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ORIGINAL RESEARCH

Examining the Impact of 45 Minutes of Daily Physical Education on Cognitive Ability, Fitness Performance, and Body Composition of African American Youth

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Object: Increased importance on academic achievement has resulted in many school districts focusing on improved academic performance leading to reductions in physical education time. The purpose was to examine the effects of 45 minutes of daily physical education on the cognitive ability, fitness performance and body composition of African American elementary and middle school youth. ***Methods:*** Participants completing the informed consent in grades 2nd to 8th were included in the study. A pre/posttest design was used with repeated measures analysis of variance. Experimental and control school participants were pretested on the cognitive measures (ie, Fluid Intelligence and Perceptual Speed) and Fitnessgram[R] physical fitness test items (eg, aerobic capacity, muscular strength and muscular endurance, body composition) in September 2009 and posttested in May 2010. ***Results:*** Experimental elementary and middle school participants observed significantly greater improvements compared with control elementary and middle school participants on 7 of 16 fitness and body composition measures and on 8 of 26 cognitive measures. These fitness, body composition, and cognitive improvement differences were more noticeable among elementary and middle school females. ***Conclusions:*** Providing 45 minutes of daily physical education can perhaps increase cognitive ability while increasing fitness and decreasing the prevalence of overweight and obese youth.

Keywords: exercise, physical activity, health

Participating in regular physical activity can provide a range of health benefits.[1–4] Yet the positive impact on learning and brain plasticity among youth is often overlooked,[5] thereby limiting the ability to identify potential links between physical activity and cognition. Available data suggests that physically active children tend to have greater academic achievement and enhanced cognition compared with their inactive peers.[6–8]

Physical activity has been documented to increase brain-derived neurotrophic factor (BDNF), which supports learning capacity and cognition and is regulated by physical activity.[9–11] Regular physical activity stimulates structural changes in the hippocampus region of the brain, an important area for memory, along with increasing neurons, dendrites, and synapses—essential structural elements located throughout the central and peripheral nervous systems.[9–11]

Hillman and colleagues[12] examined the effect of an acute bout of moderate treadmill walking on behavioral and neuroelectric indexes of the cognitive skills associated in school-based academic performance. Results from their research indicate an improvement in response accuracy, larger P3 amplitude, and better performance on academic achievement tests following aerobic exercise when compared with the resting session. These findings indicate that single, acute bouts of moderately-intense aerobic exercise (ie, walking) may improve the cognitive control of attention in preadolescent children, and further support the use of moderate acute exercise as a contributing factor for increasing academic performance.[12]

A review by Sibley and Etnier[6] found that exercise training is significantly linked to improved youth cognition; and being an overweight child has been reported to be associated with poor IQ test performance.[7,8] Judge and Jahns[13] investigated the associations between overweight children and academic performance from data collected in the Early Childhood Longitudinal Study and found that overweight 3rd-grade children had significantly lower math and reading tests scores in comparison with nonoverweight children in the same grade. Blakemore[14] reported that the brain is activated during physical activity by increasing blood flow to essential areas that stimulate learning. Strong associations between the cerebellum and memory, spatial perception, language attention, emotion, nonverbal cues, and the decision making ability of students have also been found.[11,14]

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Less than 4% and 8% of US public elementary and middle schools, respectively, provide daily physical education.[15] A review paper by Keeley and Fox[16] examining the impact of physical activity and fitness on academic achievement and cognition of youth suggests there is insufficient evidence to conclude additional physical education can increase academic achievement, however the Texas Education Agency recently examined over 2.4 million students and found higher levels of physical fitness (measured by Fitnessgram^R) were associated with better academic performance. Counties with high levels of cardiovascular fitness tended to have higher passing rates on the Texas Assessment of Knowledge and Skills (TAKS), a state-administered standardized test.[17] Carlson and colleagues[18] examined the link between time spent in physical education and academic achievement from data collected on children from kindergarten through 5th grade and found a significant increase in academic achievement in math and reading among girls enrolled in higher amounts of weekly physical education. It is important to note that one of the missing links in this specific area of research is dearth of studies using controls. This study helps to fill this gap by expanding the knowledge base in this important area.

The primary purpose of the current study was to examine the effects of providing 45 minutes of daily physical education on the cognitive ability, fitness performance and body composition of African American elementary and middle school youth attending a Title I charter school in the southeast. The following purpose statements guided this study: a) Assess the impact of 45 minutes of daily physical education on the cognitive ability (measured by Fluid Intelligence and Perceptual Speed) of elementary and middle school participants, b)The secondary purpose of the current study was to evaluate the effects of 45 minutes of daily physical education on Fitnessgram^R physical fitness tests [eg, aerobic capacity (PACER), muscular strength and muscular endurance (Push-up & Curl-up), and body composition]. One Title I elementary control school and one Title I middle control school were identified and used as comparisons.

Methods

Background on Experimental School and Title I

The experimental school in the current study was a small neighborhood kindergarten through 8th-grade public charter Title I school. The purpose of Title I is to improve the academic achievement of the disadvantaged and to ensure that all children in the US have a fair, equal, and significant opportunity to obtain a high-quality education and reach, at a minimum, proficiency on challenging state academic achievement standards and state academic assessments.[19] Ninety-eight percent of all children attending the experimental school are African American.

Physical Education at Experimental School and Control Schools

In the fall of 2009, the experimental school implemented a comprehensive, multifaceted approach to education based on the premise that a 'sound body nurtures a sound mind.' Two certified physical education teachers were hired to provide 45 minutes of daily physical education, 5 days a week to all children in all grades. The physical education requirements in this southeastern school district for elementary schools (ie, control) is 45 minutes 1 day a week for grades 1st–5th and 30 minutes 1 day a week for kindergarteners. Middle schools (ie, control) provide 50 minutes of daily physical education for 1 semester in grades 6th–8th. Physical education at the experimental school and both control schools were taught by certified physical education instructors. Elementary school physical education content at both the experimental school and control school used a developmental curriculum with an emphasis on fundamental skills. Middle school physical education at both the experimental school and control school used a multiactivity sport theme curriculum. Control middle school students in grades 6th–8th received 50 minutes of daily physical education daily for the fall semester only. Elementary control school students in grades 2nd–5th received only 45 minutes of PE 1 day per week for the entire school year.

Testing Procedures and Research Design

All participants completing the Informed Consent at the experimental and control schools enrolled in grades 2nd–8th participated in the current study. Internal Review Board (IRB) procedures were strictly followed. A representative sample of participants at the elementary and middle school control schools was selected from grades 2nd–8th. A pre/posttest design was used in the current study. Experimental and control school participants were pretested on the cognitive measures (ie, Fluid Intelligence and Perceptual Speed) and Fitnessgram^R physical fitness test items during the first week of September 2009. Study participants were posttested at the end of the school year during the last 2 weeks of May 2010. Time limitations for middle school control students prevented the administration of the Perceptual Speed test for this study's year. The cognitive measures were administered by the research staff. Fitnessgram^R physical fitness test items were administered by each school's physical educator(s) assisted by the research staff.

Cognitive Measures

Fluid Intelligence. Most cognitive studies of intelligence have largely focused on Fluid Intelligence because of its relationship with chronological age. Fluid Intelligence is theorized to be less affected by differences in socioeconomic status or educational background, and thus more of a "culture-fair" indicator of intelligence.[20]

Moreover, some researchers have identified Fluid Intelligence as being equivalent to the *g*-factor of intelligence (ie, *g* = general intelligence).[21] Carroll[22] in his 3-stratum model of human intelligence identified Fluid Intelligence as the second-order factor most dominated by *g*.

Fluid Intelligence derives from work by Cattell and colleagues[20,23,24] differentiating between 2 types of intelligence.[25] Crystallized Intelligence represents the knowledge that individuals acquire across the lifespan. In contrast, according to Reddick,[25] Fluid Intelligence represents the ability to adapt to novelty and to reason in situations that have not been encountered previously. Evidence for the distinction between Fluid Intelligence and Crystallized Intelligence was found by examining the lifespan trajectory of each kind of intelligence.[25] Fluid Intelligence tends to increase until early adulthood and then declines, whereas Crystallized Intelligence tends to gradually increase and remain intact through late adulthood.[24,25]

Fluid Intelligence Test. The Standard Progressive Matrices (SPM) Test designed by Raven, Raven and Court[26] has been used for decades in more than 2500 published research studies. The SPM test used in the current study was designed to measure eductive components of general intelligence and cognitive ability. Eductive ability, according to Raven et al,[26] is the ability to forge new insights, the ability to discern meaning in confusion, the ability to perceive, and the ability to identify relationships. The SPM Fluid Intelligence Test was designed for homes, schools, workplaces, and laboratory settings. The SPM Fluid Intelligence Test is comprised of sets or series of diagrammatic puzzles exhibiting a serial change in 2 dimensions simultaneously. Each puzzle has a part missing, which the person taking the test has to find among the options provided.[26] The Standard Test consists of 60 problems divided into 5 sets of 12 questions each (A, B, C, D, and E). A total score (ranging from 0–12) is calculated for each of the 5 sets and each score is analyzed separately as a continuous outcome. Therefore, Fluid Intelligence is evaluated as 5 separate outcomes. More than 40 studies examining the reliability of the SPM Fluid Intelligence Test have been reported in the literature. The general findings include sound reliability in regards to internal consistency and retest reliability.[26] Each study participant in the current study completed the SPM Fluid Intelligence test in 40 minutes or less.

Perceptual Speed. Perceptual Speed has been identified as one of the most meaningful ways to conceptualize mental capacity.[27] The basic idea of human processing speed was outlined by Salthouse.[28] An individual with a faster information-processing speed, according Salthouse[28] is able to complete more cognitive operations within a specified amount of time, and is also more likely to use and update the results of previous operations before they decay below a certain threshold; if unrecoverable, future operations dependent on that information would be delayed until previous results had been recomputed.[25] Perceptual Speed is a specific type of information-processing speed theorized to be important for cognition.[25] Perceptual Speed is assessed by the speed of responding (usually on a paper-and pencil test) if everyone would be perfect if there were no time limits.[25]

Perceptual Speed tasks often involve elementary comparison search and substitution operations, with the test score consisting of the number of items correctly completed in the specified time.[29] Similar Perceptual Speed definitions have been used in psychometric research.[22,30] Three measures make up the Perceptual Speed factor in the Educational Testing Service Kit of factor-referenced cognitive tests:[30,31] Finding A's, Identical Pictures, and Number Comparison. Salthouse and colleagues[27,28] have primarily used variants of the Number Comparison task (Letter Comparison/Pattern Comparison) as support for their view that Perceptual Speed is responsible for developmental differences in higher-order cognition. Although the exact content varies depending on the type of task, generally examinees are instructed to compare 2 stimuli and mark on a line separating them indicating whether the items are the same or different. Subsequent research has also shown that comparison tasks account for a substantial proportion of the age-related variance on Fluid Intelligence tasks such as Ravens.[32]

Perceptual Speed Test. Perceptual Speed is the ability to rapidly compare visual configurations and identify 2 figures as similar or identical or to identify some particular detail that is buried in distracting material. The Perceptual Speed Test developed by Salthouse[28] is a pattern comparison whereby participants were asked to identify if 2 patterns of lines were the same or different. The patterns contained 3, 6, or 9 line segments. If the 2 patterns were the SAME, the participant was asked to write an 'S' on the line between the patterns. If they were DIFFERENT, the participant was asked to write a 'D.' There were 3 test sections each containing 32 patterns; each participant was provided 30 seconds per section. A total score (ranging from 0–32) is calculated for each of the 3 sections and each score is analyzed separately as a continuous outcome. Therefore, Perceptual Speed is evaluated as 3 separate outcomes.

Measures of Physical Fitness Using Fitnessgram[R]. Fitnessgram[R33] was developed by the Cooper Institute in an effort to provide physical educators with a tool that would facilitate communicating fitness testing results to students and to parents. Fitnessgram's[R33] physical fitness assessment program includes a variety of health related physical fitness tests designed to assess aerobic capacity (PACER), muscular strength, and muscular endurance (Push-up/Curl-up). There are several types of standards commonly used with fitness tests. Fitnessgram[R14] uses criterion-referenced health standards or standards associated with good health. Scientific information is used to determine the amount of fitness needed to meet minimum health levels. PACER (time in seconds to complete a 15-m shuttle run for elementary school and a 20-m shuttle run for middle school), push-ups (total no. possible), and curl-ups (total no. possible with a maximum of 75) are all evaluated as 3 separate continuous outcomes.

***Institutional Testing of Fitnessgram*R.** Institutional Testing per FitnessgramR33 manual is designed to help teachers and educators determine the fitness level of groups of participants at the experimental and control schools. It is important to note that fitness scores will typically be higher at the end of the school year than they are at the beginning of the school year because the students are three-quarters of a year older. Older students do better on fitness tests than younger students.[33] Furthermore, a significant amount of fitness test performance can be explained by heredity.[33–36] Although maturation and heredity contribute to physical fitness, so does frequency and duration of physical education time.

Previous Day Physical Activity Recall. A random sample of experimental and control school participants completed the *Previous Day Physical Activity Recall (PDPAR)* to assess the perceptions of physical activity. The rationale for administering the PDPAR was to identify if physical activity differences of experimental and control school participants could have influenced the results. The purpose of the PDPAR is to evaluate physical activity from the previous day after school. MET values are assigned to all of the activities and summed to compute 1 score for each child. The Compendium of Physical Activities: Classification of Energy Costs of Human Physical Activities was used to validate MET values.[37] No significant differences ($P > .05$) were observed on the PDPAR, providing additional evidence that 45 minutes of daily physical education contributed to the significant cognitive and fitness score differences between experimental and control participants.

Body Composition. Childhood obesity is one of the most dangerous health threats facing youth.[38] Body composition in the current study was initially assessed using FitnessgramR33 to calculate a BMI value for all participants. BMI is a number calculated from a child's weight and height. BMI is a reliable indicator of body fatness for most children and teens. BMI does not measure body fat directly, but research has shown that BMI correlates to direct measures of body fat, such as underwater weighing and dual energy x-ray absorptiometry (DEXA).[38] BMI can be considered an alternative for direct measures of body fat.[38] In addition, BMI is an inexpensive and easy-to-perform method of screening for weight categories that may lead to health problems. For children and teens, BMI is age- and sex-specific, and is often referred to as BMI-for-age. After BMI was calculated for children and teens, the BMI number was plotted on the CDC BMI-for-age growth charts (for either girls or boys) to obtain a percentile ranking. Percentiles are the most commonly used indicator to assess the size and growth patterns of individual children in the United States. The percentile indicates the relative position of the child's BMI number among children of the same sex and age. The growth charts show the weight status categories used with children and teens (underweight, healthy weight, overweight, and obese).[38–42] Lastly, BMI percentile is evaluated as a continuous outcome.

Statistical Analysis

All analyses were performed with SAS version 9.2. Descriptive statistics were computed for the experimental and control schools by demographics using chi-square tests and *t* tests. 2×2 repeated measures analysis of variance (ANOVA), a mixed effect linear model, was used to evaluate the effectiveness of 45 minutes of daily physical education on cognitive ability, fitness performance and body composition. Each analysis was stratified by gender and grade level (elementary school/middle school) and adjusted by age to help control for baseline differences by school. However, body composition analyses were not adjusted by age because the main outcome, body mass index percentile, inherently controls for age. The mean change within school (experimental/controls) across time (pre/post), between schools at each time point, and the interaction between time and school was estimated for each outcome. The unstructured, compound symmetry or first-order autoregressive correlation structure was controlled for serial autocorrelation. Akaike's Information Criterion and Bayesian Information Criterion were used to select among correlation structures. The data met all assumptions required of a mixed effect linear model. All P-values are 2-sided with $\alpha = .05$.

Results

Participants

Two Title I schools (1 elementary and 1 middle) were identified as controls; however, the demography of the student population at the 2 control schools differed from the experimental school. Therefore, oversampling techniques were used to identify a representative comparison sample of participants at both control schools. Control school administrators oversampled by grade level to provide additional classes with African American youth in grades 2nd–8th to serve as comparisons. The differences in demographics among the participants in grades 2nd–8th from the experimental and control schools are listed in Table 1.

Fluid Intelligence Findings

Elementary School. Elementary school females among both the experimental school and control school significantly improved on most, if not all, sections in Fluid Intelligence at the posttest assessment (Table 2). However, experimental elementary school females who received 45 minutes of daily physical education did not significantly improve their scores more than the control elementary school females.

Table 1 Participants From Experimental School and Control Schools by Demographics

Demographics	Experimental (N = 165)	Control (N = 305)	*P*
Gender, n (%)			0.348
Male	78 (47.3)	158 (51.8)	
Female	87 (52.7)	147 (48.2)	
Age (years), mean (SD)	10.2 (2.3)	11.2 (1.9)	<.0001
Grade level, n (%)			<.0001
Elementary school	104 (63.0)	85 (27.9)	
Middle school	61 (37.0)	220 (72.1)	

Experimental elementary school males significantly improved on sections A–D in Fluid Intelligence at the posttest assessment; whereas, control elementary school males did not significantly improve on any section. More importantly, experimental school males who received 45 minutes of daily physical education improved their scores significantly more than control school males on section D ($P = .02$). There were marginally significant differences in improvement between experimental and control elementary school males on section B and section C ($P = .09$, $P = .08$, respectively).

Middle School. The experimental middle school females who received 45 minutes of daily physical education improved on sections B, C, D, and E in Fluid Intelligence significantly more than control middle school females ($P = .03$, $P = .002$, $P = .003$, $P = .002$, respectively). Moreover, there was a significant drop on latter sections C, D, and E on Fluid Intelligence at the posttest assessment among control middle school females.

Similarly, control middle school males had a significant drop on the latter sections C, D, and E in Fluid Intelligence at the posttest assessment. Section E of Fluid Intelligence was the only section where experimental middle school males who received 45 minutes of daily physical education improved their scores significantly more than the control school males ($P = .002$).

Perceptual Speed Findings. Experimental elementary school females significantly improved on all sections of Perceptual Speed at the posttest assessment; whereas, control elementary school females did not significantly improve on any section (Table 3). More importantly, the experimental elementary school females who received 45 minutes of daily physical education improved on sections 2 and 3 of Perceptual Speed significantly more than the control elementary school females ($P = .006$, $P = .005$, respectively).

Elementary school males among both the experimental school and control school significantly improved on most, if not all, sections on Perceptual Speed at the posttest assessment. However, the experimental elementary school males who received 45 minutes of daily physical education did not improve their scores significantly more than control elementary school males.

Fitnessgram^R Findings: Aerobic Capacity, Muscular Strength, and Muscular Endurance

Elementary School. Experimental elementary school females significantly improved on all sections of Fitnessgram^R's fitness battery at the posttest assessment; whereas, control elementary school females only significantly improved on aerobic capacity (Table 4). Further, experimental elementary school females who received 45 minutes of daily physical education improved on curl-ups and push-ups significantly more than the control elementary school females ($P = .001$, $P = .001$, respectively).

Elementary school males among both the experimental school and control school significantly improved on most, if not all, sections of the Fitnessgram^R at the posttest assessment. However, experimental elementary school males who received 45 minutes of daily physical education did not improve their scores significantly more than control elementary school males. There was a marginally significant difference in improvement between experimental and control elementary school males in curl-ups ($P = .07$).

Middle School. The experimental middle school females who received 45 minutes of daily physical education improved on aerobic capacity, curl-ups, and push-ups significantly more than the control middle school females ($P < .0001$, $P < .0001$, $P = .02$, respectively). Moreover, there was a significant drop in aerobic capacity and curl-ups at the posttest assessment among control middle school females.

Similarly, control middle school males had a significant drop in aerobic capacity, curl-ups, and push-ups at the posttest assessment. Curl-ups was the only Fitnessgram^R test item where experimental middle school males who received 45 minutes of daily physical education improved upon significantly more than the control school males ($P = .0001$).

Table 2 Age-Adjusted SPM Raven Fluid Intelligence Pre-Post Test Scores

	ES & Female				ES & Male			
Raven test	Experimental	Control	Experimental—control	*P*-value[a]	Experimental	Control	Experimental—control	*P*-value[a]
A-Pre	7.5	7.6	0.1 (–1.2, 1.0)	0.94	7.9	9.1	–1.2 (–2.3, –0.1)*	0.19
A-Post	9.2	9.3	–0.1 (–0.9, 0.8)		9.0	9.4	–0.4 (–1.2, 0.3)	
A- A- Post-Pre	1.7 (0.9, 2.6)*	1.7 (0.8, 2.5)*			1.0 (0.3, 1.8)*	0.3 (–0.6, 1.2)		
B-Pre	6.1	6.4	–0.3 (–1.7, 1.1)	0.46	5.9	8.1	–2.2 (–3.5, –0.8)*	0.09
B-Post	8.3	8.0	0.3 (–1.2, 1.7)		7.8	8.6	–0.8 (–2.1, 0.6)	
B- B- Post-Pre	2.2 (1.1, 3.3)*	1.6 (0.5, 2.7)*			1.9 (0.9, 2.9)*	0.5 (–0.7, 1.7)		
C-Pre	3.8	3.5	0.3 (–0.8, 1.5)	0.40	3.5	5.3	–1.9 (–3.1, –0.7)*	0.08
C-Post	5.7	5.8	–0.1 (–1.3, 1.1)		5.2	5.9	–0.8 (–2.0, 0.5)	
C- C- Post-Pre	1.8 (1.0, 2.6)*	2.3 (1.5, 3.2)*			1.7 (0.9, 2.5)*	0.6 (–0.4, 1.6)		
D-Pre	3.2	3.5	–0.3 (–1.8, 1.1)	0.85	2.9	5.7	–2.8 (–4.2, 1.4)*	0.02
D-Post	4.7	5.2	–0.5 (–2.0, 1.0)		5.0	6.1	–1.1 (–2.5, 0.3)	
D- D- Post-Pre	1.6 (0.5, 2.6)*	1.7 (0.6, 2.8)*			2.1 (1.1, 3.0)*	0.3 (–0.8, 1.5)		
E-Pre	0.8	0.9	–0.1 (–0.6, 0.3)	0.56	0.9	1.4	–0.5 (–1.1, 0.03)	0.47
E-Post	1.1	1.5	–0.3 (–1.0, 0.4)		1.2	1.5	–0.3 (–0.9, 0.3)	
E- E- Post-Pre	0.4 (–0.1, 0.9)	0.6 (0.1, 1.1)*			0.3 (–0.2, 0.7)	0.1 (–0.5, 0.5)		
	MS & Female				MS & Male			
Raven test	Experimental	Control	Experimental—control	*P*-value[a]	Experimental	Control	Experimental—control	*P*-value[a]
A-Pre	10.4	10.4	0.0 (–1.0, 1.0)	0.09	9.7	10.4	–0.8 (–1.6, 0.1)	0.19
A-Post	11.2	10.4	0.7 (–0.0, 1.5)		10.3	10.5	–0.2 (–1.2, 0.8)	
F- A- Post-Pre	0.8 (0.2, 1.3)*	0.0 (–0.7, 0.7)			0.6 (–0.04, 1.3)	0.1 (–0.4, 0.5)		
B-Pre	10.0	9.9	0.1 (–1.2, 1.3)	0.03	9.2	10.0	–0.8 (–2.0, 0.4)	0.20
B-Post	10.7	9.3	1.4 (0.2, 2.6)*		10.1	10.1	–0.0 (–1.2, 1.2)	
G- B- Post-Pre	0.8 (–0.0, 1.6)	–0.6 (–1.5, 0.3)			0.9 (–0.1, 1.9)	0.1 (–0.6, 0.8)		
C-Pre	8.0	8.3	–0.3 (–1.5, 0.9)	0.002	7.6	8.4	–0.8 (–1.6, 0.03)	0.13
C-Post	8.6	7.0	1.5 (0.4, 2.6)*		6.9	6.8	0.1 (–1.1, 1.3)	
H- C- Post-Pre	0.5 (–0.2, 1.3)	–1.3 (–2.2, –0.4)*			–0.7 (–1.6, 0.3)	–1.6 (–2.2, –0.9)*		
D-Pre	6.9	6.5	0.4 (–1.2, 2.1)	0.003	7.5	8.1	–0.6 (–2.1, 0.8)	0.14
D-Post	8.4	5.1	3.3 (1.8, 4.7)*		7.4	7.0	0.5 (–0.9, 1.8)	
I- D- Post-Pre	1.5 (0.3, 2.7)*	–1.3 (–2.7, 0.01)*			–0.1 (–1.2, 1.2)	–1.1 (–2.0, –0.3)*		
E-Pre	2.6	3.1	–0.5 (–1.6, 0.6)	0.001	1.9	3.7	–1.8 (–3.0, –0.7)*	0.002
E-Post	3.5	1.8	1.6 (0.7, 2.6)*		2.4	2.4	0.0 (–0.9, 0.9)	
J- E- Post-Pre	0.9 (0.1, 1.7)*	–1.2 (–2.1, –0.4)*			0.5 (–0.5, 1.4)	–1.4 (–2.1, –0.7)*		

* $P < .05$.

[a] Test for an interaction between school and time.

Note. Differences may vary due to rounding.

Table 3 Age-Adjusted Perceptual Speed Test Scores

Perceptual speed test	ES & Female				ES & Male			
	Experimental	Control	Experimental—control	*P*-value[a]	Experimental	Control	Experimental—control	*P*-value[a]
Sec.1-Pre	13.9	13.5	0.4 (–2.4, 3.2)	0.36	13.0	13.2	–0.2 (–2.9, 2.5)	0.19
Sec.1-Post	16.7	15.0	1.7 (–0.5, 3.8)		16.2	14.6	1.6 (–0.4, 3.6)	
K- Sec.1-	2.8 (1.0, 4.7)*	1.6 (–0.4, 3.5)			3.3 (1.4, 5.1)*	1.4 (–0.6, 3.5)		
L- Post-Pre								
Sec.2-Pre	10.1	13.5	–3.4 (–5.6, –1.2)*	0.006	12.7	12.6	0.1 (–2.2, 2.4)	0.41
Sec.2-Post	14.8	14.8	–0.0 (–1.4, 1.4)		15.7	14.7	1.0 (–0.6, 2.6)	
M- Sec.2-	4.7 (3.1, 6.3)*	1.3 (–0.4, 3.0)			3.0 (1.5, 4.5)*	2.0 (0.4, 3.7)*		
N- Post-Pre								
Sec.3-Pre	10.2	11.8	–1.7 (–3.3, –0.01)*	0.005	11.7	11.0	0.7 (–0.8, 2.1)	0.82
Sec.3-Post	13.6	12.4	1.2 (–0.1, 2.6)		13.8	13.3	0.4 (–1.1, 2.0)	
O- Sec.3-	3.4 (2.0, 4.8)*	0.5 (–0.9, 2.0)			2.1 (0.9, 3.3)*	2.3 (0.9, 3.7)*		
P- Post-Pre								

* $P < .05$.

[a] Test for an interaction between school and time.

Note. Differences may vary due to rounding.

Table 4 Age-Adjusted Fitnessgram[R] Test Scores

	ES & Female				ES & Male			
Fitnessgram[R] tests	Experimental	Control	Experimental—control	*P*-value[a]	Experimental	Control	Experimental—control	*P*-value[a]
Pacer-Pre	23.7	16.8	6.9 (1.7, 12.1)*	0.65	17.2	14.0	3.2 (–0.9, 7.3)	0.83
Pacer -Post	31.2	23.1	8.2 (1.9, 14.5)*		20.3	16.7	3.6 (–0.6, 7.8)	
Q- Pacer - R- Post-Pre	7.6 (3.6, 11.5)*	6.3 (2.2, 10.3)*			3.1 (0.9, 5.4)*	2.8 (0.2, 5.3)*		
Curl up-Pre	15.2	20.6	–5.4 (–11.8, 0.9)	0.001	13.9	17.3	–3.4 (–9.1, 2.2)	0.07
Curl up -Post	23.8	18.3	5.5 (0.4, 10.6)*		20.4	20.5	–0.1 (–5.8, 5.6)	
S- Curl up - T- Post-Pre	8.6 (4.1, 13.1)*	–2.3 (–6.9, 2.2)			6.5 (4.1, 9.0)*	3.2 (0.4, 5.9)*		
Push up-Pre	10.1	6.7	3.5 (1.0, 6.0)*	0.001	5.7	8.2	–2.5 (–4.8, –0.2)*	0.28
Push up -Post	13.4	6.3	7.2 (4.6, 9.7)*		7.9	9.3	–1.5 (–4.1, 1.2)	
Push up - Post-Pre	3.3 (1.8, 4.8)*	–0.4 (–1.9, 1.1)			2.2 (1.0, 3.4)*	1.2 (–0.2, 2.5)		

	MS & Female				MS & Male			
Fitnessgram[R] tests	Experimental	Control	Experimental—control	*P*-value[a]	Experimental	Control	Experimental—control	*P*-value[a]
Pacer-Pre	26.2	43.2	–17.1 (–24.8, –9.4)*	<.0001	18.7	23.2	–4.5 (–9.7, 0.8)	0.08
Pacer -Post	32.0	21.2	10.8 (4.0, 17.6)*		18.2	17.3	1.0 (–4.1, 6.0)	
Pacer - Post-Pre	5.8 (–1.4, 13.0)	–22.1 (–26.6, –17.5)*			–0.5 (–6.1, 5.1)	–5.9 (–8.4, –3.3)*		
Curl up-Pre	28.2	46.2	–18.0 (–26.6, –9.5)*	<.0001	18.8	28.1	–9.2 (–17.4, –1.1)*	0.0001
Curl up -Post	33.2	33.7	–0.5 (–7.5, 6.5)		25.8	20.9	4.9 (–1.9, 11.8)	
Curl up - Post-Pre	5.0 (–2.3, 12.3)	–12.5 (–17.4, –7.7)*			6.9 (–0.2, 14.0)	–7.2 (–10.7, –3.8)*		
Push up-Pre	9.6	8.4	1.2 (–0.8, 3.1)	0.02	4.2	8.3	–4.1 (–6.7, –1.4)*	0.07
Push up -Post	13.0	8.2	4.8 (1.6, 8.0)*		4.8	5.9	–1.0 (–4.0, 1.9)	
Push up - Post-Pre	3.4 (0.9, 5.9)*	–0.2 (–1.9, 1.5)			0.6 (–2.3, 3.6)	–2.4 (–3.9, –1.0)*		

* $P < .05$.

[a] Test for an interaction between school and time.

Note. Differences may vary due to rounding.

Body Composition Findings

Elementary School. Experimental elementary school females who received 45 minutes of daily physical education improved their body mass index percentile significantly more than control elementary school females ($P = 0.0004$). There was a significant increase in body mass index percentile at the posttest assessment among control elementary school females. There were no significant changes in body mass index percentiles observed for elementary school males among either the experimental school or control school (Table 5).

Middle School. There were no significant changes in body mass index percentile observed for middle school females or middle school males among either the experimental school or control school as well.

Discussion

Cognitive Findings

Providing 45 minutes of daily physical education can improve fitness and is perhaps linked to increases in Fluid Intelligence and Perceptual Speed. Experimental elementary and middle school participants observed significantly greater improvements compared with control elementary and middle school participants in 7 of 16 fitness and body composition measures and in 8 of 26 cognitive measures. These fitness, body composition, and cognitive improvement differences were more noticeable among elementary and middle school females.

Examining the relationship between exercise training history and performance on Fluid Intelligence, Lochbaum and colleagues[43] found that aerobically trained or physically active participants performed significantly better on the Fluid Intelligence task than untrained or inactive participants. A more recent study published by Singh-Manoux and colleagues,[44] which investigated the impact of physical activity on cognitive function of middle-age individuals, revealed that low levels of physical activity was identified as a risk factor for poor performance on Fluid Intelligence tasks.

This finding is similar to the research by Davis and her colleagues at the Medical College of Georgia. Davis et al[45] tested the effect of aerobic training on Executive Function in overweight children. Executive Function tends to correlate highly with Fluid Intelligence and is an appropriate comparison for the current study. Fluid Intelligence, similar to Executive Function, is related to planning and organizing information, and was related to physical activity in their study. Davis et al[45] found that children who received the high-dose of physical activity had higher planning scores than the controls. Exercise, according to these researchers, may be a simple but important method to enhance mental function.[43]

Furthermore, Reed and colleagues[5] examined the impact of integrating physical activity into core curricula approximately 30 minutes a day, 3 days a week among 3rd graders and found that children in the experimental group performed significantly better on the SPM Fluid Intelligence Test. Children in the experimental group also performed significantly better on the social studies state mandated academic achievement test. Experimental group children received higher scores on the English/language arts, math and science achievements tests, but were not statistically significant compared with control group children.

Perceptual Speed has also been defined as a cognitive ability described as "speed in comparing figures or symbols, scanning to find figures or symbols, or carrying out other very simple tasks involving visual perception"[30]. Allen[46] illustrated how this ability influences performance of untrained users who search information retrieval systems. Evidence from the current study suggests that Perceptual Speed is perhaps linked to increases in aerobic capacity, muscular strength, and muscular endurance, in light of the fact that experimental participants improved significantly on a number of the Fitnessgram[R] measures by gender and grade level. Additional studies should be performed to expand the knowledge base in this important area of research.

Fitness and Body Composition Findings

Three out of every five (65.4%) adults in this southeastern state are overweight or obese.[47] Overweight or obesity is more prevalent in males (71.5%) than females (59.4), and among African American adults (73.6% vs. 63% for whites).[47] Approximately 32% of high school students in this southeastern state are overweight or obese;[47] and nearly 48% of all African American rural children ages 10–17 years old in are overweight or obese, compared with 23% of white rural children. Equally disturbing, over 25% of low-income children ages 2–5 are overweight or obese in this southeastern state.[47] Recent data collected by this southeastern school district revealed that 36% of Caucasian youth, 44% of Hispanic youth, and 49% of African American youth are overweight and/or obese.[48] A lack of participation in regular physical activity has perhaps contributed to this epidemic. The experimental elementary school females who received 45 minutes of daily physical education did improve their body mass index percentile significantly more than the control elementary school females. Similarly a significant increase in body mass index percentile at the posttest assessment among control elementary school females was also found. However, there were no significant changes in body mass index percentile observed for middle school females or middle school males among either the experimental school or control school. Continuing to examine the impact of body composition on academic performance, achievement and cognition is important considering researchers at the RAND Institute identified that overweight kindergartners had significantly lower math and reading test scores in comparison with children who were not overweight.[49] Furthermore, overweight and obese youth compared with their peers, are more likely to have risk factors associated with cardiovascular disease, such as high blood pressure, high cholesterol, and

Table 5 Body Composition Findings

	ES & Female				ES & Male			
BMI %ile	Experimental	Control	Experimental—control	P-value[a]	Experimental	Control	Experimental—control	P-value[a]
Pre	67.7	78.6	–10.9 (–21.6, –0.3)*	0.0004	73.5	77.4	–3.9 (–16.8, 8.9)	0.475
Post	63.4	84.2	–20.8 (–31.6, –10.0)*		77.4	78.2	–0.8 (–14.2, 12.6)	
Post-Pre	–4.3 (–8.0, –0.6)*	5.6 (1.8, 9.4)*			3.9 (–1.6, 9.5)	0.8 (–5.8, 7.5)		
	MS & Female				**MS & Male**			
BMI %ile	**Experimental**	**Control**	**Experimental—control**	**P-value[a]**	**Experimental**	**Control**	**Experimental—control**	**P-value[a]**
Pre	65.1	74.1	–9.3 (–21.0, 2.3)	0.768	74.5	74.8	–0.3 (–12.9, 12.3)	0.649
Post	67.0	74.4	–7.1 (–17.7, 3.5)		79.7	75.9	3.8 (–11.1, 18.7)	
Post-Pre	1.9 (–11.1, 14.9)	–0.3 (–7.6, 7.0)			5.2 (–11.4, 21.8)	1.1 (–5.1, 7.4)		

* $P < .05$.

[a] Test for an interaction between school and time.

Note. Differences may vary due to rounding.

type 2 diabetes.[50] According to the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), more than 80% of individuals with type 2 diabetes are overweight.[50] Close to 60% of 12-year-olds exhibit 1 modifiable coronary artery disease risk factor, while 27% exhibit 2 factors, possibly attributable to a lack of regular physical activity.[51]

Experimental elementary and middle school participants observed significantly greater improvements compared with control elementary and middle school participants in 7 of 16 fitness and body composition measures and in 8 of 26 cognitive measures. These fitness, body composition, and cognitive improvement differences were more noticeable among elementary and middle school females. Recent findings from this particular state's YRBS statistics reveal that 49% of middle school and 67% of high school students respectively, did not meet recommended levels of physical activity; and 38% of middle school and 66% of high school students, respectively do not attend physical education classes at least once a week.[52] The Centers for Disease Control and Prevention provide several strategies schools can use to help students meet national physical activity recommendations without negatively impacting academic performance that include increasing the amount of time students spend in physical education.[53]

Conclusions

Findings from the current study demonstrate that providing 45 minutes of daily physical education can perhaps increase cognitive ability-while enhancing fitness and decreasing the prevalence of overweight and obese youth. The US public school system functions as an egalitarian institution. Regardless of race, ethnicity, socioeconomic status or gender, all children have the right to attend public school. For many children, it is their only opportunity to be physically active. The current emphasis on performance pedagogy and standardized testing such as the No Child Left Behind Act (NCLB), have led many school districts to reduce physical education offerings. In extreme cases the amount of daily recess has also been drastically reduced or eliminated to increase classroom contact hours in an effort to boost test scores.[54]

A recent brief from Active Living Research Program Office sponsored by the Robert Wood Johnson Foundation[54] further validates the impact of physical activity on cognition, academic achievement, and performance. It is reasonable to assume, according to Ernst and colleagues[55] that if schools and communities work together that physical activity levels of youth could be increased. Such increases in activity would, no doubt, help many adolescent youth to meet minimal criterion level fitness standards[55] and perhaps increase their cognitive ability. Furthermore, the Centers for Disease Control and Prevention revealed in a recent review paper examining links between physical education and academic performance that 11 of the 14 studies had 1 or more positive associations between school-based physical education and academic performance indicators.[53] In addition, the review found that physical activity can have an impact on cognition-an important component of improved academic performance.[53]

Limitations

The primary limitation in the current study was the variability in sample sizes among the experimental and control schools. The experimental school in the current study was a small neighborhood Title I charter school with limited enrollment. Approximately, 40 students per grade level were enrolled in kindergarten through 2nd grade, with 20–25 students per grade level in grades 3rd–8th. A representative subsample of elementary and middle school control participants was reanalyzed following the initial analysis of the data. This analysis yielded similar results suggesting that sample size differential did not statistically affect the results.

The demography of the 2 control schools was also a limitation in the current study. Oversampling techniques were used to identify enough minority participants in grades 2nd–8th to serve as controls. Although the physical education curriculum at the experimental and control schools mirrored each other-the lessons were not identical.

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