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Examining the Impact of Daily Physical Education on Perceptual Speed among Underserved Elementary and Middle School Youth

Reed JA*, Kilpatrick E, Malafronte N and King S

Department of Health Sciences, Furman University Greenville, SC 29613, USA

***Corresponding author:** Julian A. Reed, Associate Professor Health Sciences Furman University Greenville, SC 29613, USA, Tel: 864-294-2328; E-mail: julian.reed@furman.edu

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Abstract

Developmental research has demonstrated that Perceptual Speed is related to higher cognitive abilities and linked to physical activity participation. PURPOSE: The purpose of the study was to examine the impact of 45 minutes of daily physical education on Perceptual Speed among youth attending Legacy Charter School.

Methods: An analysis of variance (ANOVA) mixed effect linear model was used to evaluate the effectiveness of 45 minutes of daily physical education and Perceptual Speed among youth in grades 2nd-8th attending Legacy Charter, a Title I school in the southeastern US. Gain scores (final post-test assessment in May 2014 - original pre-test assessment in September 2013) were calculated and analyzed for significance and for the interaction between school and time was estimated for each outcome. Each analysis was stratified by gender and adjusted by age to control for baseline differences by school. Two Title I control schools who did not provide daily physical education were identified and utilized as comparisons.

Results: Legacy Charter School students observed significant gain increases on: 4 of 4 ($p<0.05$) Perceptual Speed sections including the Total section, compared to 0 of 4 for controls ($p<0.05$). Legacy Charter School females significantly improved on Perceptual Speed Section 1 (Gain Score=3.18; F=7.18, df=1,409, p=0.008), Section 2 (Gain Score=2.45; F=7.64, df=1,409, p=0.004) and the Total Section (Gain Score=7.60; F=14.27, df=1,408, p=0.000). Legacy Charter School males significantly improved on Perceptual Speed Section 1, Section 2 and the Total Section ($p<0.05$) at the post-test assessment as well. Legacy elementary school females and males significantly improved on Perceptual Speed Sections 1 at the post-test assessments ($p<0.05$); no significant improvements in Perceptual Speed among control elementary school female and male students ($p>0.05$) were observed.

Conclusions: 45 minutes of daily physical education led to increases in Perceptual Speed among Legacy Charter male and female elementary and middle school students.

Keywords: Healthy; Childhood; Physically; Skills; Knowledge; Cognitive; Control; Perceptual

Introduction

According to the Institute of Medicine (IOM) [1] obesity prevalence among youth in the United States (US) is 17%; which is approximately three times what it was over three decades ago. Youth spend up to half their waking hours in school, schools therefore have the ability to support and encourage obesity prevention strategies through implementing effective policies. These strategies should include promoting and providing opportunities for physical activity, physical education, and healthy eating [1]. The rise in childhood obesity, according to the Surgeon General of the US, is attributed to reductions in physical activity opportunities in schools, primarily in physical education. Cawley et al. [2] recently examined the impact of physical activity on obesity among elementary school children using data from the Early Childhood Longitudinal Study; and found that physical education (i.e., 150 minutes per week) reduces the probability of obesity [2].

The 2012 South Carolina Children's Health Assessment Survey (CHAS) revealed that a low percentage of adolescents are participating in daily physical activity. As high as 72% of youth between the ages of 5 and 17 reported not exercising, playing a sport, or participating in physical activity for at least 60 minutes that made them sweat or breathe hard during the previous 7 days [3]. Unfortunately, federal mandates continue to emphasize academic achievement, leading many school districts to provide only curricula to improve test scores, resulting in instruction time reductions for physical education [1].

Physical education, physical activity and brain health

The research agenda investigating the impacts of regular physical activity, physical education on cognition, academic performance and academic achievement continues to be understudied. However, promising findings from the IOM document positive associations between participation in regular physical activity and brain health [1]. Less than 4% and 8% of US public elementary and middle schools, respectively, provide daily physical education [4]. These low percentages limit the availability to identify all of the potential associations between physical activity, and a variety of cognitive measures. Nonetheless, available data from recent studies highlighted by the IOM [1] and the Centers for Disease Control and Prevention (CDC) [5] substantiate that physically active and physically fit children have greater academic performance, academic achievement and enhanced cognition compared to their less active peers. Furthermore, 11 of the 14 studies described in the CDC's report had at least one positive association between physical education and academic outcomes, including tests scores and grades. Equally important to these findings, research shows that increased time devoted to physical education did not adversely affect academic outcomes regardless of less time spent on core classroom curriculum [5].

Evidence supporting the association between physical activity and academic performance has been demonstrated most recently in Texas. The Texas Education Agency examined over 2.4 million students and found higher levels of physical fitness (measured by Fitnessgram^{R}) [6] were associated with better academic performance. Higher levels of fitness were also associated with better school attendance and fewer disciplinary incidents, including those associated with drugs, alcohol, violence, and truancy. 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 [7].

A growing body of scientific literature reveals a relationship between vigorous and moderate-intensity physical activity and the structure and brain function [1,8-10,15,16]. Both acute bouts and steady behavior of vigorous and moderate-intensity physical activity have positive effects on brain health [10-15]. Additionally, the concept that healthy children learn better is empirically supported and well accepted in the literature [10-15]. Sibley and Etnier [11] revealed in their review paper that exercise is significantly linked to improved cognition in youth. Physical activity has also been documented to increase brain-derived neurotrophic factor (BDNF), which supports learning capacity and cognition and is regulated by physical activity [11-13]. Regular physical activity can also stimulate structural changes in the hippocampus region of the brain, an important area for memory [13].

Legacy Charter is the only public school in South Carolina to provide daily physical education. Physical education is where youth learn essential skills to become physically active adults--yet few US public elementary and middle schools provide daily physical education. [4] Developmental researches has demonstrated that Perceptual Speed is related to higher cognitive abilities and linked to physical activity participation. The purpose of the present study was to examine the impact of providing 45 minutes of daily physical education on cognition (i.e., Perceptual Speed) of elementary and middle school youth at Legacy Charter School in Greenville, South Carolina. One control elementary school and one control middle school that did not provide daily physical education were identified as controls. In the present study, the physical education requirements for the control elementary school was 45 minutes one day per week for grades 2nd-5th. At the control middle school, students received 50 minutes of daily physical education for only the fall semester in grades 6th-8th.

Methodology

Background on Legacy Charter School

Legacy Charter School is a public Title I school located in Greenville, South Carolina. The purpose of Title I is to ensure that all children 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. Title I designation enables all children at Legacy Charter School to receive a free breakfast, lunch, and snack five days per week.

Physical education at Legacy Charter School and Control schools

Legacy Charter School is the only school in South Carolina to provide all children, in all grades, 45 minutes of physical education 5 days per week. Physical education content was standardized for consistency at Legacy Charter School and the control schools. Legacy Charter and the control schools utilized developmental curricula with an emphasis on fundamental skills and fitness. The elementary control school provided 45 minutes of physical education one day per week. The middle control school provided 50 minutes of physical education for only the fall semester. Both control schools had similar demography to Legacy Charter School and were also Title 1 schools.

Participants

Six-hundred and two (N=602) elementary and middle school students at Legacy Charter School participated in the present study. Two Title I schools were identified as controls (N=505). All participants in grades 2-8 from Legacy and controls participated in the present study.

Testing Procedures and Research Design

All students at Legacy Charter School enrolled in grades 2-8 participated in the present evaluation. Internal Review Board (IRB) procedures were strictly followed. A pre/post-test design was utilized in the present study. All participants were pre-tested on the cognitive measures (i.e., Perceptual Speed), during the first week of September, 2013. Students were post-tested during the last two weeks of May, 2014. All cognitive measures were administered by the research team.

Statistical Methods

An analysis of variance (ANOVA) mixed effect linear model was used to evaluate the effectiveness of 45 minutes of daily physical education on Perceptual Speed among youth in grades 2nd-8th attending Legacy Charter, a Title I school in the southeastern US. Gain scores (final post-test assessment in May 2014 - original pre-test assessment in September 2013) were calculated and analyzed for significance. Also for the interaction between school and time was estimated for each outcome. Two Title I control schools who did not provide daily physical education were identified and utilized as comparisons.

Data Analysis

Gain scores were analyzed for significance and the interaction between school and time was estimated for each outcome. Each analysis was stratified by grade level to help control for baseline differences by school. The Statistical Package for Social Sciences (SPSS [21.0]) was used to examine the data.

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Perceptual Speed Test

In tests of Perceptual Speed the items to be compared may be presented at the same time or one after the other. Subjects may also be asked to compare a present object with a remembered object. Among the most meaningful ways to conceptualize mental capacity is in terms of an individual's processing speed [17]. Perceptual Speed is also used to establish a profile of scores on a selection of well-known primary mental abilities. One of the primary mental abilities in visual thinking that has been identified repeatedly is Perceptual Speed. It is the ability to rapidly compare visual configurations and identify two figures as similar or identical. It is also the ability to identify some particular detail that is buried in distracting material. The Perceptual Speed Test developed by Salthouse [18] is a pattern comparison in which participants were asked to identify whether two patterns of lines were the same or different. The patterns contained 3, 6 or 9 line segments. If the two 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 three test sections in the present study; each participant was provided 30 seconds per section.

Results

Legacy Charter students improved significantly on all four (p<0.05) grade adjusted Perceptual Speed sections (including the Total) following the post-test assessments (Table 1) compared to control school students.

School	N	Section 1			Section 2			Section 3			Total		
		Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain
Legacy Charter School	602	13.85	17.01*	3.47*(F=13.46 df=1,859 p=0.000)	13.92	16.54*	2.57*(F=12.74 df=1,859 p=0.000)	12.5	14.36*	1.99*(F=6.20 df=1,861 p=0.013)	40.43	47.77*	7.97*(F=22.06 df=1,857 p=0.000)
Control Schools	505	14.48	16.39	2.35	14.96	16.29	1.65	13.15	14.17	1.45	42.58	46.86	5.5

Table 1: Perceptual speed pre-post grade adjusted test scores.

Examination of the data by gender revealed similar results. Legacy Charter School females significantly improved on Perceptual Speed Section 1 (Gain Score=3.18; F=7.18; df=1,409; p=0.008), Section 2 (Gain Score=2.45; F=7.64; df=1,409; p=0.004) and the Total Section (Gain Score=4.60; F=14.27, df=1,408, p=0.000). Legacy Charter School males significantly improved on Perceptual Speed Section 1 (Gain Score=3.74; F=6.75; df=1,450; p=0.010), Section 2 (Gain Score=2.68, F=5.53, df=1,450; p=0.019) and the Total Section (Gain Score=8.32; F=8.90; df=1,449; p=0.003) at the post-test assessment as well. Control school females and males did not significantly improve on any of the Perceptual Speed Sections, including the Total Section at the post-test assessment (p>0.05). The Perceptual Speed raw and gain scores for Legacy Charter and control school females and males are listed in Table 2 below.

School	Gender	N	Section 1			Section 2			Section 3			Total		
			Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain
Legacy Charter School	Female	279	14.07	17.31	3.18*(F=7.18; df=1,409; p=0.008)	14.36	16.72	2.45*(F=7.64; df=1,409; p=0.004)	12.50	14.39	2.02	41.04	48.28	7.60*(F=14.27; df=1,408; p=0.000)
	Mal e	323	13.66	16.72	3.74*(F=6.75; df=1,450; p=0.010)	13.55	16.37	2.68*(F=5.53; df=1,450; p=0.019)	12.52	14.33	1.96	39.94	47.28	8.32*(F=8.90; df=1,449; p=0.003)
Control Schools	Female	242	14.76	16.54	2.01	15.19	16.36	1.45	13.17	14.18	1.42	43.13	46.89	4.70
	Mal e	267	14.23	16.26	2.64	14.77	16.23	1.82	13.13	14.16	1.47	42.11	46.83	5.78

Table 2: Perceptual speed pre-post grade adjusted test scores for gender.

Examination of the findings adjusted by grade level and gender for both Legacy Charter School females and males revealed significant Perceptual Speed increases at the post-test assessments. Legacy elementary school females and males significantly improved in Perceptual Speed Section 1 at the post-test assesments (p<0.05); no significant improvements in Perceptual Speed among control elementary school female and male students (p>0.05) were observed .

Legacy Charter middle school females significantly improved on Perceptual Speed Section 2 (Gain Score=2.42; F=6.69; df=1,229; p=0.010) at the post-test assessment. No significant improvements in Perceptual Speed among control middle school female and male students (p>0.05) were observed. The Perceptual Speed raw and gain scores for Legacy Charter and control school females and males by grade level are listed in Table 3 below.

School	Gender	N	Section 1			Section 2			Section 3			Total		
			Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain
Legacy Elementary	Female	125	10.84	14.25	3.66*(F=4.10; df=1,218; p=0.044)	12.20	14.69	2.53	10.55	12.75	2.23	33.58	41.67	8.42*(F=3.92 df=1,217 p=0.049)
	Male	176	11.10	14.39	3.88*(F=10.59; df=1,259; p=0.001)	11.42	14.50	3.04*(F=9.77; df=1,25; p=0.002)	10.61	12.66	2.26	33.09	41.27	9.05*(F=9.56; df=1,259; p=0.002)
Elementary School Control	Female	94	10.59	13.20	2.93	11.90	13.53	1.96	10.16	11.60	1.83	32.57	38.40	6.95
	Male	96	11.92	13.78	2.74	12.10	13.79	2.10	10.71	12.28	2.17	34.76	40.20	7.15
Legacy Middle	Female	154	16.69	19.44	2.76	16.13	18.21	2.42*(F=66.9 df=1,229 p=0.010)	14.18	15.59	1.82	47.21	53.12	6.90*(F=10.94; df=1,229 p=0.001)
	Male	147	16.61	18.92	3.08	16.22	18.19	1.88	14.78	16.12	1.54	48.10	53.30	6.50
Middle School Control	Female	148	17.36	19.12	1.49	17.18	18.38	1.06	14.90	16.00	1.14	49.44	53.00	3.23
	Male	167	15.69	18.15	2.83	16.22	18.07	1.85	14.57	15.51	1.00	46.43	51.71	5.67

Table 3: Perceptual speed pre-post grade adjusted test scores for gender and grade level.

Discussion

Developmental research has demonstrated that Perceptual Speed is related to higher cognitive abilities [18]. Several different kinds of mental speed are identified in the psychological literature [17]. The basic idea of human processing speed was outlined by Salthouse [18]. An individual with faster information-processing speed, according to Salthouse [18] is able to complete more cognitive operations within a specified amount of time, he/she is also more likely to utilize 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 [19] Salthouse and Babcock [17] provided an example of this concept in terms of performing mental arithmetic. Suppose an individual is asked to calculate the product of 2 two digit numbers (e.g., 23 × 14=?). The conventional way to solve this problem would be to multiply 23 by 4 first, multiply 23 by 10 next, and then sum the two products period [17] An individual with a faster processing speed would compute the individual operations more quickly than an individual with a slower processing speed period [17] For a slower individual, because each product takes longer to produce, a greater amount of time would elapse during the two calculations. If enough time passes, the memory trace of the first product could decay below a critical threshold before the individual could sum the products [17,19].

Perceptual Speed is a specific type of information-processing speed theorized to be important for cognition [20]. Perceptual Speed is assessed by the speed of responding if everyone would be perfect if there were no time limits [17,19]. 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 [19] Similar Perceptual Speed definitions have been used in psychometric research [21]. Three measures make up the Perceptual Speed factor in the Educational Testing Service Kit of factor-referenced cognitive tests: Finding A's, Identical Pictures, and Number Comparison. Salthouse et al. [19] 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 two stimuli and mark on a line separating them whether the items are the same or different.

Comparison tasks accounted for all but 1.1% of the age-related performance on a Working Memory Capacity composite, more than that accounted for by performance on processing-only or storage only components of the Working Memory Capacity tasks, suggesting that Perceptual Speed is highly correlated with Working Memory Capacity [17,19]. 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 [19].

Results from the present study found that youth attending Legacy Charter School significantly improved in Perceptual Speed at the post-test assessments compared to controls regardless of grade level or gender. Legacy Charter provided each student 45 minutes of daily physical education for the entire school year, while the control elementary school only provided 45 minutes of physical education one day per week and the middle school provided physical education for only the fall semester. Studies have shown that students who participate in daily physical education programs have much larger gains in physical fitness compared to those who participate on a weekly occurrence [22,23].

Physical education provides a variety of movement experiences [24]. Including the development of cognitive skills such as enhanced memory, better concentration and increased problem-solving abilities

[24]. Unfortunately, South Carolina is one of the nation's leaders in the percentage of children (50%) who do not participate in afterschool team sports or lessons [25] and 83% of high school students currently do not attend daily physical education when in school. Furthermore, 65% of high school students currently do not attend physical education classes [25] in an average week. The CDC's State Indicator Report on Physical Activity for 2010 [25] found that only 20% of high school students are physically active.

In 1991 Drs. James Sallis and Thomas McKenzie published a seminal paper entitled: Physical Education's Role in Public Health, which has become one of the most cited papers in the history of the Research Quarterly for Exercise and Sport. This paper successfully defined the role of public health in regards to the importance of daily physical education [26]. Twenty years later, the authors along with some of their esteemed colleagues re-examined the rationale and goals of their original work in Physical Education's Role in Public Health: Steps Forward and Backward over 20 Years and HOPE for the Future [26] published in June, 2012.

Apparent from this retrospection is the continued importance of a quality physical education in reducing society's ills linked to obesity and inactivity. One of the physical education's major roles is to improve the health of all children. To accomplish this, the authors emphasize the importance of federal, state and local policy makers to encourage all health professionals to collaborate to "optimize" physical education's contributions by promoting health and wellness across the lifespan. The most impactful way to ensure that children have daily physical activity opportunities, including daily physical education is to implement the US National Activity Plan released in 2010. The Plan's vision is that one day, all Americans will be physically active and will live, work, and play in environments facilitating regular physical activity [27].

The Plan is a comprehensive set of policies, programs, and initiatives designed to increase physical activity in all segments of the population including physical education; with specific strategies addressing the role of physical education to improve the health of youth, consistent with the academic outcomes of schools. The Plan seeks to create a national culture that supports physically active lifestyles that will improve health, prevent disease and disability, and enhance quality of life of all Americans in all age groups. Although the US Physical Activity Plan outlines steps to re-engineer physical activity into daily living, previous policy initiatives (e.g., Healthy People 2000 and Healthy People 2010) struggled to meet their benchmarks and objectives, providing doubt that The Plan can't be successful unless public health professionals and elected officials to work together to provide every child the ability to be active throughout their lifetime. Yet, only 20% of school districts in the US had a wellness policy that required daily recess, and children who are at the highest risk of obesity are the least likely to attend schools that do offer recess [28].

Being an overweight child has been linked to poor IQ test performance [15]. Judge and Jahns [29] 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 to non-overweight children in the same grade. Researchers at the RAND Institute found that overweight kindergartners had significantly lower math and reading test scores in comparison to children who were not overweight [30].

Kolb and Whinshaw [31] identified how the pattern of neural specialization (often referred to as the pruning of synapses in the nervous system) can be determined in part by environmental stimulation. Hillman et al. [16] examined EEG brain activity in children who were considered to have high levels and low levels of fitness while performing a choice-reaction test. Children who were considered to possess a high level of fitness performed this task more rapidly and had larger P3 amplitudes, which are consistent with enhanced executive functioning. The links between time spent in physical education and academic achievement have also been documented in numerous studies. Carlson et al. [32] investigated 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. Blakemore [33] 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 [12,33]. An established relationship between physical activity and the cognitive abilities of the cerebellum has also been identified. Research additionally suggests that increased blood flow as a result of movement enhances the cerebellum by promoting specific cognitive functions [13,29,32,34].

Hillman et al. [14] 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 to the resting session. These findings indicate that single, acute bouts of moderately-intense aerobic exercise (i.e., 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 attention and academic performance [14].

Conclusions, Implications and Limitations

Results from the present study illustrate that providing 45 minutes of daily physical education to all students can increase cognition. For many children, school is the only setting in which they can participate in regular physical activity. The emphasis on performance pedagogy and standardized testing has 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. The female to male ratio not being equal is a limitation in the present study.

The CDC's Division of Adolescent and School Health in 2010 disseminated a review of 50 studies from 43 research articles entitled: The Association between School Based Physical Activity, Including Physical Education, and Academic Performance [5]. The findings from this review found that approximately 51% of the associations identified were positive, thus evidence is available documenting that physical activity can help improve academic achievement and cognitive skills, which are important components of improved academic performance.

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