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Linear/Nonlinear Relations of Activity and Fitness with Children's Academic Achievement

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Abstract

A growing research base suggests the benefits of physical activity (PA) and aerobic fitness for children extend beyond overall health/well-being to include academic achievement (AA). The majority of research studies on relations of PA and fitness with AA have utilized linear-only analytic approaches, thereby precluding the possibility that PA and fitness could have a differing impact on AA for those more/less active or fit.

Objective—Evaluate both linear and non-linear associations of PA and aerobic fitness with children's AA among a sample of 687 2nd and 3rd grade students from 17 Midwest schools.

Study Design—Using baseline data (fall 2011) from a larger 3-year intervention trial, multi-level regression analyses examined the linear and non-linear associations of AA with PA and with PACER laps (i.e., aerobic fitness), controlling for relevant covariates.

Results—Fitness, but not PA, had a significant quadratic association with both spelling and math achievement. Results indicate that 22–28 laps on the PACER was the point at which the associated increase in achievement per lap plateaued for spelling and math.

Conclusions—Increasing fitness could potentially have the greatest impact on children's AA for those below the 50th fitness percentile on the PACER.

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Keywords

Academic Performance; Weschsler Individual Achievement Test; Accelerometer; Aerobic Fitness; Children; PACER

INTRODUCTION

The health benefits of physical activity (PA) and aerobic fitness for children are well established (22, 25, 32). An emerging research base suggests PA and fitness may also have benefits for children's academic achievement (AA; (24, 26). In general, published research indicates a positive, or at worst, a null association of PA and aerobic fitness with AA (1, 6, 10, 11). These positive findings suggest interventions to improve children's AA by increasing their PA/fitness, and findings from one study provide initial support for this supposition. Donnelly et al. (10) conducted a three-year randomized trial with elementary aged-students to increase their PA to at least 90 weekly minutes by integrating PA and academic lessons in intervention classrooms. Secondary results from that study indicated significant improvements in AA for children in the intervention schools compared to children in control group schools (14). As researchers consider recommending increasing PA/fitness to improve children's AA, research needs to address important questions about the efficacy of this approach (1) for children across the spectrum of PA and fitness levels and (2) for achievement across different academic subjects.

The prevailing linear analytic approach in most published research examining the relation of AA with PA and fitness makes the tacit assumption that the impact of PA and fitness on AA will be constant across all levels of children's PA and fitness. That is, the relation of PA and fitness with AA for children in lower PA/fitness percentiles is presumed the same for children in higher percentiles. Research on health correlates of fitness suggests that the relation of PA/fitness with AA may not follow linear patterns. For example, moving children from the lowest fit quartile to the next fitness quartile appears to have a larger impact on lowering metabolic risk than moving children in the higher quartiles up to the next quartile (34). One study that evaluated non-linear associations of fitness and AA (21) found a significant cubic association between mathematics achievement (but not reading) and aerobic fitness among a population of 5th, 7th, and 9th grade students; unfortunately, the author neither further explored nor interpreted this non-linear finding.

The research literature indicates there are important caveats regarding the relation of AA with PA/fitness. First, the relation of PA/fitness with AA may differ by academic subject, with generally a stronger association for mathematics than for other subjects, such as reading (e.g., (12). Second, overall, the amount of variance in AA explained by PA/fitness tends to be relatively small, approximately 1 to 5% depending on academic subject (21, 39), raising concerns about the practical significance of the relations. The omission of relevant constructs (e.g., parental education) (27) could be a contributing factor to the small effect size. Additionally, since the relation of AA and socioeconomic factors is well established (16), inclusion of socioeconomic variables is needed to protect against potential confounds in the relation of AA with fitness and PA. Finally, the AA-fitness association has generally been more consistent compared to the AA-PA association, although some of this could be due to the use of less robust measures of PA (e.g., self-reported). Overall then, these emerging patterns and limitations of past research suggest correcting for relevant issues (e.g., measurement) to ensure that findings on the relation of PA/fitness with AA are robust.

Extant research findings on the potential of PA and fitness to support children's AA are encouraging, but an almost exclusive reliance on linear-only analytic models leaves important questions unanswered about the efficacy of increasing PA and fitness to boost children's academic achievement across subject areas. Thus, the aim of this study was to evaluate whether the relation between PA/fitness and AA in three subject areas was linear or non-linear across all levels of children's PA/fitness.

METHODS

Study Overview

Data reported in this paper were collected during the baseline assessment phase of the Academic Achievement and Physical Activity Across the Curriculum (A+PAAC) three-year intervention study designed to assess the impact of active academic lessons on AA. Further details regarding the A+PAAC study methodology can be found elsewhere (15). Briefly, the goal of A+PAAC is to compare changes in academic achievement between elementary schools that provide academic lessons delivered by classroom teachers using moderate-to-vigorous PA (100 minutes/week, >3 METs, metabolic equivalent of task (23). Seventeen elementary schools in northeast Kansas were randomized to receive A+PAAC (n = 9) or serve as controls (n = 8). The study was approved by the Human Subjects Committee at the University of Kansas. The authors declare there are no conflicts of interest.

Participants

All parents/guardians of students in 2nd and 3rd grades received a flyer describing the study (including exclusion criteria and assessment procedures) and had the opportunity to attend information sessions held at each school. Due to a large response, a random sample of 2nd and 3rd grade students (stratified by grade and gender) in each school was selected from those who provided parental consent/child assent to complete the outcome assessments used for this study. There were 687 students (age 7.8 ± 0.6 years) in baseline assessments. Participant characteristics are provided in Table 1.

Measures

Academic Achievement—The Weschsler Individual Achievement Test-Third Edition (WIAT-III) was used to assess academic achievement (37). The WIAT-III is comprised of 16 subtests. For this study, five subtests were selected: reading comprehension, oral reading fluency, spelling, mathematics problem solving, and numerical operations. The two reading subtests and two mathematics subtests each form a composite score. The WIAT-III was individually administered by test examiners who were blinded to study hypotheses and goals. These test examiners were trained and supervised by a co-investigator who met the testing company's required WIAT-III administration qualifications. This co-investigator monitored the test administration throughout the data collection to ensure protocol procedures were followed by test examiners. The test administration took approximately 45–50 minutes per student. A trained member of the research team checked all protocols for accuracy and entered the scores into the WIAT-III computerized scoring assistant, which automatically disallows out-of-range values and computes subtest and composite scores.

The WIAT-III has excellent inter-scorer reliability (i.e., 0.92 to 0.99), internal consistency, split-half method (e.g., by age-range from 0.83 to 0.98), and test-retest stability (e.g., for children 6 to 12 years of age, 0.87 to 0.96 over 2 to 32 days; (3). Validity is supported via item reviews of curriculum experts and by correlations with other tests, including the WIAT-II (e.g., .62 to .86) and other measures of academic achievement (e.g., 0.60 to 0.82; (3).

Cardiovascular Fitness—The Progressive Aerobic Cardiovascular Endurance Run (PACER, version 8) was used to assess aerobic fitness. The PACER is based on the 20-meter shuttle run (28) with substantial validity and reliability across several age groups (38). Students were instructed to run back and forth between two lines, 20-meters apart, as the time allowed. The pace was initially slow and progressively increased. Students were paced by a beep recorded on a CD (FITNESSGRAM®) to indicate when they should reach each end of the 20-meter course. Trained research team members observed the test to ensure that the student traversed the 20-meter distance. The test ended for each student when he/she failed to traverse the 20-meter distance in the time allotted on two (not necessarily consecutive) occasions. Aerobic fitness was interpreted as the total number of laps completed on the PACER, with a higher number of laps indicating a higher level of aerobic capacity.

Physical Activity (PA)—To measure PA, children wore an ActiGraph GT3X+ portable accelerometer (ActiGraph LLC, Pensacola, FL) on a belt over the non-dominant hip for 4 consecutive days (including 1 weekend day; (31). The model GT3X+ accelerometer (3.8 × 3.7 × 1.8 cm; 27 g) contains a solid-state digital accelerometer that measures accelerations by generating an electrical signal proportional to the force acting on it along three axes. The GT3X+ detects accelerations ranging in magnitude from 0.05 to 2.5 g and frequency ranging from 0.25 to 2.5 Hz. The acceleration signal is digitized by a 12-bit analog-to-digital converter with a sampling rate set at 30 Hz. The data obtained are called 'activity counts' and are stored in the device's internal memory in one-second intervals.

Activity counts collected were summarized in one-minute epochs using ActiGraph software. These activity counts reflect the duration and intensity of activity during a given sampling epoch. Non-wear time was defined by an interval of at least 20 consecutive minutes of activity counts of zero counts/minute with an allowance for 1–2 minutes of counts between 0 and 100. Spurious data time was defined as activity counts ≥ 16,000 counts/minute and malfunction time was defined as consecutive identical counts/minute > zero (e.g., 32,767) for > 20 minutes. A valid day was defined as ≥ 10 hours of valid data (36). A minimum of three valid wear days were required to be included in analyses (33). Four hundred and two children (58.5%) met these criteria. Mean counts/minute was calculated by dividing the sum of activity counts for a valid day by the number of minutes of valid data time and averaged across all valid days. Higher mean activity counts indicate a greater amount of PA.

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Analysis—Multilevel regression was used to identify the pattern of relationship between PA/aerobic fitness and AA accounting for clustering of students (level-1) within schools (level-2). A relatively small correlation between PA and PACER laps ($r = 0.27$, $p < .001$) indicated minimal collinearity. Thus, analysis was conducted separately for PA and fitness. Given PA, fitness, and AA may be associated with socio-cultural and economic factors, models included the following covariates: grade, gender, race, ethnicity, mother's education level, household income, and body mass index (BMI). The covariates and PA/PACER laps (i.e., its degree terms) were all grand-mean centered, and their corresponding school-level variables (i.e., centered school means or proportions), as well as school- and cross-level degree terms, were also included in the models in order to estimate the effects unique at each level. A linear or non-linear pattern of relationship was determined by sequentially comparing model likelihood statistics between two competing models (null model with an n^{th}-degree term vs. alternative model with this term and an $n+1^{th}$-degree term, where $n = 1, \ldots, n$), until the statistically significant highest-degree term was identified.

Outliers observed at $p < 0.01$ in either tail of the distribution were excluded from the modeling ($n = 11$ for PA, 24 for PACER laps; 3, 7, and 8 for reading, spelling, and math scores, respectively). Normality was confirmed by inspecting histograms and probability plots in each grade and both grades combined. All analyses were conducted using SAS 9.3 (SAS Institute, 2002–2010).

RESULTS

Descriptive statistics of study variables are displayed in Table 2. Intra-class correlations showed non-negligible variability at the school level (0 to 0.21 for covariates, 0.09 for PA, 0.06 for PACER laps, and 0.05, 0.07, and 0.06 for reading, spelling, and math scores, respectively), supporting the use of multilevel regression. Multilevel regression results for PA (Table 3) indicated no significant linear or non-linear association between PA and any of the three AA (all *p's* > 0.05). The final models with PA as the predictor explained 8%, 7%, and 11% of the total student-level variance in reading, spelling, and math scores, respectively.

Multilevel regression results for aerobic fitness (Table 4) indicated there was (1) no significant linear or non-linear association between fitness and reading achievement ($p > 0.05$), but (2) a significant quadratic association between fitness and both spelling and math achievement (both *p's* < 0.01). No contextual effect (i.e., the difference between the student-level and school-level effects) was significant for the quadratic associations. On average, there was an increase in achievement scores up to 22.7 PACER laps for spelling and 27.1 laps for math (Figure 1). The final models with fitness as the predictor, along with all covariates, explained 10%, 5%, and 15% of the total student-level variance in reading, spelling, and math scores, respectively. The PACER laps accounted for 35% of the *explained* student-level variance in spelling scores (or uniquely 2% of *total* student-level variance) and 37% in math scores (or uniquely 5% of *total* student-level variance).

DISCUSSION

This study evaluated if the relation of PA/aerobic fitness with AA was constant across all levels of PA/fitness and if the association was consistent across academic subjects. The findings indicated that (1) fitness, but not PA, was significantly correlated with AA, (2) the relationship between fitness and AA was non-linear for spelling and math scores, with no significant relation between AA and reading scores, and (3) the magnitude of the non-linear association for fitness was stronger for math than spelling.

Fitness and Academic Achievement

This study's findings suggest that increasing aerobic fitness might have a greater impact on spelling and math achievement for children below a particular fitness threshold than on those above. The results indicated that approximately 22–28 laps on the PACER measure was the "inflection" point—the point at which the associated positive slope for AA per lap plateaued for spelling and math—suggesting maximal benefits for AA through increasing aerobic fitness among children below a 22–28 lap threshold. Compared to aerobic fitness percentiles for children ages 8–10 (7), the inflection point in this study is associated with the 50–75% PACER percentiles. Clearly, the findings in this study do not reflect causal relations given that the study was cross-sectional. However, they suggest that future research focus on evaluating the potential benefits of improving aerobic fitness for AA among children classified in lower fitness percentiles.

The strength of the association between aerobic fitness and both spelling and mathematics achievement in this study is similar in magnitude to these associations in existing research (21, 39), which has reported an effect size (i.e., variance explained) in the range of 1–5%. In this study, aerobic fitness uniquely explained 2% and 5% of the total student-level variance in spelling and mathematics achievement, respectively. As a proportion of the explained student-level variance in AA, however, fitness accounted for just over one-third of the variance, which is considerable in magnitude. The strength of the relation of fitness with spelling and math scores could reflect this study's measure of fitness: aerobic fitness was assessed as the total number of PACER laps completed, while other studies have created a fitness composite score that includes muscular strength, endurance, etc., along with aerobic fitness. Although non-aerobic measures of fitness (e.g., flexibility, strength) were not included in the present study, at least one other study has indicated that, among the components of the FITNESSGRAM®, the PACER has the strongest correlation with AA (8). Thus, the current findings and existing research suggests that among the different measures of fitness, aerobic fitness may be particularly potent for AA.

Although there was an association between fitness and both math and spelling, this study failed to find a significant association between fitness and reading achievement. This overall pattern is consistent with other research (10). The relation of math with fitness could reflect the role of fitness in supporting children's executive function (2, 4, 13, 18, 19). Executive function refers to supervisory control of cognitive functions to achieve a goal and involves allocation of attention and memory, response selection and inhibition, goal setting, self-control, self-monitoring, and skillful and flexible use of strategies (29). Research within the cognitive function literature indicates that children of lower mathematical ability have difficulties performing tasks involving components of executive, such inhibition of prepotent information (e.g., Stroop interference) and learned strategies (e.g. Wisconsin Card Sorting Task) and difficulties maintaining information in working memory (5). Reading and spelling have typically been associated with executive function in cases where cognitive dysfunction or a learning disability is present (30). The null findings of this study between reading and fitness is consistent with an executive function explanation, but the significant relation between fitness and spelling is not and warrants further research to determine if the relation is robust.

Physical Activity and Academic Achievement

The findings on the relation of PA and AA in research literature have been inconsistent, with either a significant positive relation or null relation (1, 9, 10, 14, 17, 20, 35). In this study, PA was not significantly correlated with AA, either linearly or non-linearly. There could be several reasons for this “null finding.” First, PA may not have a direct relation with AA. However, given the obvious role that moderate-to-vigorous PA over time plays in improving or maintaining aerobic fitness, it seems more likely that this null finding is attributable to other factors. It could be that the unit of measure for PA in this study—aggregate of 3–4 days of accelerometer data with valid data across four consecutive days—may not have adequately represented the full scope of these children’s “typical” activity levels. Valid PA data was also missing for a substantial proportion of children in this study (41.5%), and thus this smaller subsample may not have adequately represented the relation of PA and AA for the entire sample. The present findings, however, point to the need for longitudinal designs that assess PA over longer periods or on multiple occasions in order to unmask any potential relation between PA and AA.

Conclusions

This study has particular strengths and limitations that should be noted. Although the cross-sectional design limits any evaluation of how/if PA and aerobic fitness levels relate to AA over time, the findings indicated that many children in this study were below recommended PA and fitness levels. Barring hereditary and maturational limits on children’s fitness levels, most children should be capable of reaching recommended levels of PA and aerobic fitness (38), and the present findings suggest increases in these levels might benefit their AA. (Increasing PA is argued a requisite for increasing fitness.) The use of salient covariates in the analyses, including gender, race, ethnicity, parental education level, household income, and BMI, strengthened the findings by ruling out their potential influence on the relation of PA and aerobic fitness with AA. We suggest researchers at minimum measure and evaluate the influence of these covariates in future studies in which AA is included. It should also be noted that this study’s sample was homogenous in terms of race (predominantly white) and there was a relatively high proportion of high-income families (21%), which limits generalizability. Lastly, there is limited validity evidence available for the 20-meter PACER in 7–8 year old children and the potential for confounding by motivation to perform or other confounding due to the age of the sample is possible.

Overall, the present study contributes to an emerging literature linking aerobic fitness and PA with AA. This research implies that providing more opportunities to be active and improve fitness could improve AA, at least partially, and schools are uniquely situated to provide such opportunities. With recent financial constraints on educational budgets and increased pressures on schools to meet mandated achievement standards, educators may be tempted to increase their focus on academics, perhaps to the detriment of PA opportunities for children in school. The findings of this study, along with existing research, suggest this response could ultimately be detrimental to children's AA. While further research is needed to better understand the longitudinal effects of increasing aerobic fitness and PA on children's learning, the present findings suggest a more proactive approach to increasing fitness is warranted.

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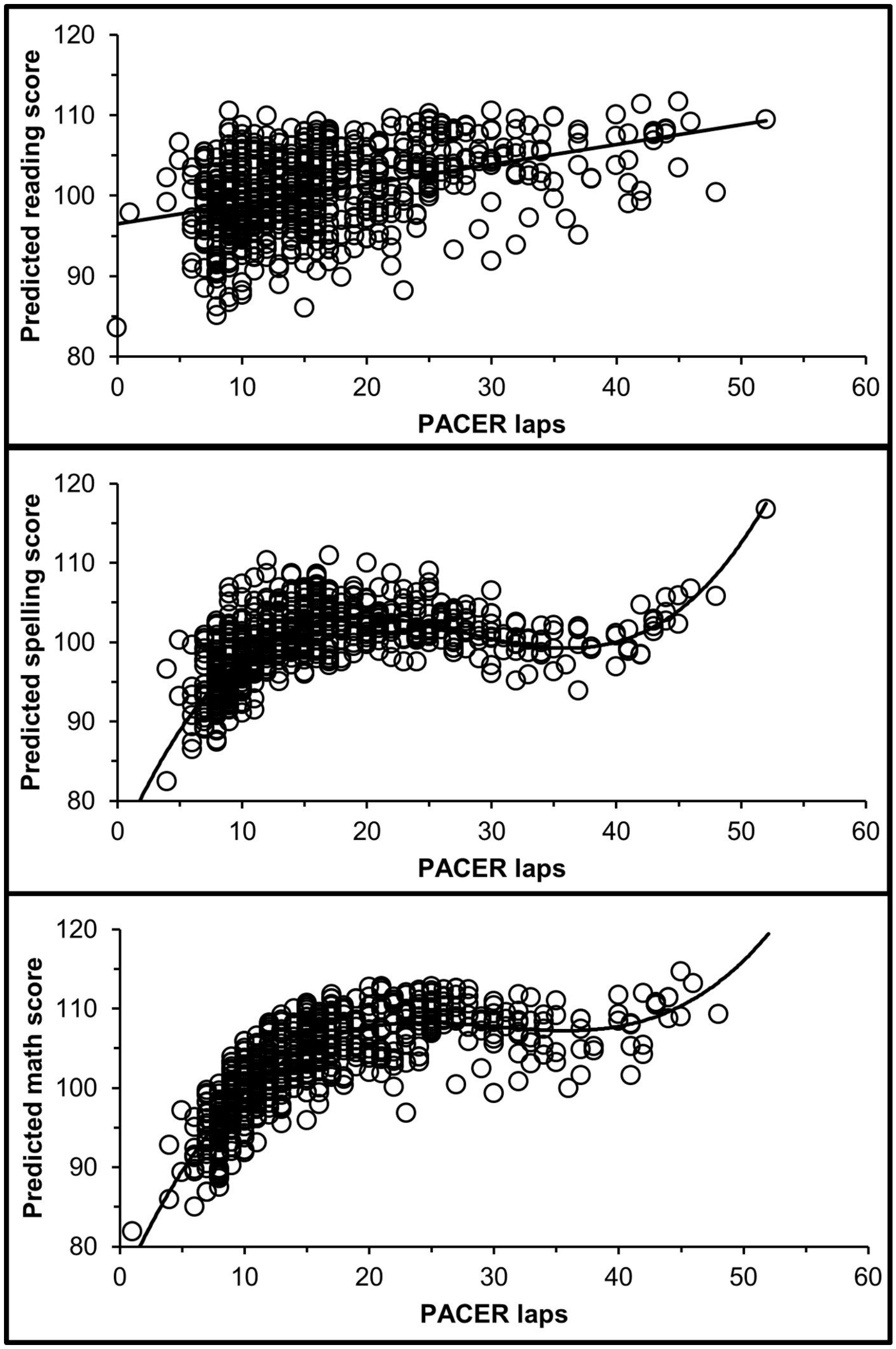

Figure 1.
Predicted achievement scores and trend lines for reading, math, and spelling

Table 1

Participant Demographics

Variable	N	%
Grade		
Grade 2	339	49.1%
Grade 3	352	50.9%
Gender		
Male	343	49.6%
Female	348	50.4%
Race		
White	555	80.3%
Black/African American	30	4.3%
Native Hawaiian/Pacific Islander	1	0.1%
Asian	10	1.4%
American Indian/Alaska Native	9	1.3%
Two or more races	72	10.4%
Unknown	5	0.7%
Refused/missing	9	1.3%
Ethnicity		
Not Hispanic/Latino	585	84.7%
Hispanic/Latino	73	10.6%
Unknown	16	2.3%
Refused/missing	17	2.5%
Education level (mother)		
Less than high school	7	1.0%
Some high school	21	3.0%
Completed high school	78	11.3%
Some college/associate's degree	234	33.9%
Bachelor's degree	209	30.2%
Advanced degree	135	19.5%
Refused/missing	7	1.0%
Household income		
<$10,000	36	5.2%
$10,000–$20,000	48	6.9%
$21,000–$30,000	67	9.7%
$31,000–$30,000	61	8.8%
$41,000–$50,000	62	9.0%
$51,000–$60,000	42	6.1%
$61,000–$70,000	49	7.1%
$71,000–$80,000	59	8.5%
$81,000–$90,000	38	5.5%
$91,000–$100,000	57	8.2%

Variable	**N**	**%**
>$100,000	146	21.1%
Refused/missing	26	3.8%

Note. Baseline data collected in fall of 2011 on 2nd and 3rd grade students from 17 schools in the Midwest.

Table 2

Study Variables by Grade and Gender

Variable	All			Male			Female		
	N	M	SD	N	M	SD	N	M	SD
BMI[a]	678	17.43	3.12	336	17.45	2.99	342	17.41	3.26
PA[b]	402	561.23	181.76	186	597.57	188.70	216	529.94	169.85
PACER[c] laps	685	16.47	8.91	339	18.26	10.12	346	14.73	7.13
Reading	669	100.58	14.81	329	100.35	15.63	340	100.79	13.99
Spelling	681	99.64	12.94	338	98.93	14.88	343	100.34	10.67
Math	680	103.02	13.38	337	104.26	15.02	343	101.80	11.44

Grade 2	All			Male			Female		
	N	M	SD	N	M	SD	N	M	SD
BMI	334	17.16	3.00	172	17.01	2.59	162	17.33	3.37
PA	201	578.75	180.42	91	615.58	191.80	110	548.28	165.17
PACER laps	336	14.62	7.04	172	15.83	7.87	164	13.36	5.80
Reading	321	100.01	14.47	162	99.74	14.30	159	100.28	14.68
Spelling	330	98.49	12.48	169	97.88	13.43	161	99.14	11.40
Math	330	102.73	12.51	169	104.36	13.53	161	101.02	11.13

Grade 3	All			Male			Female		
	N	M	SD	N	M	SD	N	M	SD
BMI	344	17.69	3.23	164	17.91	3.30	180	17.48	3.16
PA	201	543.71	181.85	95	580.31	185.05	106	510.91	173.31
PACER laps	349	18.26	10.09	167	20.76	11.49	182	15.96	7.97
Reading	348	101.10	15.12	167	100.95	16.85	181	101.24	13.37
Spelling	351	100.72	13.29	169	99.99	16.17	182	101.40	9.90
Math	350	103.29	14.17	168	104.16	16.42	182	102.48	11.70

[a]Body Mass Index,

[b]Physical activity counts per minute measured by accelerometer,

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[c]Progressive Aerobic Cardiovascular Endurance Run.

Note. Baseline data collected in fall of 2011 on 2nd and 3rd grade students from 17 schools in the Midwest.

Table 3

Regression Results for the Relation of Physical Activity and Academic Achievement

	Reading			Spell			Math		
Parameter	**b**	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**
Fixed effect									
Intercept	102.12 [99.53; 104.72]	1.13	<0.001	101.03 [98.28; 103.78]	1.19	<0.001	104.31 [101.98; 106.65]	1.01	<0.001
Grade 2	−1.52 [−4.34; 1.30]	1.43	0.291	−3.21 [−5.54; −0.89]	1.18	0.007	0.41 [−1.94; 2.76]	1.20	0.731
Male	0.54 [−2.32; 3.40]	1.45	0.709	−0.02 [−2.38; 2.35]	1.20	0.990	2.48 [0.09; 4.86]	1.21	0.042
White	2.91 [−1.22; 7.03]	2.10	0.166	0.42 [−3.02; 3.85]	1.75	0.811	2.23 [−1.25; 5.71]	1.77	0.209
Hispanic	4.63 [−0.69; 9.95]	2.70	0.088	4.51 [0.12; 8.90]	2.23	0.044	1.60 [−2.84; 6.03]	2.26	0.479
Education level (mother)	3.27 [1.72; 4.83]	0.79	<0.001	1.52 [0.24; 2.80]	0.65	0.020	2.22 [0.92; 3.52]	0.66	0.001
Household income	0.29[−0.26; 0.85]	0.28	0.299	0.25 [−0.21; 0.71]	0.23	0.279	0.67 [0.21; 1.13]	0.23	0.005
BMI[a]	−0.23 [−0.81; 0.35]	0.29	0.434	0.12 [−0.36; 0.60]	0.24	0.627	0.01 [−0.47; 0.50]	0.24	0.952
PA[b]	−0.01 [−0.02; 0.00]	0.01	0.169	0.00 [−0.01; 0.01]	0.00	0.913	−0.01 [−0.01; 0.00]	0.00	0.136
Grade 2*	33.61 [−51.90; 119.12]	43.46	0.440	58.28 [−31.92; 148.49]	45.85	0.205	−33.56 [−110.37; 43.26]	39.04	0.391
Male*	16.84 [−37.80; 71.48]	27.77	0.545	19.05 [−37.33; 75.43]	28.65	0.507	−9.20 [−57.48; 39.08]	24.54	0.708
White*	24.24 [−8.11; 56.59]	16.44	0.141	25.72 [−8.58; 60.02]	17.43	0.141	0.15 [−28.98; 29.27]	14.80	0.992
Hispanic*	23.50 [−19.13; 66.12]	21.66	0.279	21.75 [−23.75; 67.24]	23.12	0.348	−5.96 [−44.60; 32.67]	19.64	0.762
Education level (mother)*	6.48 [−9.13; 22.09]	7.94	0.415	−0.69 [−17.22; 15.84]	8.40	0.935	4.77 [−9.29; 18.82]	7.14	0.505
Household income*	−1.68 [−5.29; 1.94]	1.84	0.362	0.57 [−3.23; 4.38]	1.94	0.767	−0.77 [−4.02; 2.47]	1.65	0.639
BMI*	−2.48 [−7.48; 2.51]	2.54	0.328	−1.19 [−6.51; 4.13]	2.71	0.660	0.35 [−4.16; 4.87]	2.30	0.878
PA*	0.01 [−0.05; 0.07]	0.03	0.854	−0.01 [−0.07; 0.06]	0.03	0.833	0.01 [−0.04; 0.07]	0.03	0.654
Random effect									
Intercept	12.66			18.15			11.36		
Residual	164.38			111.43			114.06		
Intra-class correlation	0.07			0.14			0.09		

[a]Body Mass Index,

[b]Physical activity counts per minute measured by accelerometer,

*School means or proportions.

Note. Values in the brackets are lower and upper limits of 95% confidence band.

Table 4

Regression Results for the Relation of Fitness and Academic Achievement

	Reading			Spell			Math		
Parameter	**b**	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**
Fixed effect									
Intercept	101.00 [99.12; 102.87]	0.81	<0.001	101.78 [98.25; 105.31]	1.49	<0.001	104.20 [101.35; 107.05]	1.21	<0.001
Grade 2	−2.01 [−4.17; 0.15]	1.10	0.069	−2.74 [−4.56; −0.92]	0.92	0.003	−0.06 [−1.84; 1.73]	0.91	0.951
Male	0.09 [−2.06; 2.24]	1.10	0.936	−0.90 [−2.70; 0.91]	0.92	0.331	1.81 [0.05; 3.58]	0.90	0.044
White	3.10 [0.08; 6.12]	1.54	0.044	0.76 [−1.79; 3.31]	1.30	0.558	2.20 [−0.29; 4.69]	1.27	0.084
Hispanic	4.46 [0.68; 8.23]	1.92	0.021	1.54 [−1.62; 4.70]	1.61	0.339	−1.00 [−4.10; 2.09]	1.58	0.524
Education level (mother)	2.52 [1.32; 3.71]	0.61	<0.001	0.81 [−0.18; 1.80]	0.50	0.109	1.72 [0.74; 2.70]	0.50	0.001
Household income	0.57 [0.15; 0.98]	0.21	0.008	0.30 [−0.05; 0.65]	0.18	0.095	0.41 [0.07; 0.76]	0.18	0.019
BMI[a]	0.02 [−0.41; 0.46]	0.22	0.920	0.49 [0.12; 0.86]	0.19	0.010	0.48 [0.12; 0.84]	0.18	0.009
PACER[b] laps	0.06 [−0.10; 0.22]	0.08	0.463	0.32 [0.14; 0.50]	0.09	0.001	0.55 [0.37; 0.72]	0.09	<0.001
PACER laps^2				−0.02 [−0.04; −0.01]	0.01	0.005	−0.02 [−0.04; −0.01]	0.01	0.002
Grade 2*	−57.00 [−147.95; 33.95]	46.30	0.219	−41.20 [−139.95; 57.56]	50.28	0.413	−79.90 [−158.04; −1.75]	39.78	0.045
Male*	−61.99 [−130.05; 6.07]	34.65	0.074	−54.94 [−129.86; 19.98]	38.14	0.150	−55.45 [−114.85; 3.95]	30.24	0.067
White*	20.26 [−6.89; 47.40]	13.82	0.143	32.20 [2.90; 61.50]	14.92	0.031	13.77 [−9.45; 36.99]	11.82	0.245
Hispanic*	−50.81 [−104.57; 2.96]	27.37	0.064	−45.31 [−103.78; 13.15]	29.76	0.129	−35.44 [−81.82; 10.95]	23.61	0.134
Education level (mother)*	2.49 [−8.36; 13.33]	5.52	0.653	0.95 [−10.96; 12.87]	6.07	0.875	7.24 [−2.23; 16.70]	4.82	0.134
Household income*	0.86 [−2.29; 4.02]	1.61	0.592	2.30 [−1.26; 5.87]	1.82	0.205	0.21 [−2.63; 3.06]	1.45	0.883
BMI*	−0.86 [−4.97; 3.26]	2.09	0.682	1.40 [−3.30; 6.09]	2.39	0.559	1.60 [−2.13; 5.33]	1.90	0.399
PACER laps*	−2.78 [−5.56; −0.00]	1.42	0.050	−3.57 [−6.74; −0.41]	1.61	0.027	−2.61 [−5.12; −0.10]	1.28	0.042
PACER laps^2*				−0.15 [−0.64; 0.33]	0.25	0.536	−0.01 [−0.40; 0.38]	0.20	0.971
PACER laps × PACER laps*				0.01 [−0.06; 0.09]	0.04	0.713	0.00 [−0.07; 0.08]	0.04	0.897
Random effect									
Intercept	6.17			9.46			4.85		
Residual	160.84			113.77			109.04		
Intra-class correlation	0.04			0.08			0.04		

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[a]Body Mass Index,

[b]Progressive Aerobic Cardiovascular Endurance Run,

*School means or proportions.

Note. Values in the brackets are lower and upper limits of 95% confidence band.