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# Indirect and direct relations between aerobic fitness, physical activity, and academic achievement in elementary school students

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ABSTRACT

*Background:* There is evidence to suggest that increasing physical activity (PA) improves academic achievement (AA) in children and that aerobic fitness is associated with both cognitive function and AA. However, it is not known how these variables are interrelated and analyses with adequate control for socioeconomic variables are needed. It was hypothesized that PA would not directly affect AA but would have an indirect effect on AA through its effect on aerobic fitness. The purpose of this study was to test this hypothesized mediation using path analysis.
*Methods:* Cross-sectional data including AA, aerobic fitness, and daily PA assessed through accelerometry were collected from a large sample ($N = 687$) of 2nd and 3rd grade students. Demographic data were assessed via parent self-report.
*Results:* A total of 401 students wore the accelerometer for at least 10 h on 3 days or more and were included in the final path analysis to evaluate potential relations among PA (predictor), aerobic fitness (mediator), and WIAT-III subtest standard scores (outcomes; i.e., reading, spelling, and mathematics). Findings showed a direct effect of PA on aerobic fitness ($b = .009$, $p < .001$) and an indirect effect (mediation) of PA via fitness on math achievement ($b = .003$, $p < .01$) after controlling for student's grade, gender, body mass index, mother's education level, and household income, as well as intraclass correlations among classes and schools. Neither PA nor aerobic fitness were correlated with WIAT-III reading or spelling scores.
*Conclusions:* Mediation analysis indicated that PA exerted an influence on math achievement through its effects on aerobic fitness but was not associated with reading or spelling achievement scores.


## 1. Background

Childhood obesity is prevalent in the United States (Ogden, 2010), presenting a major threat to public health. Childhood obesity has been associated with both physical health problems (Krebs & Jacobson, 2003) and poorer academic achievement (AA) (Howie & Pate, 2012; Judge & Jahns, 2007). Increasing physical activity (PA) and aerobic fitness are often proposed as a way to improve children's health and AA but there has been some inconsistency across studies concerning the relation between PA, aerobic fitness, and AA. This is due in part to measurement and methodological issues (e.g., measuring only PA or aerobic fitness, lack of adequate control for socioeconomic variables), but the overall pattern of findings indicates either a positive or null association (Castelli, Hillman, Buck, & Erwin, 2007; Centers for Disease Control and Prevention; Chaddock, Pontifex, Hillman, & Kramer, 2011; Coe, Pivarnik, Womack, Reeves, & Malina, 2006; Davis, 2011; Donnelly et al., 2009; Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001). Rarely is a negative association reported (Ahamed et al., 2007; Centers for Disease Control and Prevention; Sallis et al., 1999; Tremblay, Inman, & Willms, 2000). Missing from this literature is a clear understanding of how each indicator (PA and aerobic fitness) operates together and separately to influence AA.

Active children generally display healthier cardiovascular profiles (Boreham & Riddoch, 2001), and past research has shown that aerobic fitness and PA are moderately correlated in this population (Pate, Dowda, & Ross, 1990). In a cohort study of 248 children (ages 8–11), time spent in vigorous PA was correlated with $VO_{2peak}$, a measure of aerobic fitness, in both boys and girls ($r = .32$ and $r = .30$ respectively,

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both $p < .05$ (Dencker et al., 2006)). However, few studies on the relation of PA, aerobic fitness, and AA have measured both PA and aerobic fitness. In studies that have, the associations with AA have been evaluated in separate models, thereby failing to statistically account for possible collinearity (e.g., shared variance of PA and aerobic fitness) (Dwyer et al., 2001). Additionally, the relationship between PA and aerobic fitness suggests mediated effects on AA (Welk & Meredith, 2008). Specifically, the effect of PA on AA could be transmitted through its effect on aerobic fitness (Chaddock et al., 2011). Aerobic fitness reflects the capacity of the body to do physical work (Bray et al., 2009), and can be measured in children using maximal (American College of Sports Medicine, 2012) and submaximal exercise tests such as the Progressive Aerobic Cardiovascular Endurance Run (PACER) (Leger, Mercier, Gadoury, & Lambert, 1988; Welk & Meredith, 2008). Aerobic fitness is influenced by hereditary factors and lifestyle factors, including PA level (Bray et al., 2009). Several studies have demonstrated that aerobic fitness is associated with better cognitive function and AA (Chaddock et al., 2011; Hillman, Castelli, & Buck, 2005; Voss et al., 2011; Welk & Meredith, 2008). Research is needed to better understand the interrelationships between PA, aerobic fitness, and AA.

The purpose of the present study was to evaluate how both PA and aerobic fitness are related to AA in a sample of 2nd and 3rd grade students. Given the limitations in past research, this study included important controls for socioeconomic variables and separate measures of PA and aerobic fitness.

## 2. Methods

### 2.1. Participants

Seventeen schools were recruited to participate in the present study, which is part of a larger investigation of the effects of physically active academic lessons on academic outcomes (NIH R01 DK085317). The parents of students in 2nd and 3rd grades received a flyer describing the study, including exclusion criteria and assessment procedures. Parents of students interested in participation provided their contact information to the 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, including AA, aerobic fitness, and daily PA. Participants also completed tests of cognitive function, anthropometrics, blood pressure, and blood chemistry for the larger study. The study was approved by the Human Subjects Committee at the University of Kansas.

### 2.2. Procedure

All assessments were completed at the respective schools by trained research staff blinded to study condition. More detail on the training of the staff is provided in the instrumentation section. Testing for this study was completed over the course of 2 days, with each visit lasting approximately 1 h. The accelerometer was issued at one of the visits and collected at a later date. All of the measures were completed prior to the initiation of the exercise intervention for the larger study.

### 2.3. Instruments

Demographics. Parents completed a demographic questionnaire that assessed the grade, age, gender, ethnicity, and race of their student, as well as the education level of the mother and household income.

Academic achievement (AA). AA was assessed using the Weschsler Individual Achievement Test-Third Edition (WIAT-III) (Wechsler, 2009). The WIAT-III was individually administered by research staff trained and supervised by a qualified co-investigator. Following WIAT-III score computation guidelines, three scores were generated for this study based on five WIAT-III subtests (reading comprehension and oral reading fluency, spelling, and mathematics problem solving and numerical operations): composite reading (reading comprehension and oral reading fluency subtests), composite mathematics (mathematics problem solving and numerical operations subtests), and spelling. The test took approximately 40–50 min to complete.

The research staff completed a 3-h training delivered by the qualified co-investigator, and followed by several practice administrations and a passing grade on a WIAT scoring test. The initial tests administered by the research staff were supervised by the qualified co-investigator and corrective feedback was provided if necessary. The WIAT-III was scored by the research staff who administered thte test and all tests were checked for accuracy by a trained investigator. Any discrepancy in scores between the research staff and the trained investigator was resolved by the qualified co-investigator. Scores were entered into the WIAT-III computerized scoring assistant, which automatically disallowed out-of-range values and computed subtest and composite scores.

Aerobic fitness. Aerobic fitness was assessed using the PACER (Welk & Meredith, 2008) which is based on the 20-m shuttle run (Leger et al., 1988). There is extensive literature describing the reliability and validity of the 20-m PACER across several age groups (Carrel et al., 2012; Leger et al., 1988; Mechelen, Hlobil, & Kemper, 1986; Welk & Meredith, 2008). The 20-m PACER is commonly used around the world in children of a wide age range (age 6–19 years) as evidenced by a meta-analysis of 418,026 children in 37 countries (Olds, Tomkinson, Léger, & Cazorla, 2006). Utilizing the 20-m PACER test affords a greater ability to compare and contrast to a wider range of studies in this area. The 20-m PACER will permit monitoring of aerobic fitness changes over the 3-year A + PAAC study as the children progress to 5th and 6th grade.

To perform the PACER, the student was instructed to run back and forth between 2 lines, 20-m apart, as the time allowed. The student was paced by a beep recorded on a CD to indicate when he or she should reach each end of the 20-m course. The pace began slowly and progressively increased. The test ended for each student when he or she failed to traverse the 20-m distance in the time allotted on 2 occasions. Research staff were trained by a qualified co-investigator to identify and track when a student failed to traverse the required distance. Staff were supervised by a co-investigator with extensive experience administering the PACER. The longer a student continued (i.e., more laps) indicated a higher level of aerobic capacity. The measure used in the analysis was the total number of laps completed.

Daily Physical Activity. The student 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). Accelerometer data were collected and summarized in 1-min epochs with a minimum of 10 h of wear time constituting a valid monitored day. ActiGraphs were distributed to each student on Wednesdays and Fridays and returned to the school following completion of the 4-day monitoring period. The measure for daily PA was the average ActiGraph counts/min over the 4-day period. Data were analyzed using custom software that was developed by a co-investigator for the larger trial.

### 2.4. Data analysis

Four-hundred and one students wore the accelerometer for $\geq 3$ valid days and were retained for analysis. Study variables were examined for distributional properties and all were normally