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Review

Physical activity and academic achievement in children: A historical perspective

Erin K. Howie*, Russell R. Pate

Department of Exercise Science, University of South Carolina, Columbia, SC 29205, USA

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Abstract

As the focus on academic achievement has increased, physical activity (PA) opportunities in schools have decreased in the United States. In an attempt to discover how the decline in PA may affect academic achievement, researchers have been studying the effects of PA on cognition and academic achievement in children for more than 50 years. This review takes a historical perspective on the science of PA and academic achievement prior to and during the past 5 years. A total of 125 published articles were included and reviewed. Fifty-three of these articles were published in the past 5 years. In recent years, the overall quality of the studies has increased, but the results continue to be inconsistent. Many use cross-sectional designs and the methods vary substantially. The majority of conclusions show a positive effect of PA on constructs related to academic achievement. Future studies should use strong study designs to examine the types and doses of PA needed to produce improvements in academic achievement.

Keywords: Academic achievement; Children; Cognition; Fitness; Physical activity

1. Introduction

Children and youth receive numerous physical health benefits from physical activity (PA), including improved fitness, cardiovascular function, metabolic function, and bone health.[1] Despite these health benefits, many children continually fail to meet PA recommendations.[2] To increase PA in a large number of children, experts have targeted schools as a setting in which to promote PA.[3,4] Most efforts to sell PA to school administrators and policymakers have emphasized its health benefits, with little success. Therefore, advocates have searched for an alternative approach to persuade decision makers to include PA in the school day. One approach has been to associate PA with academic achievement.

Because the primary goal of schools is student academic achievement, the key to increasing PA in schools would be to show that PA improves academics. Academic outcomes have become even more important since 2001, when the No Child Left Behind legislation raised the stakes of standardized academic achievement tests in the United States. As administrators have increased the focus on academic achievement since then, schools increasingly have eliminated PA opportunities.[5] In response, public health researchers have searched for the "holy grail" of PA in schools: a positive connection between PA and academic achievement. If scientific evidence verifies and supports a positive connection between PA and academics, administrators may be more likely to increase PA opportunities during the school day.

Researchers have been studying PA and academic achievement for over half a century. Now, many researchers

* Corresponding author.
E-mail address: howieek@email.sc.edu (E.K. Howie)
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contend that sufficient evidence exists to institute school PA policies that will improve (or at least not detract from) academic achievement. If this conclusion is promoted before definitive data are available, however, negative consequences may result. If researchers promote PA as a way to improve academics, and administrators later fail to see this association, promotion of PA in schools could fall several steps backwards.

Government agencies have conducted reviews on PA and academic achievement that have potential policy implications. The Centers for Disease Control and Prevention (CDC) reviewed the literature through 2008 on PA during the school day and academic achievement.[6] The CDC review concluded that PA may have a positive effect or no effect on academic performance. Additionally, the PA Guidelines Advisory Committee reviewed literature through 2007 on the health benefits of PA for children and youth, including the mental health benefits.[1] In its report, the Committee concluded, "Although observational studies have found relationships between physical fitness and grades and test scores, those between PA and direct measures of academic achievement often have had null findings."[1]

These two reviews did not include articles published since June 2007[1] or October 2008.[6] In November 2011, the American College of Sports Medicine held the Physical Activity, Cognitive Function and Academic Achievement Conference. Leading researchers, educators, and policymakers presented and discussed the most recent evidence, much of which has accumulated in the past 5 years. In order to develop a research and policy advocacy agenda for the future, it is important to consider previous work on this topic and the contemporary state of the science. The purpose of this review is to inclusively examine the literature about the connection between PA and academic performance in children in order to identify gaps for future research. This review takes a historical perspective of the literature in an attempt to answer the question: has enough evidence accumulated to support a positive relationship between PA and academic achievement?

School settings offer significant potential to increase PA in children, and several school-based interventions have successfully increased PA in this population.[7] Because children are required to attend school, schools have the potential to increase PA in more than 50 million children and youth[8] through recess, PA in the classroom and physical education. School day PA accounts for at least 70% of children's moderate-to-vigorous PA.[9] For these reasons, the American Heart Association[3] and the National Physical Activity Plan[10] advocated the essential role that schools should play in establishing policies and practices that promote PA. These policies should include regular physical education, recess, and other PA opportunities throughout the school day.

Unfortunately, PA opportunities are disappearing from America's schools.[11] Many school districts report cutting physical education in response to No Child Left Behind. The Center for Education Policy reports that 68% of schools reported funding decreases to staff in non-core academic areas, including physical education, with another 50% anticipating further cuts during the 2011–2012 school year.[5] With the increasing focus on academics, researchers have attempted to link PA to positive academic and cognitive outcomes. Several recent reviews[6,12–19] have found trends towards positive effects, but concluded that many studies used weak methodology.

A 2003 review of PA and cognition in children by Sibley and Etnier[15] found an overall effect size of 0.32 from 44 studies. The authors concluded that there is a significant positive relationship between PA and cognition. Seven categories of cognitive assessments were used, with the largest positive effect on perceptual skill tests and the smallest effect on memory tasks. Six years later, Keeley and Fox[16] used more rigorous inclusion criteria and reviewed 18 studies on the effects of PA or fitness on academic achievement or cognitive functions. The majority of studies used academic tests or grades as the outcome variables. They found that none of the studies examined the effects of PA on cognitive functions, and noted that many studies used weak methodology. The authors noted that, "there is insufficient evidence to conclude that additional physical education time increases academic achievement; however, there is no evidence that it is detrimental."[16] Because studies in adults have suggested that PA may improve executive functions, a type of higher cognitive function,[20] Best and Miller[14] restricted their review to experimental studies that examined the effect of PA on children's executive functions. They found that both acute and chronic exercise may produce improvements in executive functions.

Several reviews on PA, cognition and academic achievement were published in 2011. Ahn and Fedewa[12] reviewed studies on PA and several mental health outcomes, including cognitive impairment and conduct problems, and found a positive association with cognitive functions in randomized studies. Fedewa and Ahn[19] also conducted a thorough meta-analysis of 59 studies that examined the effects of PA or fitness on academic achievement or cognitive functions. The overall effect size was 0.32, identical to that found earlier by Sibley and Etnier.[15] The greatest effects were on math achievement, intelligence quotient (IQ), and reading achievement. In a different type of review, Tomporowski et al.[13] described the diverse PA interventions used to assess the effect of PA on children's mental functions. The review summarized intervention studies on both acute and chronic PA, finding benefits to children's academic and cognitive performance from both. The authors propose a complex meditational model by which PA may affect academic performance and advocate for studies to integrate these multiple factors.

The importance of this topic led the CDC to conduct a review of PA performed during the school day and academic achievement.[6] It found half of the associations between PA and academic achievement to be positive, with most of the others reporting null associations and only a small percentage finding negative associations. The review concluded that there is either a positive or no relationship between PA and academic performance.

As the focus on academics has increased in schools, No Child Left Behind has also taken action to close the achievement gap that exists in academic performance between

white and black students. Health disparities accompany the academic achievement gap, including disparities in fitness and obesity between these populations. Efrat[18] reviewed seven studies that examined the relationship between PA or fitness and academic-related outcomes in minority children, and found an overall positive relationship. The most recent review[17] examined 14 prospective or intervention studies that investigated the effects of PA or fitness on academics and cognition. Most of the studies included in the review used either self-reported grades or a cognitive testing battery as the outcome measure, and the authors did not break down the results by specific outcomes. The authors found a positive relationship between PA participation and academic performance but only two of the studies were rated as high-quality studies.

The explosion of reviews on this topic with slightly different review methodologies has led to slightly different conclusions. To help make sense of the accumulating information, Biddle and Asare[21] conducted a review of reviews of PA training interventions and cognitive functioning. Examining the mass of information, they concluded that there is "evidence that routine PA can be associated with improved cognitive performance and academic achievement, but these associations are usually small and inconsistent."[21] To date, the previous reviews of this literature do not suggest an overwhelming positive effect of PA on academic achievement.

2. Methods

We conducted a review of the literature in order to identify published articles about the association between PA and academic achievement. Numerous databases including PubMed, Medline, Academic Search Premier, Education Resources Information Center, and PsychInfo, were searched for the following search terms: academic, cognitive, PA, fitness, sport, exercise, and training. Previous reviews[6,12–19,21] were checked for additional references.

Studies included in this review were published before April 2012 and reported cognitive or academic achievement as an outcome of a primary study. Reviews were excluded. Observational studies had to examine an exposure of PA, fitness, sports participation, or physical education and experimental studies had to conduct a PA intervention. Studies had to include school-age children from age 6 to 18. Multiple papers that reported on the same research study were included in the review. A total of 125 (72 before 2007, 53 during or after 2007) published articles were included. A list of articles included in the review may be obtained by contacting the authors.

Study designs were defined as observational or experimental. Observational studies were further classified into cross-sectional or longitudinal studies. Experimental studies were further classified as randomized, quasi-experimental (included a control group but were not randomized), or within-subject designs. Randomized designs are considered to provide the strongest evidence of causality.[22]

Exposures and outcomes of all studies were identified. Independent variables included PA, fitness, and sports participation. PA, or any energy expenditure above resting,[23] is most commonly measured through self-report or objective measures including pedometers or accelerometers. Sports participation included the specific involvement in an organized sports team. For the purposes of this review, PA was used as the broad umbrella term for the independent variables (including sports participation, fitness, and physical education), unless otherwise noted.

Dependent variables were identified as cognitive or academic outcomes. For the purpose of this review, cognition was defined as the mental processes used to obtain knowledge.[24] Cognition encompasses a wide array of mental processes including, but not limited to, attention, executive functions, and perception. While IQ may be considered a separate construct, for this review, IQ measures were considered a composite measure of cognitive processes and included as a cognitive outcome. Executive functions include the ability to plan, organize, prioritize, and quickly shift between activities based on the inter-related skills of response inhibition, working memory, and set shifting.[25] Measures of cognitive variables included researcher-developed tasks and standardized batteries that assessed memory, spatial organization, problem solving, attention, and/or executive functions. Cognitive measures were further classified into the cognitive construct they measured. If the author did not specify the cognitive construct, a categorization of neurocognitive domains from Smith et al.[26] was used to classify the construct. The primary domains were executive functions (including working memory, inhibition, and flexibility[27]), memory, attention, and IQ.

Academic achievement was defined as relating to school performance or the quantity or quality of a student's work. It included content-specific knowledge, school performance, dropout, and school engagement. Measures of academic achievement included standardized tests, academic grades, teacher reports, or direct observations of classroom behavior. For this review, the terms academic achievement or academic performance will be used interchangeably to refer to the multiple dependent variables in this review, including cognition, unless otherwise noted.

The hypothesized relationship and operational conception of the above describe variables described above can be seen in Fig. 1. The relationships are operationalized for the purposes of this review, and more research is necessary before conclusions about potential mediators can be drawn.

3. Results

A total of 125 studies were included in this review with 72 published prior to 2007 and 53 published from 2007 through April 2012. Fig. 2 shows the number of publications per year.

In the past 5 years, 10.6 primary articles have been published per year, compared to 1.4 studies per year in the previous 50 years. Table 1 presents a summary of the studies.

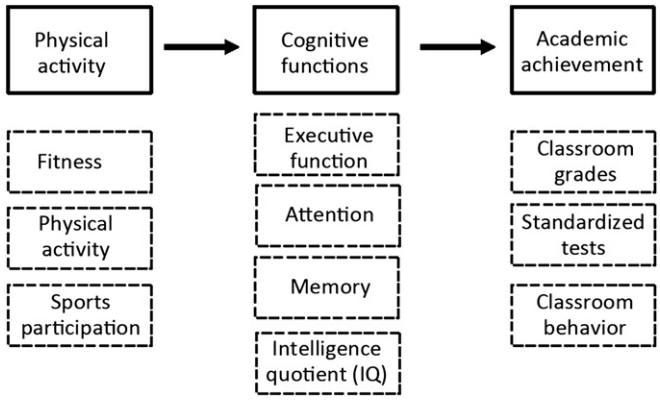

Fig. 1. The relationship of physical activity, cognitive functions, and academic achievement as defined for this review.

3.1. Academic achievement

3.1.1. Observational

Prior to 2007, 32 observational studies examined the association between some measure of PA and academic achievement. The majority of these studies were cross-sectional, only six were longitudinal. Sixteen studies examined sports participation as the independent variable, 11 studies examined fitness, eight examined PA, and one examined physical education. The average sample size was 33,126 (range of 89 to 88,715), with a median of 1000. All of the studies that examined PA used self-reported measures of PA. Multiple fitness batteries were used to assess fitness, with only one study using FITNESSGRAM.[28] Fifteen of the studies used grades or GPA reported by students or guidance counselors as the single measure of academic achievement, while 13 used standardized achievement tests. The only achievement test used in multiple studies was the Stanford Achievement Test, used in two studies.[28,29] Twenty-two of the studies (69%) reported at least one positive outcome as part of their primary findings. Only three studies reported negative outcomes, and nine studies reported a null association.

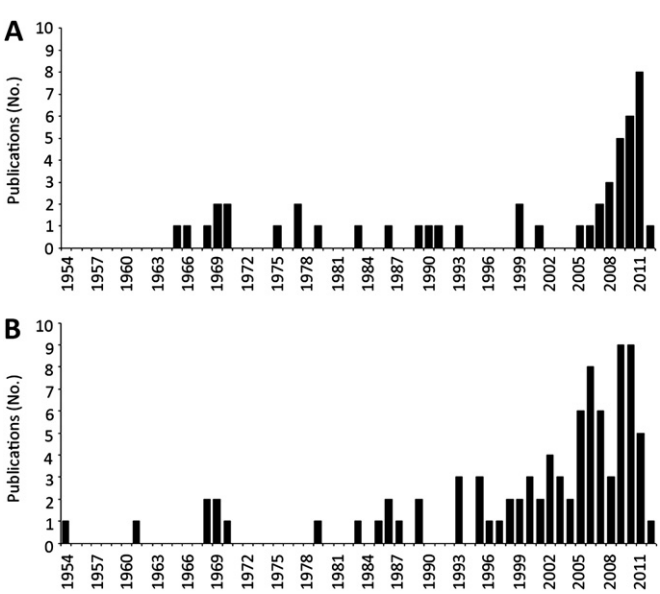

Fig. 2. The number of studies between physical activity and (A) cognition or (B) academic achievement in children per year.

Since 2007, 21 observational studies have been published, with 10 examining fitness as the exposure, seven PA, four physical education, two recess, and one sports participation. Four of the studies were longitudinal. The average sample size was 19,859 (range of 134−254,743) with a median of 1989. Seven of the 10 studies that examined the association between fitness and academics used FITNESSGRAM as the measure of fitness. Of the seven studies with PA as the independent variable, six used self-reported measures of PA[30−35] and one used accelerometers.[36] Seven studies used self-reported grades or GPA as the measure of academic achievement, with the remaining 14 using various standardized achievement tests. Nineteen studies (95%) reported overall positive associations. Two studies found no association between PA and academic achievement. Only one study reported a negative association in addition to a positive association.

3.1.2. Experimental

Prior to 2007, 23 studies examined the relationship between PA and academics using an experimental design. Less than half (39%) used a randomized design. Eight studies used a within-subjects design, five were quasi-experimental, and one study was a single-subject design. The average sample size was 228 (range of 1−2282), with a median of 88. One study examined children with intellectual disabilities[37] and two examined hyperactive children.[38,39] Of the PA interventions, 13 were physical training interventions and 10 examined the acute effects of PA. Many of the interventions modified physical education classes.[40−48] Interventions ranged in duration from 5 min of exercise[38,39,49] to 90-min PA classes[50] and included various modes of activity, including active relaxation,[51] paced walking,[52] recess,[53−55] and physical education adaptations.[40,41,44,46−48] Eighteen of the studies reported at least one positive outcome (78%). No study reported a negative finding and seven studies reported null findings.

Since 2007, 12 experimental studies that examined the effect of PA on academic performance have been published. Seven of the 12 used a randomized design, two used a within-subjects design and three were quasi-experimental. The average sample size was 313 (range of 20−1214), with a median of 163. One experimental study examined children with intellectual disabilities and utilized a home-based PA intervention.[56] Ten of the studies were PA training studies and two examined acute effects of PA. Several of the interventions included active exercise breaks, led by classroom teachers, in the classroom.[57−62] Ten studies (83%) reported overall positive outcomes. Two studies reported no effects of the intervention on the primary outcome, and one study found that the control group had greater improvements in math and reading than the experimental group.[60]

Table 1
Summary of studies on physical activity and academic achievement included in the review (number of studies).

Parameters	Before 2007 (n = 72)	2007–2012 (n = 53)
Sample size		
Average (range)	14,553 (1–884,715)	8019 (18–254,743)
Median	122	203
Research design		
Observational	34	31
Longitudinal	6	4
Experimental	38	22
Randomized control	15	12
Within-subject	12	7
Age		
Young children (<5 years)	2	0
Children (5–12 years)	35	43
Adolescents (>12 years)	34	17
Population		
Intellectual or physical disabilities	6	1
Hyperactive	3	1
Location		
North America	54	39
Outside North America	18	14
Independent variables		
Fitness	15	20
Physical activity	8	8
Sports participation	17	3
Physical education	1	4
Type of intervention		
Acute physical activity	18	8
Physical activity training	20	14
Outcome variables		
Cognition	17	20
Academic achievement	50	28
Both	5	5
Academic measures		
School grades	24	10
Standardized test	24	23
Direct observation	6	1

3.2. Cognition

3.2.1. Observational

Prior to 2007, four observational studies examined the relationship between fitness and cognition and one examined the relationship between sports participation and cognition. Four of the studies used a cross-sectional design and one was longitudinal. The average sample size was 193 (range of 24–414), with a median of 98. All five studies used different fitness and cognitive batteries. Three of the five studies reported positive associations, one found no association, and one found both negative and null associations with multiple outcomes. Specifically, the three positive associations were with IQ, behavioral control, and executive functions. The null and negative associations were with select components of IQ.

In the past 5 years, 11 observational studies that examined cognition as an outcome have been published, one of which was longitudinal. The majority (10 of 11) of these studies examined the association between fitness and cognition. One study examined sports participation[63] and one study also included PA measured by accelerometer.[64] The average sample size was 232 (range of 18–1820), with a median of 48. The most common fitness measures were FITNESSGRAM and modified Balke treadmill protocol. The majority of these studies were conducted by the same laboratory.[65–72] Several studies from this laboratory utilized the modified flanker and EEG monitoring as cognitive measures.[68–70,72] Other measures included the Stroop test[65,73] and batteries such as the Cognitive Assessment System[74,75] and the SRA test of educational ability.[63] All of the studies reported positive associations between fitness and cognition. While Ruiz et al.[63] found a positive association with sports participation, they found no association with fitness. Schott[73] found associations with fitness and select measures of executive functions. Specifically, 10 positive associations were found with executive functions, including inhibition and working memory. One positive association was found with IQ. Null associations were also found with executive functions and working memory.

3.2.2. Experimental

Before 2007, 17 studies used experimental designs to test the relationship between PA and some measure of cognition. Less than half (47%) were randomized, five were quasi-experimental and four were within-subject designs. The average sample size was 59 (range of 6–154), with a median of 40. Approximately half were PA training interventions (9 studies) and half were acute effects of PA (8 studies). Interventions included physical education and movement classes as well as yoga,[76] stretching and walking,[77] and strength training.[78] Eighteen different measures of cognition were used. The only outcome used in multiple studies was the Wecshler Intelligence Scale for Children.[79–81] Of the PA interventions, three were conducted in children with intellectual disabilities,[78,80,82] one with hyperactive children,[81] and two with children with physical disabilities.[83,84] Thirteen studies (76%) reported positive effects of the PA intervention on cognition and six reported null associations. Of the positive outcomes, two were associations with general cognitive abilities, one with concentration, two with creativity, three with learning tasks, one with perception, one with reflection-impulsivity and three with IQ. Of the null associations, two were null associations with IQ, while the other four outcomes with null associations were attention, concentration, memory, and perception.

Fourteen experimental studies on the effects of PA on cognition in children have been published since 2007. Seven used a randomized design, five were within-subject, one was

quasi-experimental, and one was a pre-post design. The average sample size was 173 (range of 20−1224), with a median of 77. Eight studies examined the acute effects of exercise and six studies looked at the effects of a PA training program. Intervention exposures ranged from a single 5-min classroom exercise break[85] to daily, semester or yearlong afterschool interventions.[74,75,86] The measures also varied and included flanker tasks[71,85,87] and standardized cognitive batteries.[74,75,88] All studies reported positive outcomes, with two studies also reporting null effects from a 5-min exercise break[85] and an acute 20-min bout.[87] Of the null associations, one was with attention, the other with executive functions. Two studies found positive effects on attention and eight studies reported positive effects on executive functions, including inhibition and working memory. One study each found positive effects on fluid intelligence, memory, and reaction time.

4. Discussion

Both the quantity and quality of studies on PA and academic achievement have increased markedly in the past 5 years. The experimental studies used stronger study designs and larger sample sizes, and more studies used valid and standardized measures of PA exposure and cognitive and academic outcomes. Despite these gains, however, several research gaps remain.

4.1. The science then

Based on the science available 5 years ago, it was difficult to draw definitive conclusions regarding the relationship between PA and academic achievement. The CDC review found just over half of the associations between PA and academic achievement in children to be positive, slightly under half to be non-significant, and 1.5% to be negative.[6] Based upon the literature at the time, the review concluded that PA either has a null or positive relationship with academic performance. It also noted the weak methodological rigor[21] that resulted from weak study designs, small samples, and inconsistent exposures and outcomes. These conclusions are supported by the present review. Many different measures were used in the studies prior to 2007 to measure cognitive and academic outcomes, and the range of outcomes included IQ, behavior, attention, concentration, creativity and learning. The exposures also varied greatly, from passive exercise to daily physical education.

4.2. The science now

While the number and quality of studies have increased in the past 5 years, it is still difficult to draw definitive conclusions regarding the relationship between PA and academic achievement. The overall findings continue to be positive; as PA increases, cognitive function and academic achievement generally increase. Almost all studies in the past 5 years have had at least one positive finding, but findings continue to be inconsistent. The most consistent positive findings, and most commonly-measured outcome, have been with executive functions, particularly inhibition and working memory. This is comparable to prior findings,[14] particularly in adults.[20] Executive functions have shown to be highly predictive of academic achievement with early assessments of executive functions predicting later academic success.[89,90] Working memory, a component of executive functions, is a predictor of vocabulary and mathematical reasoning tasks.[89] In addition, executive functions deficiencies have been researched extensively in relation to learning disabilities, including ADHD, in clinical populations;[91] children with learning disabilities have impaired executive functions. Recent research has shown that neuroelectric activity increases with fitness and also increases academic achievement.[92]

The improved consistency in study results may be a result of improved cognitive measures. More studies since 2007 used valid measures of specific cognitive functions, such as electroencephalography[93] and functional magnetic resonance imaging.[75] Using valid measures improves internal validity, but the ecological validity of how these measures relate to overall academic achievement is not well known. As previously described, executive functions have been shown to predict later academic achievement.[89,90] Intelligence measures have been shown to be the single biggest predictor of academic achievement, but only account for 20%−30% of the variance in academic achievement.[94] While this is a relatively large percent of achievement explained, this leaves a great deal of the variance in achievement unexplained. Three-quarters of achievement remains unexplained by cognitive tests. In addition, Best et al.[90] showed that this relationship appears to vary between ages and subtests of both executive functions and academic achievement. With the increased emphasis on standardized test scores resulting from No Child Left Behind, academic performance outcomes may be the most meaningful to school administrators, policymakers and teachers. Future studies need to consider the ecological validity of the cognitive measures and continue to translate results into meaningful academic outcomes.

Many nuances exist in the complicated relationship between PA and academic performance, and many studies published in the past 5 years continue to find positive effects with one measure or population and no effects in other measures. Different interventions and exposures (sports, PA, vigorous PA, fitness) continue to have widely varied and sometimes contradicting effects.[33,36] Studies in the past 5 years have found effects in girls and not boys[95] or boys and not girls.[35] Additionally, when looking at outcomes, some studies have found effects only with math,[41,57,75] only with reading,[71] or only with specific components of cognitive tests.[61,96]

Despite these mixed findings, authors often highlight positive outcomes in overall conclusions. The overall increase in positive results may be the results of a trend, intended or not, towards a positive outcome-reporting bias,[97,98] where non-significant or negative associations in selected outcome variables are not reported. Including multiple outcome variables in a study increases the likelihood that at least one

positive association is found. Based on our examination of the literature, there appears to be an emphasis on positive findings. Additionally, publication bias may also result in researchers not publishing null or negative results.[99]

4.3. The science still needed

While the science on PA and academic achievement has made great strides in the past 5 years, plenty of work remains to be done. The large majority of studies continues to be cross-sectional. Almost as many observational studies have been published in the past 5 years as in the previous half-century. With the plethora of observational studies, it is important to note that causal inferences cannot be made from cross-sectional correlations.[100] Within observational studies, more studies using prospective cohort designs are needed. Randomized controlled or within-subject designs will continue to provide stronger evidence of relationships. As mentioned previously, better measures of exposures and outcomes are needed, including objective measures of PA, standardized cognitive testing batteries, and limited self-report of grades. When multiple measures are used, all outcomes should be presented in final results. One way to select outcomes for a study is to work with school administrators and personnel to identify the most appropriate and relevant outcomes. Including school staff in a community participatory research model in all stages of research will help to make study results meaningful to the policymakers the results are intended to reach.

In addition to addressing methodological issues, future studies should continue to explore unanswered questions in this area of research. Experts in the field attending the Physical Activity, Cognitive Function and Academic Achievement Conference in November 2011 identified two large gaps in the research: identifying the dose and type of PA needed to optimally benefit academic performance.[101] Schools have limited resources, particularly time, making it necessary to advocate for an effective and efficient type of PA. Only a few studies overall have looked at variations in dose and type on academic outcomes, with conflicting findings.[48,85,96] Within the past 5 years, Davis et al.[75] found a dose response with 20 min and 40 min of exercise compared to a control condition, but in an earlier analysis, only the high-dose significantly improved executive functions.[74]

The optimal type of PA to improve academic outcomes is also unknown. While sports participation was the most common exposure in observation studies in the previous 50 years, few studies in the past 5 years have explored sports participation as an exposure or intervention. Adele Diamond, a developmental cognitive neuroscientist, argues that executive functions may benefit the most from sports participation compared to physical exercise alone.[102] Sports participation, such as martial arts, includes character development and other social skills that contribute to and benefit complex, higher-level executive functions. Unfortunately, the varied types of PA opportunities during the school day—physical education, recess, classroom exercise breaks, extracurricular activitie—have rarely been directly compared through experimental designs. Only Kubesch et al.[85] directly compared 5 min of a teacher-led classroom exercise break to 30 min of physical education and found that only the 30-min activity resulted in improvements in cognitive functions. Diamond et al.[102] point out that the effects of PA on cognitive functions are likely to differ by type of PA.

Finally, while ongoing research continues into the hypothesized mechanisms for these effects of PA on cognitive and academic performance, no inclusive mechanistic model exists.[24] PA likely influences multiple pathways including physiological, neurological, psychological, and social factors that may lead to improved academic achievement. Physiologically, regular PA has been shown to increase Brain-Derived Neurotrophic Factor (BDNF) and hippocampal neurogenesis to improve brain function.[103] Neuroelectric measures have shown improved cognitive control and attention in children after acute and chronic PA.[94] PA may also influence fitness, other social cognitive factors, and other health characteristics that may serve as mediators or moderators of this relationship.[13] Additionally, different types of PA, such as acute exercise compared to PA training, may affect different mechanisms. Research continues on these underlying mechanisms.[104–106]

This review has several limitations. To increase the breadth, the review included a wide range of published studies on PA and academics with less rigorous exclusion criteria than previous reviews. Inclusion criteria did not limit multiple publications from a single study, thus studies with multiple publications may have biased the results. Only studies published in peer-reviewed journals were included, excluding dissertations.

5. Conclusion

Researchers have made considerable progress in examining PA and academics in the past 5 years, yet results are still inconsistent. The overwhelming majority of published articles report positive associations between PA and cognition, particularly executive functions, and academic achievement. Little to no evidence that suggests a negative relationship between PA and academics has been published, but results may be prone to reporting bias. While the strength of research has increased substantially in the past 5 years, inconsistencies in exposures and outcomes make it difficult to draw strong conclusions. Thus, researchers must select arguments wisely when talking to school districts. To build an impenetrable case, researchers must carefully continue to identify the type, dose, and relevant outcomes using strong research designs.

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