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VII. THE HISTORY OF PHYSICAL ACTIVITY AND ACADEMIC PERFORMANCE RESEARCH: INFORMING THE FUTURE

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ABSTRACT The study of physical activity, physical fitness, and academic performance research are reviewed from a historical perspective, by providing an overview of existing publications focused on children and adolescents. Using rigorous inclusion criteria, the studies were quantified and qualified using both meta-analytic and descriptive evaluations analyses, first by time-period and then as an overall summary, particularly focusing on secular trends and future directions. This review is timely because the body of literature is growing exponentially, resulting in the emergence of new terminology, methodologies, and identification of mediating and moderating factors. Implications and recommendations for future research are summarized.

It is well established that healthier children learn better, as educators and scientists alike have come to recognize the vital role of physical, cognitive, and brain health in education (Basch, 2011). National physical activity guidelines suggest that a minimal threshold of 60-min of moderate to vigorous physical activity, can serve as both prevention and treatment of risk for disease (USDHHS, 2008), which in turn can facilitate academic success. Specifically, children who engage in daily physical activity, a behavior requiring energy expenditure beyond rest, reap multiple health benefits. Relative to the rate of physical activity participation are the resulting benefits that include, but are not limited to: increased physical fitness as a proxy measure of health, increased bone density, reductions in overweight/obesity, decreased risk for cardiovascular disease, and lowered likelihood of depression (Janssen & LeBlanc, 2010). Many of these health indicators have been directly and indirectly associated with academic performance. Further, the findings among observational and epidemiological research studies suggest that there is a dose–response relation with physical activity, in that, the greater the volume of physical activity engaged in, the more benefits that were evident.

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Yet, this conclusion must be applied with caution. That is, some children may view the goal of 60-min of physical activity as highly intimidating, whereas others may participate at a rate leading to overuse syndrome and possible injury. High-risk individuals accumulate the greatest gains as they initially move from a sedentary to active lifestyle; however, regardless of values, physical activity participation is necessary for all children if they are to attain and maintain the associated health benefits. The pandemic level of physical inactivity and its effect on normal growth and maturation (see Chapters 1 and 2), suggest there is much work to be done to reduce risk for disease and to maximize one's potential to succeed in school.

Children have a primary responsibility of attending school and providing evidence that they are achieving the content standards of their given grade level. If children engage in unhealthy behaviors like poor eating habits, obtaining an insufficient amount of sleep, or overindulging in screen time or other sedentary behaviors, they are less likely to experience developmentally appropriate learning. Sustained engagement in inappropriate behaviors has health consequences. For instance, children who enter school overweight or become overweight in their first few years of formalized schooling have lower academic performance on standardized tests than those children of a healthy body weight (Datar & Sturm, 2006; Datar, Sturm, & Magnabosco, 2004). Additionally, aerobically fit children (Carlson et al., 2008; Castelli, Hillman, Buck, & Erwin, 2007; Chomitz et al., 2009; Wittberg, Northrup, & Cottrell, 2009, 2012) demonstrate enhanced academic performance over their inactive and unfit peers.

With intervention, incidence of obesity and elevated risk for disease can be prevented, as these are associated with low levels of physical activity and fitness among children (Gordon-Larsen, Adair, Nelson, & Popkin, 2004; Ogden, Carroll, Curtin, Lamb, & Flegal, 2010). Of particular interest are the findings that physically active (Black, 1995; Meredith & Dwyer, 1991), physically fit (Welk et al., 2010), and normal weight children (Geier et al., 2007; Schwimmer, Burwinkle, & Varni, 2003) are less likely to miss school, because school funding formulas are often tied to student attendance statistics. Moreover, single sessions of physical activity across the school day are also beneficial, as they have been related to increased attention and on-task behaviors in the classroom (Della, Valle, et al., 1986; Grieco, Jowers, & Bartholomew, 2009; Mahar et al., 2006). Generally, the effects of attaining physical fitness and regularly engaging in physical activity on academic performance have been positive; however, study findings vary by frequency, duration, intensity, physical activity type, and cognitive task. Broadly, this body of research suggests that there may be a specificity effect, in that meeting the national physical activity guidelines results in improved physical and cognitive health (Castelli, Hillman, Hirsch, Hirsch, & Drollette, 2011; Davis et al., 2007, 2011; Van Dusen, Kelder, Kohl, Ranjit, & Perry, 2011; see Chapters 3 and 4).

Background

Several noteworthy and comprehensive reviews that address the relationships between physical activity and academic performance have been published. Systematic reviews provide snapshots of significant findings in the field and therefore, must be considered if the historical emergence of the line of inquiry is to be fully understood. Tracing the evolution of the findings of reviews may provide us with important information regarding where the research started and what future directions will reshape the landscape.

The research addressing physical activity and academic performance has quite a diversified history dating back to 1967, the point at which researchers began studying the relationship between physical activity and academic achievement in children (Ismail, 1967). Yet, it was not until 1995, when Keays and Allison examined the effects of physical activity on student outcomes, that the research of the previous 30 years was first summarized. Up until this point, studies were centered around male and female participation with a focus on aerobic intensity in physical education classes and how such participation may have affected their achievement in the classroom. Instead of the standardized assessment techniques that are commonplace today, academic performance was measured using grading scales and subjective assessments such as teacher driven exams. Keays and Allison's (1995) review recommended that schools consider increasing the amount of moderate to vigorous physical activity within the physical education lessons, as they found it to offer benefits associated with: overall health, academic performance, attitudes, and classroom behavior.

Two additional reviews emerged in 1997 demonstrating expanded interest in this area. The first review identified over 200 studies on this topic and concluded that physical activity had a small, but positive effect on cognition (Etnier et al., 1997). But, because the review was not focused on a specific stage of the lifespan, it has limited application to school-aged children. In the second review, Shephard (1997) identified the need for more curriculum time in physical education and recommended policy modification that would support such changes. This finding was juxtaposed to the *Nation at Risk Report* (National Commission on Excellence in Education, 1983) that suggested that school curricula lacked rigor because they were filled with "frills such as driver's education and physical education." Accordingly, Shephard's review represented a subtle paradigm shift from one narrowly focused on standards-based education as a means of enhancing academic performance, to one endorsing health-related experiences and development of the whole child as essential elements of the school curriculum.

By the start of the new millennium, research regarding the positive associations between physical activity and academic performance had increased, allowing the field to gain momentum until the instatement of

No Child Left Behind (NCLB) in 2002. This law emphasized the need for more mainstream instructional time thereby limiting, and in some circumstances even cutting, physical education and physical activity opportunities such as recess out of a child's school day. Positive evidence surrounding the benefits of such opportunities intersected with an increased prevalence of disease stemming from sedentary behaviors, thus prompting the implementation of school policies supporting student health and wellness (Sibley & Etnier, 2003). Despite the increase of evidence-based health initiatives, the influence of NCLB had unintended consequences whereby school administrators elected to reallocate time reserved for physical activity to academic remediation programs and standardized test preparation (Pellgrini & Smith, 1993). Although comprehensive, empirical scientific evidence did not yet exist, the magnitude of this moment in the field resulted in the continued pursuit for more rigorous ways to verify the idea that physical activity was cognitively beneficial and therefore justified for students.

In the mid-to-late 2000s, specifically 2005 through 2009, six reviews were published and although many continued to rely on correlational methodologies, significant breakthroughs in the field occurred. Strong et al.'s (2005) review concluded that physical activity duration should increase from 30 to 45 min 3–5 days/week to 60 min daily, and suggested that multiple health benefits including improved academic performance were outcomes of regular engagement. Subsequent to this, Etnier, Nowell, Landers, and Sibley (2006) identified a shift in emphasis from physical activity to aerobic fitness and its link to cognitive performance. Furthermore, recommendations for future research urged scholars to test the specific dose–response relationship between aerobic fitness and academic performance, a relationship many researchers are still examining today. By the end of 2009, the reviews had highlighted two new directions for research on physical activity and school performance. The first direction sought to examine the enhancement of children's mental functioning (Tomporowski, Davis, Lambourne, Gregoski, & Tkacz, 2008) and the second direction introduced the concept of cognitive control functioning to school-aged children, or the processes such as attention and working memory that underlie academic performance (Hillman, Erickson, & Kramer, 2008; see Chapters 3 and 4).

The current body of research is considerably larger than that from past decades as the findings of each new study continue to supersede their predecessors. Twelve reviews of the literature were published between 2010 and 2012 providing robust evidence of the evolution of the field. While national and state policies such as NCLB (2002) posit that children will perform better on tests if more time is spent in the classroom, the Robert Wood Johnson Foundation's (RWJF, 2009) recent review of the relationship between physical activity and academic performance suggests otherwise. That is, this review concluded that academic success does not increase when physical education is removed from the curriculum. Furthermore, research indicates that factors such as cognitive functioning, attendance, and concentration can benefit from physical activity. Using a cross-disciplinary approach, Best (2010) followed-up on these findings and concluded that executive function is best served by physical activity that is more "cognitively engaging" and that "both acute and chronic aerobic exercise promote children's executive function" (p. 331). This component is significant for future attempts to isolate the variables that are most effective at improving academic performance and was later corroborated by another review (Howie & Pate, 2012). As such, a summary of the reviews suggested that research should focus on what *kind* or *type* of physical activity (i.e., sports participation, everyday activities, recreational exercise) that produces the best outcomes for students as well as the *amount* of activity that is needed to obtain the highest levels of academic success.

An additional point to consider when assessing the current trajectory of the work on physical activity and academic performance is the progression of measurements of cognition. Howie and Pate (2012) distinguish between the studies measuring academic achievement and those measuring cognition. Furthermore, they explain that researchers have begun to measure cognition not just in terms of IQ, but in other ways, such as using memory assessments, spatial organization tasks, and problem-solving tasks.

While the quantity of research on the relationship between physical activity and cognitive performance has continued to increase, some believe that the quality of the research being conducted has not been able to keep pace. Singh, Uijtdewilligen, Twisk, van Mechelen, and Chinapaw (2012) carried out a systematic review, concluding that all of the studies that met their inclusion criteria produced findings suggesting a positive relationship between physical activity and academic performance. Although these results are encouraging, Singh et al. (2012) illustrated the need for future studies to utilize higher quality methodologies and more rigorous research designs. This stems from their review of ten observational/longitudinal studies and four intervention studies; only two of which were deemed by the researchers as ranking high in methodological quality. Therefore, given the conclusions reached by Singh et al. (2012) and Howie and Pate (2012), it seems that the field would benefit from the utilization of more rigorous methodological approaches.

By examining the aforementioned reviews, one is able to look at the physical education and academic performance research and gain a better understanding of the progress made in the field. Past and present research perspectives indicate that the field would benefit from pursuing certain routes of inquiry in the future. For instance, what is the dose–response relationship between physical activity and cognition and how can it best be utilized to improve academic performance? Furthermore, as stated throughout this review, researchers have continued to struggle with the adoption of more rigorous methodologies. Addressing this issue is an essential component for the enhancement of this field of study, especially if scholars continue to explore the various dimensions of academic performance via their understanding of specific aspects of cognition such as cognitive control function. Moreover, providing direct evidence of the effectiveness policies that mandate additional time and resources to physical activity programs within schools will continue to be pursued.

Accordingly, the present review is justified for two reasons: (1) to date, no known review has discussed the evolution of the research from a historical perspective and its relevance to future directions in both laboratory and applied settings, and (2) this body of literature is growing exponentially, and a substantial amount of new information has been published since the last review. As such, the purpose of this chapter is to provide a systematic review of the existing literature, as a means of identifying current trends in research related to physical fitness and physical activity engagement on academic performance in school-aged children. Unlike previous reviews, both a meta-analytic and qualitative analysis of the research are provided over the last 45 years. The following research questions guided this review:

1. How has the relationship between physical activity, physical fitness, and academic performance been examined over time and what were the conclusions?
2. What are the common correlates contributing to the associations among and between physical activity, physical fitness, and academic performance and how were these accounted for?
3. How have research findings from previous decades influenced the continued study of said variables?

METHODOLOGY

Selection of Relevant Literature

After clearly outlining the purpose, goals of the review, and definitions of terms, key search terms were identified for use in online database searches (e.g., physical activity, exercise, inactivity, sedentary behavior, physical fitness, fitness, aerobic capacity, muscular fitness, body composition, BMI, academic performance, academic achievement, executive control, executive function, working memory, memory, attention, attendance, on-task behavior, youth, child, children, adolescent, student). This computerized search was conducted through Academic Search Complete, EBSCOhost, MEDLINE, PsychINFO, PubMed, Sport Discus, and Science Direct (Elsevier). Google

Scholar was not part of the initial search but was later utilized to confirm that all relevant articles were captured by the other databases used. In addition to online searching, the references from previous literature reviews were studied to ensure inclusion of significant studies. Using these methods, 215 articles were identified.

Inclusion Criteria

A consort diagram outlining the process for the systematic screening may be found in Figure 4. It is important to note that for the purpose of this review, physical activity was defined as any behavior requiring gross motor movement and energy expenditure, while the term physical fitness was considered a trait or characteristic. It was decided among the research team that the term academic performance would be utilized and would include school attendance, on-task behaviors, standardized tests, attention, memory, and executive/cognitive control.

Rigorous adherence to the inclusion/exclusion criteria determined if the article was to be subject to further review. The initial screening criteria included: (1) written in English; (2) published between January 1, 1967, and August 1, 2013; (3) peer-reviewed; (4) an original investigation with priority

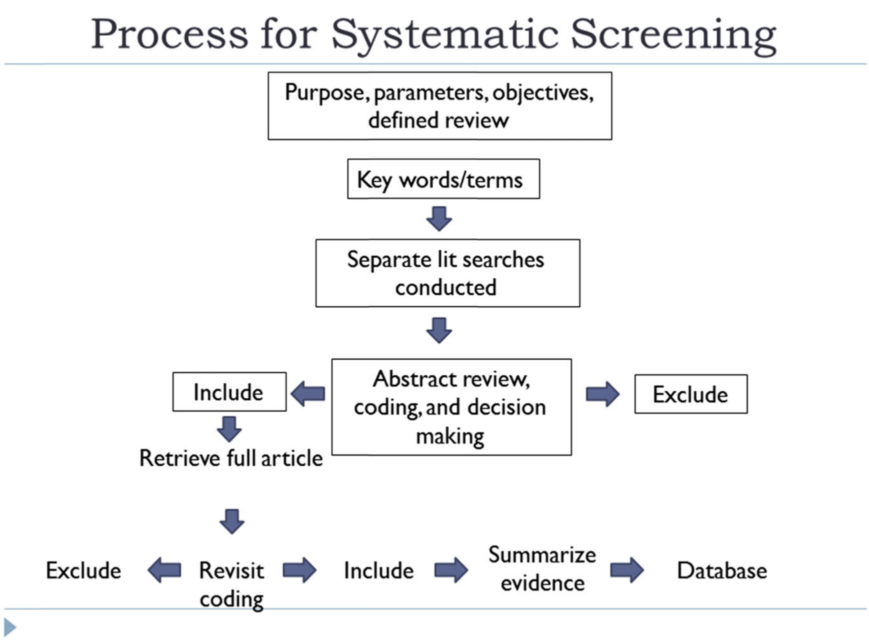

FIGURE 4.—Consort diagram.

given to intervention and randomized control trials; (5) involved human subjects between the ages of 4 and 18 (only included 18-year-olds if they were in the secondary or high school setting), who, to the best of our knowledge were of normal intelligence and neurologically typical makeup; and (6) addressed physical activity or physical fitness and academic performance as main antecedents. It is important to note that three additional exclusion criteria were different in this current study from other previously conducted systematic reviews [see Howie and Pate (2012) as an example]: (1) studies where intelligence quotient (IQ) and selected subcomponents of IQ were the only measure of cognitive performance; (2) studies that measured academic performance, but did not measure physical activity, physical fitness, or sport participation; and (3) studies using student grades as the single measure of academic performance.

Meta-Analysis Inclusion Criteria

Eligible studies were included if they met all of the following criteria: (1) experimental design having a control and treatment groups or pre- and post-treatment groups; (2) the association between physical activity and academic performance as the primary or secondary outcome; and (3) a clear definition of methods used to assess academic performance. Studies were excluded if: (1) the research design was cross-sectional, case control or interventional and/or (2) no means or standard deviations were provided.

Level of Scientific Evidence

Once the articles were selected for inclusion, priority was given to those studies employing a randomized controlled or experimental design. Among the prioritized research, the investigators attempted to identify the strength of the relationship between physical activity and academic performance and physical fitness and academic performance as evidenced by mean difference, correlation values, effect size, and observed statistical power. Whenever possible, the values were used to conduct a meta-analytic calculation for one of three time-periods (1967–1999; 2000–2009; 2010–2013) as well as in a systematic summary of the research across the decades. A secondary priority was applied to the type of cognitive measurement, validity and reliability, and standardization of the assessment. Reaction time and accuracy on cognitive tasks were included in the analysis, if academic performance data were also examined within the study.

Data Analysis

All 215 articles that met the initial inclusion criteria were coded using the Downs and Black checklist (1998) and subjected to qualitative and quantitative analysis using frequency counts and descriptive statistics, for individual studies, studies by time-period, and as an overall summary. Of particular interest in this study were the future directions and recommendations that were included in the implications section of the research articles. Accordingly, these were coded and described by time-period as well as included in an overall summary. Only empirical experimentally designed research studies having both control and treatment groups were included in the remaining meta analyses. Similar to previous reviews (Etnier et al., 1997; Sibley & Etnier, 2003), we used Hedge's formula to calculate the effect size. For academic performance measures, weighted mean differences in treatment group(s) versus control were calculated. Standard deviations, together with the sample size, were used to compute the weight given to each study. For a study with a control condition, the ES were calculated to compare the academic performance of the experimental group to that of the control group. If standard deviations were not available, ES was calculated using F, t, or N. When experimental groups had no control groups, means for control and treatment groups were replaced with means of pre- and post-treatment groups, respectively. Heterogeneity was assessed by using the *Q-statistic* among studies (Cooper, Hedges, & Valentine, 2009). Significance of the *Q-statistic* test ($p < .05$) indicates a substantial level of heterogeneity. When heterogeneity was found, pooled effects were calculated using a random-effects model. To assess the potential trend in the effects of physical activity, subgroup analyses were performed, stratifying three groups including studies published: (1) before 2000, (2) between 2000 and 2009, and (3) after 2010.

RESULTS AND DESCRIPTIVE INTERPRETATION BY TIME-PERIOD

The number of published articles by time-period increased exponentially from 1967 to 2013. In the end, only 20 total articles that were coded as experimentally designed research with both treatment and control conditions were included in the meta-analytic portion of this review (see Table 4). Combining data from all studies comparing physical activity group with control group showed that children who participated in physical activity had significantly improved academic performance including academic achievement and cognitive function with a random-effect model [effect size = .383; $Z = 4.934$ ($SE = .078$); $p < .05$]. For subgroup analysis, there was a difference in the change of academic performance among studies. Studies published after 2010 (ES = .564, 95% confidence interval (CI) = .421–.707) had better association between physical activity and academic performance compared to those published before 2000 (ES = .212, 95% CI = .025–.400) ($p < .05$), but there was no significant difference between studies published after 2010 and those published from 2000 to 2009 [ES (95% CI) = .496 (.119–.872)].

TABLE 4

STUDIES USING AN EXPERIMENTAL DESIGN INCLUDED IN THE META-ANALYSIS

References	Participants, N	Age	Assessment of Academic Performance	Physical Activity, min/week	ES, δ	ES by Period (δ) (95% CI)
Time period: before 2000						
McCormick (1968)	28	6	Grade level	45 min of perceptual motor, 2 times per week for 7 weeks	.226	
Klein and Deffenbacher (1977)	12	8	Continuous performance task	20 min of strenuous exercise, 3 times per week for 3 weeks	−.363	
Gabbard and Barton (1979)	106	7	Math test	50 min of relays	.448	
Dwyer, Coonan, Worsley, and Leitch (1979)	328	10	Math scores	Endurance fitness program, 5 times per week for 14 weeks in PE	.094	.212
McNaughten and Gabbard (1993)	60	11.3	Math tests	40 min of aerobic walking, 3 times per week for 3 weeks	.687	
Zervas, Danis, and Klissouras (1991)	17	13.1	Cognition test	60 min of running, 3 times per week for 25 weeks	−.093	
Caterino and Polak (1999)	176	7 and 9	Concentration	15 min of walking	.434	
Sallis et al. (1999)	183	9.5	Metropolitan achievement tests	30 min of PE w/specialist, 3 times per week for 2 years	−.237	
Time period: 2000–2009						
Ahamed et al. (2007)	298	9–11	Canadian achievement test	15 min of PA in classroom, 5 times per week for 10 weeks	−.116	
Mahar et al. (2006)	243	8–9	Systematic observation on-task behavior	10 min of PA in classroom, 5 times per week for 12 weeks	.852	
Fredericks, Kokot, and Krog (2006)	26	5–7	Aptitude test	20 min of PA	.9565	.496 (.119–.872)
Davis et al. (2007)	61	9.2	Cognitive assessment system (CAS)	40 min of aerobic PA, 5 times per week for 15 weeks	.637	
Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, and Tidow (2008)	99	14.9	D2 test of attention and concentration	10 min coordinated PA	.325	
Time period: before 2010–2013						
Vanhelst et al. (2010)	52	7–17	Academic performance	120 min of aerobic PA	.830	
Kamijo et al. (2011)	43	7–9	Sternberg task and WRAT	70 min of aerobic PA, 5 times per week for 9 months	.173	
Davis et al. (2011)	116	9.3	Cognitive assessment system (CAS)	40 min of aerobic PA, 5 times per week for 13 weeks	.373	.564 (.421–.707)[a]
Monti, Hillman, and Cohen (2012)	44	9.4	Eye and relational movement	70 min of aerobic PA	.200	
Staiano, Abraham, and Calvert (2012)	36	16.4	Delis–Kaplan executive function system	Exergaming	.783	
Gao, Hannan, Xiang, Stodden, and Valdez (2013)	153	10.3	Math test	30 min of DDR in recess, 3 times per week for 9 months	.734	
Chaddock-Heyman et al. (2013)	23	8 and 9	Cognitive assessment congruent/incongruent	70 min of aerobic PA, 5 times per week for 9 months	.574	

Note. PE, physical education; PA, physical activity; ES, effect size; CI, confidence interval.
Test for overall effect: ES = .383; $Z = 4.934$ ($SE = .078$); $p < .05$.
[a]Significant difference between studies published in 2010 and studies published before 2000, $p < .05$.

In the larger database of studies, 79% of the articles reported positive associations between physical activity or physical fitness and academic performance with remaining studies finding null or neutral associations. Imaging studies utilizing electroencephalography (EEG) or magnetic resonance imaging (MRI) accounted for 17% of the published studies, with the greatest emergence transpiring in the last decade. Four percent of the studies focused on memory or attention and included direct observational assessment (e.g., teachers' report of child attention, child self-report of attention, EEG, MRI). On/off-task behaviors and delinquency were the cognitive variables collected in the remainder of the studies.

The Early Research 1967–1999

Within this time-period, the mean overall ES, based on eight studies (years 1967–1989 = 4 studies; 1990–1999 = 4 studies), was .212 (CI = .025–.400). Descriptive analysis largely revealed the many limitations to the research in this era. Although the locations where these studies took place were largely homogeneous, many research designs neglected to account for the possible effects of demographic and psychological and physiological variables such as socio-economic status (SES), body mass index (BMI), physical fitness, parental involvement, among others. Further, the quantification and qualification of the physical activity was incomplete. For example, the identification of the ideal dose (e.g., type, intensity, and duration) of physical activity that would likely produce cognitive benefits, such as improved academic performance, is still being pursued today. With regard to the cognitive measures employed in this era, it is important to note that the designs of the academic achievement tests were not standardized by the state and reporting of test validation data was scarce.

There were specific trends that we hypothesize were directly reflective of the educational climate, specifically linked to national initiatives and state mandates. Among early research from 1967 to 1979 there were three experimental research studies involving children that led to this conclusion. Initially, Ismail (1967) found exercise to have positive effects on academic performance, as measured by standardized testing, which was also conducted in the school setting. Although excluded in our meta-analytic analysis because of the characteristics of the sample, research by O'Connor (1969) and Flynn (1972) helped to shape the emergence of this line of inquiry by examining the effects of physical activity in school on academic performance. Interestingly, the underlying premises of this early research holds true today, whereby O'Connor suggested that there are many factors that might influence academic performance and that such factors need to be measure or controlled in future research. Yet there is difficulty with conducting experimental design research within the school setting, especially when trying to control outside factors such as fidelity to treatment and differences in how teachers build classroom climates and provide learning opportunities. Today, we commonly refer to these as nesting issues, which interfere with implementation of a program.

Grounded in the inverted U theory of arousal, Flynn (1972) used a within-subjects design to study controlled exercise protocols on a bicycle, with the goal of examining how performance of mathematical tasks may change among 9–11 years olds. The study confirmed that performance was lowest at the lowest and highest intensities, while performance was optimal at the moderate intensities. This was the first study of its kind to demonstrate the importance of capturing physical activity intensity when examining its acute effects on academic performance. This concern continues today, as some studies control intensities while other correlational studies do not account for such characteristics of the exercise–cognition relationship.

Dwyer, Coonan, Worsley, and Leitch (1979) were among the first to examine the effects of physical activity on cardiovascular health relative to academic performance. Specifically, children engaged in aerobic activity or a combination of resistance, fitness, and aerobic activities. In general, although included in this review, three of the four research studies would likely not withstand the rigorous demands of publication today, as most used quasi-experimental designs, with no study using growth modeling to account for the potential effects associated with maturation. The inclusion of physical activity intensity (e.g., the level of physical exertion by the child) was sporadic, at best. In this early research, only Dwyer et al. (1979) included data collection of physiological measures such as heart rate, energy expenditure, or caloric expenditure during the physical activity interventions. By contrast, Klein and Deffenbacher (1977) did not account for any physiological measures, or activity intensity. Klein only described differences among the treatment groups and did not account for various factors that might have impacted results.

Moving Into the Standards-Based Era (1980–1989)

Much of the research in the 1980s is centered on the relationship between sport participation and academic performance. Given the correlational nature and the multiple confounding variables in this research, it was excluded from this review. For example, higher grades among those participating in high school athletics may be a result of the mandated requirements for participation (e.g., must have a letter grade of "C" or better to participate in interscholastic sports) or a byproduct of chronic engagement in physical activity. Further, constraints such as the amount of playing time, type of sport, and length of the season were not controlled.

In this pursuit of understanding the effects of sport, some researchers explored the interaction between several psycho-social variables such as self-esteem (Mechanic & Hansell, 1987) and self-concept (Schumaker, Small, & Wood, 1986) with sport participation and academic performance, and found mixed results. Some studies had positive results (Cooper, Valentine, Nye, & Lindsay, 1999; Dexter, 1999; Fox, Barr-Anderson, Neumark-Sztainer, & Wall, 2010; Linder, 1999; Ruiz et al., 2010; Stephens & Schaben, 2002), while others found no association between sport and academic performance (Daley & Ryan, 2000; Fisher, Juszczak, & Friedman, 1996).

Employing an intervention design, Tuckman and Hinkle (1986) researched the relationship between running program participation on in-class behavior and creativity as indirect measures of academic performance. The well-known longitudinal study entitled, *Trois Rivieres* examined health, psychomotor function, and academic performance of children as they progressed from grades 1 through 6, concluding that physical activity delivered within the school day enhanced academic performance (Shephard et al., 1984; Shephard, 1986). Subsequent follow-up studies examining the cognitive health of these participants as adults have been published.

Many of the future research suggestions focused on better understanding these relationships and the long-term effects of the variables on children's adult lives. In relation to academic achievement, many studies found little relationships among their variables and academic achievement, which led to suggestions of future research to conduct more studies to investigate the relationships. Several studies reiterated the importance of directionality in terms of the relationship among variables and suggested pursuing research questions with directionality.

Modern Education (1990–1999)

In this decade, randomized controlled trials were used to assess the effects of specific programs, such as Sports, Play and Active Recreation for Kids (SPARK) to determine the primary effects of physical activity on childhood health and secondary outcomes like academic performance. After 2 years of implementation, multiple health benefits were evidenced; however, a significant difference in academic performance between those children who participated in SPARK compared to those who had not was not evident (Sallis et al., 1999). The conclusion was there were no adverse effects on academic performance by spending additional time in physical education over more time in subject matters. It was also argued that the participants in this sample might have experienced a ceiling effect with test scores already being high at baseline. In a small, but highly controlled, study, Zervas, Danis, and Klissouras (1991) examined response accuracy and decision-making time on a mental test among trained/untrained twins. After 6 months the exercise group demonstrated significant improvement; however, their performance was not significantly different from their untrained twins, suggesting that chronic physical activity may be cognitively beneficial.

Researchers from this 10-year period were the first to investigate acute bouts of physical activity within the school day. Using recess as an opportunity for physical activity, two studies (Caterino & Polak, 1999; Jarrett et al., 1998) examined its effects on classroom concentration, measured by the Woodcock-Johnson Test, and classroom behavior. In the first study, participation in recess resulted in positive or null findings, with the findings dependent on grade (e.g., positive increases in concentration for 4th graders, but not for second or third graders; Caterino & Polak, 1999). Yet on days when students participated in recess there were significantly fewer off-task behaviors in the majority of children, especially among those with attention deficit disorder (Jarrett et al., 1998). In general, positive findings about physical activity involvement was evident among the research (Cooper et al., 1999; Hinkle, Tuckman, & Sampson, 1993; Raviv & Low, 1990), with other studies (Fisher et al., 1996; Melnick, Sabo, & Vanfossen, 1992) demonstrating null findings, and no study presenting negative effects for physical activity or physical fitness. The common conclusion among the research was that there are no known negative effects associated with taking time away from academics to participate in recess, physical education, or other physical activity breaks.

Although the studies in this time-period have specific limitations, the recommendations for future research may still hold true today. Studies suggested that future research investigate the effects of physical activity intensity (Bluechardt & Shephard, 1995; Zervas et al., 1991) by looking at specific settings such as recess (Jarrett et al., 1998), physical education (Raviv & Low, 1990; Sallis et al., 1999), and sport (Fischer et al., 1996; Melnick et al., 1992), across all grade levels (Caterino & Polak, 1999). Evidence in this era also led to calls for policy research (Jarrett et al., 1998), longitudinal research (Dexter, 1999), and more rigorous statistical analyses, specifically those that could demonstrate directionality (Cooper et al., 1999). Many researchers suggested further examination of variables in relation with academic achievement and academic performance; therefore, researchers began to include mediating and moderating variables associated with academic performance. It was also suggested future research address specific demographic variables including SES, gender, race, among others.

Turn of the Century (2000–2009)

After examining seven studies, the mean overall ES, based on five studies, was .496 (CI = .119–.872). Large-scale, cross-sectional research, with sample sizes in the hundreds of thousands, dominated the landscape as public health researchers began to more broadly investigate the health benefits of physical activity engagement. A shift away from adolescence to early childhood occurred as 50% of the research studies included in this period targeted children 3–10 years old. National and state surveillance of early childhood and kindergarten students as well as fitness test scores from children in grades 3–12 supported these analyses (e.g., Early Childhood Longitudinal Study-Kindergarten; Texas Youth Fitness Study). The utilization of existing databases translated into publications predominantly centered around physical fitness and student achievement test data (Carlson et al., 2008; Castelli et al., 2007; Cooper et al., 2010; Cottrell, Northrup, & Wittberg, 2007; Eveland-Sayers, Farley, Fuller, Morgan, & Caputo, 2009; Grissom, 2005; Sigfusdottir, Kristjansson, & Allegrent, 2006; Tremblay, Inman, & Williams, 2000; Wittberg, Cottrell, Davis, & Northrup, 2010). Taking a slightly different perspective, one large-scale study of 547 Virginia elementary schools suggested that reductions in physical education, art, and music, or more time spent in academic subject matters such as math and reading did not result in higher academic performance (Wilkins et al., 2003).

Randomized controlled trials, Action School! BC (AS! BC), Physical Activity across the Curriculum (PACC), and Fitness Improves Thinking (FITKids) provided influential research. Utilizing a cluster randomization with 24 schools (Donnelly et al., 2009) the PACC study largely focused on the reduction of BMI through participation in classroom breaks, but also discovered a positive association between physical activity and academic achievement (Donnelly et al., 2009). Similar to the PACC, the AS! BC intervention focused on increasing school-based activity by integrating physical activity into the classroom setting; however, a more comprehensive approach attempted to increase activity engagement on the playground, in the gym, and in the hallways as well (Ahamed et al., 2007). Findings from the comprehensive school physical activity program suggest that it is feasible for schools to offer opportunities for children to be active across the school day, without sacrificing academic performance.

Through an afterschool program that provided more than 70 min of moderate to vigorous physical activity, the FITKids program exceeded the daily recommendations for children's physical activity to find that children's aerobic fitness can improve significantly over waitlist controls (Castelli et al., 2011). Further, it was concluded that aerobic fitness (Kamijo et al., 2011) and centralized adiposity (Kamijo et al., 2012) were related to aspects of cognitive control. Studies examining child executive function and its relation to physical activity (Davis et al., 2007; Hillman et al., 2009; Kubesch et al., 2009) and physical fitness (Buck, Hillman, & Castelli, 2008; Stroth et al., 2009) continued to grow (see Chapters 3 and 4), but the overall number of studies was kept to a minimum ($n = 5$ or 12%).

Many authors that examined the relationship between academic achievement, physical activity, physical fitness, and other variables during the dawn of the millennium agreed on the type of future research studies that should occur. Scientific recommendations from this era included carrying out large-scale studies to confirm the effects of physical activity as a treatment on cerebellar function and cognitive skills such as literacy (Stephens & Schaben, 2002). Longitudinal studies that begin in early childhood were also endorsed (Ahmed et al., 2007; Ericsson, 2008; Fredericks, Kokot, & Krog, 2006) as a way to elucidate both the acute and chronic effects of physical activity on child development. Toward the end of the decade, translational research within the school setting was identified as a key to the future understandings of the intricate relationship between the variables of interest. In addition to examining directional relationships among all variables tested, a few researchers began to translate scientific findings for school personnel and policy makers. They urged changes within school policy and called for a redesign of the school day.

Recent Evidence (2010–2012)

The mean overall ES, based on seven studies, was .564 (CI = .421–.707), which was significantly different from the first time-period identified ($p < .05$), but not the previous decade of research. Test for overall effect (ES = .383; $Z = 4.934$; $SE = .078$) was also significant ($p < .05$). There was a significant difference between studies published in 2010 and studies published before 2000 ($p < .05$). The results indicate that the ES of studies in the most recent era is significantly higher than early research. In this comparison of experimental research across the time-periods, the magnitude of effect of the treatment (physical activity programs) on academic performance in children is on the rise. This trend has ramifications for future research.

Among the non-randomized studies of this era, cross-sectional designs continued to be the norm (Abdelalim et al., 2012; Barrigas and Fragoso, 2012; Baxter, Royer, Hardin, Guinn, & Devlin, 2011; Chih & Chen, 2011; London & Castrechini, 2011; Morales et al., 2011; Telford, Cunningham, Telford, & Abharatna, 2012; Van Dusen et al., 2011). For the first time, studies considered the economic impact of interaction between these variables (Dills, Morgan, & Rothoff, 2011). The focus remained on children ages 3–10 years. One study examined the relationship of motor skill and cognitive development, which may emerge as a mediator with more study (Niederer et al., 2011). Most studies involved a large sample size, although studies that used imaging diagnostics continued to be small. During the initial years of this decade, there was a sharp increase in the number of studies that focused on cognitive control function as the outcome variable (Chaddock, Hillman, Buck, & Cohen, 2011; Davis et al., 2011; Pontifex et al., 2010, 2013; see Chapter 3). Based on the data in this review, it is anticipated that there will be more than 120 published articles addressing physical activity and academic performance by the conclusion of this decade. These values are close to three times those in any other 10-year period. It is important to note that only positive and neutral studies have been published to date, despite the greater sensitivity in the cognitive measures and large-scale samples being recruited.

FUTURE DIRECTIONS FOR RESEARCH

Throughout the last 45 years, researchers have been examining the relationship between physical activity, physical fitness, and academic performance. While investigating these relationships researchers have suggested which direction the research should head in order to determine the "true" relationship among these variables. The following is a culmination of future research directions suggested by researchers as well as our suggestions to the field about future directions. There are many commonalities among the 215 articles that were examined and these have been combined with the reviewers suggestions and categorized into four sections: (1) Examine the dose–response effects with replicable measures, (2) account for confounding variables, (3) conduct rigorous research in the laboratory and authentic settings, and (4) bring neuroscience to schools.

Examine the Dose–Response Effects With Replicable Measures

Changing terminology over time has potentially inhibited progress in this field. Vocabulary surrounding academics, cognition, and physical activity were inconsistently applied in this body of research. Scholars assumed that the youth participants were regularly attending school, but few studies formally confirmed this assertion. Attending school is the first step in the learning process, thus making attendance a proxy measure of academic success (Baxter et al., 2011). Accordingly, findings from this review suggest that future research should collect school attendance data to draw accurate conclusions about learning or academic success in schools.

As previously discussed, cognitive performance was measured in a variety of ways. Among the various factors were academic behaviors, attitudes, attendance, time on task, homework completion, attention/concentration, memory, creativity, fluid intelligence, verbal ability, grades, and academic achievement on standardized test scores. Specifically, it has been observed that the measure of achievement in school changed from being called *academic behaviors* and *attitudes* to student *academic achievement.* In this study, we determined that *academic performance* was the term that most comprehensively described student success in school. Future research should provide precise measurement and description of the exact cognitive or achievement processes that are being examined.

Early studies used the term exercise (defined as bodily movement that is planned, structured, and repetitive), while later research used the term physical activity (defined as any bodily movement producing energy expenditure; Caspersen, Powell, & Christenson, 1985). Moreover, these terms, and even the term physical fitness, were inappropriately applied interchangeably. Because there are initial signs of a dose–response relationship between physical activity and cognitive performance (Castelli et al., 2011; Davis et al., 2007; Van Dusen et al., 2011) it is suggested that researchers select terms that accurately describe the "dose" of physical activity. Words such as *light*, *moderate*, or *vigorous* can be acceptable in some cases; however, heart rate, METsm or caloric values would be the preferred means for reporting physical activity intensity and energy expenditure. Future studies should quantify the effects of intervention programs aimed at increasing habitual physical activity in youth and other health behaviors and further investigate how participation in school sports may be causally related to the reduced risk of certain negative health behaviors (Pate, Heath, Dowda, & Trost, 1996).

Account for Confounding Variables

Academic performance is not a direct result of academic seat time. Reviewed research provides empirical evidence that achievement in the classroom is affected by fitness level, activity level, and BMI. Yet correlational data and interaction effects suggest gender, SES, age, various psychosocial variables, home environment, nutritional habits, and intellect may also exhibit mediating properties. Beginning in the 1990s, researchers began calling for the inclusion of variables that might impact the relationships of academic performance, physical activity, and physical fitness. Research from the past 20 years has contributed to the growing awareness of these mediating and moderating factors. For example, in a study examining the effects of aerobic fitness, girls and boys did not demonstrate congruent results (Wittberg et al., 2010). Similarly, studies have found positive relationships for a specific age from an intervention that had no effect at a different maturation level (Caterino & Polak, 1999). Perhaps the most influential factor is SES, which has been shown to directly affect academic achievement (Tomul & Savasci, 2012; Vellymalay, 2012). Additional factors, beyond a child's intelligence, have been confirmed, but are not limited to SES, parental involvement in school, perceived competence, and student–teacher relationships (Topor, Keane, Shelton, & Calkins, 2010). Prior to the turn of the century, the majority of studies did not collect data on SES. Recently, however, studies have begun to collect SES information to use as a covariate.

No single study exemplifies this recommendation more than the one conducted by Kwak et al. (2009), conducted with Swedish 9th grade students. By carefully controlling for the confounding factors, Kwak et al. (2009) discovered differing effects on academic achievement by gender and fitness, where vigorous physical activity mediated achievement in girls and fitness mediated achievement in boys. Moreover, nutrition is rarely considered and measured simultaneously with physical activity and academic performance. Gaining a better understanding of the association between physical activity and dietary behavior in children and adolescents is important, as both may impact academic success (Pate et al., 1996). As scholars continue to assess the relationship between physical activity and academic performance, it is predicted that studies will more fully embrace advanced statistical analyses such as multivariate analyses and structural equation modeling, as well as more rigorous designs, in an attempt to further elucidate possible causality.

Conduct Rigorous Research in the Laboratory and Authentic Settings

Ecological validity is an important component of research design that is influenced by points of access, and the ever-changing context of schools in relation to the control of the laboratory setting. As a line of inquiry develops, descriptive and correlational research designs are initially enacted, and as the associations between variables are defined, explanatory variables are controlled. In this present review, it was discovered that the landscape of the research is largely shaped by cross-sectional research studies with a wide range in the number of participants. Although cross-sectional research is a beneficial means to provide researchers with a preview of existing relationships, and can help guide policy making in public health, the implications are limited given the lack of causality that can be assumed with this type of design. In addition, research lacked examination of known confounding variables that could influence the outcome of data analysis. As described in the previous recommendation, variables such as SES should be common measure in research designs exploring the predictors of academic performance (Caldas & Bankston, 1997; Sirin, 2005).

Currently, there are only four known randomized trials that have primary aims dedicated to academic performance. The rigor of these designs has permitted researchers to make inferences about the potential underlying mechanisms that may foster academic performance (e.g., aerobic fitness; Kamijo et al., 2011), regular engagement in physical activity (Ahamed et al., 2007; Donnelly et al., 2009), and BMI (Davis et al., 2007; Davis et al., 2011). The design of such studies is unique in that the methods, materials, and setting attempted to approximate the real world (e.g., through physical activity programming carried out in the school environment), while simultaneously employing strategies such as randomization to condition and a measure of potentially confounding variables (e.g., the use of three different data points as a representation of SES). In this current review, only two studies (Edwards, Mauch, & Winkleman, 2011; Signfusdottir et al., 2006) comprehensively accounted for the effects of both diet and exercise. Research should consider ecological validity as part of each study design; however, this future direction is supported by the notion that a trade-off between the validity of the laboratory versus application to authentic educational settings has consequence for the implications stemming from this line of research. Moreover, researchers employing a rigorous design have an obligation to report relevant statistical values by condition and report effect size whenever possible, so others may replicate their work and compare different studies.

While still acknowledging the importance of randomized controlled trials, scholars should move beyond correlational studies and seek to provide prolonged physical activity interventions that foster an understanding of the contextual issues faced by teachers, administrators, and students during the school day, as well as by parents within the home environment. By first carrying out process evaluations of the effectiveness of physical activity programs that exist in schools, researchers can more appropriately design interventions targeting the needs of the children and the educators who implement the programming. No known study has utilized such methods to elucidate the underlying meaning of significant associations between physical activity, physical fitness, and academic achievement.

Bring Neuroscience to Schools

Because findings in this research since 1967 are predominantly positive, scholars need to place this information in the hands of the people who need it the most—teachers and administrators. The state of public education is vastly different than it was 50 years ago, as schools are a microcosm of societal norms and tendencies. Modern parenting styles, different dietary choices, and technology access continue to change the structure of society. Therefore, the phenotype of children is changing as the prevalence of obese and overweight is on the rise (USDHHS, 2012). As sedentary behavior across the population increases, time in physical education classes in our public schools decreases (McMurrer, 2007), presumably to provide additional opportunities for academic learning time. With the majority of the school day dedicated to advancing student content knowledge and preparing for academic achievement testing, it leaves little time for school personnel to focus on improving the health and well-being of children. These conditions magnify the issue that schools are largely sedentary places.

Given the findings of this review, being physically active, having a lower BMI, and being physically fit are contributory to learning in the school environment. So why do school officials keep cutting key opportunities for children to be physically active in the school environment? One explanation may be that teachers and administrators may not have reviewed the research that has emerged over the last decade. It became very clear throughout the current review that researchers believe more studies need to be conducted within the school setting and school policies surrounding physical activity opportunities and fitness opportunities should be changed, as many called for it within their future directions (Ahamed et al., 2007; Aktop, 2010; Castelli et al., 2011; Chaddock-Heyman et al., 2013; Davis et al., 2007, 2011; Dills et al., 2011; Ericsson, 2008; Fox et al., 2010; Gao, Hannan, Xiang, Stodden, & Valdez, 2013; Harrington, 2013; Kristjánsson, Sigfúsdóttir, & Allegrante, 2010; Kristjansson, Sigfúsdóttir, Allegrante, & Helgason, 2009; London & Castrechini, 2011; Mahar et al., 2006; Sallis et al., 1999; Ullrich-French, McDonough, & French, 2012; Welk et al., 2010; Wittberg et al., 2010). However, few if any researchers give a detailed prescription of how it should be changed. Making this information accessible for school personnel is key to change in the school environment. It must be published not only in the scientific journals, but each article should be accompanied by a practical article that gives suggestions of the type and dose of changes that should be happening in the school setting. This might mean those scientists are teaming up with education specialists, such as physical education scholars or physical activity interventionists to provide proper prescriptions for schools.

In addition, those who have been informed by this crucial information have not been given the tools or the professional development to successfully adopt research into instructional practice (Castelli, Centerior, & Nicksic, 2013). The pressure that schools are under for children to succeed results in unintended outcomes such as an overabundance of seatwork. However, with help from the research environment and translations of the dose and intensity of physical activity that should be occurring in the school setting, school climate change is possible (Ahamed et al., 2007).

Teachers and administrators should be provided with professional development focusing on factors associated with improved academic success. Researchers need to begin translating findings so that they can be applicable in the school setting. Empirically based recommendations for school schedules that maximize student and teacher productivity should be provided to administrators. Educators also need effective implementation strategies. For example, teachers and administrators should be challenged to think beyond the traditional school day to one that focuses on the integration of physical activity, not just during recess and physical education, but also before, during, and after school. Future and practicing educators alike need to learn how to integrate a beneficial level of physical activity. Each new school initiative should consider health as part of the adoption process, as without translating and disseminating this information into the hands of school personnel, there will be limited impact on the public and on the advancement of academic performance (Basch, 2011).

CONCLUSION

It is clear that the issues surrounding academic performance and physical activity, as a proxy measure of cognitive health, are of interest to and being investigated by neuroscientists and educational researchers, spanning from a molecular to policy perspective. Findings from this systematic review suggest that this line of inquiry is growing exponentially and that valuable discoveries about children's health have implications for educational practice, public policy, and funding priorities. Yet further epidemiological and randomized controlled study designs are needed. As the cornerstone of public health, epidemiology is the study of patterns, causes, and effects of conditions within defined populations. These typically large-scale research studies are advantageous for broad-reaching applications such as the creation of public policy. Results of this study identify a need for a better understanding of the effects of health policies within the school environment and its subsequent effects on learning among youth. Increasing governmental emphasis placed on academic performance and school attendance will perhaps lead to this line of inquiry becoming a top-level priority. Establishment of national surveillances of emerging trends could meet this demand, given the potential effects of sedentary behaviors on cognitive health in youth.

Dose–response effects of physical activity type, frequency, duration, and intensity on learning need to be decomposed in ecologically valid, but applicable, settings. Through mixed-method research designs, teachers and their students within the school environment will foster an enhanced understanding of how culture and climate, as well as local policy, affect the number of opportunities that children have to be physically active within a school environment. Given the body of evidence suggesting that healthy children learn better, the continued rigorous study of the link between physical activity and academic performance, along with a targeted dissemination of results, must transpire for teaching and learning to be maximized.

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