Concurrent Effects of School-Based Physical Activity Intervention on BMI Status and Academic Achievement in School-Aged Children.

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Abstract

Objectives*: Research has documented an increased prevalence of obesity rates and low level achievement in mathematics for school aged children in America. However, despite the preponderance of research, there has been very little done to systematically review school based physical activity (PA) intervention effects on both BMI status and academic achievement in children. The purpose of this systematic review was to examine concurrent effects of school-based PA interventions on both BMI and academic achievement in children and the role of BMI in this effect.* ***Methods:*** *Seven experimental studies that met the inclusion criteria for this review were extracted from 218 peer-reviewed articles.* ***Results****: This review found that participation in daily 40-minute vigorous aerobic PA for 13-15 weeks yielded significant intervention effects in executive function and the math achievement tests, but not in the reading tests and BMI z-scores for sedentary, overweight children. However, participation in either daily 15 minute sessions of physically active academic lessons or weekly 90-minute aerobic PAs for a year, yielded concurrent significant positive changes in BMI percentiles and higher scores in math achievement tests for children with varying BMI statuses and diverse ethnic backgrounds. In particular, a significantly greater proportion of the obese and at-risk for obesity children involved in the intervention, decreased their BMI percentiles compared to the control peers. In addition, the obese children gained the most significant improvement in the math achievement tests compared to other two groups.* ***Conclusions:*** *longitudinal and regular school-based PA interventions generate positive improvements in BMI percentiles and math achievement tests among school-aged children regardless of their weight status, ethnic backgrounds, and socioeconomic situations.*

Keywords: *Obesity, Academic Achievement, Executive Function, Physical Activity.*

Introduction

There are national concerns about the childhood obesity epidemic and American students' weak achievement in mathematics.[1-4] Although at the surface these two variables may not appear to be linked, together they can be said to make a huge impact upon the overall academic success of each individual student. Approximately 17% of youth in the United States are obese, with rates of obese and overweight children averaging approximately 32%.[1] In the 2012 Programme for International Student Assessment (PISA) Mathematics Assessment,[3] 25% of U.S. students did not reach the baseline goal, level 2. Among the 34 countries in the Organization for Economic Co-operation and Development (OECD), the United States performed below average in mathematics in 2012.[3] Given these challenges in public health and school education, a growing body of research has recently investigated the impact of pediatric obesity on academic achievement, executive function, and academic behaviors in school-aged children.[5-10]

Similar to the research about obesity that has reported an adverse effect on health, there have also been analogous reports which demonstrate an adverse association between obesity and academic achievement in school-aged children.[5-10] Three longitudinal studies [5-7] of 6,250-11,000 children found that overweight/obese children scored significantly lower than their normal weight peers on math and reading tests at Kindergarten entry, the end of the first-grade, and the end of the third-grade. Notably, in one study obesity had a more negative effect on mathematics than reading achievement in elementary school children.[8] In this study, children in the persistent obese group (becoming obese from Kindergarten through fifth-grade) and children in the later onset obese group (becoming obese at third- and fifth-grade) had significantly poorer math scores compared to their non-obese peers.[8] Correspondingly, overweight/obese children had low executive function and cognitive

abilities, such as a lack of attention, cognitive control, and mental perseverance, slow reaction time, and inflexible mental adjustment, compared to their normal weight peers.[8-14]

Due to the health risks associated with obesity, health professions suggest several strategies for combating the prevalence of childhood obesity. Since physical activity (PA) has been empirically identified as an effective means to promote physical health and to help fight against childhood obesity [8, 14-25], one such strategy is to engage school-aged children in 60 minutes or more of daily moderate-to-vigorous physical activity (MVPA).[4] This seems particularly relevant since research shows that overweight/obese children are less physically active than their normal weight peers and are more likely to be at risk for physical inactivity.[1, 4] In addition, empirical studies suggest that engaging in the recommended amount of daily MVPA is beneficial to cognitive functioning of the brain and academic achievement.[4] In an attempt to reverse the negative effects of obesity on academic achievement and behavior in school-aged children, researchers have begun to explore the potentially beneficial effects of PA on obesity and cognitive health simultaneously. More recently, a handful of studies have found that PA interventions had significant effects on improving overweight/obese children's academic achievement and behaviors compared to their normal weight peers.[14-21]

To date, extant meta-analyses and systematic reviews have examined the relationship between PA and academic achievement and behaviors.[22-25, 28-33] They concluded that time spent in PA during a physical education (PE), a recess, and an active classroom did not have harmful effects and in some cases had a positive effect on students' academic achievement and behaviors. However, the extant meta-analyses and systematic reviews did not specify what specific PA intervention (i.e., type, intensity, duration and frequency of PA) resulted in positive improvements in academic achievement, academic behaviors, and BMI percentiles in children of varying BMI status. In particular, they did not synthesize the effects of school-based PA intervention on both BMI status and academic achievement among the students who were from low-income family and/or were at high-risk for obesity and poor academic performance.[19, 20]

To fill the gaps in extant reviews and to meet the preeminent priority of improving children's health and educational outcomes, there is a critical need to conduct a systematic review of studies that examine the role of BMI in the effect of PA interventions on BMI and academic achievement in children. This systematic review aimed at examining concurrent effects of school-based PA interventions on both BMI and academic achievement in children of varying BMI status, looking specifically at the role of BMI in this effect. The significance of this review lies in helping gain a better understanding of the relationship among PA, BMI status, and academic achievement in children. Furthermore, it will provide empirical insight for health professions and schools to design effective academic and PA programs to fight against childhood obesity and to enhance students' academic achievement.

Method

2.1 Data Sources

Six database engines, including ERIC, Google scholar, Medline, PsychINFO, PubMed, and Sport Discus, were used to conduct an original literature search of studies that were published since 1995. Two types of key words were paired with BMI and obesity in each database search, the first type being PA (e.g., physical activity, exercise, physical fitness, motor skills, movements, sports, physical education, recess, physical activity breaks, classroom-based physical activity) and the second being academic achievement (e.g., academic achievement, grade point average, academic performance, classroom behaviors, cognitive function, brain health, and brain function). All searched articles were screened to eliminate the duplicates. Published meta-analysis and systematic reviews were cross-checked with the searched articles in order to include any articles that were missed from the original search. As a result of the screening and the cross-check, 218 articles in PA associated with academic achievement and behaviors, brain cognitions, and BMI were downloaded.

Prior to reviewing the abstracts of 218 articles, two investigators were trained in identifying different types of research designs and learning the inclusion and exclusion criteria used in this review. In this review, the inclusion criteria were (a) intervention studies that used pre-post, quasi experimental, or randomized controlled

trial research designs published in peer-reviewed journals since 1995; (b) children and adolescents aged between 5 to 18 years without learning disabilities; and (c) outcome measures must include the combination of physical activity, BMI, and academic achievement, academic behaviors, or brain cognitions. The exclusion criteria included (a) review articles, theoretical articles, and correlational/cross-sectional studies in the outcome measures mentioned above; (b) any article that did not examine the concurrent effect of PA intervention on both BMI and academic achievement/behaviors.

Three strategic steps were used in the process of data extraction. First, to accurately exclude any research articles that used correlational /cross-sectional study design from the downloaded 218 articles, inter-rater reliability between the two investigators was checked through independently reviewing and evaluating three articles as either correlational/cross-sectional study, pre-post intervention study, quasi-experimental research design, or randomized controlled trial study. After reaching 100% agreement on the evaluation of the three articles, the two investigators began to independently review and exclude the articles that were correlational/cross-sectional studies from the pool of 218 articles. The two investigators then cross-checked each excluded article to ensure it was a correlational/cross-sectional study. After this process, 64 articles remained in the pool and 154 articles were excluded. At this stage, the two investigators sorted the articles that met the inclusion criteria for this review and then cross-checked the sorted articles again. They excluded any articles that did not examine the combination of the measures PA, BMI status, and academic achievement/time on task/cognitive functioning from the remaining 64 articles. As a result of the data screening, extraction, and sorting process, seven intervention studies that met the inclusion and exclusion criteria were included in this review. Given the limited number of studies, a systematic review was conducted.

2.2 Data Extraction

The investigators independently read the full texts of the seven articles and then reached 100% of the agreement on each article's meeting the inclusion criteria in this review. The seven studies were then extracted using the standard data extraction template. It included location of study, year of publication, research purpose, participant characteristics, research design, outcome measures, and key results with significant levels. The extracted data are described in table 1.

2.3 Data Syntheses

The seven studies were analyzed descriptively in terms of location, years of publication, participant characteristics, and intervention characteristics. Then, Assessing Quality of Reports of Randomized Clinical Trials checklist[26] was used to evaluate the study quality of each article. The checklist consisted of 10 items with a 2-point rating scale: "yes" =1 or "no" =0. After becoming familiar with the checklist and understanding how to evaluate each article with the checklist, the first two authors used the checklist to independently evaluate the study quality of each article with the 10 items on "yes" =1 or "no" =0 rating scale. The inter-rater reliability was 84% between the two investigators' independent evaluation of each article, and the overall composite score of the study quality were calculated.

Results

3.1 Study Quality

Of the seven intervention studies, the overall average quality score was 7.71, ranging from 5 to 10 points rated as 1 vs 0 on 10 items (see table 2). Three studies' overall quality score was above the average score, ranging from 9 to 10 (16-18). Of the three studies with a high quality score, Davis et al.[16] and Donnelly et al.[18] met all criteria, while Davis et al.[17] met 9 out of 10 criteria, except for missing the description of research objectives. In contrast, the other four studies' overall quality score was below the average score, ranging from 6 to 7. Of the four studies, one [21] used a randomized controlled trial, while the other three studies [15, 19-20] utilized a quasi-

experimental design. Those four studies did not conduct a power analysis of the sample size.[15, 19-21]. Three out of the four studies failed to meet one of the two criteria such as Evaluation Blinded and Withdrawal.[15, 19-21]

3.2 Descriptive Analysis

Of the seven intervention studies, all were completed in elementary schools, six of them in the USA [15-20] and one in Australia.[21] All seven studies [15-21] were published in 2007 or later. The sample size varied widely across the studies. In two studies [15, 16,] the sample size was less than 100, ranging from 94 to 97 elementary school students. The sample size of three studies ranged from 171 to 620 students,[17, 19, 21] and two studies' sample sizes were over 1,000, ranging from 1,073 to 1,527 school-aged children.[18, 20] Regarding the age group, six of the seven studies targeted students in grades 3-5 at baseline,[15-17, 19-21] the exception targeted students in grades 2-3 at baseline.[18] With respect to ethnic background of the student population, students were predominantly white ranging from 69% to 86% in three studies [15, 18, 21]; student populations were predominantly African American ranging from 61% to 75% in two studies [17, 16]; student populations were predominantly Hispanic (65.9%) in one study [20]; in one study, the majority of students were from economically disadvantaged, Latino immigrant families.[19]

The type and duration of the PA interventions varied as well. Two studies used two doses of after school aerobic-exercise interventions 5 days per week, lasting for 15 weeks and 13 weeks, respectively.[16, 17] One study used a physically active academic lesson as an intervention strategy for one year.[15] Two studies used physically active academic lessons as the intervention strategies lasting for 2 years [20] and 3 years.[18] One study[19] used the combination of Dance Dance Revolution (DDR) exergames with aerobic fitness activities as the physically active recess intervention, lasting for two years. One study used specialist-taught PE lessons as the intervention strategy for two years.[21]

3.3 Immediate Effect of PA Intervention

Grieco et al.[15] examined the immediate effects of a series of 10-15 minute physically active academic lessons on time-on-task (TOT) of children with varying BMI status at pre- and post- intervention compared to a control group that was inactive during the 10-15 minute lessons. The study found that the students in the normal weight, the at-risk for overweight, and the overweight groups showed statistically significant decreases in TOT following the inactive academic lesson, than they showed prior to the lesson. The highest magnitude of the decreased TOT was in the overweight group, followed by the at-risk for overweight group, while the least change in TOT was the normal weight group. Conversely, in the 10-15 minute physically active academic lesson condition, students in all BMI groups exhibited slightly, but not statistically significant increases in TOT from before to after the physically active academic lesson without significant interaction effects with BMI.

3.4 Short duration of PA interventions

Two studies [16, 17] examined the effects of after-school aerobic physical activity (PA) interventions on executive function, academic achievement, and BMI in sedentary overweight children. The children were randomly assigned to high-dose (40 minutes of aerobic exercise per day, 5 days per week), or low-does (20 minutes of aerobic exercise per day, 5 days per week) in the two studies. Of the two studies, one intervention lasted for 15 weeks,[16] another one lasted for 13 weeks. [17] The control group did not receive any after-school aerobic exercises. The two studies [16, 17] consistently found that overweight children in the high-dose group scored statistically higher than the control overweight peers on the Cognitive Assessment System (CAS), Planning scale (executive function processes) and the Broad Math test at post-test, but not on the Broad Reading test. However, there were equivocal findings when comparing the intervention effects on the executive function and Broad Math test between the low-dose group and the control group. One study[16] reported that children in the low-dose group did not score significantly higher than the control peers on CAS Planning scale at post-test. In

contrast, the other study [17] found that the low-dose group scored statistically higher than the control on the Planning scale at the post-test, but there was no statistical difference in the Broad Math and Reading scores between the low-dose and the control groups. Additionally, the study[16] found no significant intervention effects on the three groups' BMI z-score.

3.5 Long Duration of PA interventions

Four studies [18-21] reported that when students took part in a PA intervention that lasted at least 75 minutes/week for at least a year regardless where the intervention took place (PE class, classroom, or recess), there were significant intervention effects on BMI status and math test scores. In Donnelly et al.'s study,[18] children in the Physical Activity Across the Curriculum (PAAC) group received 90 minutes of moderate-to-vigorous physically active academic lessons along with a 60-minute PE lesson per week. The study found that, in the three-year intervention, PAAC schools that had greater than 75-minute PAAC lessons per week showed significantly lower increases in BMI compared to schools that had less than 75-minute PAAC lessons per week. In particular, 21.8% of PAAC children who were at risk for obesity moved to the normal BMI percentile from baseline to year three, compared to the 16.8% in the control children. Over the three years of testing, PAAC children scored significantly higher in the composite, reading, math, and spelling skills on the Wechsler Individual Achievement Test-2nd Edition as assessed by trained psychologists who were blinded to conditions, compared to the control children.

Similarly, in the study by Hollar et al.,[20] the intervention children received daily 10-15 minutes of physically active academic lessons along with daily physically active recesses per week throughout the year 2 of the two year intervention (Year 1 did not include PA intervention), while the control children did not receive any intervention. Hollar et al.[20] found that significantly more intervention children stayed within the normal BMI percentile range than did the control children. Additionally, obese children in the intervention schools decreased their BMI percentile by 4.4%, compared to their counterparts (2.5%) in the control school. The intervention children exhibited significantly higher scores in math on the Florida Comprehensive Achievement Test (FACT) than did the control children, but not in the FACT reading score. When the FACT results were further analyzed by BMI percentile group, the study found that both the intervention normal weight and the intervention obese children exhibited significant increases in math scores (greater than or equal to Level 3, the state learning requirement). In addition, the intervention obese children had significant improvements in math scores (greater than or equal to Level 2, the state minimum learning requirement).

Likewise, in Gao et al.'s study,[19] the fourth-grade students received 15-minute DDR-based exercises and 15-minute aerobic fitness activities 3 times per week, while third- and fifth-grade students served as the control group in year 1 and year 2, respectively. Gao et al.[18] found significant changes in the intervention children's four BMI groups in year 1 only. Higher percentage of the intervention children (61% in year 1, 64% in year 2) remained in the Health Fitness Zone (HFZ), compared with 48% of the control children in year 1 and 52% of the control children in year 2. The intervention children scored significantly higher than the control peers on the Utah Criterion-Referenced math test, but not on the reading test in both years of the intervention in low-income Latino school-aged children.

Telford et al.[21] examined the effect of a 2-year PE intervention taught by specialists on both body composition and academic achievement. The study found that the students who received 150 minutes of PE lessons per week taught by the PE specialist for two year showed significantly less increases in percentage of body fat (.66%) than did the students in the classroom teacher-taught PE lessons. The PE intervention students showed a greater improvement in math scores than did the control students, but no difference was observed in writing and reading tests over the two years.

Discussion

This review is central to examining the concurrent effects of PA interventions on BMI and academic achievement in school-aged children. The discussion is organized into three parts: (a) intervention effects on BMI and academic achievement, (b) strengths and implications of the studies, and (c) limitations of the studies and recommendations for future studies.

4.1 Intervention Effects on BMI and Academic Achievement

This review found that 40 minutes of daily aerobic PA for 13-15 weeks did not yield significant changes in BMI z-scores, but did generate significant improvements in executive function and math achievement tests for sedentary overweight children.[16, 17] In other words, while the sedentary overweight children gained significant benefits, through the increase in their executive function and math test scores, they did not reap the health benefits, which come from significantly reducing their BMI z-scores. In line with the present results, several meta-analysis and systematic reviews [22-25, 27-32] stated that aerobic exercise yielded the strongest effects on executive function in school-aged children and older adults, compared to other types of PA. Furthermore, in a series of studies that examined the effects of aerobic fitness on executive functions in school-aged children, the results provided empirical insights into the mechanisms underlying the causal link between aerobic exercises and executive functions. [29-41] these studies [37-41] indicated that the higher-fit children exhibited greater P3 amplitude (e.g., increased attention to and discrimination of a stimulus) and shorter P3 latency (e.g., faster cognitive processing speed during the completion of stimulus-response tasks), compared to lower-fit counterparts. The higher-fit children demonstrated more accurate responses and more flexible regulation of cognitive control in both compatible and incompatible conditions. In contrast, the lower-fit children showed less accurate responses as the task difficulty increased and no modulation of cognitive control across the task conditions. The higher-fit children displayed smaller ERN (error-related negative) amplitudes compared to the lower-fit peers during a rapid response task. Also, the higher-fit children exhibited a greater flexibility and efficiency in modulation of action monitoring processes responding to more demanding tasks relative to the lower-fit children.

Although those studies [37-41] did not examine the direct association between regular aerobic PA and changes in elements of executive functions, the results provided empirical support for the significant effects of aerobic PA on improved elements of executive functions, such as allocation of attention resources, quick and accurate responses, and self-monitoring goal-oriented actions.[37-41]

Also, this review found that aerobic PA interventions that lasted at least one year yielded concurrent significant positive changes in BMI percentiles and greater improvements on math achievement tests in children with varying BMI statuses and diverse ethnic backgrounds.[18-20] Although the intervention strategies varied across the studies, including a one-year intervention with daily 10-15 minute physically active academic lessons in conjunction with physically active recess, a three-year intervention with weekly 75 minutes or more of physically active academic lessons combined with a 60-minute PE lesson per week, and a one-year intervention with 30-minute structured aerobic exercise at recess three times per week, the results were consistent across all three studies.[18-20]

Further, this review found that the role of BMI in the intervention effect on BMI percentile shifts and academic achievement was significantly greater for obese and the at-risk for obesity children in the intervention groups, compared to the control peers. In each of these studies the obese and at risk for obesity children significantly decreased their BMI percentiles compared to the control peers [18-20]. In addition, the obese children in the intervention gained the most significant improvement in the math achievement tests compared to the normal weight and at-risk for obesity groups.[20] Besides those, Grieco et al. [15] reported that in the control condition (physically inactive academic lesson), overweight children showed the largest magnitude of a significant reduction in time-on-task, followed by the at-risk for overweight, and the normal weight children. In contrast, in the physically actively academic lesson intervention conditions, the children in all three BMI status groups did not show any decreases in time-on-task. Partially corroborating the present results, Coe et al. [42] reported that children who participated in daily 60 or more minutes of MVPA have higher academic grades, compared to

children who did not meet the physical activity guidelines. Furthermore, in a meta-analysis of 59 studies and analyzing 86 effective size (ES) extracted from 39 experimental studies, Fedewa and Ahn [24] stated that aerobic exercises had the greatest significant effect on cognitive outcomes in children compared to the other types of PA interventions. Likewise, a very recent systematic review of eight randomized controlled trials [43] noted that aerobic PAs had a significantly positive effect on children's academic performance. Consistent with previous findings reported in the systematic reviews, [24, 43] Telford et al.[21] reported that the intervention children who participated in aerobic PA during most of the PE lessons gained significant improvements on the math achievement test, compared to the control children.

4.2 Strengths and Implications

This review synthesized two unique findings that were not reported in the extant meta-analysis and systematic reviews. They were (a) participation in a daily 15-minute physically active academic lessons per week for three years, or weekly 90-minute aerobic PA for one year yielded significantly higher math scores and positive changes in BMI percentiles in the intervention children compared to the control counterparts; (b) as a result of participation in a daily 10-15 minutes of physically active academic lessons, or weekly 90-minute aerobic PA, the obese/overweight children gained the most improvements in the math achievement tests and the most positive change in the BMI percentile compared to the normal weight peers.

This review suggests that school should promote physically active academic lessons throughout a school day in conjunction with quality physical education, structured recess, and after school physical activity participation programs. This review also lends a support for the Comprehensive School Physical Activity Program (CSPAP) that suggests classroom-based physical activity breaks are one of five key components contributing to students' daily physical activity participation.[44] This review confirms the results of the recent systematic review of nine classroom-based studies [31] that showed the positive relationship between the classroom-based PAs and academic performance.

4.3 Limitations and Recommendations for Future Studies

While this review indicated the positive concurrent PA intervention effects on BMI and academic achievement, it has yet to conclude the causal link between specific PA intervention strategies and the two outcomes. The undetermined causal intervention effects are largely related to methodological limitations of the studies.

One limitation was that, four of the seven studies did not describe whether or not both the intervention and the control children participated in similar PE and/or recess programs during the school day and after school programs. If the study did not use similar situations to control these variables, it would be difficult to indicate that the results of the study were mainly caused by the intervention strategy versus other factors. Another limitation of the studies was related to intervention fidelity. While two studies [15,18] assessed the fidelity of the intervention implementation across the school year by trained research assistants, the other five studies did not describe whether or not researchers used a validated instrument to assess the intervention implementation in terms of lesson objectives, content, organization, levels and durations of students' involvement in each lesson, and students' intensity levels of physical activity in each lesson.[16-17, 19-21] In addition, the studies did not provide specific information about the number of intervention sessions implemented across the intervention years even though one study reported the children's average attendance of the intervention exercise.[16] The studies were limited to comparing aerobic-typed PA intervention strategies with control conditions, rather than comparing the intervention effects between two different experimental conditions such as two different types of PA intervention strategies. It still remained unknown about whether other types of exercises such as age-appropriate yoga, Pilates, eye-hand coordination activities, and brain-gym PAs integrated into physically active academic lessons were also effective in improving students' BMI, academic achievement, academic behaviors, and executive function. Lastly, six out of the seven studies did not have daily or weekly accelerometer-measured MVPA data during the intervention.

Given the limitations of the present studies in this review, the recommendations for future studies are provided as follows:

While keeping environmental variables under similar conditions, future study is warranted to focus on examining the concurrent effects of one specific intervention program on students' BMI and academic achievement.

Future intervention may consist of multi-facet intervention programs including quality PE, structured recess, physically active academic lessons during a school day as opposed to one single intervention component to promote students' academic performance and healthy body weight.

Future study should utilize a reliable and validated instrument to assess the fidelity of the intervention implementation by trained researchers, in conjunction with teachers' daily self-recording of their implementation.

Future study should investigate the effects of different types of objectively-measured PA on students' academic achievement and BMI.

While the present studies mainly target elementary school students, future studies should target students in pre-schools, middle schools, and high schools. This is important because students at different developmental stages will have different perceptions, motivations, and attitudes toward the intervention strategies and the intervention effects may vary.

4.4 Conclusions

In this review, two studies consistently reported that daily 40-minute vigorous aerobic PA for 13-15 weeks yielded significant improvements in executive functions and math achievement scores for sedentary, overweight children. However, this specific intervention did not produce any beneficial changes in BMI z-scores for sedentary, overweight children. In contrast, participation in interventions that lasted three-years and included 15 minutes of daily physically active academic lessons, or one-year with weekly 90-minute aerobic PAs generated both significantly positive shifts in BMI percentiles and significantly higher math achievement scores. In particular, a significantly larger proportion of the students maintained their healthy body weight status and reduced their BMI percentiles from the overweight to the at-risk overweight level. As a result of participating in an intervention that lasted one- year with 10-15 minutes of daily physically active academic lessons, the Hispanic and low-income obese children gained the most significant improvement in the math achievement test, compared to their normal weight and at-risk for overweight peers. This review suggests that longitudinal and regular school-based PA interventions generate positive improvements in BMI percentiles and math achievement tests among school-aged children regardless of their weight status, ethnic backgrounds, and socioeconomic situations.

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Table 1. A Summary of the Studies by Duration of Intervention

Study Citation	Research Purpose	Participants	Study Design	Outcome Measures	Key Results
Grieco, L. A. *et al*. (15) Physically Active Academic Lessons and Time on Task: The Moderating Effect of Body Mass Index *Med Sci Sports Exerc* 2009; 41: 1921-1926	Examined the effects of a physically active classroom lesson on BMI, TOT (time on-task) in elementary school children	97 students -9 third-grade classes -69.3% white, 13.9% Hispanic, 10.9% African American 5.8% Asian/Pacific Islander -Ages 8.7 ± .41 yr. -43% boys, 57% girls BMI categories: -normal weight -at risk overweight -overweight	Quasi-experimental design One time intervention Two conditions: -Experimental condition: 10-15 min of moderate-vigorous physically active academic lessons /day -Control condition: physically inactive, regular academic lesson	Time-on-Task (TOT) --15 min before and after physically active lesson -15 min before and after physically inactive lesson BMI	TOT: -In inactive condition, TOT decreased significantly from before and after the lesson for all BMI groups ($p < .05$) -Inverse association between BMI groups and TOT after the inactive lesson -In active condition, no significant increases in TOT after the active lesson ($p > .05$) BMI -No significant interaction with TOT after the active lesson
Davis C.L. *et al*. (16) Effects of Aerobic Exercise on Overweight Children's Cognitive Functioning: A Randomized Controlled Trial *Res Q Exerc Sport*. 2007; 78:510-519	Investigated the impact of aerobic exercise training on executive function in overweight children	94 overweight children -Ages: 7-11 years -Grade: 2-3 -56 girls, 38 boys -Ethnicity: 75% African American; 25% Caucasian -Overweight: 85th percentile -Average BMI=25.8	15-week randomized Control Trial 3 conditions: -40 min aerobic exercise 5 days/week after school -20 min aerobic exercise 5 days/week after school -control: no exercise	BMI and BMI z-scores Aerobic fitness treadmill test Cognitive Assessment System (CAS) measures: -Planning -Attention -Simultaneous -Successive	BMI: -no significant group differences ($p > .05$) Treadmill times: -High/low doses < control ($p < .05$) -No significant difference between high and low doses ($p > .05$) CAS: Executive Function (Planning) -High dose > Low dose /control ($p < .05$) -No significant difference between Low dose and control ($p > .05$)

Davis, C.L. *et al*. (17) Exercise Improves Executive Function and Achievement and Alters Brain Activation in Overweight Children: A Randomized Controlled Trial *Health Psychol.* 2011; 30: 91-98	Examined whether aerobic exercise training improved executive function in sedentary, overweight children	171 overweight children -Ages 7-11 years -Grade: 2-3 -44% boys, 56% girls -Ethnicity: 61% African American; 39% Caucasian -Average BMI=26	13-week randomized Control Trial 3 conditions: -40 min aerobic exercise 5 days/week after school -20 min aerobic exercise 5 days/week after school -control: no exercise	Cognitive Assessment System (CAS): -Planning -Attention -Simultaneous -Successive Woodcock-Johnson Tests of Achievement III: -Broad Mathematics -Broad Reading fMRI-measured brain activity during executive function tasks (sub-sample N=20)	CAS: Executive Function (Planning) -High dose > Low dose ($p < .05$) -High/Low doses > control ($p < .05$) Broad Math: -High dose > Low dose ($p < .05$) -No significant differences between Low dose and control ($p > .05$) -Broad Reading: No effects fMRI: -Increased prefrontal cortex activity in high /low doses ($p < .05$) -Reduced posterior parietal cortex activity in high/low doses ($p < .05$) -Motor regions, no significant difference between groups ($p > .05$)
Donnelly, J.E. *et al*. (18) Physical Activity Across the Curriculum (PAAC): A randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary	Examined the effects of PAAC on BMI, daily physical activity (PA), and academic achievement.	1490 students -Grades 2 and 3 at baseline -48.8% males, 51.7% females -814 participants in PAAC -713 participants in control -77.4% Caucasian, 10.1% Hispanic, 6.2% African American -43% qualified for free/reduced lunch	3-year randomized controlled trial 2 conditions: -PAAC Experimental Condition: 90 min / week moderate to vigorous physically active academic lessons, intermittently throughout day -Control condition: regular classroom instruction w/o	BMI scores Daily PA minutes Academic Achievement tests -reading -writing -mathematics -oral language skills	Changes in BMI: -No differences between PAAC schools and control schools ($p > .05$) -Significant lower increases between >75 min PAAC schools and <75 min PAAC schools % of children moved out of overweight category: -PAAC schools >

school children *Pre Med* 2009; 49: 336-341		BMI categories: -normal weight -at risk overweight -overweight	physically active lessons		control schools ($p < .05$) Daily PA minutes: -PAAC schools > control schools ($p = .05$) Academic Achievement tests (reading, math, and spelling scores): -PAAC schools > control schools ($p < .05$)
Gao, Z. *et al.* (19) Video Game-Based Exercise, Latino Children's Physical Health, and Academic Achievement *Am J Pre Med* 2013; 44:5240-5246	Investigated the impact of a video game exercise program (DDR) on the cardio respiratory endurance, BMI status, and academic achievement in urban Latino children.	208 students -Grades 3-5 -Ages 10-12 -121 boys, 87 girls -Ethnicity: Latino	2-year quasi-experimental design 2 conditions -Experimental condition (Grade 4): 30 min DDR + group fitness activities 3 days/week during recess -Comparison (regular recess): -Year 1=Grades 3-5 -Year 2=Grades 5-6	BMI Utah Criterion Referenced Test Scores: -Math -Reading	BMI: Health Fitness Zone (HFZ) percentage -Year 1: Significant percentage of HFZ in intervention group > comparison ($p < .05$) -Year 2: No significant changes in HFZ percentage ($p > .05$) Academic achievement tests: -Math Improvement: intervention > comparison ($p < .05$) -Reading: No difference in scores ($p > .05$)
Hollar, D. *et al.* (20) Effect of a Two-Year Obesity Prevention Intervention on Percentile Changes in Body Mass Index and Academic Performance	Investigated the effects of a school-based obesity prevention intervention on BMI and academic performance on low-income elementary school children.	1197 children -974 children in intervention schools -199 children in control school -Similar demographics and socioeconomic characteristics -qualified for free/reduced lunch -4 intervention	2-year quasi experimental design Two conditions: -Experimental condition: -HOPS (Healthier Options for Public Schoolchildren) -PA intervention conditions in year 2: -10-15 min desk-	Florida Comprehensive Achievement Test (FCAT) BMI	BMI -More intervention children stayed within normal BMI percentile than control children ($p < .05$) -More obese children in intervention schools decreased their BMI than

in Low-Income Elementary School Children *Am J Pub Health* 2010; 100: 646-653		schools, 1 control school -68% Hispanic	side physical activities (WISERCISE! TAKE10!) -Structured physically active recess. -Control condition: regular practices in classroom and recess		control schools, but no significant difference ($p > .05$) FCAT: -Intervention children FCAT math scores > control children ($p < .05$) -No significant group difference in FCAT reading scores ($p > .05$)
Telford, R.D. *et al.* (21) Physical Education, Obesity, and Academic Achievement: A 2-year Longitudinal Investigation of Australian Elementary School Children *Am J Pub Health* 2012; 102: 368-374	Examined the influence of specialized-taught physical education on academic performance and obesity in elementary school students.	620 participants -Grade 3 -29 Schools from an Australian education jurisdiction -86% white, 8% Asian, 3% Australian native -317 students, 32 classes in specialist-taught PE group. -303 students, 36 classes in the common-practice PE group. -Matched in terms of socioeconomic statuses of their suburbs, facilities, general administration, and teaching methods	2-year randomized control trial Two conditions: -Specialist-taught PE condition -Taught by 1 of 3 specialists -2 classes of 45 to 50 min/week -75 to 80 weeks of school over 2 years -Specialist-taught PE was mostly strength, balance, postural control -Common-practice PE Condition: -PE taught by classroom teachers -Mostly running activities	Academic achievement test: -Literacy and Numeracy -Writing -Reading Percentage of body fat	Percentage of body fat: -Increase of body fat in specialist-taught group < common-practice group ($p < .05$) Academic achievement tests: -Numeracy Scores in specialist-taught group > common-practice group ($p < .05$) -No significant group difference in writing scores ($p > .05$) -No significant group difference in reading scores ($p > .05$)

Table 2. Assessing quality of each intervention study

Criteria	Grieco et al. (15)	Davis et al. (16)	Davis et al. (17)	Donnelly et al. (18)	Gao et al. (19)	Hollar et al. (20)	Telford et al. (21)
Randomization	0	1	1	1	0	0	1
Evaluation Blind	1	1	1	1	0	0	0
Withdrawals	0	1	1	1	0	0	1
Objectives of study	1	1	0	1	1	1	1
Inclusion/exclusion criteria	1	1	1	1	1	0	0
Outcome measures	1	1	1	1	1	1	1
Power analysis	0	1	1	1	0	0	0
Description of intervention	1	1	1	1	1	1	1
Comparison group	1	1	1	1	1	1	1
Statistical analysis	1	1	1	1	1	1	1
Overall score	7	10	9	10	6	5	7