adjusted for area poverty, found that girls who had a substantial increase in fitness relative to their peers (0.36 percentile points per year compared with the reference group) showed the largest increase in academic ranking (1.06 percentile points per year). (Bezold et al., 2014)

Overall, this literature suggests that both exposure to poverty and sex may be important predictors of the youth fitness-school outcomes association; however, prior work has not examined whether patterns in this relationship are consistent at different levels of exposure to poverty and across sex. In this analysis, we tested the effects of five poverty measures at the student (individual household), school (percent of

students who qualify for free/reduced price school meals and percent of students who are living in high poverty neighborhoods), and neighborhood (home- and school-area poverty) levels on the longitudinal fitness-absenteeism association and across sex in 6 cohorts of NYC public middle school students individually followed over 4 years. Based on the above body of literature, it was hypothesized that improvements in student fitness would be most strongly associated with lower subsequent absenteeism in girls vs. boys exposed to higher poverty at the individual, school, and neighborhood levels in comparison to those exposed to lower poverty. Findings from this study may serve to inform youth physical activity interventions aiming to promote school-based outcomes. (Haskell et al., 2009)

2. Methods

2.1. Data sources and study population

Data for this study were drawn from the NYC FITNESSGRAM (Fitnessgram) dataset jointly managed by NYC Department of Education (DOE) and Department of Health and Mental Hygiene (DOHMH), and described elsewhere. (D'Agostino et al., 2018a) Briefly, the Fitnessgram is comprised of annual fitness assessments related to present and future health outcomes and collected by DOE for approximately 870,000 NYC public school students per year (grades K-12) starting in 2006–07. (NYC Department of Education, 2017a) The Fitnessgram is based on the Cooper Institute's FitnessGram®, which is demonstrated to have both strong reliability and validity. (Plowman and Meredith, 2013) NYC schools are mandated to have $\geq 85\%$ of eligible students complete the Fitnessgram assessment each year. (NYC Department of Education, 2017a) The Fitnessgram is administered following a consistent annual testing schedule by physical education teachers who receive formal training on conducting the test, including manuals, video-based training, and site visits, as well as calibrated scales. (Plowman and Meredith, 2013; NYC Department of Education, 2017a)

Inclusion criteria for this study were enrollment in a NYC public school for ≥ 2 consecutive years in grades 6–8 while attending a school that collected Fitnessgram measurements. Student cohorts were defined based on year of initiating grade 6. Fitness-change data from grades 5–6, 6–7 and 7–8 was paired with days absent per year for grades 6, 7, and 8, respectively. The final sample of 6-8th graders included 360,743 unique students nested in 624 schools (median school population = 327 students; IQR = 495). Students contributed 675,320 observations during the study period (2006–2013). The study was approved by the City University of New York and DOHMH Institutional Review Boards.

2.2. Measures

The primary exposure was a categorical variable representing age- and sex-specific percent change in fitness composite percentile scores based on the sum of percentile scores for the Progressive Aerobic Cardiovascular Endurance Run (PACER), muscle strength and endurance (curl-up and push-up) tests. (Plowman and Meredith, 2013) Scores were converted to percentiles to account for expected improvements in performance with increasing age and sex. The fitness variable was categorized as $> 20\%$ decrease, 10–20% decrease, $< 10\%$ change, 10–20% increase, and $> 20\%$ increase in performance from the year prior consistent with longitudinal research on fitness and academic outcomes drawing from the Fitnessgram dataset. (D'Agostino et al., 2018a; Bezold et al., 2014; D'Agostino et al., 2018c)

The primary outcome for this analysis was child-level number of days absent per year. Annual enrollment and attendance records were matched to Fitnessgram results by a unique student identifier.

2.3. Poverty context and measures

A high proportion of the student population attending NYC schools is exposed to individual or area-level poverty. For example, 64% of the middle school population tested for the NYC Fitnessgram have high household poverty defined by eligibility for free/reduce price school meals, and 48% attend schools in high or very high poverty neighborhoods. (D'Agostino et al., 2018a) City-wide, 73%, 75%, and 74% NYC school youth in grades K-12 are facing poverty at the individual student, school, and district levels, respectively, based on the number of students with families who have qualified for free or reduced price school meals, and/or are eligible for Human Resources Administration (HRA) benefits. Seventy percent, 69% and 68% of students demonstrate economic need at the individual, school, and district levels, respectively, based on percentage of students attending the school facing economic hardship. (NYC Department of Education, n.d.)

Given the distribution of student poverty in NYC, individual student household poverty (high vs. low) was based on student eligibility/non-eligibility for free/reduced price school meals through the National School Lunch Program which provides meal assistance according to household income at or below 185% of the federal poverty level. (U.S. Department of Agriculture, Food and Nutrition Services, 2012)

Two school-level poverty measures were based on 1) percent of students attending the school who qualified for free/reduced price school meals (greater than or equal to the grand mean [categorized as high poverty] vs. less than the grand mean [categorized as low poverty]); 2) percent of students attending the school who lived in high/very high poverty neighborhoods based on American Community Survey (ACS) 2008–2012 data (greater than or equal to the grand mean [categorized as high poverty] vs. less than the grand mean [categorized as low poverty]).

Consistent with NYC DOHMH guidelines, (Toprani and Hadler, 2013) neighborhood level poverty data were drawn from the ACS (2008–2012) and categorized as the percentage of households in the zip code living below the federal poverty threshold (low/mid [$< 20\%$] or high/very high [$\geq 20\%$] area poverty). (United States Census Bureau, 2015) Two neighborhood-level poverty measures were defined according to 1) home-area poverty level (percent of individuals in the home zip code living in poverty, categorized as low [$< 20\%$] poverty vs. high [$\geq 20\%$] poverty), and 2) school-area poverty (percent of individuals in the school zip code living in poverty, categorized as low [$< 20\%$] poverty vs. high [$\geq 20\%$] poverty).

2.4. Effect modifier and covariates

Sex (potential effect modifier) was based on parent report. Potential confounding variables included time, grade, race/ethnicity, place of birth (US or foreign born), change in obesity status, and school size. These covariates are shown in the literature to predict both fitness and absenteeism. (Bezold et al., 2017; Coe et al., 2013; Kristjánsson et al., 2010; Crump et al., 2013; Grauer, 2017; Ruiz-de-Velasco and Fix, 2000; Singh et al., 2008)

Time (calendar year) at height and weight measurement was treated as a continuous variable. Race/ethnicity was based on parent report and was grouped into 5 categories: Hispanic, non-Hispanic black, non-Hispanic white, non-Hispanic Asian/Pacific Islander, and other (including multiple races). A binary school size variable was based on count of individuals attending each school. Per the literature, schools with < 400 students were considered small schools, and schools with 400 or more students were considered non-small schools. (Grauer, 2017)

Change in obesity status from the year prior (obese to not obese, consistently not obese, consistently obese, not obese to obese) was also included as a potential confounder in lieu of weight category (i.e. obesity status) to capture meaningful shifts or trajectories in body composition associated with school outcomes as described elsewhere in

the literature. (Bezold et al., 2014; London and Castrechini, 2011) Body mass index (BMI) is collected annually as part of the Fitnessgram curriculum. Obesity was defined as having a BMI ≥ 95 th percentile for youth in the same sex and age group according to CDC guidelines. (Centers for Disease Control, Prevention (CDC), 2010) Change in obesity status category was chosen in lieu of changes in BMI percentile to capture meaningful shifts in body composition associated with school outcomes. (Egger et al., 2009)

2.5. Statistical methods

Descriptive statistics were computed to summarize sample characteristics. Trends in absenteeism (days absent) for each poverty measure were examined across grade and sex. Means were used for absenteeism at the aggregate level (school/neighborhood) based on Gaussian distribution. Medians were used for individual level absenteeism based on Poisson distribution.

The longitudinal association between change in fitness and lagged number of days absent per year was assessed by fitting negative binomial longitudinal mixed models with random-intercepts, the exposure, child-specific change in fitness from the year prior, and an offset term representing total instructional days per school year. Exponentiated beta coefficients (incidence rate ratios (IRR)) represented the association of each level of exposure ($> 20\%$ increase, 10–20% increase, $< 10\%$ change and 10–20% decrease in fitness) with the outcome (one-year lagged number of days absent per year), relative to the reference category ($> 20\%$ decrease in fitness). Separate crude and adjusted models were run stratified by each student, school and neighborhood poverty measure, and sex. *P*-values for modeled estimates were assessed using Type III Tests of Fixed Effects.

In all analyses, students contributed fitness-change data for 5-6th, 6th-7th, and/or 7th-8th grades ($n = 360,743$ unique students; 675,320 observations). Statistical analyses were performed using SAS 9.3 software (Cary, NC).

3. Results

The largest demographic groups were males (51%), Hispanics (39%) and non-Hispanic blacks (28%), students who spoke English in the home (57%) and those born in the United States (US; 85%; Table 1). By change in fitness, the largest group had a $< 10\%$ change from the prior year (37%), followed by the group with a $> 20\%$ decrease in fitness (20%). Most students were consistently not obese (73%) or consistently obese (17%) from the prior year. Sixty-nine percent qualified for free/reduced price school meals, and most lived in neighborhoods with mid (34%) or high (25%) poverty, or attended schools located in mid (33%) or high (28%) poverty areas. Similar patterns in demographics and fitness characteristics were found for boys and girls across poverty subgroups, with the exception of change in obesity status (6% difference across boys and girls; See Supplemental Table 1).

3.1. Tabulated absenteeism descriptives

Median absenteeism at the student level was 7.00 days per year (interquartile range (IQR) = 12.00). Across all poverty exposures measures and grades, absenteeism was higher for high compared with low poverty youth (Fig. 1; Supplemental Table 2). Absenteeism was highest for eighth grade students attending schools with a high proportion of students qualifying for free/reduced price school meals (mean = 13.76 days per year [standard deviation (SD) = 14.40]), followed by youth attending schools with a high proportion of students living in high/very high poverty neighborhoods (mean = 13.66 days per year [SD = 14.51]). Absenteeism was lowest for 6th and 7th grade students who did not qualify for free/reduced price school meals (median = 6.00 [IQR = 10.00] for both).

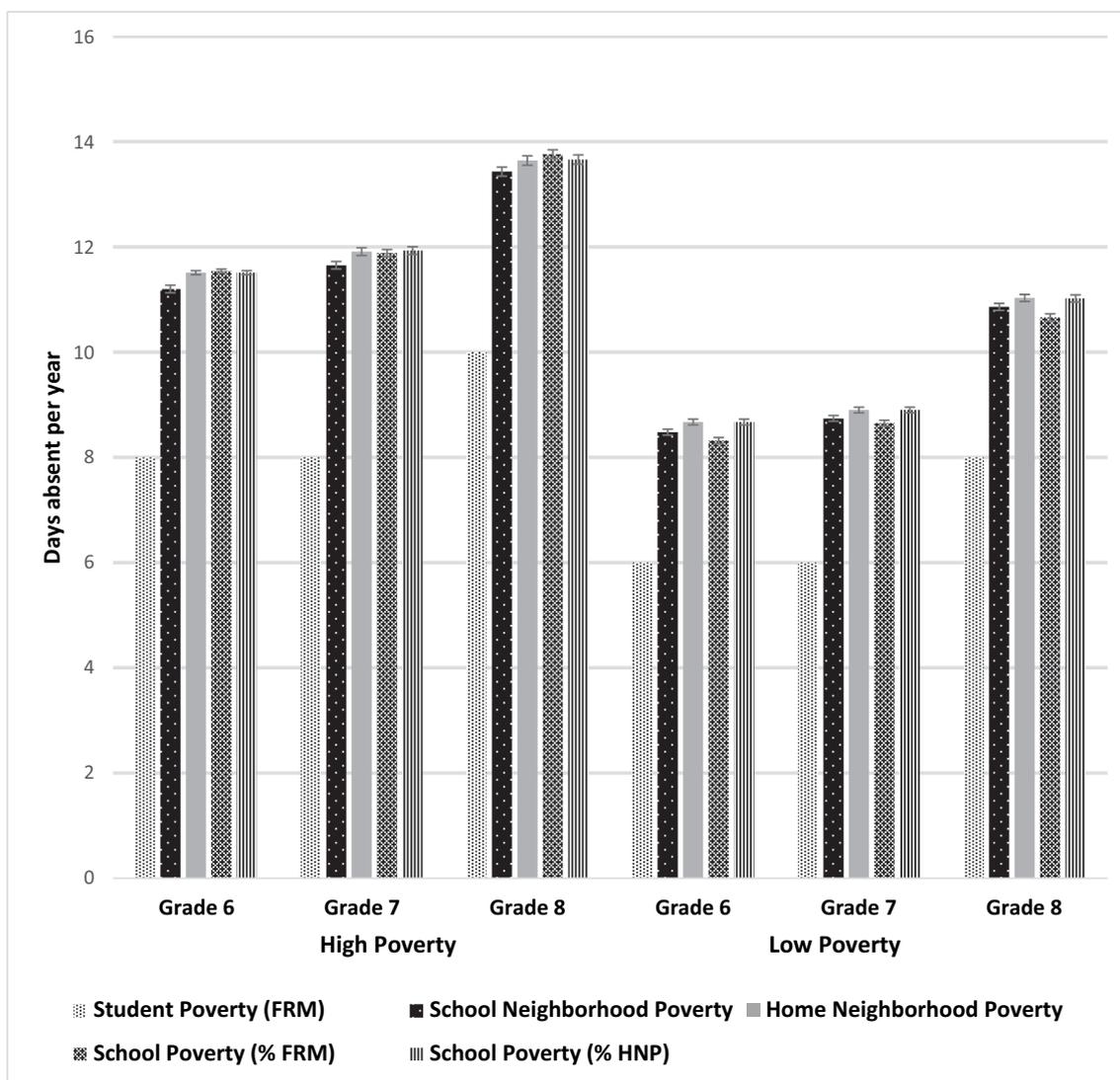


Fig. 1. Absenteeism across school grade and poverty measures in New York City middle school youth, 2006/7–2012/13. Tabulated days absent from school per year for New York City middle school students across grades 6–8 and across student, school and neighborhood poverty measures ($N = 360,743$ unique students; 675,320 observations). School and home neighborhood poverty based on percent of households in the school and student's home zip codes, respectively, living below the federal poverty line. Student Poverty (FRM) based on free/reduced price school meals eligibility. School poverty (% FRM) based on percent of students who qualified for free/reduced price school meals. School poverty (% HNP) based on percent of students who lived in high/very high poverty neighborhoods. Means were used for absenteeism at the aggregate level (school/neighborhood) based on Gaussian distribution. Medians were used for individual level absenteeism based on Poisson distribution. Error bars indicate standard errors of the mean. Abbreviations: FRM: Free/reduced price school meals eligibility; % FRM: Percent qualifying for free/reduced price school meals; % HNP: Percent living in high/very high neighborhood poverty.

3.2. Longitudinal effects of poverty measures on the fitness-absenteeism association in girls

Adjusted estimates showed that for all poverty measures, girls in high poverty demonstrated an inverse dose-response relationship between fitness and absenteeism (Table 2, Fig. 2). For example, in girls exposed to high poverty based on school neighborhood, absenteeism decreased by 11.3% (IRR = -0.12, 95% CI: -0.20, -0.04), 10.4% (IRR = -0.11, 95% CI: -0.21, -0.02), 6.8% (IRR = -0.07, 95% CI: -0.14, 0.00) and 4.9% (IRR = -0.05, 95% CI: -0.15, 0.04) for students who had a > 20% increase, 10–20% increase, < 10% change, and 10–20% decrease in fitness from the prior year, respectively, relative to the reference group (> 20% decrease in fitness). This pattern for girls exposed to high poverty was consistent across all poverty measures.

In contrast, for girls in low poverty, no trends in absenteeism were apparent across changes in fitness from the prior year, as long as fitness did not decrease (Table 2; Fig. 3). For example, after adjusting for

confounders, in girls with low exposure to student poverty based on percent of students at the school qualifying for free/reduced price school meals, absenteeism decreased by 10.7% (IRR = -0.11, 95% CI: -0.17, -0.06), 12.2% (IRR = -0.13, 95% CI: -0.19, -0.07) and 13.0% (IRR = -0.14, 95% CI: -0.19, -0.09) for students who had a > 20% increase, 10–20% increase, and < 10% change in fitness from the prior year, respectively, and 7.4% (IRR = -0.08, 95% CI: -0.14, -0.01) for students with a 10–20% decrease in fitness relative to the reference group (> 20% decrease in fitness).

3.3. Longitudinal effects of poverty measures on the fitness-absenteeism association in boys

Fitness-absenteeism patterns for boys exposed to high compared with low poverty were similar to girls, showing an inverse dose-response relationship between changes in fitness and days absent the following year only for boys in high poverty subgroups. However,

Table 1
Demographic and fitness-change characteristics of in New York City public middle school students (N = 360,743), 2006/7–2012/13.

	n ^{a,b}	%
Sex		
Male	183,057	51
Female	177,686	49
Race/Ethnicity		
Hispanic	141,712	39
Non-Hispanic black	102,150	28
Asian and/or Pacific Islander	58,514	16
Non-Hispanic white	57,093	16
Language spoken at home		
English	206,466	57
Spanish	89,089	25
Other language	65,370	18
Place of birth		
US	306,232	85
Foreign	54,593	15
Change in Fitness ^c (all years)		
> 20% decrease	134,754	20
10–20% decrease	82,117	13
< 10% change	253,162	37
10–20% increase	79,172	12
> 20% increase	126,115	19
Change in obesity status ^d (all years)		
Obese to not obese	36,029	5
Consistently not obese	504,764	73
Consistently obese	119,235	17
Not obese to obese	27,274	4
Attending small schools (< 400 students)	68,286	19
Attending non-small schools (≥ 400 students)	292,639	81
Student poverty (FRM)		
Full-price meals	111,353	31
Free/reduced meals	249,572	69
School poverty (% FRM)		
Low poverty	167,663	46
High poverty	193,262	54
School poverty (% HNP)		
Low poverty	173,440	48
High poverty	187,485	52
Home neighborhood poverty ^e		
Low poverty	55,409	16
Mid poverty	112,916	33
High poverty	95,912	28
Very high poverty	82,931	24
School neighborhood poverty ^e		
Low poverty	64,702	18
Mid poverty	122,517	34
High poverty	91,060	25
Very high poverty	82,640	23

^a N_{missing} Gender = 182; N_{missing} Place of Birth = 100; N_{missing} or > 1 Race/Ethnicity = 1456; N_{missing} Home Neighborhood Poverty = 13,575

^b Students in 6th, 7th and 8th grades contributed 675,320 observations.

^c Based on change in fitness composite percentile scores for the PACER, push-up and curl-up FitnessGram® tests from the year prior.

^d Obesity status was defined as a body mass index ≥ 95th percentile for youth in the same gender and age in months according to Centers for Disease Control growth chart-derived norms.

^e School and home neighborhood poverty based on percent of households in the school and student's home zip codes, respectively, living below the federal poverty line.

Abbreviations: FRM: Free/reduced price school meals eligibility; % FRM: Percent qualifying for free/reduced price school meals; % HNP: percent living in high/very high home neighborhood poverty.

estimates for the fitness-absenteeism relationship in low and high poverty boys had wide confidence intervals for all poverty measures compared with girls (Table 2).

4. Discussion

This study found that the relationship between fitness and subsequent school absenteeism in middle school students is strongest in high compared with low poverty youth. Specifically, adjusted estimates for high, but not low, poverty youth showed an inverse-dose response fitness-absenteeism relationship across student, school and neighborhood poverty measures. Across sex, patterns for high and low poverty youth were similar, although estimates for boys compared with girls had wider confidence intervals across all poverty subgroups.

Our findings are consistent with prior studies that have separately addressed youth poverty at different levels and its effects related to physical activity/fitness and school outcomes. At the individual student level, for example, household poverty can directly influence both youth physical activity (Janssen et al., 2006) and academic outcomes. (Bramley and Karley, 2007; Myers Jr et al., 2004; Entwisle and Alexander, 1992) For example, the odds of physical inactivity in middle and high school students have been shown to be associated with decreasing family material wealth. (Janssen et al., 2006) Likewise, individual student family economic status based on student's subsidized school meals status in first and second grade students has been shown to be the most important source of variation in mathematics achievement. (Entwisle and Alexander, 1992) Student individual household poverty may also impact parental investments in their child's school academics and related behaviors, (Bramley and Karley, 2007; Myers Jr et al., 2004) such as regular school attendance, and also school commitment (such as parent teacher association participation). (Bramley and Karley, 2007) Moreover, student household poverty may limit parents' ability to devote time and attention to children's physical activity, particularly if this activity is costly or time-consuming.

Similarly, school-level poverty based on percent of students attending a school who qualify for free/reduced price school meals has been shown to be inversely associated with student health-related fitness (Bai et al., 2016) and academic performance. (Bramley and Karley, 2007; Caldas and Bankston, 1997; Myers Jr et al., 2004) Peer environment, for example, is considered a primary influence on adolescent behavior. (Boustani, 2015) Peer groups have potential to influence youth attitudes and behavior, (Caldas and Bankston, 1997; Boustani, 2015) and to this end may predict physical activity levels and academic outcomes. School-based initiatives and teaching staff also have the potential to affect student behaviors related to both physical activity and academics. (Caldas and Bankston, 1997; NYC Department of Education, 2017b; Zahner et al., 2006; Dunn et al., 2012; Van Kann et al., 2017) School facility conditions and resources (e.g., access to technology, specialized teaching staff, and well maintained physical activity equipment), also can impact student fitness and achievement. (Bramley and Karley, 2007; Bezold et al., 2017) Moreover, schools with high proportions of students living in poverty or receiving free/subsidized school meals may increase youths' exposure to chronic absenteeism, and may influence attendance norms and/or teacher resources that can be dedicated towards supporting individual student's attendance or health-promoting behaviors (Bramley and Karley, 2007; Myers Jr et al., 2004).

At the neighborhood level, area poverty is associated with reduced density of built environment recreation, such as accessible/well-maintained playgrounds and parks, (Vanhelst et al., 2013) and lower levels of resident physical activity. (Yen and Kaplan, 1998) School neighborhood poverty is shown to predict lower youth fitness, (D'Agostino et al., 2018a) physically active leisure, (Boone-Heinonen et al., 2010; Saelens et al., 2003) and health, (Yen and Kaplan, 1998; Zhu et al., 2010) and furthermore may impact community perceptions of safety pertaining to physical activity engagement. (Zhu et al., 2010; Lovasi et al., 2012) Whereas some studies have found no association between density of school neighborhood physical activity resources and student fitness changes, (Bezold et al., 2017) others have shown that area-level socioeconomic status based on unemployment rates, education and

Table 2
Crude and adjusted longitudinal effects of fitness-change^a on absenteeism in middle school youth^b across poverty^c exposures, 2006/7–2012/13.

Girls	> 20% fitness increase			10–20% fitness increase			< 10% fitness change			10–20% fitness decrease			p-Value ^d
	IRR ^f		95% CI	IRR ^f		95% CI	IRR ^f		95% CI	IRR ^f		95% CI	
	Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper		
Crude models													
Low student poverty (FRM)	-0.14	-0.29	0.00	-0.14	-0.30	0.03	-0.12	-0.25	0.01	-0.05	-0.22	0.11	0.27
Low home neighborhood poverty	-0.15	-0.23	-0.06	-0.13	-0.23	-0.03	-0.12	-0.20	-0.05	-0.06	-0.16	0.04	0.00
Low school neighborhood poverty	-0.14	-0.24	-0.04	-0.12	-0.24	-0.01	-0.12	-0.21	-0.03	-0.06	-0.17	0.06	0.04
Low school poverty (% FRM)	-0.13	-0.21	-0.06	-0.13	-0.21	-0.05	-0.12	-0.19	-0.06	-0.06	-0.14	0.02	< 0.001
Low school poverty (% HNP)	-0.14	-0.23	-0.06	-0.13	-0.23	-0.03	-0.12	-0.20	-0.05	-0.06	-0.16	0.04	0.01
High student poverty (FRM)	-0.13	-0.20	-0.05	-0.11	-0.19	-0.02	-0.07	-0.13	-0.01	-0.05	-0.13	0.04	0.01
High home neighborhood poverty	-0.11	-0.23	0.01	-0.09	-0.23	0.04	-0.04	-0.14	0.06	-0.03	-0.17	0.10	0.36
High school neighborhood poverty	-0.12	-0.21	-0.04	-0.11	-0.21	-0.01	-0.05	-0.12	0.03	-0.04	-0.14	0.06	0.05
High school poverty (% FRM)	-0.13	-0.31	0.04	-0.10	-0.31	0.11	-0.04	-0.20	0.12	-0.04	-0.24	0.17	0.62
High school poverty (% HNP)	-0.11	-0.23	0.01	-0.09	-0.23	0.05	-0.04	-0.14	0.07	-0.03	-0.17	0.11	0.37
Adjusted models ^e													
Low student poverty (FRM)	-0.12	-0.23	-0.01	-0.13	-0.26	-0.01	-0.13	-0.23	-0.03	-0.06	-0.19	-0.06	0.09
Low home neighborhood poverty	-0.13	-0.20	-0.06	-0.13	-0.21	-0.05	-0.14	-0.20	-0.07	-0.08	-0.16	0.00	0.00
Low school neighborhood poverty	-0.12	-0.20	-0.04	-0.12	-0.21	-0.03	-0.13	-0.20	-0.06	-0.07	-0.16	0.02	0.00
Low school poverty (% FRM)	-0.11	-0.17	-0.06	-0.13	-0.19	-0.07	-0.14	-0.19	-0.09	-0.08	-0.14	-0.01	< 0.001
Low school poverty (% HNP)	-0.12	-0.18	-0.06	-0.13	-0.20	-0.06	-0.14	-0.19	-0.08	-0.08	-0.15	-0.01	< 0.001
High student poverty (FRM)	-0.11	-0.18	-0.05	-0.11	-0.18	-0.04	-0.09	-0.14	-0.03	-0.06	-0.13	-0.01	0.00
High home neighborhood poverty	-0.11	-0.23	0.00	-0.10	-0.23	0.03	-0.06	-0.16	0.04	-0.04	-0.17	0.09	0.34
High school neighborhood poverty	-0.12	-0.20	-0.04	-0.11	-0.21	-0.02	-0.07	-0.14	0.00	-0.05	-0.15	0.04	0.04
High school poverty (% FRM)	-0.12	-0.02	-0.01	-0.10	-0.24	0.03	-0.06	-0.16	-0.04	-0.05	-0.18	-0.09	0.30
High school poverty (% HNP)	-0.11	-0.20	-0.01	-0.10	-0.21	0.01	-0.06	-0.14	0.02	-0.04	-0.15	0.07	0.20
Boys													
Boys	> 20% fitness increase			10–20% fitness increase			< 10% fitness change			10–20% fitness decrease			p-Value ^d
	IRR ^f		95% CI	IRR ^f		95% CI	IRR ^f		95% CI	IRR ^f		95% CI	
	Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper		
Crude models													
Low student poverty (FRM)	-0.13	-0.34	0.08	-0.15	-0.38	0.09	-0.11	-0.29	0.07	-0.08	-0.31	0.16	0.69
Low home neighborhood poverty	-0.14	-0.28	0.00	-0.13	-0.30	0.03	-0.10	-0.23	0.02	-0.07	-0.24	0.09	0.35
Low school neighborhood poverty	-0.14	-0.37	0.10	-0.13	-0.39	0.13	-0.10	-0.30	0.10	-0.07	-0.33	0.20	0.08
Low school poverty (% FRM)	-0.13	-0.24	-0.02	-0.12	-0.25	0.00	-0.09	-0.18	0.01	-0.06	-0.19	0.06	0.17
Low school poverty (% HNP)	-0.14	-0.28	0.00	-0.13	-0.29	0.02	-0.10	-0.22	0.02	-0.07	-0.22	0.09	0.33
High student poverty (FRM)	-0.14	-0.25	-0.02	-0.12	-0.25	0.01	-0.07	-0.17	0.03	-0.05	-0.18	0.08	0.16
High home neighborhood poverty	-0.12	-0.35	0.10	-0.11	-0.37	0.14	-0.05	-0.25	0.15	-0.04	-0.30	0.22	0.82
High school neighborhood poverty	-0.14	-0.27	-0.01	-0.13	-0.28	0.02	-0.07	-0.18	0.05	-0.05	-0.20	0.09	0.26
High school poverty (% FRM)	-0.14	-1.10	0.81	-0.13	-1.23	0.98	-0.06	-0.91	0.78	-0.05	-1.16	1.06	1.00
High school poverty (% HNP)	-0.12	-0.35	0.10	-0.12	-0.38	0.15	-0.05	-0.25	0.15	-0.04	-0.30	0.22	0.83
Adjusted models ^e													
Low student poverty (FRM)	-0.11	-0.27	0.06	-0.13	-0.32	0.05	-0.12	-0.26	0.03	-0.08	-0.27	0.11	0.56
Low home neighborhood poverty	-0.12	-0.25	0.01	-0.12	-0.26	0.02	-0.11	-0.22	0.00	-0.07	-0.21	0.08	0.31
Low school neighborhood poverty	-0.11	-0.28	0.06	-0.11	-0.30	0.08	-0.10	-0.25	0.05	-0.06	-0.26	0.14	0.69
Low school poverty (% FRM)	-0.11	-0.19	-0.02	-0.12	-0.21	-0.02	-0.10	-0.17	-0.03	-0.07	-0.16	-0.03	0.05
Low school poverty (% HNP)	-0.11	-0.21	-0.02	-0.12	-0.22	-0.01	-0.11	-0.19	-0.02	-0.07	-0.18	0.04	0.08
High student poverty (FRM)	-0.12	-0.23	-0.01	-0.11	-0.24	0.02	-0.08	-0.18	-0.02	-0.05	-0.18	-0.08	0.27
High home neighborhood poverty	-0.12	-0.46	0.23	-0.11	-0.51	0.28	-0.06	-0.37	0.24	-0.05	-0.44	0.35	0.97
High school neighborhood poverty	-0.13	-0.29	0.03	-0.13	-0.31	0.06	-0.08	-0.22	0.06	-0.06	-0.25	0.12	0.56
High school poverty (% FRM)	-0.12	-0.65	0.41	-0.11	-0.72	0.50	-0.07	-0.54	-0.40	-0.05	-0.67	-0.56	0.99
High school poverty (% HNP)	-0.11	-0.34	0.12	-0.11	-0.38	0.15	-0.06	-0.27	0.14	-0.05	-0.32	0.22	0.89

^a Change in fitness composite percentile scores based on PACER (progressive aerobic cardiovascular endurance run) push-up and curl-up FitnessGram® tests from the year prior.

^b N = 360,743 students; 675,320 observations; 624 schools.

^c School and home neighborhood poverty based on percent of households in the school and student's home zip codes, respectively, living below the federal poverty line. Student poverty (FRM) based on free/reduced price school meals eligibility. School poverty (FRM) based on percent of students enrolled at the school-level who qualified for free/reduced price school meals. School poverty (% HNP) based on percent of students who lived in zip codes with high poverty.

^d P-values were calculated using adjusted negative binomial longitudinal mixed models; statistical significance of number of days absent per year was assessed using Type III Tests of Fixed Effects.

^e Adjusted for time, grade, race/ethnicity, place of birth (US or foreign born), change in obesity status, and school size.

^f Relative to the reference group (> 20% fitness decrease).

Abbreviations: FRM: Free/reduced price school meals eligibility; % FRM: Percent qualifying for free/reduced price school meals; % HNP: Percent living in high/very high neighborhood poverty; IRR: Incident rate ratio.

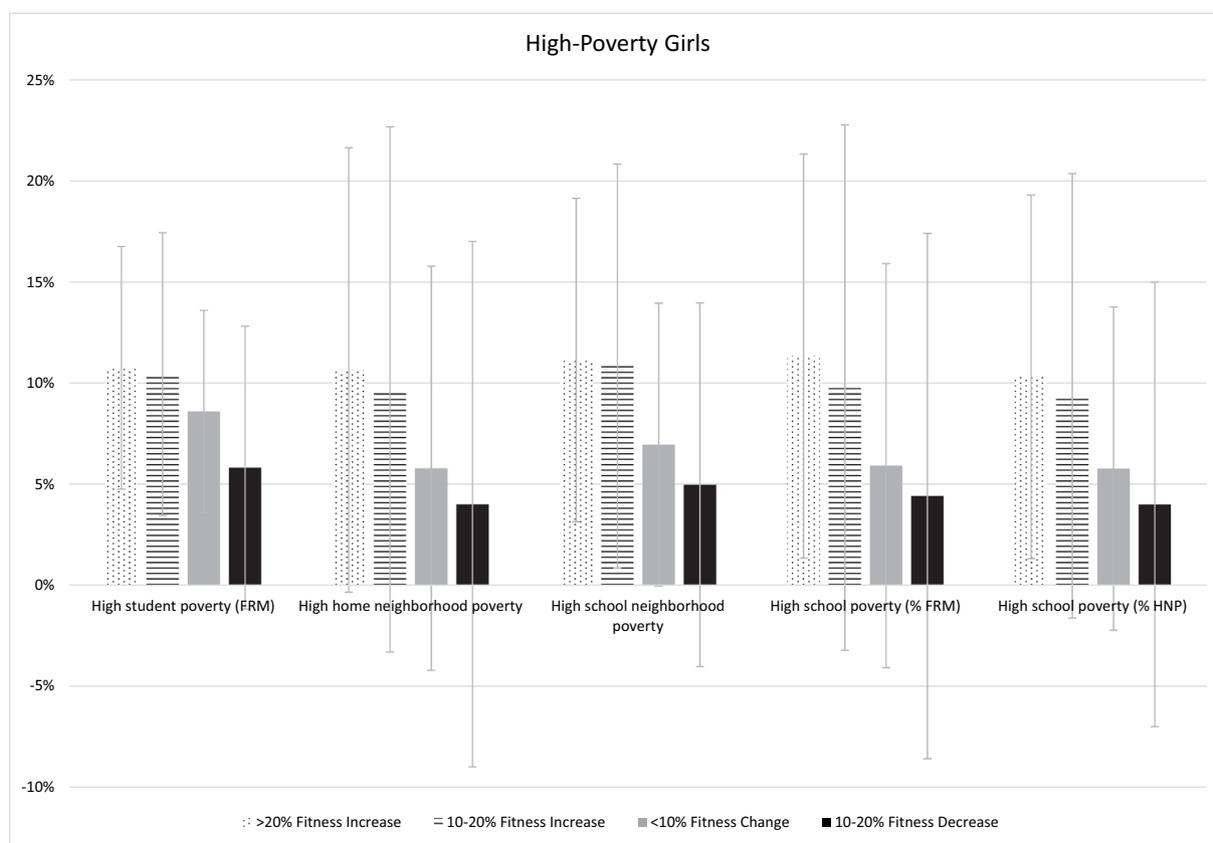


Fig. 2. Relationship in high poverty girls between changes in fitness and subsequent changes in absenteeism (days absent; one-year lagged) per year relative to the reference group (> 20% Fitness Decrease) and across student, school and neighborhood poverty measures among high poverty New York City middle school girls (2006/7–2012/13). Estimates generated by fitting negative binomial longitudinal mixed models with random-intercepts. Abbreviations: FRM: Free/reduced price school meals eligibility; % FRM: Percent qualifying for free/reduced price school meals; % HNP: Percent living in high/very high poverty neighborhoods. Error bars indicate 95% confidence interval estimates.

income is related to youth physical activity. (Janssen et al., 2006) Children exposed to high neighborhood poverty also have the highest absenteeism rates. (Balfanz and Byrnes, 2012; Balfanz and Legters, 2004) Specifically, one-fifth to one-third of students attending schools located in high poverty, urban school districts do not attend school regularly (missing ≥ 6 days per year). (Balfanz and Byrnes, 2012)

Interestingly, this study found that the nature of the relationship between fitness and absenteeism in low compared with high poverty youth was distinct. More specifically, in all subgroups of low poverty youth the magnitude of the association between changes in fitness and absenteeism was highest in girls and boys who had < 10% change in fitness from the prior year, although similar magnitude of effects were found for their counterparts with a 10–20% increase and > 20% increase in fitness. In other words, as long as low poverty youth did not have diminished fitness, they showed a strong and consistent relationship between fitness and absenteeism. In contrast, an inverse dose-response relationship was found among all subgroups of high poverty youth between improvements in fitness and subsequent absenteeism. In this sense, although the overall magnitude of effects was similar across the strata, it is the pattern of the relationship between improvements in fitness and attendance that differed across low vs. high poverty youth, with more narrow confidence intervals observed in girls compared with boys.

Based on the findings from this study, future work should examine the impact of physical activity interventions on absenteeism related to poverty exposures at different levels. Specifically, more work should be performed studying the effects of physical activity resources provided to individual households (such as fitness club and transportation vouchers), schools (school fitness equipment and maintenance), and

neighborhoods (such as improving access/safety/equipment quality at playgrounds and parks in regions proximal to homes and schools).

4.1. Strengths and limitations

Strengths of this analysis include a large and diverse study sample, drawing from longitudinal data, and lagging the outcome (days absent per year) to changes in fitness from the prior year. This study is also strengthened by its exploration of five distinct poverty measures corresponding to three levels of observation (individual student, school, and neighborhood), to examine the nuanced impact of poverty on the fitness-absenteeism relationship and across sex.

This study has several limitations. Although we lagged absenteeism to fitness data, this study is observational and causality inference is limited. We also used a proxy for individual household poverty (i.e., free/reduced price school meals eligibility status) which may be limited given this information is collected by schools for administrative purposes and may not accurately reflect individual household income. Our dichotomization of the school and neighborhood poverty variables based on the grand mean may have led to misclassification and information bias given more than half of the population studied was exposed to poverty at the different levels (including 73%, 75%, and 74% NYC school youth in grades K-12 facing poverty at the individual student, school, and district levels, respectively), although this would likely have driven estimates towards the null.

This study may also have selection bias and differential measurement error, attributable to the Fitnessgram data collected for surveillance purposes with schools required to test just 85% of their enrollees. Shifts in data collection timing from one year to the next may also have

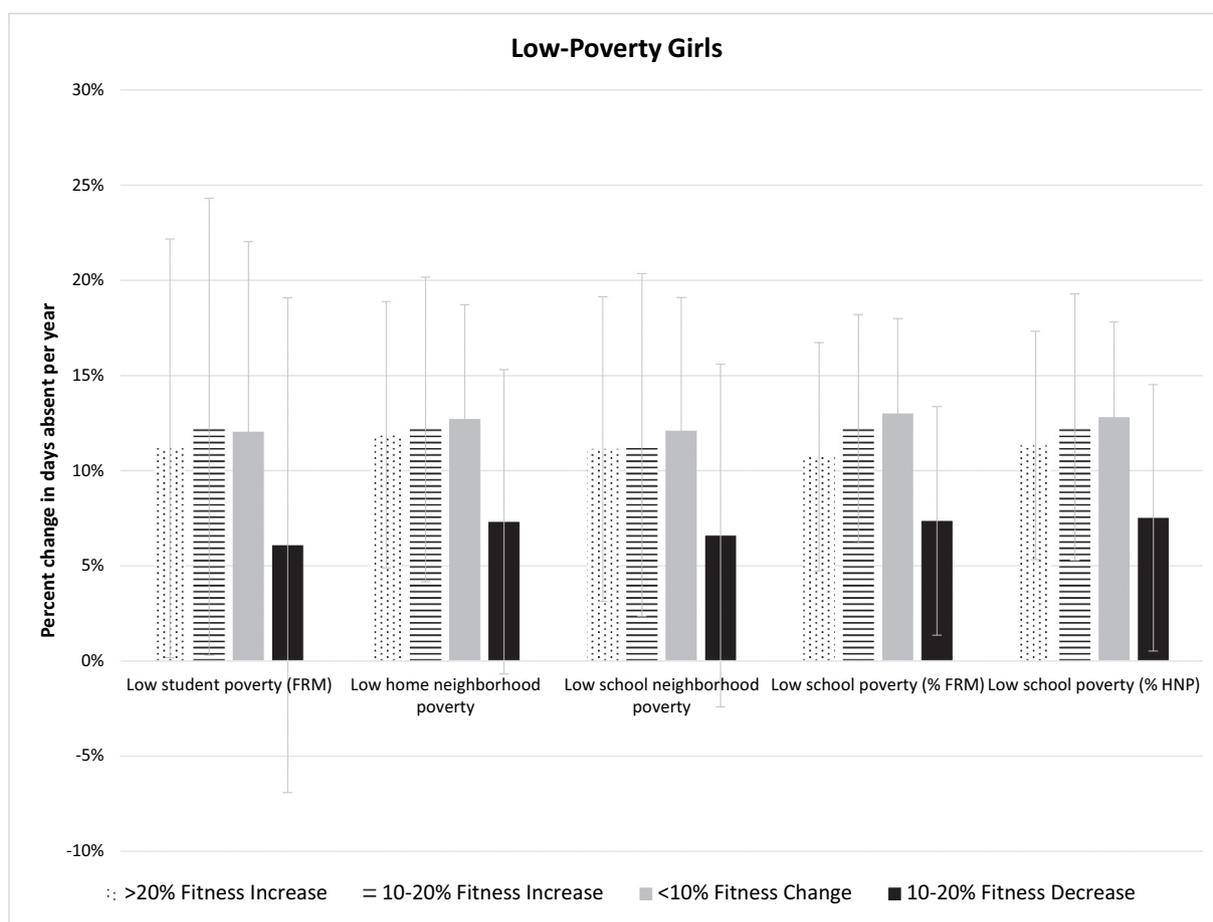


Fig. 3. Relationship in low poverty girls between changes in fitness and subsequent changes in absenteeism (days absent; one-year lagged) per year relative to the reference group (> 20% Fitness Decrease) and across student, school and neighborhood poverty measures among low poverty New York City middle school girls (2006/7–2012/13). Estimates generated by fitting negative binomial longitudinal mixed models with random-intercepts. Abbreviations: FRM: Free/reduced price school meals eligibility; % FRM: Percent qualifying for free/reduced price school meals; % HNP: Percent living in high/very high poverty neighborhoods. Error bars indicate 95% confidence interval estimates.

impacted findings. However, school performance ratings incorporate Fitnessgram testing rates, therein incentivizing greater participation levels, and schools typically follow a testing schedule that is maintained across years.

In addition, data for this study may not be generalizable to all youth given an urban and particularly racially/ethnically diverse setting. Data also were not available on factors that may have impacted fitness and/or absenteeism, such as physical activity levels/participation in organized sports programs, resulting in potential confounding. Although we hypothesized that physical activity would act as an antecedent to the fitness-absenteeism relationship, increased absenteeism may also explain why low physical activity and fitness levels are shown to be negatively associated with academic outcomes among youth residing in disadvantaged areas based on the prior literature. (Gall et al., 2017; Gall et al., 2018) We also did not test the independent effects of muscular and cardiorespiratory fitness on school absenteeism, although additional research in this area is warranted to inform the kinds of physical activities/exercise with the greatest potential to reduce school absenteeism. (Armstrong et al., 2011) Moreover, we cannot assess the fitness-absenteeism relationship across home area poverty for 7% of youth who were missing home neighborhood poverty, resulting in possible bias for the home poverty analysis.

5. Conclusions

This study examined the pattern of effects of student, school, and

neighborhood poverty measures on the longitudinal fitness-absenteeism relationship in NYC middle school youth and across sex. Findings here demonstrate that across all levels of poverty exposures included in this analysis, a stronger fitness-absenteeism relationship is observed in high compared with low poverty youth. Future research should explore the effectiveness of tailored interventions for youth that aim to promote youth physical activity at each of the individual, school and neighborhood levels, and particularly among high poverty subgroups.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ypmed.2019.105820>.

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