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The relationship between school-based physical activity and academic achievement among 4th grade students in Georgia public schools

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Bachelor of Science
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A thesis submitted to the Faculty of the
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Abstract

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Background: More than 50% of children aged 6-17 fall short of the nationally recommended 60 minutes of daily PA. Serving 35 million children nationwide, elementary schools provide a compelling environment to increase PA. However, overcrowded curricula designed to enhance standardized test performance restrict students' PA opportunities. If PA is consistently associated with higher academic achievement, school districts may more highly prioritize it as an integral part of the school day. Specific objectives of this analysis included 1) to examine the effect of a school-based PA intervention, *Health Empowers You!*, on physical activity levels, physical fitness levels, and academic achievement (AA), 2) to assess whether changes in PA and physical fitness impacted standardized test scores, and 3) to evaluate the effects of sex and socioeconomic status (SES) on the relationship between PA and AA.
Methods: HealthMPowers collected data on a total of 1,829 4th grade students from 23 intervention and 7 control schools in 3 Atlanta school districts during the 2015-2016 academic year. Standardized test scores were obtained from school districts and linked with PA data by students' Georgia Testing IDs. Two sample t-tests of mean differences between students attending intervention and control schools were conducted on the following variables: SES, sex, classroom steps, PACER laps, BMI percentiles, and test scores for Mathematics, English Language Arts (ELA), and Lexile reading. Multiple linear regression models were fit for each test subject.
Results: Though control students were significantly higher at baseline, intervention students consistently increased their steps to attain a higher overall average than controls (3416.1 vs. 3182.8, $p<0.0001$). Intervention students obtained significantly higher standardized test scores in math (524.6 vs. 517.6, $p=0.0051$) and in Lexile reading (825.3 vs. 794.2, $p=0.0008$). Changes in PA variables over time were not significantly associated with AA. However, SES was significantly associated with higher scores in all subjects, indicating an important covariate between health and achievement.
Conclusion: This analysis contributes to the expanding body of literature on the impact of school-based PA on AA. As evidence strengthens, educational programs and policies may integrate public health and education to enhance students' physical health and academic success.

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LITERATURE REVIEW

Effects of Physical Activity

Broadly defined, physical activity (PA) is any bodily movement produced by skeletal muscle contractions that increases energy expenditure above resting. Types of PA are numerous and diverse ranging from structured, aerobic movements like running and fitness classes to lower intensity movements such as gardening and walking [1]. Empirically-based organizations, including the Centers for Disease Control and Prevention (CDC) and the Office of Disease Prevention and Health Promotion (ODPHP), point to PA as one of the most important behaviors for optimum health since it has been associated with the following positive outcomes: increased physical fitness, which is a complex set of functional capabilities that includes cardiovascular fitness, muscular strength, and endurance [2]; regulated metabolism and blood pressure [3]; and reduced stress and anxiety [1, 3].

Conversely, lack of PA or physical inactivity is a major behavioral risk factor for several chronic disease outcomes, one of the most serious being obesity, which has an estimated prevalence of 17.5% among 6-11 year-olds [4]. Other serious health problems include type 2 diabetes and cardiovascular disease [5]. Though chronic diseases are multi-factorial in nature, physical inactivity is perhaps the most important [3]; it is the fourth leading risk factor for mortality, responsible for 6% of global deaths [6].

The associations between regular PA and physical health are widely accepted, but the effects of PA on cognitive well-being and academic performance are less clear-cut [7]. Academic performance describes an array of factors that influence the success of students in school and is divided into three areas: cognitive skills and attitudes, academic behaviors, and academic achievement [8, 9]. Researchers have hypothesized positive effects of regular PA on a number of aspects of academic performance: improved classroom conduct such as fewer behavior and attention deficit issues, better processing speed and memory, and most importantly higher academic achievement (AA) on standardized tests and other assessments [10].

Physical Activity Trends and Efforts

Since PA is so critical to the health and well-being of youth, national reports, most notably the *2008 Physical Activity Guidelines for Americans,* urge children and adolescents aged 6-17 to attain at least 60 minutes of physical activity daily [11, 12]. Further, more than 50% of that time should be moderate-to-vigorous physical activity (MVPA), meaning that their heart rates increase and they breathe heavily [12]. Despite the abundance of evidence recognizing that PA is a vital component of health, more than half of children aged 6-17 in the U.S. fall short of the standard. Even more troubling is the fact that the proportion of children and adolescents achieving the recommendation *declines* with age [10].

The 2014 National Physical Activity Plan (NPAP) report card further highlights the sedentary tendencies of America's youth. Overall physical activity was rated a D-, meaning that only approximately 25% of children attained 60 minutes or more of MVPA on at least 5 days per week [13]. The NPAP report also rates schools as a C-, based on their lack of provision of adequate PA opportunities throughout the school day. In 2012, almost all U.S. school districts (94%) required elementary schools to teach PE, however this does not ensure adequate quality, duration, frequency, or intensity of classes. Surprisingly, only 59% of the districts required regularly scheduled recess for children and even fewer (12%) required any PA breaks outside of PE and recess time [13].

As a result of noticeably low PA trends especially in schools, there have been many efforts to persuade schools to enhance the number and quality of PA opportunities [11, 14, 15]. The federal government's evidence-based agenda for a healthier nation, Healthy People 2020, dedicated two of its objectives to the prioritization of PA in the school setting: "Increase the proportion of the nation's public and private schools that require daily physical education for all students" and "Increase the proportion of adolescents who participate in daily school physical education" [14]. Authoritative international agencies like the World Health Organization (WHO) and medical organizations like the American Heart Association (AHA) also support schools' role in promoting students' well being by providing adequate PA opportunities [15].

Further, the *Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation* report outlines strategies for schools. It calls on departments of education to implement quality PE standards for all grades and urges school districts to enhance the conduciveness of school environments to PA in order to make schools a focal point for obesity prevention [11]. Also involved in school-based efforts is a component of Michelle Obama's comprehensive White House initiative, *Let's Move! Active Schools*. With a primary goal of reversing trends of physical inactivity and obesity among youth, this program seeks to strengthen PE and make 60 minutes of school-based PA the "norm," using the Comprehensive School Physical Activity Program (CSPAP) [10].To date, *Let's Move! Active Schools* has recruited more than 20,000 schools and affected more than 11 million students nationwide [16].

Though there are many top-down recommendations, efforts, and programs, there are no national standards for classroom physical activity and there is not a single universally correct method for improving PA for elementary-aged children. Most important though is that metabolic and cardiovascular problems associated with lack of adequate activity levels are being observed among younger and younger populations [11]. These risks, along with their undesirable behaviors, will track across the lifespan if left unchanged [6]. Adequate physical activity is critical during children's formative years to promote healthy physical and cognitive development and longevity [6] so targeted interventions must prioritize building healthy habits by getting students moving.

The Rationale for School-Based Interventions

A very compelling rationale exists for why elementary schools provide a unique and vital setting to promote PA among children. More than 95% of children in the United States attend school; this approximates to 35 million elementary-aged students [17]. Due to numbers alone, schools' programs and policies have the opportunity to make realistic, far-reaching impacts. In addition, children spend at least 30 hours per week at school, providing schools with a lot of contact time [6]. PA integrated into the school day can satisfy most of children's daily PA needs while boosting their physical fitness levels [18]. Since schools are undoubtedly a central part of children's daily lives, it seems obvious that they assume an integral role in cultivating healthy behaviors like PA [19].

Though educators have many opportunities to get students moving during the 7-8 hour school day, relatively little structured activity is being incorporated into elementary classrooms [6, 20]. As a result, students are not moving enough during the school day. From the schools' standpoint though, there are several hindrances to incorporating strong school-based physical activity programs. First, schools are limited by staff and resources. They have few well-trained personnel who can implement effective classroom PA strategies, run high quality PE classes, and engage students in adequate amounts of MVPA [6, 18]. In addition, they lack equipment for PE and other activities [10]. The biggest barriers to school-based PA, however, are a primary responsibility to educate and, consequently, time.

Because of laws like the No Child Left Behind Act of 2001, academic achievement standards are very highly regarded and standardized test performance is over-emphasized [20, 21]. Teachers are expected to cover a breadth of subject material to adequately prepare students for the next grade level, so school administrations dedicate more time throughout the school day to learning [9]. As a result of this "crowded curriculum" and pressure to increase scores, non-academic activities with PE at the forefront are often cut [6, 9]. In fact, nearly half (44%) of school administrators reported cutting significant time from PE and recess after the enactment of the 2001 law [10]. As such, in 2014 only 3.6% of all elementary schools required daily PE [14]. Though a body of evidence supports the fact that PE classes are physically and cognitively beneficial for students, there is no evidence indicating improved AA as a result of cutting PE [8]. Somehow this trend of cutting PE in favor for instructional time persists and academics wholly overshadow health promotion [6, 9].

School districts and administrations are clearly very invested in students' educational success and prioritize what they think will advance their academic-minded efforts. Though there is a general accord that PA positively impacts academics and should be an integral part of the school day, this will not happen unless schools recognize it as an integral part of academic success [22]. Referred to as the "holy grail," if a positive connection between PA and academic achievement is well evidenced, then departments of education and local school districts may require increased PA time throughout the day, setting students on the right track for not only academic success but also lifelong health [15]. The current situation of constraints and pressures necessitates more evidence-based research though.

Physical Activity and Academic Achievement

In general, there is much interest in the topic of PA and AA and a large volume of recent literature supporting positive associations between them, but a lack of strong evidence still exists. Perhaps the most definitive notion is that school-based PA does not have any negative effects on academic performance [2, 23]. Though this justifies maintaining PA programs in schools, it does not necessarily provide evidence the *need* for them. Schools will not be inclined to change their curricula to prioritize PA in favor of academic time unless they are confident it will be worthwhile. Recently, the consistency of positive results is supported by the fact that almost all studies (95%) examining the relationship between PA and AA since 2007 have found at least one positive result; only 1 study presented a negative result [15]. Several recent systematic reviews of relevant studies produced similar findings [7, 21, 23].

A 2013 review of 8 randomized controlled trials (RCTs) included 4 studies that assessed the impact of aerobic physical activity interventions on academic achievement and reported improved standardized test performance among students receiving the intervention, indicating a promising, positive effect between PA and AA [7]. Only 2 of the studies included elementary-aged populations in the U.S., however. The first, a 3-year cluster RCT (n=527 2nd and 3rd graders), found that students who participated in the intervention of 45 minutes of weekly aerobic PA sessions performed significantly better, improving by approximately 6% more, in math and reading than their control counterparts [24]. The second study [25] was a shorter, only 4 months long, RCT (n=155 3rd graders) that tested the integration of aerobic PA into core curriculum 3 times per week; children in the APA group had higher, though non-significant, achievement test scores in math and English Language Arts (ELA). Small sample size availability may have underpowered this study and limits the generalizability of results. This review also highlights the few number of randomized studies that have been conducted among U.S. elementary-aged students.

A 2016 systematic review examined physical activity, physical fitness, and academic achievement through the impact of PA and FITNESSGRAM (FG) tests on standardized test performance. Positive associations between fitness and academic success were found in all 3 longitudinal studies examining this relationship [21]. In one, students who maintained high scores on the FG test for aerobic capacity averaged higher scores on AA tests than those students who did ran fewer PACER laps [26]. This review builds upon earlier intervention studies that assess physical fitness via FG tests. One showed a statistically significant positive linear relationship between physical fitness and AA on standardized tests, meaning that students who improved their fitness scores on the battery of six FG tests saw improvements in their test scores [22]. Another echoed these results showing that cardiovascular/aerobic fitness on FG was significantly positively associated with AA in math and reading [27]. Yet another found increased odds ranging from two-to-four-fold of standardized AA in math and reading among students who achieved the Healthy Fitness Zone for the PACER test of aerobic capacity [28].

Further, a 2010 CDC in-depth systematic review included 43 articles from an initial review of more than 400. Approximately half (50.5%) of all associations tested were positive, indicating that PA consistently improved elementary-aged students' educational outcomes including academic achievement, academic behavior, and cognition [23]. Of 14 school-based PE studies that examined the frequency (2 times/week vs. daily), duration (20 vs. 30 or 40 minutes/class), or intensity (MVPA) of classes, 11 studies (79%) found that increased time in PA had a positive effect on AA [23]. Another 9 studies explored the integration of short PA breaks into classroom time, and 8 of them found positive associations with measures of cognitive skills and academic behaviors, which are classroom indicators that affect standardized test scores. The impact of classroom PA was also evidenced by a 2-year quasi-experimental study, which showed significantly higher math scores and non-significantly higher reading scores on state standardized tests as a result of a school-based obesity prevention intervention [29].

Although standardized test scores are generally positively associated with PA levels, there are some mixed results in terms of strength of association for subject level outcomes [21, 23]. Some studies found significant positive linear relationships between PA and both reading and math achievement scores [21, 22]. Another showed that classroom-based PA significantly improved test scores in math, reading, and spelling but noted that the relationship was especially apparent in math, where scores were approximately 6 points higher [20]. A previously-mentioned review [21] summarized varied results from 14 intervention studies, 5 finding clear improvements in all test subjects, 3 finding impact in math, and 6 finding no significant improvements. None of the 14 studies specifically examining PA and academics found negative associations though, which adds to the argument that time spent in PA is not detrimental to AA. Other studies have only found significant results for a certain subject like math [29] or social studies [25] while one RCT indicated no significant effect on AA [30]. In general, there is a lack of clarity as to whether PA improves all aspects of AA of just some domains. These results indicate that studies should examine subject-specific outcomes, e.g. score on reading separately from mathematics.

Factors Associated with PA and AA

In addition to analyzing AA on standardized test scores as a subject-specific outcome, there are a few major considerations for potential covariates: gender and SES [15]. The relationship between PA and AA has been shown to vary by these factors. One study showed a significant interaction effect of sex with the rate of change in mean achievement test scores as a result of increased fitness being greater among females; the most fit females scored 17 points higher than the most unfit females in reading while this difference was only 12 points among males [22]. Another revealed that males had higher adjusted odds of academic success in math and reading compared to females [28] while other review articles indicated no significant differences in test scores by gender [9]. Despite conflicting evidence on the role of sex, many researches recommend collecting and examining its potential mediating effects during analyses [15, 21, 23].

Socioeconomic status (SES) is another factor that impacts the relationship between PA and AA. In one study, students of low SES status scored significantly lower on all standardized achievement tests than students of high SES; further SES was found to be the strongest indicator of AA [31]. Since SES measures are often not available [23], some studies have used participation in the National School Lunch Program (NSLP) for free or reduced lunch (FRL) as a proxy for SES. One study found that although test scores increased for students of both high and low SES levels as a result of increased fitness, a greater proportion of *non*-FRL students achieved higher physical fitness [22]. In other words, fit students who were of a higher SES performed significantly better academically than fit students who were of a lower SES; alternatively, students with low physical fitness and low SES had the lowest AA.

It has been noted that there is much difficulty in obtaining accurate SES data [23] and a lack of available studies have been able to control for SES [31] in examining the relationship between PA and AA among children. Nonetheless, it is advised the researchers try to control for SES in some proximal way [21] since it has been indicative of both better health and higher achievement and could confound the PA-AA relationship [22].

In sum, increased time in PE did not negatively impact AA. Of the 23 years of literature analyzed by systematic reviews, only 4 associations in total, or 1.5%, were negative [23]. PA does not negatively detract from learning time or cause adverse academic effects; schools can enhance or reinstate, if previously cut, their PA programming without risking students' academic success [9]. Many studies have even found significant positive effects of increased frequency, duration, and intensity of physical activity throughout the school day on students' AA. Potential modifiers, such as sex and SES, should be measured and controlled for in analyzing the relationship between PA and AA [21-23]. Researchers postulate several limitations that, if addressed, would enrich the rigor of methodology, ensure higher quality studies, and better evidence conclusions for improving school-based physical activity.

Limitations with Existing Research

In terms of exposure variables, physical activity and fitness are examined through several different constructs, including steps, minutes of MVPA, duration or frequency of PE classes, and fitness scores like the FG PACER test. Some of these measures have low methodological quality and lack validity since many are self-reported or collected by PE teachers and other staff [32]; this introduces potential bias and measurement error as these may not accurately indicate students' activity levels [2]. Due to these challenges, there is not a clear-cut conclusion or recommendation coming out of the literature, which can be misleading for schools or other bodies to base policies on [7, 32].

Other current limitations include difficulty obtaining complete PA data as well as academic data for entire samples [22] and missing measurements or inappropriate proxies for effect modifiers like SES as mentioned [9, 31]. A final limitation is the cross-sectional nature of many studies. Some methodologically strong RCTs [24, 25] have been conducted, but many studies have been cross-sectional, which does not satisfy causality assumptions since the exposure of PA does not necessarily precede the outcome of AA [2, 31]. More large-scale high-quality studies have been conducted in other countries like Australia, Norway, and Scotland where school schedules, testing content, and physical activity patterns both in and out of school are not necessarily generalizable to US trends. Thus, to examine the relationship between school-based physical activity interventions and academic outcomes in the US, more high-quality studies are needed.

Goals & Objectives

The primary goal of this analysis is to examine the association between school-based physical activity and academic achievement among a population of 4th graders in metropolitan Atlanta, Georgia. Specific objectives include the following:

1. To examine the effect of a school-based physical activity intervention on 4th grade students' physical activity levels, physical fitness levels, and academic achievement
2. To assess whether changes in physical activity, measured by daily step counts, and changes in physical fitness, measured by FG tests of PACER and BMI, have an impact on GA Milestone standardized test scores
3. To evaluate the effects of sex and socioeconomic status on the relationship between physical activity and academic achievement

METHODS

Study Design

With support from Blue Cross Blue Shield (BCBS) of Georgia Foundation, this intervention-control study was conducted in three metropolitan Atlanta school districts during the 2015-2016 academic year. Twenty-eight elementary schools (17 schools in District A and 11 in District B) were enrolled in the study to receive the *Health Empowers You!* intervention. Beginning in August of 2015, district-level Health and PE Coordinators assisted with school recruitment and worked directly with HealthMPowers staff to facilitate participation. The coordinators obtained a convenience sample of schools by contacting PE teachers in their respective districts. PE teachers spoke with 4th grade teachers and/or school principals, who ultimately decided whether the school would participate. Once a school consented, all 4th grade classrooms within that school participated. By the study's kick-off training in October 2015, all 28 intervention schools were enrolled.

With additional funding becoming available from Ardmore Health Institute, seven elementary schools from District C were added to the study as controls in January 2016. Similar recruitment methods were used for control schools. HealthMPowers staff conducted brief tutorials for teachers on the data collection devices and requested that teachers not change anything in their classrooms since the purpose of the controls was to obtain data on typical physical activity behavior. Each teacher received $200 compensation for their assistance during the study, which included serving as the research team's point of contact, coordinating logistics with the data collection devices, and uploading physical activity data to the research team.

Study Population

The study population consisted of 4,881 4th grade students who attended 35 public elementary schools enrolled in the *Health Empowers You!* study during the 2015-2016 academic year. The students came from one of the three participating school districts: 2,804 from District A; 1,085 from District B; and 992 from District C.

Fourth grade students were selected as the target population for two primary reasons. First, 4^{th} graders remain in the same classroom for most of the school day. Thus, it was feasible to implement the intervention among 4^{th} grade teachers at each participating school rather than coordinating among rotating class schedules. Second, 4^{th} grade is the first grade level for which the state of Georgia requires FITNESSGRAM (FG) reporting. These physical fitness tests can be taken at younger grade levels, but FG standards are not available because results are not reliable.

Intervention Program

Since 1999, HealthMPowers has worked to tackle the nation's increasing obesity trends by promoting physical activity in schools. Under the mission to empower healthy habits and transform environments where children live, learn, and play, the non-profit has impacted more than half a million people in underserved communities [33]. Its programs have improved major health indicators including cardiovascular fitness, moderate-to-vigorous physical activity, and BMI among elementary-aged children in Georgia by training schools and teachers to incorporate an additional 30 minutes of physical activity into the school day. HealthMPowers has many strengths including its wide reach throughout the state of Georgia, its staff expertise in school-based behavioral interventions, and its track record of improving student health behaviors statewide.

Designed using evidence-based strategies identified by the CDC, *Health Empowers You!* is a fully developed intervention that has impacted more than 20,000 students [33]. It has been recognized as a practice tested intervention by the United States Department of Agriculture (USDA) and National Collaborative for Childhood Obesity Research (NCCOR). Its comprehensive approach relies on HealthMPowers' resources, Emory University research support, and schools' facilities and personnel to conduct the following activities: implement trainings, provide resources, collect data, and improve the school environment. *Health Empowers You!* is designed to enhance student physical activity and fitness levels in order to improve educational outcomes, such as standardized test performance, ultimately impacting physical activity practices and policies [Figure 1].

The *Health Empowers You!* program consisted of 5 main components: establish a school health team, implement trainings, obtain physical activity data, provide resources, and provide technical assistance [Appendix 1]. School teams comprised of one physical education teacher, one fourth-grade teacher, and one other staff member attended trainings and served as the point of contact throughout the study. HealthMPowers delivered three trainings throughout the 2015-2016 school year, which focused on how teachers could incorporate additional physical activity into their classrooms and strategies to increase MVPA in physical education. Physical activity data was collected on 4th grade students throughout the academic year using Pebble activity trackers and Gopher FITstep Pro devices. Finally, HealthMPowers provided enrolled schools with physical activity resources, such as PA videos and sports equipment, and technical assistance.

Data Sources

Prior to any data collection efforts, Institutional Review Board (IRB) approval was completed in each of the three participating school districts. Fourth grade teachers distributed consent forms to the parents of the students in their class and requested that the form be signed and returned. The consent form included the parent's name, student's name, and student's unique Georgia Testing Identification number (GTID). Signed parental consent allowed the school system to provide the research team with individual student information including Georgia Milestone test results for Mathematics, English Language Arts, and Lexile reading. If parental consent was not obtained, the students still participated in all components of the intervention; however, their test scores were not released to HealthMPowers.

HealthMPowers staff, 4th grade classroom teachers, and PE teachers collected extensive data throughout the 2015-2016 academic year. Data sources are briefly described below and summarized in Appendix 2.

FITstep Pro Pedometers

FITstep Pro Pedometers are small clip-on activity measurement devices that serve as both a pedometer and accelerometer. During use, the FITstep Pro software internally calculates the frequency, intensity, and time of movement. Once the wearer attains 10 minutes of consecutive movement, he/she reaches the moderate-to-vigorous threshold and the device begins totaling minutes of MVPA. The device's algorithms generate a report of time of movement and steps taken during use.

FITstep Pros were provided to PE teachers in all enrolled schools to objectively measure the number of steps and minutes in MVPA that students attained during PE class. Four students from each participating school wore the devices at 5 time points throughout the school year (approximately once per month) during PE class only. After class, the students downloaded their information to a spreadsheet in the teacher's computer via a USB-linked docking device. PE teachers compiled their students' results and provided a monthly report of MVPA data to HealthMPowers.

Pebble Pedometers

Pebbles Pedometers are small and unobtrusive 1-inch circle devices that clip on to the waist. These devices accurately measure activity levels by recording the acceleration and deceleration of movement. They internally record the number of steps taken without displaying it for the wearer to see. Pebbles also have Bluetooth uploading capabilities and can store data for up to 21 days. The Pebbles were utilized for classroom step data collection.

Sets of 30-35 Pebbles were shared among 3-4 teachers at each participating intervention school. A rotational calendar was set up to facilitate the transfer of Pebbles and to keep students on track to wear the devices for approximately 1 week each month of the academic year. Step data collection took place between October 2015 and May 2016 among intervention schools. Similar schedules were established for control schools but Pebbles were only shared between 2 teachers maximum. Since control data collection began in January 2016, this ensured adequate time to collect all measurements from all students.

The 4^{th} grade teacher ensured that each of his/her students wore a Pebble from the beginning of the school day until the end of the school day for 5 consecutive days, Monday through Friday. A student wore the same device for all 5 days. Each Friday, teachers uploaded the Pebble data and rotated the box to the next teacher. This system occurred until every 4^{th} grade student had 5-day step data for a minimum of 5 weeks, totaling 25 days of step data.

FITNESSGRAM

FITNESSSGRAM (FG) is a comprehensive battery of health-related physical fitness tests, widely considered to be one of the most psychometrically sound assessments of fitness among youth [34]. FG uses a criterion-referenced, health-related approach to develop age- and gender-specific standards for aerobic capacity, body composition, and other fitness measures. The full battery of tests includes the following: Progressive Aerobic Cardiovascular Endurance Run (PACER), height/weight measurements for Body Mass Index (BMI), Curl Ups, 90° Push Ups, and the Sit and Reach test.

As a result of the Georgia Student Health and Physical Education (SHAPE) Act of 2009, all public schools in the state of Georgia were required to complete the full battery of FG tests on all 4th-12th grade students, who were enrolled in PE class, *once* per academic year beginning in the 2011-2012 school year [34]. PE teachers, who have received professional FG training, conduct these tests, record results during PE class, and report them to the state each school year.

The usual FG assessment was completed in May for all students. Additional measurements of PACER and height/weight for BMI were added to provide baseline measures for these health-related fitness variables. These specific measures were added because they have been validated as indicative measures of aerobic fitness and body composition respectively, are the most widely used FG tests, and are less subject to judgment and error when collecting. PE teachers completed these baseline measurements in September for intervention students and in January for control students.

The PACER test is 20-meter multi-stage shuttle run designed to measure aerobic capacity. Its objective is to run for as long as possible while maintaining a specific pace. PE teachers collect and report the number of completed laps for each student during each assessment. BMI, which is used as an indicator of body composition, is calculated by dividing weight in kilograms by the square of height in meters to obtain a weight-to-height-ratio. PE teachers collected height using a height chart taped to the wall and weight using a flat digital scale and reported the raw measurements for each student during each assessment.

Department of Education

The Department of Education (DOE) served as the data source for academic achievement outcomes. All 3rd through 8th grade students in the Georgia public school system complete the Georgia Milestone End-of-Grade (EOG) Assessment at the end of each academic year. Using a variety of content domains, the test assesses the learning proficiency of students in several academic subjects and provides information regarding how well students have mastered grade-specific content standards [35].

Fourth graders complete assessments in Mathematics and English Language Arts (ELA). The five Mathematics domains include Operations and Algebraic Thinking, Number and Operations in Base 10, Number and Operations-Fractions, Measurement and Data, and Geometry. The two English Language Arts domains include Reading and Vocabulary and Writing and Language. Students also receive a separate score for reading, or Lexile, which is based off of their performance on the reading portion of the ELA section. The Lexile matches a student's reading ability with the difficulty of the textual material that that student can read.

Students took the Georgia Milestone EOG Assessment in the spring of the 2015-2016 school year. Participating school districts then collected the standardized test scores in Math, ELA, and Lexile reading for all 4th grade students whose parents had provided signed consent for release of scores. They reported the scores in the form of Excel files to HealthMPowers by the end of 2016.

DOE was also the source for important demographic characteristics. Every public school in the state of Georgia collects information on the proportion of students who are eligible for free and reduced price of school meals, known as Free and Reduced Lunch (FRL). This percentage is based on the Ten-Day Count taken in schools every fall. On the 10th day of school, a count of the number of students on FRL is taken. It is compared to the total number of students in the school to calculate the proportion that is on FRL. FRL was collected by the schools and reported to the Department of Education. HealthMPowers obtained the FRL percentages for each school from the participating school districts.

Classroom Teachers

Classroom teachers were responsible for reporting student sex. Upon initial contact with participating 4th grade teachers, the research team obtained student ID number, sex, and date of birth. This information was critical to ensuring that all individual student-level data was correctly linked. Sex has also been considered an important mediator in the association between physical activity and academic achievement.

Data Measures

Exposure Variables

Intervention Status. The primary exposure variable of interest was the *Health Empowers You!* intervention. This was coded dichotomously as 1 for students who attended any of the 28 schools in the intervention group and 0 for students who attended any of the 7 schools in the control group.

Moderate-to-Vigorous Physical Activity. Collected on a subset of only four students from each participating school, MVPA was considered a secondary physical activity variable. The number of steps taken and minutes spent in MVPA during PE class were obtained as continuous values from the FITstep Pro devices. Each of the students provided five days of MVPA data, approximately one day per month. Averages were calculated for overall steps and MVPA minutes for each student and by intervention status group. Changes in steps and MVPA minutes were also calculated by subtracting each student's first day measure from his/her fifth day measure; these were also averaged to obtain group-level average change.

Classroom Steps. Classroom step data was measured on all 4th grade students in each enrolled school. It is used as an indicator of in-school physical activity and a secondary exposure variable. Students wore the Pebbles for 5 consecutive days at 5 different time points throughout the school year. Each student had 25 daily step counts, reported as the continuous number of steps taken from the beginning to the end of the school day. This allowed for the following calculations at the individual level: weekly step averages by summing each week's step count and dividing by 5 days; overall averages by summing all step counts and dividing by 25; and change in average steps from baseline to the final follow-up by subtracting the week 1 step average from week 5 step average. Group-level calculations were made by finding these average values for all students in the intervention group and comparing them to the average values for all students in the control group.

Aerobic Capacity. A validated indicator of aerobic capacity, the PACER test was considered a health-related fitness variable and a secondary exposure. Students completed the PACER as part of FG twice, which provided pre- and post-measurements of the number of 20-meter laps they ran. The continuous PACER scores were examined as averages at each time point and compared between intervention and control groups. A group-level measure of average change was calculated by subtracting each student's pre score from his/her post score, summing the differences, and dividing by the number of students in each group. A categorical measure of change was created based off of this change calculation to determine if students improved, maintained, or decreased their score between pre-assessment in September (intervention) or January (control) and post-assessment in May.

Body Mass Index Percentiles. Students' heights and weights were measured twice during the 2015-2016 academic year, which allowed for the calculation of BMI by dividing weight in kilograms by the square of height in meters. Like PACER, BMI was used a health-related fitness variable and secondary exposure. The BMI-for-age percentiles that corresponded to students' BMI values were examined as averages for each time point and compared between intervention and control groups. Measures of BMI change based on percentiles were calculated by subtracting pre- from post- measurements to examine differences between pre-assessment in September (intervention) or January (control) and post-assessment in May.

Outcome Variable

Georgia Milestone Standardized Test Scores. The primary outcome variable of interest was Georgia Milestone standardized test scores of 4th graders in public elementary schools. Test scores for Mathematics and ELA were obtained as continuous scale scores that ranged from 270-715 in Math and 210-775 in ELA. Scale scores represent mathematical transformations of the total number of points earned by each student in order to make interpretation easier and comparison across subject domains possible. Averages were obtained for each group for each subject by summing the total scores of each student in the group and dividing by the number of students in that group.

Based on pre-determined scale score ranges, students were categorized into 1 of 4 achievement levels for each subject: beginning learner, developing learner, proficient learner, or distinguished learner [Appendix 3]. These were coded as 1, 2, 3, and 4 respectively. The proportions of students belonging to each category for each subject were calculated and compared between groups.

Lexile scores were first examined continuously as an average group score and then categorically based on the "College & Career Ready" Lexile band for 4th graders, which ranges from 740L to 940L. A student's reading status indicator was "Below Grade Level" and coded as 1 if he/she had a Lexile score below or "Grade Level or Above" and coded as 0 if he/she had a Lexile score of 740 or higher.

Covariates

Sex. Student-level sex, which was obtained from teachers at the enrolled schools, was considered to be an important covariate in the relationship between PA and AA. Sex was dichotomized and coded as 0 for male and 1 for female.

Socioeconomic Status. Since the effects of PA on AA have been shown to vary by socioeconomic status, it is also considered to be an important control variable. Since student-level SES data could not be collected, the proportion of students at each school who qualified for Free and Reduced Lunch (FRL) served as a school-level proxy variable for SES. Each student attending a particular school was designated that school's approximated FRL proportion in order to allow for comparisons between students attending schools of higher and lower socioeconomic status. DOE reports FRL percentages greater than 95% with an asterisk; any asterisked values were coded as 95. A higher percentage of FRL generally indicates lower SES at the school level. A dichotomous variable was created to represent high FRL and coded as 1 for FRL proportion greater than or equal to 65% and 0 for under 65%. Consequently, a SES variable was created and coded as 1 if FRL was 0 and 0 if FRL was 1.

Data Analysis

Data were obtained in Microsoft Excel spreadsheets and imported into SAS for merging and analysis. This analysis utilized 2 datasets: PA contains exposure and covariate data, including all physical activity, demographic, and health-related variables (n=3,396); DOE contains outcome data, including standardized test scores (n=2,108) [Figure 2]. Data from four schools were excluded due to insufficient data on several variables. Prior to merging the 2 datasets by GTID number, students were excluded for having missing GTIDs (n=267) or for having test scores reported from a non-enrolled school (n=20). Of the 3,287 students in the merged data set, 77 were excluded for having mismatching school variables (i.e. the PA dataset suggested they attended a different school than the DOE dataset). Another 1,199 students were excluded because they did not have any academic data; in other words, their parents did not provide signed consent in order to release test scores. An additional 182 students were excluded because they were missing data for all physical activity variables (n=158) or they were absent on test day (n=24), resulting in 1,829 students included in this analysis. The analytic dataset was further sub-divided based on the completeness of physical activity data: 1,761 students had step data, 1,244 had pre- and post- PACER laps, 1,505 had pre- and post-BMI data, and 82 had MVPA data.

After merging, data cleaning was performed, and outlier values for steps and PACER were excluded. Daily classroom step counts less than or equal to 500 or greater than or equal to 15,000 steps were considered implausible and set to missing. Implausible PACER lap scores of less than 8 or greater than 95 were set to missing.

Descriptive statistics for all exposure, outcome, and control variables were examined as frequencies for categorical variables and means for continuous variables. Two-sample independent t-tests were used to assess significant differences in average values for FRL, classroom steps, MVPA minutes and steps, PACER laps, BMI percentiles, and standardized test scores in math, ELA, and reading between students attending intervention schools and those attending control schools. Pearson chi-square tests were run on categorical variables to test the equality of the proportion of males as well as the proportion of students in each achievement level (beginning, developing, proficient, and distinguished) between the intervention and control groups. Two-sample paired t-tests were run to examine the significance of changes in average classroom steps, MVPA minutes and steps, PACER laps, and BMI percentiles from pre- to post-assessment between intervention and control students.

Pearson product-moment correlational analyses were run to examine the bivariate relationships between potential exposures and covariates, including step averages, changes in MVPA, PACER, and BMI percentiles, sex, and SES, and the outcomes of continuous standardized test scores in math, ELA, and reading. Multiple linear regression models were fit for each of the three academic test subjects to assess the impact of the main effect of the intervention, covariates of sex and SES, and change in physical activity variables. Backwards elimination was used to determine which interaction terms and subsequently which predictors were significantly associated with test scores and should thus be included in the final models. A significance level of 0.05 was used for all statistical analyses. All analyses were performed using Statistical Analysis Software, version 9.4 (Cary, NC).

RESULTS

Descriptive Statistics

Physical activity and academic achievement data were analyzed for 1,829 4th grade students who attended 30 Georgia public elementary schools during the 2015-2016 academic year. A total of 1,178 students (64.4% of the sample) attended 23 intervention schools and 651 students attended 7 control schools [Table 1]. Approximately half of the 4th graders in each group were male, 621 (52.7%) in the intervention group and 330 (50.7%) in the control group. The mean proportion of the total school population eligible for the Free and Reduced Lunch program (FRL) was significantly higher among the intervention group (67.0% vs. 56.5%, $p<0.0001$), indicating lower socioeconomic status at the school level among intervention schools compared to controls.

At baseline,[1] control students averaged 3258.3 steps (SD=591.8) which was significantly higher than the average of 3129.0 steps (SD=706.9) among intervention students ($p<0.0001$) [Table 1]. Control students also averaged significantly more steps during PE class ($p=0.0262$) and approximately 1.7 more minutes in MVPA at baseline for MVPA[2] [Appendix 4]. Control students performed significantly better on the initial[3] 20-meter PACER test compared to intervention students (27.8 laps vs. 21.5 laps, $p<0.0001$). The average BMI percentile was similar between intervention and control students at baseline (66.2 vs. 68.5, $p=0.2$).

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[1] Baseline steps was based on the average of the first 5 consecutive days (week) of step data collection, October 2015 for intervention and January 2015 for control

[2] MVPA data were only collected on a subset of n=82 students, so MVPA results were presented independently of other analyses [Appendix 4]. MVPA data were collected during approximately 1 PE class per month among both intervention and controls students.

[3] Pre-measurements for PACER and BMI were taken in September 2015 for intervention students and January 2016 for control students

Changes in Physical Activity

Although the intervention group averaged significantly lower steps at baseline, they significantly increased their average steps each week and attained a significantly higher overall step average than control students (3,416 vs. 3,182, $p<0.0001$) [Figure 4]. Moreover, from baseline to the fifth and last week of follow-up, the intervention group increased their steps by an average of 578.4 compared to a decrease of 187.5 steps among controls ($p<0.0001$).

Both the intervention and control groups significantly increased the number of PACER laps completed from pre- to post- assessment ($p<0.0001$) [Table 1]. Although control students had higher lap averages at both pre- and post- assessment, intervention students increased their scores by 3.7 laps (SD=7.4) while control students increased their scores by 2.3 laps (SD=5.9), indicating a significantly greater improvement among intervention students ($p=0.0002$) [Figure 3]. There were no significant changes in BMI percentiles for either the intervention or control group nor were there significant differences between the two groups.

Patterns of change similar to daily steps were seen for MVPA data. During PE classes, intervention students took an overall average of 2,627 steps while control students took 2,345 steps per class ($p=0.0083$). Among the intervention group, both the step and minutes-in-MVPA averages steadily increased over time, but the controls' averages were less consistent, increasing between some time points and decreasing between others. Overall, intervention students spent 17.5 minutes per PE class in MVPA compared to control students' 15.4 minutes ($p=0.0129$). From the first to the last day of MVPA data collection, intervention students increased their time in MVPA by 6.9 minutes while control students decreased their time by 1.9 minutes ($p<0.0001$) [Appendix 4].

Standardized Test Scores

Compared to controls, students attending intervention schools tested higher in all subject areas of the Georgia Milestone End-of-Grade Assessment, including Mathematics, English Language Arts (ELA), and Lexile reading [Table 2]. On average, intervention students performed 7.03 points higher on the math section than their control counterparts (524.6 vs. 517.6, p=0.0051). The proportion of control students who fell into the beginning math achievement level was more than twice that of the intervention students (24.9% vs. 11.0%, p<0.0001). On the ELA section of the Georgia Milestone, intervention students averaged 4.6 points higher than controls (515.1 vs. 510.5, p=0.0905). Similar to math, a significantly higher proportion of control students fell into the ELA lowest achievement level (29.0% vs. 20.6%, p<0.0001). On the reading sub-test of the ELA section, intervention students attained a mean Lexile score of 825.3, compared to 794.2 among control students (p=0.0008). There was also a significantly higher proportion of students who read at or above the 4th grade level in the intervention group compared to the control group (66.8% vs. 60.8%, p=0.0102) [Table 2].

Bivariate Correlations

Overall, the Pearson product-moment correlation coefficients (*r*) between physical activity, academic achievement, sex, and socioeconomic status were extremely small and weak [Appendix 5]. SES was the only variable that had at least a low-to-moderate significant correlation with standardized test scores. Among the entire cohort of 4th graders, SES was significantly positively correlated with test scores in math (r=0.33), ELA (r=0.35), and reading (r=0.26), suggesting that higher SES is related to higher academic achievement (p<0.0001).

Multiple Linear Regression

Intervention status, or whether a student was exposed to the *Health Empowers You!* intervention, had a significant crude main effect on academic achievement in mathematics and reading and a marginally non-significant effect on ELA [Table 3]. On average, attending a school that received the intervention was associated with scoring 7.0 points higher on the math section of the GA Milestone ($p=0.0031$) and 31.1 points higher on the reading sub-test of the ELA section ($p=0.0009$). However, the main effect alone did not account for a large proportion of the variation in test scores in math or reading (adjusted $R^2=0.0042$ and adjusted $R^2=0.0055$, respectively).

Adding the SES-proxy variable to the linear model for test scores significantly improved the amount of explained variability. The model controlling for SES by way of school-level FRL accounted for approximately 13.5% of the variability in both math and ELA scores and 8.5% of the variability in students' grade-level reading capabilities [Table 3]. Compared to students attending a low SES school, high SES was significantly associated with scoring 37.8 points higher in math, 40.8 points higher in ELA, and 115.9 points higher in reading, given that intervention status was in the model ($p<0.0001$). Adding the sex covariate to the model containing intervention status and SES did not have a significant effect on test scores in math ($p=0.99$), ELA ($p=0.87$), or reading ($p=0.85$) and the adjusted R^2 values remained unchanged.

Backwards elimination run on the fully adjusted interaction model for each test subject yielded all interaction terms with the main effect of interaction status *insignificant* except one: intervention status*SES. Further elimination of terms that were non-significantly associated with standardized test scores yielded different models for each of the three subjects [Table 3].

Mathematics

Controlling for SES, change in PACER laps, and the interaction of SES and intervention status, students attending intervention schools scored 34.7 points higher in math on average ($p<0.0001$). Higher SES was associated with a significantly higher score in math (approximately

67 points), controlling for the other model terms. Further, with every one lap improvement in PACER from baseline to follow-up, students scored 0.4 points higher in math. There was also significant interaction between intervention status and SES. Intervention status, SES, change in PACER laps, and the interaction term accounted for nearly 25% of the variation in math test scores (adjusted R^2=0.2478).

English Language Arts

Controlling for SES and the interaction of SES and intervention status, students attending intervention schools are expected to score 30.6 points higher on ELA ($p<0.0001$). Similar to math, higher SES was associated with significantly higher scores in ELA, by approximately 63 points ($p<0.0001$). Again, significant interaction between intervention status and SES was apparent. Intervention status, SES, and the interaction between the two accounted for 16.3% of the variation in ELA scores (adjusted R^2=0.1632).

Lexile Reading

Controlling for SES and the interaction term, students attending intervention schools scored 104.3 points higher on Lexile reading standardized test sections ($p<0.0001$). Again, higher SES was associated with significantly higher scores in Lexile reading, approximately 180 points ($p<.0001$). Intervention status, SES, and the interaction between the two accounted for 10.3% of the variation in Lexile reading scores (adjusted R^2=0.1030).

DISCUSSION

This analysis aimed to evaluate the impact of a yearlong school-based physical activity intervention on academic achievement among a population of 4th graders in metropolitan Atlanta, Georgia. Specific objectives included to examine the effect of a school-based PA intervention, *Health Empowers You!*, on physical activity levels, physical fitness levels, and test scores, 2) to assess whether changes in PA and physical fitness impacted test scores, and 3) to evaluate the effects of sex and socioeconomic status on the relationship between PA and AA. The intervention itself had positive effects on 4th grade students' physical activity, fitness levels, and end-of-grade standardized test scores. However, changes in PA and fitness over the course of the school year did not impact test scores. SES had a large and significant impact on test scores in all three subjects.

The most important finding is the significant positive association between socioeconomic status and academic achievement. Above and beyond any other factor, SES made the biggest impact on standardized test scores. SES was the only variable that had significant and meaningful positive correlations with academic achievement, suggesting that higher SES was low-to-moderately correlated with higher standardized test scores in mathematics, English Language Arts, and Lexile reading. Moreover, the addition of SES to the standardized test score models resulted in a large increase in the amount of explained variation above and beyond that of the intervention alone [Table 3], indicating that SES was a largely important predictor of academic performance. In the final adjusted models, high SES was significantly associated with scoring approximately 67 points higher in math, 63 points higher in ELA, and 180 points higher in reading. Again, these effects are much greater than any other term in the test scores models.

These findings are consistent with some previous literature suggesting that SES is a highly important predictor of academic achievement [22, 31]. Grissom found that test scores increased as fitness scores on FG increased for both intervention and control groups but that the relationship was *stronger* for students of high SES [22]. Coe et al. echoed this when they found that low SES students performed significantly worse on all major standardized test subjects and that SES was the strongest indicator of academic achievement [31]. Our findings indicate that SES proved to be an especially important variable to consider since it is both associated with achievement and health and fitness.

It is also noteworthy that intervention schools had significantly higher average proportions of students on Free and Reduced Lunch (FRL) than control schools, signifying that intervention schools were generally of *lower* socioeconomic status at baseline. Nonetheless, the intervention itself had positive effects on test scores despite intervention schools generally being of lower socioeconomic status. These main effects are discussed in detail below.

Overall, this study contributes to the growing body of literature that supports positive associations between school-based PA interventions and academic achievement [15, 23]. Reed et al. found that children who participated in an intervention that integrated aerobic PA into the classroom curriculum 3 times per week achieved higher standardized test scores in math. Our findings support this: 4th grade students who attended an intervention school performed significantly better on average in mathematics than their control counterparts. According to Georgia achievement standards, the intervention students' average put them on the cusp of "Proficient Learner" status, which signifies content mastery, grade-level proficiency, and readiness for the next grade. Higher achievement in math is also in line with several studies, which found that PA effects are greater on math scores than other subjects and justify the fact that academic achievement should continue to be examined as subject-specific outcomes [20, 29].

Intervention students also scored significantly higher on the English Language Arts reading sub-test. Moreover, despite baseline differences in SES, there was a significantly higher proportion of intervention students who read at or above the 4th grade level compared to control students. Reading achievement on the Georgia Milestone is predicative of “College and Career Readiness” so excelling in this content area is especially important. Though the effects of PA on English Language Arts have been looked at [25], studies looking at Lexile reading scores and percentages of students reading at recommended grade levels have been less common or underpowered [29]. Excelling in core subjects like math and reading is critically important to elementary students’ mastery of grade-level content and skills, and PA interventions may be able to enhance their academic mastery. It is important to understand that although the main effect of the intervention was positively associated with achievement, there may be other important factors not examined in this analysis to which differences in standardized test scores may be attributable.

In addition to AA, the intervention appeared to have significant effects on *changes* in physical activity and physical fitness. Though controls had significantly higher average baseline steps, intervention students gradually increased their steps over the academic year to achieve a higher final and overall change in steps than controls. This trend of consistent improvements was echoed for MVPA data even though steps in PE class and minutes of MVPA were collected on a smaller subset of students. Similarly, physical fitness scores on the FITNESSGRAM PACER test increased *more* among students in the intervention than control group. These outcomes support the effects of previous school-based interventions on student movement during the school day [20, 24].

Of note, control schools were enrolled after the intervention schools and began data collection three months later. Thus, intervention students had a longer period of time, from September 2015 to May 2016, to show improvement in PA and PF measures while control students only had from January to May 2016. This may also explain the tendency of control students to have higher baseline averages for steps, MVPA, and PACER. Still, the patterns of change among classroom steps, MVPA steps, and MVPA minutes collected at five time points throughout the academic year revealed more consistency among intervention students in terms of gradual improvement on all measures. School-based interventions may improve the overall consistency with which students engage in PA throughout the day.

Finally, unlike a few studies [22, 28], this study did not find that sex was related to the relationship between PA and AA. Sex had no meaningful or significant effect on standardized test scores in math, ELA, or reading, which supports the findings from one review cite [9].

Strengths

This study has at least six major strengths. First, the *Health Empowers You!* intervention is CSPAP-based and was implemented by a non-profit with extensive expertise in school-based physical activity interventions. Next, the study design was strong; utilizing an intervention-based design enhanced the rigor above that of a cross-sectional study. Third, the sample size was large (n=1,829 4th graders), which provided sufficient power to detect associations that existed. Fourth, this study avoided issues of low methodological quality highlighted in several reviews [7, 23, 32] by using objective, validated data collection sources: Pebble pedometers, FITStep Pros, FITNESSGRAM, and the GA Milestone End-of-Grade Assessment. This eliminated reliance on self-report data, reduced the potential for subjectivity and measurement error, and aligned with current research methods for examining the relationship of interest [7, 21]. Further, statewide standardized scores, as opposed to classroom grades or GPAs, allowed for comparison between students from various schools in the sample. The fifth strength was the ability to link the majority of the data by individual student; this includes student-level step data, PACER scores, BMI percentiles, gender, and standardized test scores in all three subjects. Finally, this study included important covariates, sex and SES, in examining the relationship between PA and AA while many previous studies have not been able to collect data on those relevant demographic variables.

Limitations

There are at least four limitations to this study. First, methodologically, participating schools were not randomly assigned to the intervention or control group. This observational study design limits the ability to draw causal inferences, though the addition of control schools for comparison enhanced the study's rigor. Second, there was a short follow-up period of one academic year in intervention schools and half of a year in controls, which hindered analysis of change in academic achievement over time. Consequently, there was limited potential to see substantive change in aerobic fitness and body compositions since those are typically long-term fitness indicators. Some significant improvement, however, was observed for aerobic fitness on PACER tests. Third, FG assessments could have been subject to measurement error since they were collected by various PE teachers in the three participating school districts; however, all PE teachers underwent state-mandated FG training, so error was likely minimal and would have been random. Finally, an individual measure of SES was unavailable, so the proportion of students on FRL at the school-level had to be used as a proxy for each student.

FUTURE DIRECTIONS

Over the last several decades there has been an increasing number of observational studies examining the relationship between physical activity and academic achievement. Since causal inferences cannot be made from observational studies, however, the conclusions that can be drawn from these types of studies are limited. Most of the existing studies examining this relationship are not rigorous. There is a clear need for more high-quality studies, specifically randomized controlled trials [7, 23]. Currently, a larger-scale study that utilizes the *Health Empowers You!* intervention is being implemented. This four-year RCT will address potentially underlying differences between schools by utilizing only one school district and by randomizing each school to receive the intervention or serve as a control. Accelerometry will be used since it is the gold standard for PA data collection, and data will be collected on more covariates that could influence the PA-AA relationship. Further, the longer follow-up period will allow researchers to examine long-term effects of PA on physical fitness, including body composition, and academic achievement, including repeated test measures, over time.

In addition to enhancing the rigor of study methodology, future studies should improve upon the quantity and quality of MVPA data. For this study, data were only collected on approximately 3-4% of students who attended enrolled schools, yielding a small and potentially underpowered sample size. Even so, the changes in steps and minutes spent in MVPA over time were in a positive direction and encouraging that the intervention made an impact. However, larger sample sizes are needed to examine this in more detail.

Further, future studies should account for the multilevel nature of the variables. Since individual observations for students were not independent, there was likely a clustering effect by school. In other words, school-level programs, policies, or other situations that occurred throughout the study period would have affected all students attending a certain school.

Multilevel modeling could account for this non-independence of observations and other potential group-level effects.

Finally, researchers should continue to focus on SES as an important covariate in the relationship between PA and AA. Future studies must, however, ensure appropriate individual-level data for this factor. They should make efforts to obtain individual-level SES data, such as whether each student is on FRL, rather than using school-wide FRL percentages though. In this way, the data will be more individualized, more predictive of academic outcomes, and clearer in the effect of SES on the relationship between PA and AA.

Implications

Even though schools have the opportunity to satisfy much of children's recommended daily amounts of physical activity, most do not provide adequate time for students to get moving. Laws like the No Child Left Behind Act are partially responsible as they overemphasize standardized test performance, increase the amount of content that teachers are responsible for covering, and decrease the amount of PE and recess time that children have. Additionally, schools lack classroom and PE teachers who are equipped to effectively incorporate high quality physical activity into the school day. These circumstances unfortunately come at a time when chronic disease trends among youth are rising.

Since more than 35 million elementary-aged children each spend at least 30 hours per week in school, schools provide an ideally unique environment to implement physical activity programs and policies that make a meaningful impact on healthy behaviors. The associations between school-based physical activity interventions and enhanced PA over time as well as higher standardized test scores support the notion that the two are not mutually exclusive. Schools can prioritize physical activity and the health of their students without a detriment in academic achievement. Local school districts and departments of education can also enact policies to make more frequent and higher quality PA a priority in schools. The educational sector inherently has a responsibility to prepare students for a lifetime of success; and that success is multi-dimensional, including both physical and academic components. By merging public health and education, well-designed programmatic and policy-based changes in the elementary school environment have potentially far-reaching effects on students' current and future physical and cognitive health.

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TABLES

Table 1. Demographic, physical activity, and physical fitness characteristics of 4th grade students attending Georgia public elementary schools that participated in the *Health Empowers You!* study

Variable	Total (N=1,829) n (%) or mean (SD)	Intervention (n=1,178) n (%) or mean (SD)	Control (n=651) n (%) or mean (SD)	p-value*
Demographic Variables	n=1,829	n=1,178	n=651	
Male	951 (52.0%)	621 (52.7%)	330 (50.7%)	0.4065
FRL**	63.3 (33.0)	67.0 (31.2)	56.5 (35.1)	<0.0001
Classroom Steps	n=1,761	n=1,176	n=585	
Week 1	3171.9 (673.5)	3129.0 (706.9)	3258.3 (591.8)	<0.0001
Week 2	3242.3 (691.8)	3146.5 (690.6)	3435.0 (653.7)	<0.0001
Week 3	3312.6 (602.9)	3494.9 (571.0)	2946.2 (487.8)	<0.0001
Week 4	3470.4 (612.0)	3603.1 (626.6)	3203.7 (481.7)	<0.0001
Week 5	3495.9 (639.7)	3707.3 (606.0)	3070.8 (472.7)	<0.0001
Steps Change	324.0 (929.2)	578.4 (880.4)	-187.5 (806.4)	<0.0001
Overall Steps	3338.6 (414.4)	3416.1 (445.5)	3182.8 (286.)	<0.0001
PACER	n=1,244	n=613	n=631	
Pre PACER Laps	24.7 (12.9)	21.5 (10.1)	27.8 (14.5)	<0.0001
Post PACER Laps	27.7 (14.0)	25.2 (11.9)	30.2 (15.5)	<0.0001
PACER Laps Change	3.0 (6.7)	3.7 (7.4)	2.3 (5.9)	0.0003
BMI	n=1,505	n=854	n=651	
Pre BMI Percentile	67.1 (30.1)	66.2 (29.6)	68.5 (30.8)	0.2004
Post BMI Percentile	63.9 (30.8)	62.9 (30.6)	65.3 (30.9)	0.1407
BMI Percentile Change	-3.1 (12.2)	-3.3 (12.6)	-2.9 (11.7)	0.5853

Abbreviations: FRL- free and reduced lunch program; MVPA- moderate-to-vigorous physical activity; PACER- Progressive Aerobic Cardiovascular Endurance Run; BMI- body mass index

*p-value for test of significant difference between intervention and control groups; chi-square test for categorical variables, two-sample t-test for continuous variables

**Mean proportion of total school population that is eligible for FRL

Table 2. Georgia Milestone End-of-Grade standardized test scores for 4th grade students attending Georgia public elementary schools that participated in the *Health Empowers You!* study (N=1,829)

Variable	**Total (N=1,829)** n (%) or mean (SD)	**Intervention (n=1,178)** n (%) or mean (SD)	**Control (n=651)** n (%) or mean (SD)	p-value*
Scale Scores				
Mathematics	522.1 (48.8)	524.6 (45.2)	517.6 (54.3)	0.0051
ELA	513.5 (52.1)	515.1 (47.5)	510.5 (59.4)	0.0905
Lexile Reading	814.2 (191.8)	825.3 (195.1)	794.2 (184.1)	0.0008
Achievement Levels, Math				
Beginning, 270-474	291 (15.9%)	129 (11.0%)	162 (24.9%)	<0.0001
Developing, 475-524	746 (40.8%)	521 (44.2%)	225 (34.6%)	<0.0001
Proficient, 525-584	601 (32.9%)	417 (35.4%)	184 (28.3%)	0.0019
Distinguished, 585-715	191 (10.4%)	111 (9.4%)	80 (12.3%)	0.0550
Achievement Levels, ELA				
Beginning, 270-474	432 (23.6%)	243 (20.6%)	189 (29.0%)	<0.0001
Developing, 475-524	625 (34.2%)	435 (36.9%)	190 (29.2%)	0.0008
Proficient, 525-573	517 (28.3%)	352 (29.9%)	165 (25.4%)	0.0392
Distinguished, 574-775	249 (13.6%)	145 (12.3%)	104 (16.0%)	0.0286
Achievement Levels, Lexile				
On or Above Grade Level**	1179 (64.7%)	785 (66.8%)	394 (60.8%)	0.0102

Abbreviations: ELA-English Language Arts

*p-value for test of significant difference between intervention and control groups; chi-square test for categorical variables, two-sample t-test for continuous variables

**Scored 740L or above on reading sub-test of the ELA section

Table 3. Results of multiple linear regression models for GA Milestone standardized test scores

Variable	Mathematics			English Language Arts			Lexile Reading		
	Parameter Estimate (SE)	Adj. R-Square	p-value	Parameter Estimate (SE)	Adj. R-Square	p-value	Parameter Estimate (SE)	Adj. R-Square	p-value
Crude Model*									
Intercept	517.59 (1.91)	0.0042	<0.0001	510.49 (2.04)	0.0012	<0.0001	794.19 (7.51)	0.0055	<0.0001
Intervention	7.03 (2.38)		0.0031	4.60 (2.50)		0.0712	31.07 (9.36)		0.0009
Covariate-Adjusted Model									
Intercept	497.76 (2.36)	0.1353	<0.0001	488.99 (2.53)	0.1349	<0.0001	733.52 (9.57)	0.0868	<0.0001
Intervention	16.02 (2.28)		<0.0001	14.25 (2.44)		<0.0001	58.98 (9.23)		<0.0001
SES	37.70 (2.26)		<0.0001	40.63 (2.42)		<0.0001	117.20 (9.16)		<0.0001
Sex	0.04 (2.13)		0.9854	0.36 (2.27)		0.8738	-1.63 (8.61)		0.8496
Final Model									
Intercept	481.01 (2.67)	0.2478	<0.0001	477.23 (2.71)	0.1632	<0.0001	699.55 (10.35)	0.1030	<0.0001
Intervention	34.70 (3.47)		<0.0001	30.59 (3.17)		<0.0001	104.33 (12.10)		<0.0001
SES	67.13 (3.58)		<0.0001	63.40 (3.75)		<0.0001	180.38 (14.29)		<0.0001
Change in PACER	0.43 (0.19)		0.0259	--			--		--
Intervention x SES	-42.68 (5.24)		<0.0001	-38.04 (4.84)		<0.0001	-105.83 (18.48)		<0.0001

*Includes the main effect of intervention only

FIGURES

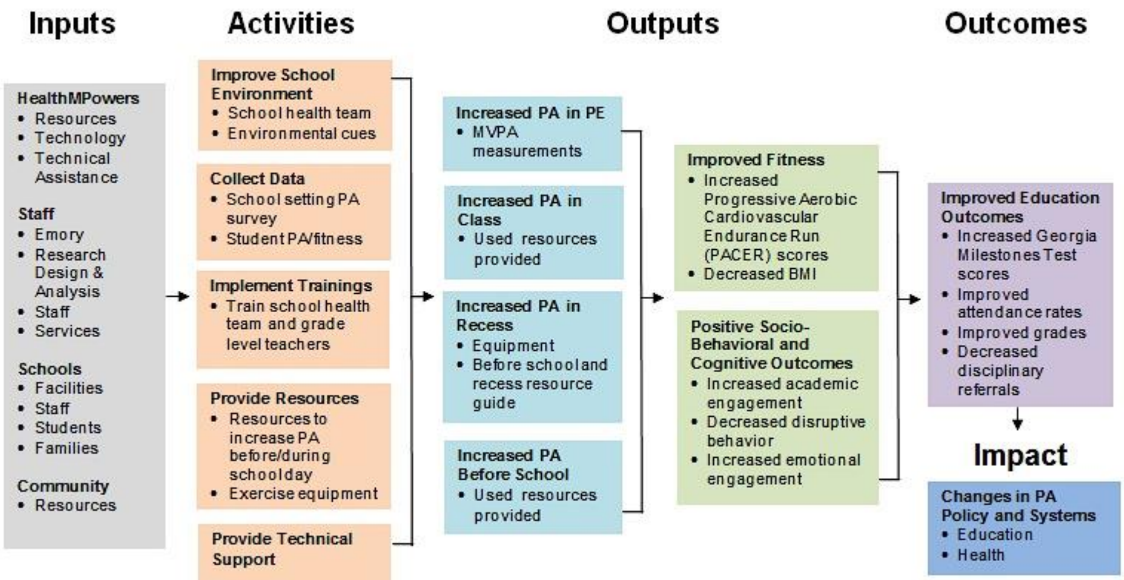


Figure 1. *Health Empowers You!* intervention logic model

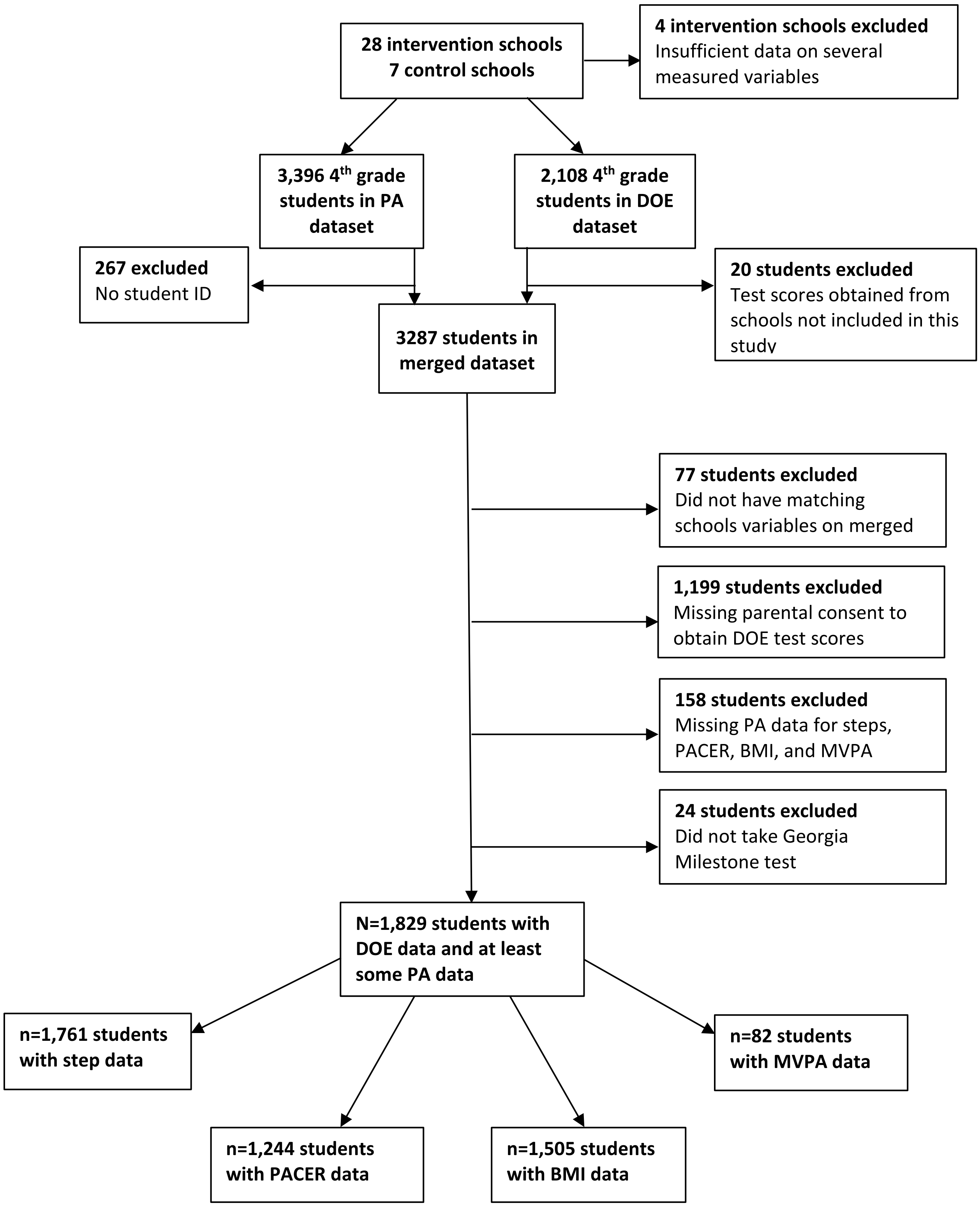


Figure 2. Flow chart of sample size for the analytic dataset.

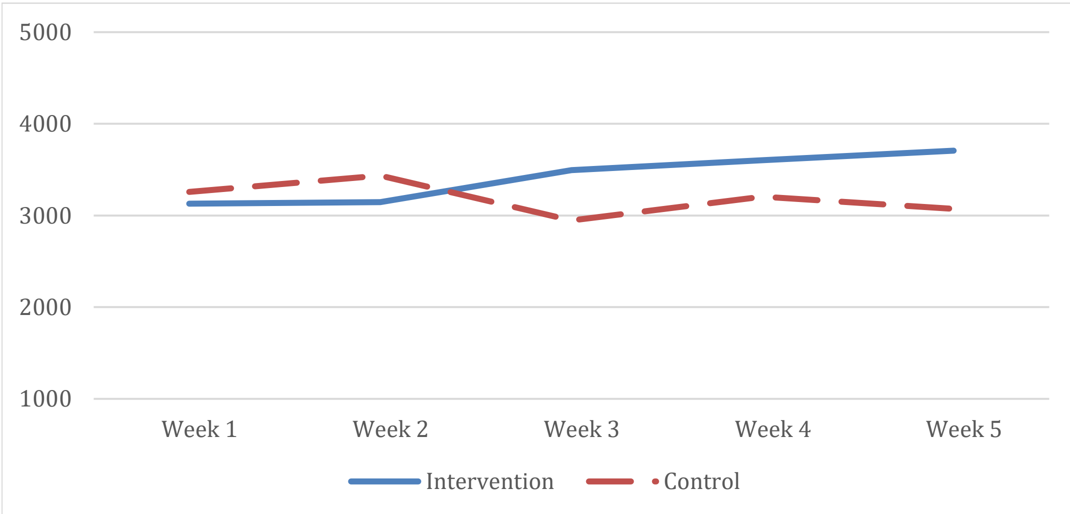


Figure 3. Average number of weekly steps taken, intervention vs. control groups

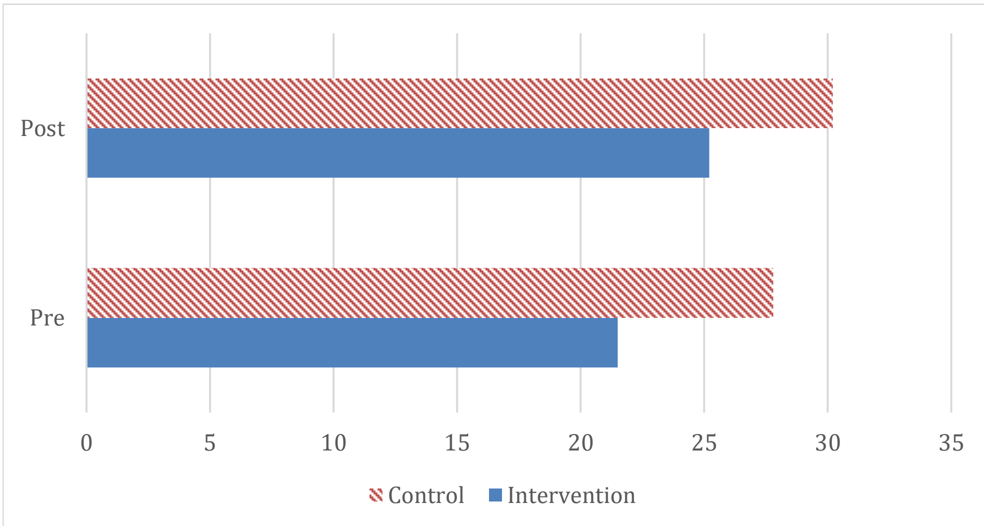


Figure 4. Average number of PACER laps completed at pre and post FITNESSRGAM assessments, intervention vs. control groups

APPENDICES

Appendix 1. Description of the *Health Empowers You!* intervention program

Component of Intervention	**Primary Activities**
Establish School Health Team	Create a three-person team with one PE teacher, one 4th grade teacher, and one other staff member to undergo program trainings, redeliver information to the schools, and serve as school's point of contact
Implement Trainings	HealthMPowers delivered three trainings throughout the 2015-2016 school year via two training modes: face-to-face and virtual. All participating schools attended the face-to-face kick-off training at the start of the intervention in October 2015. Half of the schools participated in asynchronous monthly virtual trainings for the remainder of the school year and the other half participated in two additional face-to-face trainings. Trainings focused on how teachers could incorporate additional physical activity into their classrooms, strategies to increase MVPA in physical education, and activities that could be used in recess or before/after school programs. HealthMPowers also provided PE teachers with different strategies every month, including using more equipment per class, making smaller groups, and using activities that promote more movement while allowing the teachers to teach the skills they wanted to.
Obtain Physical Activity Data	HealthMPowers staff collected data on 4th graders' physical activity behavior throughout the 2015-2016 academic year. Prior to the start of the intervention, HealthMPowers and Emory University staff evaluated five different activity measurement devices to identify the best device for this project. Based on evaluation findings, available resources, and ease of use, the Pebble activity monitor was selected to track classroom steps. The Gopher FITstep Pro was selected to track moderate-to-vigorous physical activity and steps during PE classes.
Provide Resources	HealthMPowers provided a variety of resources that teachers could use to assist students in getting additional physical activity. During the initial training, each 4th grade classroom in every school was provided with the movement-based videos (Classrooms in Action, Mind-in-Motion 1, and Mind-in-Motion 2). Mathtivity, a set of physical activities that are linked to specific grade level Georgia Performance Standards, was also provided. These resources equipped classroom teachers with "ready-made" activities to integrate into their lessons. HealthMPowers also gave each school equipment to use at recess or PE, including poly spot markers, six basketballs, footballs, kick balls, soccer balls, flying discs, cones, mesh equipment bags, and one jump rope for every two students. The FITstep Pro devices used for MVPA data collection were also retained by the physical education teacher for future use.

Provide Technical Assistance	HealthMPowers provided technical assistance when teachers asked for advice about integrating movement into their classrooms, ideas about how to transition students back into traditional classroom work, or general classroom management ideas to ensure students' full participation. Technical assistance was also provided for data collection devices, from changing out batteries and broken clips to assisting in the download of the Pebbles and FITstep Pros. The amount of technical assistance depended on the teachers' needs and varied greatly. The priority was making the teachers feel comfortable implementing physical activity in the classroom and using the physical activity data collection devices.

Appendix 2. Description of data measures, instruments, frequency, and source collected from students attending intervention (I) and control (C) schools.

Data Measure	Data Collection Instrument	Frequency/Timing of Measurement	Data Collection Source
Physical Activity			
Moderate to Physical Activity (MVPA) in PE Class	FITstep Pro	Five days I: 5 months C: 5 months	Electronic data reported monthly
In-School Step Data	Pebble pedometers	Five weeks I: 5 months C: 5 months	Waist clip activity tracker worn one week per month
Health-Related Fitness			
Aerobic Capacity	FITNESSGRAM PACER	Pre-Post I: Sept & May C: Jan & May	PE Teacher/District
Body Mass Index (BMI)	FITNESSGRAM Height/Weight	Pre-Post I: Sept & May C: Jan & May	PE Teacher
Academic Achievement			
Georgia Milestone Standardized Test Scores	DOE Records	Spring (2016)	School District
Demographic Characteristics			
Sex	Schools	October (2015)	School Teacher
Free and Reduced Lunch (FRL)	DOE Records	October (2015)	School District

Appendix 3. Georgia Milestone scale scores and descriptions for 4th grade achievement levels.

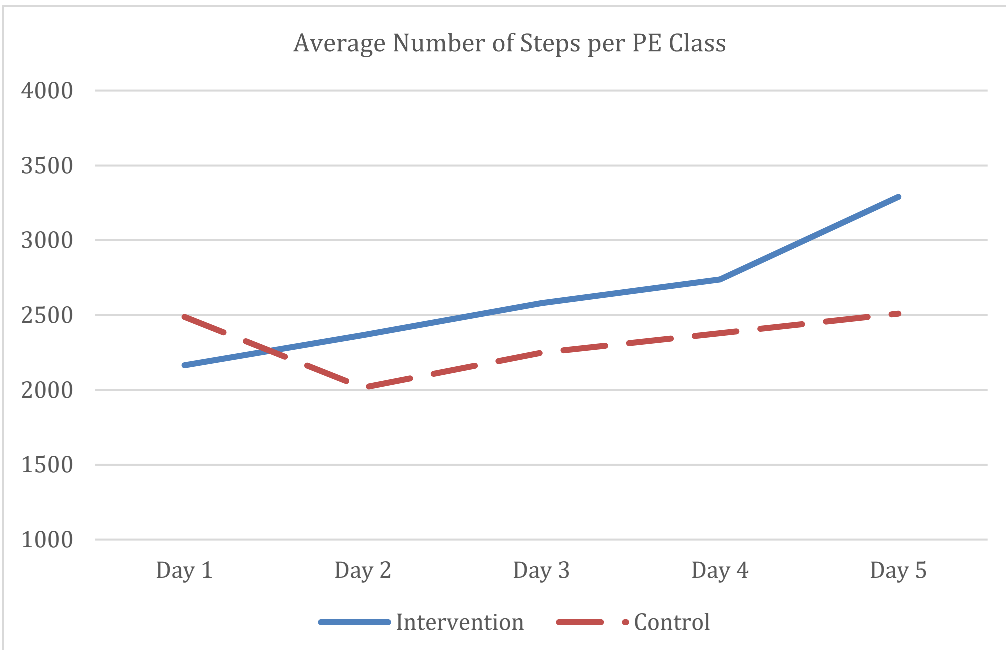
	Beginning Learner	**Developing Learner**	**Proficient Learner**	**Distinguished Learner**
English Language Arts	210-474	475-524	525-573	574-775
Mathematics	270-474	475-524	525-584	585-715
Description	Does not yet demonstrate proficiency in knowledge and skills necessary to be at this grade level and content area of learning; needs substantial academic support to be prepared of the next grade level	Demonstrates partial proficiency in the knowledge and skills necessary to be at this grade level and content area of learning; needs additional academic support to be prepared for the next grade level	Demonstrates proficiency in the knowledge and skills necessary to be at this grade level and content area of learning; is prepared for the next grade level	Demonstrates advanced proficiency in the knowledge and skills necessary to be at this grade level and content area of learning; is prepared for the next grade level

Appendix 4. Descriptive statistics and change in MVPA variables by group (N=82)

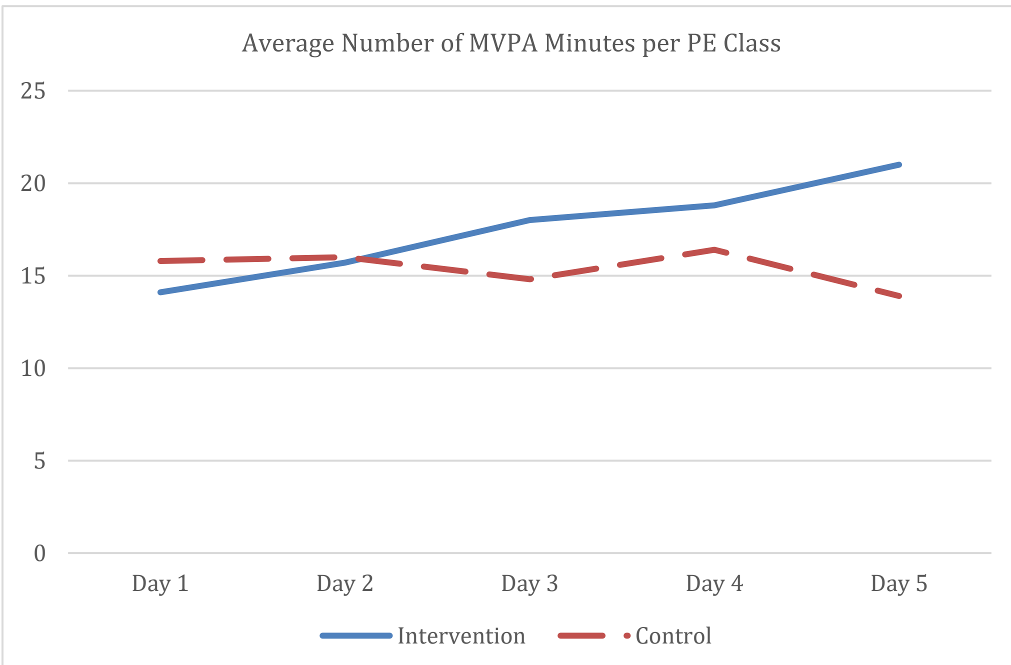
	Total (n=82)	**Intervention (n=54)**	**Control (n=28)**	
Variable	mean (SD)	mean (SD)	mean (SD)	p-value*
Steps, D1	2274.8 (824.4)	2164.6 (986.3)	2487.2 (241.2)	0.0262
Steps, D2	2276.7 (743.7)	2365.7 (852.5)	2015.0 (431.6)	0.0697
Steps, D3	2467.1 (786.6)	2580.2 (922.2)	2248.9 (334.5)	0.0210
Steps, D4	2615.6 (771.8)	2738.7 (865.3)	2378.1 (478.4)	0.0174
Steps, D5	2931.9 (827.6)	3289.6 (1115.2)	2509.6 (522.3)	<0.0001
Steps, Overall	2511.0 (590.3)	2627.8 (711.1)	2345.8 (196.0)	0.0083
Steps, D5-D1	646.8 (1024.2)	1125.0 (1303.7)	22.4 (582.1)	<0.0001
Minutes, D1	14.7 (5.3)	14.1 (6.3)	15.8 (2.5)	0.0852
Minutes, D2	15.8 (4.9)	15.7 (5.9)	16.0 (1.9)	0.7465
Minutes, D3	16.9 (7.2)	18.0 (8.0)	14.8 (4.7)	0.0226
Minutes, D4	17.9 (6.1)	18.8 (7.0)	16.4 (3.2)	0.0412
Minutes, D5	18.6 (8.0)	21.0 (8.8)	13.9 (2.4)	<0.0001
Minutes, Overall	16.8 (4.9)	17.5 (5.8)	15.4 (1.5)	0.0129
Minutes, D5-D1	3.9 (8.3)	6.9 (8.5)	-1.9(3.5)	<0.0001

Abbreviations: MVPA- moderate-to-vigorous physical activity

*p-value for 2 sample t-test; Satterthwaite method for unequal variances used



Appendix 4. Figure A. Average number of steps per PE class, intervention vs. control groups



Appendix 4. Figure B. Average number of minutes spent in moderate-to-vigorous physical activity per PE class, intervention vs. control groups

Appendix 5. Pearson Product-Moment Correlation Coefficients for PA Variables, Potential Covariates, and Standardized Test Scores

	Math Scale Score	**ELA Scale Score**	**Lexile Reading Score**
Total			
Intervention Status	**0.069***	0.042	**0.078***
Week 1 Step Average	**-0.057**	**-0.096****	**-0.053**
Week 2 Step Average	**-0.069***	**-0.063**	-0.038
Week 3 Step Average	**-0.076***	**-0.086***	**-0.054**
Week 4 Step Average	**-0.114****	**-0.0780***	**-0.061**
Week 5 Step Average	**0.075***	**0.056***	**0.059**
Overall Step Average	-0.074	-0.084	-0.045
W5 - W1 Average	0.093	0.108	0.079
Pre PACER laps	**0.058**	0.045	0.020
Post PACER laps	**0.083***	**0.059**	0.031
PACER Change^	**0.0833***	0.050	0.033
Pre BMI Percentile	**0.08***	**0.06**	-0.04
Post BMI Percentile	**-0.07**	-0.04	-0.03
BMI Percentile Change^	0.04	0.03	0.02
Sex	0.022	0.025	0.014
SES	**0.334****	**0.345****	**0.255****

^value at post-assessment minus value at pre-assessment

bolded: significant at the p<0.05 level

bolded*: significant at the p<0.005 level

bolded: significant at the p<0.0001 level**