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Does fitness make the grade? The relationship between elementary students' physical fitness and academic grades

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Abstract

Background and Objective: Increased emphasis on academic outcomes has reduced the amount of time spent in physical education and other school physical activity opportunities in many schools in the USA. However, physical fitness is a positive predictor of academic performance on standardised tests, and students who perform better on fitness measures may earn higher grades. The purpose of this study was to evaluate the relationship between physical fitness and teacher-assigned grades in fourth-grade students and examine whether the relationship is moderated by body composition, gender or ethnic background.

Design: Cross-sectional design. Students' fitness levels were assessed mid-way through the spring semester, and their third-quarter grades were obtained from the schools.

Participants and setting: Fourth-grade students ($N=80$; 38 female students; 65 non-Hispanic or Latino) from two elementary schools in the south-western USA.

Method: Students completed physical fitness measures using standard procedures from the *FITNESSGRAM* protocol, and standardised teacher-assigned grades in reading, writing, mathematics, social studies and science were compiled. Linear regression and multivariate analysis of variance (MANOVA) were performed to examine the relationship between physical fitness measures and average grades, and examine whether differences in fitness and grades existed between gender, ethnic background and body mass index (BMI) percentile rank.

Results: Aerobic fitness, as measured by the number of 20-m Progressive Aerobic Cardiovascular Endurance Run (PACER) laps completed, had a significant influence on reading, writing, mathematics and science grades. There were no significant interactions between aerobic fitness and ethnic background, gender or BMI percentile rank, meaning that aerobic fitness was the largest specific influence on average teacher-assigned grades.

Conclusion: Positive associations exist between physical fitness and academic performance, suggesting activities that help children improve their physical fitness ought to be a central component of physical education and broader school physical activity programmes.

Keywords

Academic achievement, grades, physical fitness

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Introduction

In 2001, the No Child Left Behind Act instigated a change in the school environment, placing a greater emphasis on academic achievement in the USA. As a consequence, there has been an added pressure of standardised testing, and time allocation for physical education (PE) has decreased (Center on Education Policy, 2008). This in turn has potential negative implications for young people's physical fitness (PF; Trost and Van der Mars, 2009; US Department of Education, 2008). Interestingly, studies have shown that more time spent in PE or other school physical activity programmes does not negatively impact academic performance and that it may be associated with academic benefits (Carlson et al., 2008; Castelli et al., 2015; Centers for Disease Control and Prevention [CDC], 2010; Trost and Van der Mars, 2009). PF among young people, which can be promoted through PE, has been found to be a powerful marker of health. Numerous studies show that PF is associated with a lower risk of developing premature cardiovascular and metabolic diseases, as well as with several cognitive and academic benefits (e.g. Chaddock et al., 2011, 2012; Fedewa and Ahn, 2011; Ortega et al., 2008).

Several studies have reported a positive relationship between PF and academic achievement in youth. For instance, there is evidence that schools with fitter children achieve better literacy and numeracy results (Telford et al., 2012). Similarly, according to a relevant study conducted in Texas, higher fitness rates increased the odds of schools achieving exemplary/recognised school status within the state (Welk et al., 2010). Some studies have also demonstrated a significant positive association between the number of fitness tests passed (i.e. performed at or above the healthy fitness zone [HFZ]) and academic achievement (Blom et al., 2011; Chomitz et al., 2009; Coe et al., 2013). Furthermore, the findings of London and Castrechini (2010) point to the lasting effects of the association between overall PF and academic achievement, with a potential achievement gap forming before regular PF testing commonly occurs.

The most consistent findings in this area of study relate to the positive association of aerobic fitness with academic achievement (Castelli et al., 2007; Chen et al., 2013; Desai et al., 2015; Haapala et al., 2014; Hansen et al., 2014; Rauner et al., 2013; Telford et al., 2012; Van Dusen et al., 2011; Wittberg et al., 2010). For instance, Hansen et al. (2014) found that aerobic fitness had a significant quadratic association with spelling and math achievement when controlling for demographic, socio-economic and body weight variables. Similarly, in a study conducted in 13 Texas school districts, cardiovascular fitness showed a dose–response association with standardised academic scores, independent of other socio-demographic and fitness variables (Van Dusen et al., 2011). Furthermore, Haapala et al. (2014) found that children with higher aerobic fitness in grade 1 had significantly better reading fluency and arithmetic skills in grades 1–3, even when adjusting for variables including age, parental education, body fat and physical activity. In another longitudinal study, Chen et al. (2013) found that improvements in aerobic fitness over a 3-year period were significantly related to improved academic performance.

Mixed findings seem to be the norm relative to the relationship of non-aerobic fitness components and academic achievement. For example, body composition, often measured through body mass index (BMI), has been found to be negatively correlated with academic achievement in some relevant studies (Castelli et al., 2007; Coe et al., 2013; Roberts et al., 2010) but not in others (Chen et al., 2013; Desai et al., 2015; Rauner et al., 2013; Van Dusen et al., 2011). Similarly, mixed findings have been reported for the association between muscular fitness and academic performance. A positive association between muscular strength and academic achievement has been found by some researches (Coe et al., 2013; Du Toit et al., 2011) but not by others (Castelli et al., 2007; Chen et al., 2013). Furthermore, Du Toit et al. (2011) found a positive relationship between flexibility and academic performance, whereas other researchers did not (Castelli et al., 2007; Chen et al., 2013; Coe et al., 2013).

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Beyond body weight or body composition, various other factors seem to moderate the relationship between PF and academic performance. Accordingly, researchers often control for the effect of these factors in their analyses. These factors usually include gender (Blom et al., 2011; Chen et al., 2013; Chomitz et al., 2009; Desai et al., 2015; Du Toit et al., 2011; Hansen et al., 2014; London and Castrechini, 2010; Rauner et al., 2013; Wittberg et al., 2010), ethnicity (Blom et al., 2011; Chomitz et al., 2009; Hansen et al., 2014; London and Castrechini, 2010; Rauner et al., 2013; Roberts et al., 2010; Van Dusen et al., 2011) and socio-economic status (SES; Blom et al., 2011; Chen et al., 2013; Chomitz et al., 2009; Coe et al., 2013; Desai et al., 2015; Haapala et al., 2014; Hansen et al., 2014; London and Castrechini, 2010; Rauner et al., 2013; Roberts et al., 2010; Van Dusen et al., 2011).

PF is often used as an explanatory variable used to predict or explain differences in academic achievement outcomes. While the relationship exists statistically, what is unclear is a mechanism that may explicate a potential functional relationship between PF and academic achievement. A potential mediator in the causal chain of PF and academic achievement may be cognition, as cognition is directly related to academic performance (Sadowski and Gulgoz, 1996). Several studies have shown that aerobic fitness is positively associated with various cognitive processes (Chaddock et al., 2011, 2012; Fedewa and Ahn, 2011; Moore et al., 2013; Pontifex et al., 2011), possibly through modifications to brain structures, cerebral blood flow or brain-derived neurotropic factors (Etnier et al., 2006). At the same time, the relationship between PF and academic achievement may be a reflection of the high achievement orientation of motivated students in both academics and PF or sports domains (Chomitz et al., 2009). Additionally, better overall health, a potential indicator of higher PF levels, may be positively associated with academic achievement (Chomitz et al., 2009).

Purpose

Although several studies have been conducted in this area, they almost exclusively focused on academic achievement measured through standardised tests. However, student performance determined through standardised testing may differ from teacher-assigned grades. A standardised test evaluates student performance on a given day, which may not be representative of student performance or growth throughout a whole term. Additionally, some students simply do not perform well on tests and may suffer from test anxiety. Overall, there are different factors that can be taken into consideration when evaluating student performance. Hence, the purpose of this study was to determine the relationship between fourth-grade students' PF levels and academic achievement, measured using teacher-assigned grades. Furthermore, this study aimed to examine whether the relationship between PF and grades was moderated by gender, ethnic background or body composition or whether these characteristics contributed unique variance to teacher-assigned grades.

Methods

Participants and setting

The participants in this study were fourth-grade students ($N = 80$; female students: $n = 38$) from four classes in two urban elementary schools in the south-western USA. The two schools belonged to the same school district. Participants' age varied between 9 and 11 years, with a mean of 9.39 years (standard deviation [SD] = 0.52 years). Their ethnic backgrounds were either non-Hispanic or Latino ($n = 65$) or Hispanic or Latino ($n = 15$). SES was stratified as low, moderate and high according to whether students received free or reduced-price lunch, number of parents living with,

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Table 1. Frequency and percentage of various demographic characteristics by school.

		School 1[a]	School 2[b]
SES	Low	1 (5%)	14 (33%)
	Moderate	6 (30%)	7 (17%)
	High	13 (65%)	21 (50%)
Gender	Female	18 (51%)	20 (44%)
	Male	17 (49%)	25 (56%)
Age (years)	9	21 (60%)	29 (64%)
	10	14 (40%)	15 (34%)
	11	0 (0%)	1 (2%)
Ethnicity	Non-Hispanic or Latino	31 (89%)	34 (76%)
	Hispanic or Latino	4 (11%)	11 (24%)
Race	American Indian or Alaska Native	0	0
	Asian	2 (6%)	0
	Black or African American	0	0
	Native Hawaiian or Other Pacific Islander	0	1 (2%)
	White	29 (83%)	33 (74%)
	Hispanic or Latino	4 (11%)	11 (24%)

School 1 had 15 (43%) and school 2 had 3 (7%) observations of socio-economic status (SES) missing.
[a]School 1 $n = 35$.
[b]School 2 $n = 45$.

parents' education attainment and employment status (Birnbaum et al., 2002). A summary of school-level demographics can be found in Table 1.

During the study, time allocated to PE in the participating schools was one 40-minute period per week as well as an additional 40-minute period every 3 weeks based on a rotating system. Students also received daily recess of 20 minutes in the morning and 15 minutes during their lunch break, with a possibility of an additional 40-minute recess break on Friday if they completed all their schoolwork and had no documented discipline problems. Additional physical activity opportunities at both schools included a biweekly running club that met once a week for 30 minutes from mid-October to the end of April, in which 18 student participants were enrolled. Both schools had adequate indoor and outdoor physical activity facilities.

Design and procedures

A cross-sectional design was employed. Students' fitness levels were assessed mid-way through the spring semester and their third-quarter grades were obtained from the schools. Approval for the study was obtained from the Arizona State University Institutional Review Board for research involving human subjects. Approval was also obtained from the school district the schools belonged to and the two school principals. Teachers provided consent for their classes to participate in the study, and parents/guardians provided consent for their children's involvement in the study. Students also provided their assent for participating in the study.

PF assessment. PF was assessed using FITNESSGRAM, a valid and reliable field assessment of PF for individuals aged 5 to adulthood (Meredith and Welk, 2007; Welk and Meredith, 2008). FITNESSGRAM is a comprehensive fitness assessment battery that includes a variety of tests designed to assess the five components of health-related PF: (a) cardiovascular endurance via the 20-m

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Progressive Aerobic Cardiovascular Endurance Run (PACER) test, (b) muscular strength and endurance via the push-up and curl-up tests, (c) flexibility via the back-saver sit and reach and trunk lift tests and (d) body composition via BMI. BMI provides an indication of the appropriateness of an individual's weight relative to height and was calculated as the ratio of weight in kilograms to square height in metres (i.e. weight/height^2). We reported BMI according to percentile rank categories using age-group cut-offs for underweight (BMI < 5th percentile), healthy or normal weight (5th ⩽ BMI < 85th percentile), overweight (85th ⩽ BMI < 95th percentile for age) and obese (⩾95th percentile) girls and boys (Kuczmarski et al., 2002). Weight and height were measured without shoes using a calibrated digital scale (Seca 882 Digital BMI Scale) and stadiometer (Seca 214 Portable Stadiometer).

Prior to assessing students' PF, members of the research team demonstrated all of the tests using the FITNESSGRAM protocol (Meredith and Welk, 2007) and provided students with the opportunity to practice all the tests. Subsequently, PF testing was done over two PE lessons for each class, with the first one devoted to the assessment of cardiovascular endurance (i.e. PACER) and the second one devoted to the assessment of the other four health-related PF components using stations. Throughout PF testing, students were paired up so that one partner took one test, while the other partner monitored him or her and kept his or her score. At the same time, members of the research team closely monitored and scored students. During the administration of the cardiovascular fitness test, the teacher and two members of the research team were present to monitor students and record their scores. During the second day of testing, there was one member of the research team at each testing station. For a detailed description of the PF tests administered, the reader is directed to Meredith and Welk (2007) and Welk and Meredith (2008).

Measurement of academic achievement. Academic achievement was determined using the grades from the students' third-quarter report cards. Students' report cards included grades for the academic areas of reading, writing, mathematics, social studies and science. Grades were initially on a letter scale using pluses and minuses, but they were transformed to a standardised score ($M = 0$, $SD = 1$) using a standardised values function from a statistical software package (SPSS version 20 for Windows; SPSS, Inc., Armonk, NY) that accounts for teacher differences in grading systems. Therefore, individual student grades were calculated as z-scores, or the distance from their class mean in *SD* units, and then averaged to reflect group-level differences. Grades were not normally distributed as confirmed with visual inspection of non-linear Q–Q plots and significant Kolmogorov–Smirnov tests for all subject grades, which is to be expected with teacher-assigned grades (i.e. more passing grades than failing grades). However, the use of standardised z-scores and robust general linear model procedures should minimise the effect of the lack of normality.

Data management and analysis

Descriptive statistics for PF and grade variables were obtained. We performed a multivariate analysis of variance (MANOVA) using the general linear model procedure in SAS 9.3 for Windows (SAS Institute, Cary, NC) to account for correlated dependent variables. Categorical independent variables (e.g. school and teacher) were modelled as fixed effects to identify influences specific to the observed data. Data were missing for less than 10% of observations for fitness scores and grades; however, SES had 22.5% of observations missing. We did not include SES as part of our statistical analyses, as initial models identified no significant influence on grades and was not a primary moderator effect of interest for our research questions. We reported SES data to provide contextual information on the schools, and therefore, we did not perform any missing data handling procedures.

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All hypothesis tests were conducted using a significance level of .05 from the type II sums of squares after adjusting for other model effects. Univariate follow-up contrasts with Scheffe adjustments were used for multiple comparisons for the least squares mean analysis. Effect sizes from the MANOVA are reported as partial η^2. This effect size represents the proportion of the total variance in the dependent variable explained by an individual factor, with other effects from the independent and dependent variables partialled out or controlled for. We conform to standard operational definitions of small effect sizes as $\eta^2 < .01$, medium effect sizes as $.06 < \eta^2 < .14$ and large effect sizes as $\eta^2 > .14$ (Cohen, 1988: 273–406).

Results

Fourth-grade students from two schools participated in data collection. Descriptive statistics for grades and fitness testing scores by gender and ethnic group can be found in Tables 2 and 3, respectively. In these tables, the percentage of students meeting the HFZ according to age-based criterion is reported for muscular fitness components (Welk and Meredith, 2008) and for aerobic fitness (Boiarskaia et al., 2011).

Our first research question was concerned with the relationship between PF and teacher-assigned grades. Results from the MANOVA identified a significant main effect for the number of curl-ups on the overall average grade (Wilk's $\lambda = .789$, $F(5, 46) = 2.46$, $p = .047$) with the other fitness variables having no overall significant effect. Univariate follow-up tests identified that PACER laps had a significant influence on standardised reading ($F(1, 50) = 4.05$, $p < .05$, $\eta^2 = .07$), writing ($F(1, 50) = 9.26$, $p < .004$, $\eta^2 = .156$), mathematics ($F(1, 50) = 5.02$, $p < .030$, $\eta^2 = .091$) and science ($F(1, 50) = 6.35$, $p < .020$, $\eta^2 = .113$) grades, but not social studies. All other fitness tests had no significant effect on the individual subject grades.

Our second research question investigated whether there were covariates that moderated the relationship between PF and teacher-assigned grades or whether demographic characteristics contributed any unique variance to the prediction of grades. Since aerobic fitness (i.e. PACER laps) was the most consistent PF source of variance in teacher-assigned grades, we tested whether there were moderating factors of PACER laps via ethnicity, gender or BMI percentile categories. According to the results from the general linear model analysis, there were no significant interaction effects between PACER laps and any of the demographic variables on overall teacher-assigned grades. In addition, there were no significant differences present for reading, writing, mathematics, social studies or science grades between ethnic groups or among BMI percentile strata. However, girls typically had higher grades than boys in reading (standardised mean difference = 0.61; $t(16) = 2.109$, $p < .05$). No significant gender differences were found for the other subject grades. Finally, no significant differences for average grades were seen across BMI percentile ranks.

Discussion

The purpose of this study was to investigate the relationship between different components of PF and teacher-assigned grades in a sample of fourth-grade students. The results of this study indicated that aerobic fitness, assessed through the PACER test, was the only PF component positively associated with individual teacher-assigned grades, when controlling for influences of gender, ethnic background and BMI percentile classifications. Specifically, the PACER was found to account for about 7% of the variance in reading, 15% in writing, 9% in mathematics and 11% in science grades. BMI did not significantly add to the prediction of students' academic performance over and above the PACER scores. While curl-ups had a significant omnibus test result from the MANOVA, there was no significant unique effect on the individual subject grades. This is likely due to

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Table 2. Descriptive statistics for academic grades and fitness components by gender.

	Girls				Boys			
	N	*M*	*SD*	HFZ (%)	*N*	*M*	*SD*	HFZ (%)
Grades								
ZReading	38	0.19	0.74	–	42	–0.16	1.10	–
ZWriting	38	0.17	0.91	–	42	–0.17	1.04	–
ZMathematics	38	0.11	0.82	–	42	–0.11	1.13	–
ZSocial studies	38	0.05	0.78	–	42	–0.06	1.16	–
ZScience	38	0.13	0.81	–	42	–0.10	1.13	–
Fitness components								
PACER	36	22.03	11.19	95	40	28.85	16.24	95
Push-ups	36	9.11	5.67	66	41	11.41	6.32	76
Curl-ups	36	13.39	6.46	68	41	15.88	13.08	57
Sit and reach	36	10.30	1.48	86	41	8.93	2.00	67
Trunk lift	36	7.15	1.87	67	41	7.62	1.92	56
	N	*n*	Percentage		*N*	*n*	Percentage	
BMI								
Underweight	36	4	11.11	–	37	3	8.11	–
Normal weight	36	20	55.56	–	37	26	70.27	–
Overweight	36	5	13.89	–	37	3	8.11	–
Obese	36	7	19.44	–	37	5	13.51	–

BMI: body mass index; PACER: Progressive Aerobic Cardiovascular Endurance Run; HFZ: healthy fitness zone; *SD*: standard deviation.
Mean values and standard deviations for academic grades and all fitness components except BMI, which are reported as percentage of students within each category. Minimum–maximum ranges for each fitness component were PACER (girls = 8–56 laps, boys = 8–77 laps); push-ups (girls = 2–24 reps, boys = 1–24 reps); curl-ups (girls = 2–32 reps, boys = 2–60 reps); sit and reach (girls = 6.75–12 in, boys = 4.75–12 in); trunk lift (girls = 3.5–12 in, boys = 4–12 in). Unit of measurement: PACER = no. of laps; push-ups = no. of push-ups; curl-ups = no. of curl-ups; sit and reach = inches; trunk lift = inches. HFZ = percentage of students meeting healthy fitness zone criteria from FITNESSGRAM performance standards. Frequencies and percentages for each BMI percentile (BMI < 5th percentile = underweight; 5th ⩽ BMI < 85th percentile = healthy/normal weight; 85th ⩽ BMI < 95th percentile = overweight; BMI ⩾ 95th percentile = obese). Excludes missing data (total number of girls = 38; total number of boys = 42).

differences in the computation of the test statistics for the MANOVA omnibus test that looks at any difference across any subject grade (i.e. curl-up results had an influence on the mean grades; $\mu_r \neq \mu_w \neq \mu_m \neq \mu_{ss} \neq \mu_{sci}$) and non-specific influences on an individual grade. When univariate follow-up tests were performed, there was no significant influence of curl-up performance on any of the subject mean grades.

In addition, there was no significant interaction between PACER laps and ethnicity, gender or BMI percentile rank, suggesting that aerobic fitness had the largest unique influence on the variance in average teacher-assigned grades. Moreover, there were no differences in teacher-assigned grades between non-Hispanic or Latino students or Hispanic or Latino students, or among the BMI percentile rank categories. The only covariate that contributed to differences in grades was gender, with girls scoring an average of 0.60 *SD*s higher for their reading grade, compared to boys. This suggests the influence of aerobic fitness on academic performance is consistent and not dependent on the ethnicity, gender or BMI of the student, which is consistent with the findings of other studies (e.g. Desai et al., 2015; Haapala et al., 2014; Hansen et al., 2014). Although the proportion of

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Table 3. Descriptive statistics for academic grades and fitness components by ethnic group.

	Non-Hispanic or Latino				Hispanic or Latino			
	N	*M*	*SD*	HFZ (%)	*N*	*M*	*SD*	HFZ (%)
Grades								
ZReading	65	0.16	0.92	–	15	−0.67	0.84	–
ZWriting	65	0.12	0.96	–	15	−0.55	0.99	–
ZMathematics	65	0.10	0.96	–	15	−0.44	1.05	–
ZSocial studies	65	0.10	0.89	–	15	−0.45	1.31	–
ZScience	65	0.03	1.04	–	15	−0.08	0.74	–
Fitness components								
PACER	62	27.08	14.73	95	14	19.14	11.05	93
Push-ups	63	10.67	6.15	74	14	8.86	5.86	60
Curl-ups	63	14.90	10.84	62	14	13.86	9.29	67
Sit and reach	62	9.40	1.98	73	14	10.38	1.16	87
Trunk lift	63	7.45	1.83	62	14	7.18	2.24	57
	N	*n*	Percentage		*N*	*n*	Percentage	
BMI								
Underweight	60	6	10.00	–	13	1	7.69	–
Normal weight	60	41	68.33	–	13	5	38.46	–
Overweight	60	6	10.00	–	13	2	15.38	–
Obese	60	7	11.67	–	13	5	38.46	–

BMI: body mass index; PACER: Progressive Aerobic Cardiovascular Endurance Run; HFZ: healthy fitness zone; *SD*: standard deviation.
Means and standard deviations for academic grades and all fitness components except BMI. Minimum–maximum ranges for each fitness component were PACER (non-Hispanic or Latino = 8–77 laps, Hispanic or Latino = 8–50 laps); push-ups (non-Hispanic or Latino = 1–24 reps, Hispanic or Latino = 2–21 reps); curl-ups (non-Hispanic or Latino = 2–60 reps, Hispanic or Latino = 2–33 reps); sit and reach (non-Hispanic or Latino = 4.75–12 in, Hispanic or Latino = 7.5–12 in); Trunk lift (non-Hispanic or Latino = 4–12 in, Hispanic or Latino = 3.5–12 in). Unit of measurement: PACER = no. of laps; push-ups = no. of push-ups; curl-ups = no. of curl-ups; sit and reach = inches; trunk lift = inches. HFZ = percentage of students meeting healthy fitness zone criteria from FITNESSGRAM performance standards. Frequencies and percentages for each BMI percentile (BMI < 5th percentile = underweight; 5th ⩽ BMI < 85th percentile = healthy/normal weight; 85th ⩽ BMI < 95th percentile = overweight; BMI ⩾ 95th percentile = obese). Excludes missing data (total number of non-Hispanic or Latino students = 65; total number of Hispanic or Latino students = 15).

variance in students' average grade accounted for by PACER scores may seem small, it may have significant practical implications, particularly in this era of heavy emphasis on academic achievement, since 10% is equal to half a letter grade or 1 point in a 10-point rating system.

While the potential explanations for why the more aerobically fit students tend to perform better academically are unclear, it has been suggested that this association may be a reflection of factors such as modifications to brain structures, cerebral blood flow or brain-derived neurotropic factors (Etnier et al., 2006), students' achievement orientation or overall health (Chomitz et al., 2009). Ultimately, this suggests that students who perform better on aerobic tasks as well as within the classroom may have psychosocial factors, physiological factors or habits (nutrition, exercise, etc.) that positively impact performance in these areas.

This study's findings confirm and extend the findings of previous research studies that academic achievement is directly related to aerobic fitness (Castelli et al., 2007; Chen et al., 2013; Desai et al., 2015; Haapala et al., 2014; Hansen et al., 2014; Rauner et al., 2013; Telford et al.,

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2012; Van Dusen et al., 2011; Wittberg et al., 2010). While previous research assessed academic achievement through standardised achievement tests (Castelli et al., 2007; Desai et al., 2015; Haapala et al., 2014; Hansen et al., 2014; Rauner et al., 2013; Roberts et al., 2010; Telford et al., 2012; Van Dusen et al., 2011; Wittberg et al., 2010), this study confirms the previous relationship through the use of a different and perhaps more inclusive form of assessment, teacher-assigned academic grades. Previous research has suggested the relationship was particularly relevant to math and reading scores (Castelli et al., 2007; Desai et al., 2015; Du Toit et al., 2011; Haapala et al., 2014; Hansen et al., 2014; Rauner et al., 2013; Telford et al., 2012), with this study demonstrating a positive relationship with reading, writing, mathematics and science as well.

In this study, BMI did not have a significant unique influence on students' grades beyond the contribution of aerobic fitness. One possible explanation for this finding may be the collinearity between PACER and BMI scores; that is, the two measures have been found to be significantly and moderately negatively correlated (i.e. heavier students tended to perform worse on the PACER test as compared to lighter students). This finding is consistent with the findings of other studies in which no association was found between BMI and academic achievement measures (Chen et al., 2013; Desai et al., 2015; Rauner et al., 2013; Van Dusen et al., 2011).

This study did not find a relationship among muscular fitness and flexibility components of PF and student's grades. These findings are consistent with the findings of other studies in which no significant associations between these PF components and academic performance were found (Castelli et al., 2007; Chen et al., 2013). At the same time, our findings contradict the findings of studies in which measures of muscular fitness (Coe et al., 2013; Du Toit et al., 2011) or flexibility (Du Toit et al., 2011) were positively related to academic achievement. It should be noted that different tests of PF were used in these previous studies, which could explain the conflicting findings.

The strengths of this study include the assessment of all five health-related PF components as well as the use of a valid and reliable field-based test for the assessment of students' PF. The limitations of this study include the relatively small sample size and limited information on school, teacher and student context that may contribute to variance in PF and/or grades. In interpreting the results of this study, caution should be taken in that the cross-sectional design employed does not allow for causal relationships to be assumed. Future research could be conducted to determine whether there is a cause and effect relationship between PF and grades. An example might be a randomised control trial that assigns classrooms to a PF intervention (specifically aerobic fitness), additional content instruction with no fitness training, or a concurrent fitness and instruction group to measure changes in cognition, attention and grades.

The findings of this study and numerous other studies that show positive associations between PF and health indices, academic and/or cognitive performance, suggest that PF and activities that can help children improve their PF ought to be a central component of PE and broader school physical activity programmes. Collectively, these findings can help alleviate the clash between public health and education agendas and provide support for policies that encourage physically active lifestyles. These findings can be used to counter attempts to limit school physical activity time, which are often implemented with the aim of improving academic performance despite scientific evidence suggesting otherwise (e.g. Carlson et al., 2008; Castelli et al., 2015; CDC, 2010; Trost and Van der Mars, 2009). Furthermore, despite the controversy that often surrounds PF testing in schools, PF testing can be positively and productively implemented in PE programmes (Silverman et al., 2008). However, this has implications for PE teacher education programmes and beyond, including state policies related to PF testing and how the results are used.

In conclusion, the findings of this study add to the growing literature base indicating a positive relationship between aerobic fitness and academic achievement in children. The uniqueness of this

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study primarily relates to the assessment of academic achievement through grades assigned by classroom teachers since previous studies have primarily assessed student academic achievement through standardised test scores.

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