Physical Education and Exercise Contribute to Cognitive Development and Academic Achievement in Elementary School Age Students

Abstract

This paper examines the impact of physical education and exercise on cognitive development and academic achievement in elementary school age students. The literature review touches upon contemporary aspects of physical education within the elementary curriculum such as the 'No Child Left Behind' mandate and the obesity epidemic. Drawing from correlational and experimental studies, this paper also examines the mechanisms which may explain how physical education and exercise contribute to academic achievement. External mechanisms which are explored include exercise's impact on improved nutrition and social involvement. Internal psychological mechanisms considered include self-esteem, attentiveness, and motivation. Biological mechanisms responsible for physical education's contribution to academic achievement include changes in the nervous system, endocrine system, and aerobic system.

Keywords: Education, Academic Achievement, Exercise, Nutrition, Cognitive

Physical Education and Exercise Contribute to Cognitive Development and Academic Achievement in Elementary School Age Students

As early as the 4th century BC, intellectuals such as Hippocrates and Aristotle presumed that their existed a link between exercise and overall health. Physical health benefits as a product of physical activity have indeed been verified over the past century by numerous research studies (Hedley et al., 2004). For example, there is strong support for the idea that physical activity can decrease the incidence of cardiovascular diseases (the number one leading cause of mortality in America), certain types of cancers, hypertension, type 2 diabetes and many other (preventable) pathologies (Tremblay, Inman, & Willms, 2000). Although these health benefits apply more specifically to adults than they do to children, a child's lifestyle can strongly influence future attempts to stay healthy. According to Hedley et al. (2004) "The high levels of overweight among children and obesity among adults remain a major public health concern" (p.2847). The rising epidemic regarding obesity justifies the abundant amount of research on exercise and its effect on physical health benefits, but sadly this overemphasis on controlling weight and increasing caloric expenditure has reduced the amount of research directed to observing cognitive benefits and mental health. This essay will attempt to determine whether physical education and exercise contribute to cognitive development and better academic achievement in elementary school age students. In the United States, the mandate No Child Left Behind[1] pressures school administrators to find ways to increase academic achievement. Tragically, attempts to do so are usually executed by reducing the amount of physical education classes and replacing them with academic courses (Blakemore, 2003). In order to establish a more efficient strategy, I will first examine the current findings which suggest a strong link between physical education and academic

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[1] a requirement of the government which demands that the school systems increase academic achievement

achievement. Furthermore, I will present external mechanisms, psychological mechanisms, and biological mechanisms that are hypothesized to alter cognitive and academic performance through physical activity.

Current Findings

Numerous authors desired to convey, through scientific inquiry, their disapproval of school policies which neglect physical education as a means to increase academic achievement (Coe, Pivarnik, Womack, Reeves, & Malina, 2006; Shephard, 1996; Tremblay, et al., 2000).

In order to improve the grades of students, school administrators have over the last decade reduced the amount of time dedicated to physical education. Rather than hinder the academic performance of students, Tomporowski, Davis, Miller, & Naglieri (2008) suggest that most research demonstrates a positive correlation between systematic physical education and good academic standing.

A well known longitudinal study, known as the Trois-Rivières experiment conducted by Shephard (1996) established a causal relationship between an increase in physical education and improvement in mathematical skills. From grade 1 to grade 6, 546 students from the experimental group had one hour of their daily curriculum replaced by physical education. The academic cohorts which preceded and succeeded the experimental classes were regarded as control groups. Even though the experimental group had access to less academic time, from grade 2 and onwards, higher averages were maintained in mathematical assessments.

Coe et al. (2006) sought to establish the relationship between physical education and academic success by randomly assigning 214 sixth grade students to a 55 minute long physical education class. Although academic success did not increase when students

participated in physical education classes, academic success did not decrease even though academic time was reduced by 55 minutes. According to the authors, moderate to vigorous activity was only done for 19 minutes during physical education class. This lack of movement within the physical education classes may therefore be the cause for establishing a weak relationship. By questioning the students' on their behaviours outside of school, it was discovered that ‘‘students who reached or exceeded Healthy People 2010[2] recommendations for vigorous activity performed better academically compared with students who performed only a small amount of, or no, vigorous activity’’ (Coe, et al., 2006, p.1518). My synthesis of this study is that even if physical activity is done outside of the school environment, it may nonetheless increase academic performance.

In a longitudinal study, a sample of 5316 students, representative of the population of the U.S.A. were followed from kindergarten to fifth grade. It was established that the students with higher amounts of physical education had either positive or neutral effects on academic achievement (Carlson, et al., 2008).

Castelli, Hillman, Buck, & Erwin (2007) suggest that young students who are aerobically fit benefit from an increase in academic performance. By administering tests for different components of fitness[3] to 259 students from the third and fifth grade, the authors established that, “children who displayed higher levels of physical fitness were more likely to have higher standardized test scores in reading and mathematics, regardless of […] variables such as age, sex, school characteristics (i.e., school effectiveness), and poverty index” (Castelli et al., 2007, p. 248). Said in a more explicit way, aerobically fit children have higher academic achievements. Additionally, the researchers did not find muscle strength and

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[2] The goal of Healthy People 2010 was established in 2000, following the failure of the Healthy People 2000 program. It set out to reduce obesity rates and increase health by encouraging certain behaviours, such as exercising a minimum of 30 minutes, 5 days a week.

[3] Body composition, muscular strength, and aerobic capacity.

flexibility to influence academic performance. In light of such research, I suggest that if school administrators wish to make more efficient use of the curriculum, they should ask their physical education teachers to spend more time on aerobic exercises.

External Mechanisms

Nutritional. The sheer increase in caloric intake[1] may be responsible for increasing academic performance. When individuals increase their levels of physical activity, more calories are expended (more energy is required to produce more movement). In order to maintain a neutral balance between caloric intake and caloric expenditure, an individual must therefore eat as many calories as they consume. This equation then suggests that in order to keep the same body mass, a child will have to eat more if he or she exercises more. Consequently, it is more likely that the child will eat more vitamins, proteins, and minerals (Shephard, 1996). This increase in caloric intake will help ensure that the child receives an adequate supply of essential nutrients needed for proper development and cognitive processes. Furthermore, today's physical education curriculum now incorporates information concerning healthy eating habits. These suggestions heard in physical education class may then be applied by a child who chooses which snacks to eat at home. Additionally, Tremblay et al. (2000) suggest that physical activity increases the chances that students will choose to avoid smoking. Although the absence of a smoking habit is not directly related to increasing academic performance, it will lead to a healthier lifestyle.

Social Involvement. Increase involvement in extracurricular physical activities was found by Tremblay et al. (2000) to have a positive relationship with academic achievement. Although the researchers hypothesized that genes played a major role in determining this relationship, I believe that the social environment plays a greater role. For example, a sports coach with the intention of helping his or her athletes will encourage them in pursuing good

academic results. In such cases, an athlete who does not meet the academic requirements of a thoughtful coach, may be benched until he or she has improved their academic standing.

Internal Psychological Mechanisms

Self-Esteem. Achievement in most sectors of life requires good self-esteem. When a student believes that they are not worth much, they will be less likely to strive for excellence. As a student learns better motor control during physical education class, they become less clumsy and inevitably gain more self-esteem. This feeling of self-esteem then transfers to the classroom. Additionally, Shephard (1996) hypothesized that an increased amount of physical education indirectly increased self-esteem. As activity levels increased, students developed more lean mass and less adiposity, which contributed to a better body composition and often a more desirable appearance. ‘‘An increase in vigorous physical activity levels was associated with progressive improvements in self-esteem in both females and males’’ (Tremblay et al., 2000, p. 319). In other words, when exercise was conducted at a higher intensity, levels of self-esteem increased. The implications for this study are most important for adolescent girls since they tend to be the group which is most likely to avoid physical education and also the group which tends to develop self-esteem problems (Tremblay et al., 2000).

Attentiveness. With an increase in sedentary lifestyles, is it no wonder that children are diagnosed with more and more cases of hyperactivity disorders? It has been hypothesized that exercise is a powerful tool for treating conditions such as attention deficit hyperactivity disorder, depression, fatigue and stress (Berg, 2010). Rather than participating in physically active play in the park, children are spending an increasingly higher amount of time sitting in front of a screen. During a large-scale change in the policies of certain schools in New Brunswick, which increased the amount of daily physical activity, ‘‘teachers in the experimental school reported that their students appeared more calm and attentive during

academic instruction, presented fewer disciplinary problems, and had better attendance'' (Tremblay et al., 2000, p .319). Indeed, from an anthropological perspective, I deduct that human beings have always had the need to move about. Because technology has caused us to suddenly adapt a sedentary lifestyle, our bodies have in a sense become over efficient. In the past, human beings had to chase their food for hours and days at a time and could not afford to relax and think abstractly. Today, in order for students to achieve a relaxed state, they need to expend a certain amount of energy in physical education in order to be attentive in the classroom.

Transfer. In accordance with Piaget's hypothesis, ''the skills of spatial organization required for active play carry over into an understanding of the spatial conformations and relationships that comprise words and mathematical relationships'' (Shephard, 1996, p. 33). An example of this theory can be demonstrated by a student who learns that the shape of a badminton court is rectangular and then transfers that knowledge to the mathematics class on figures and shapes. By practising intellectual exercises and motor activities, the student is more likely to retain the properties of a rectangle. This phenomenon would also consequently explain the increase in academic achievement for the younger grades learning spatial concepts such as up, down, closer and further.

Motivation. Increased motivation may arise from increased social interactions which are more likely to occur within the physical education class than any other academic course. An increase in social bonding would account for greater feelings of school spirit, which would consequently inspire students to want to learn in their school environment (Taras, 2005).

Additionally, the effort based rewards system may explain how students are more motivated to learn after having participated in physical activity (Berg, 2010). It is theorized

that humans have developed a structure in the brain, named the nucleus accumbens-striatum-cortex, as a means to develop an effort-based rewards system. This structure would have provided pre-historic man with encouragement and motivation during his constant search for basic needs. For example, after having caught a deer, the structure would liberate a sense of reward in the form of neurochemicals (neurotransmitters or hormones) such as serotonine, dopamine, or norepinephrine. The hypothesis proposed by Berg (2010) implies that regular exercise produces the same motivation factor for students participating in physical education.

Biological Mechanisms

Structure of Nervous System. The structure and consequently the functions of brain tissue are subject to change with greater fitness levels (Berg, 2010; Hillman, Castelli, & Buck, 2005; Shephard, 1996). It has been theorized that ‘‘exercise promotes brain growth, including the production of new neurons and increased intersynaptic connections’’ (Berg, 2010, p. 81). An increase in intersynaptic connections (structural change) permits neurons to transmit and receive action potentials more easily (functional change). Neurogenesis, the creation of entirely new neurons (structural change) permits the nervous system to process more information (functional change).

The cerebellum[4] is referred to as the center for postural adjustments and muscle coordination, but more recently, the cerebellum has been shown to be a key component for integrating information from all over the nervous system. According to Blakemore (2003), ‘‘the cerebellum’s link to movement and cognition implies that physical education and games have value in boosting cognition’’ (p. 25). The idea that a structure can play a role in motor control and cognitive skills provides evidence for a relationship between physical activity and cognitive skills. Although structural changes following exercise mainly occur in sectors

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4 The posterior inferior extension of the cortical brain

which are associated with physical activity (e.g., the motor cortex), the hippocampus[5] has also been observed to exhibit changes in structure (Berg, 2010).

Hormonal. The creation and maintenance of intersynaptic connections and entire neurons is accomplished by a protein, named the brain-derived neurotrophic factor (Berg, 2010). With exercise, this hormone is produced in greater quantities by skeletal muscles. When this protein reaches a designated organ namely, the brain, it acts as a catalyst for growth. Rats that exercised consequently had higher amounts of BDNF hormone and were able to complete mazes faster than rats that did not exercise. Additionally, physical activities which demand higher cognitive skills for example, rock-climbing[6] compared to running, have been associated with producing greater quantities of BDNF.

Furthermore, the hormone testosterone, which is created in greater quantities during physical activity, has been associated with higher I.Q. scores (Shephard, 1996). In this sense, an increase in testosterone would indirectly increase academic performance.

Aerobic Activity. Aerobic exercise, by definition requires oxygen. If oxygen levels are not sufficient to produce the required energy, the body modifies its structure to provide more oxygen in anticipation for future demands. The body accomplishes this by erythropoiesis[7] or by a more region-specific method, angiogenesis[8] (Berg, 2010). When a rigorous exercise program is maintained, an individual will, in addition to feeling less exhausted during exercise, benefit from an increase in capillaries and supply of oxygen to

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5 The hippocampus has mainly been associated with learning and memory

6 rock-climbing involves the cognitive skill of creating a path through rock that on first sight appears to have all the same characteristics

7 The production of erythrocytes (red blood cells), the most common method for transporting oxygen to cells

8 Angiogenesis is the production of capillaries, which increases the amount of oxygen and carbon dioxide exchanged between brain tissue and blood vessels increases.

numerous organ systems namely, the brain. This increase of oxygen to the brain permits mitochondria[9] to produce more energy, which the brain uses during cognitive processes.

In a thorough review article Tomporowski, et al. (2008) suggest that positive correlations between exercise and academic achievement were especially decisive when physical activity was of an aerobic nature compared to exercise which concentrated on balance and coordination.

In an empirical study conducted by Hillman, et al. (2005), 51 individuals were, according to their results obtained on a Vo2 max test[10], classified either as very fit or low fit. As neuroelectric measurements were taken, participants were asked to press a button as fast as they could when they saw the image of a cat, but were asked not to press the button when they saw the image of a dog. Children with greater aerobic fitness demonstrated better neuroelectric profiles on this stimulus discrimination test when compared to children with lesser aerobic fitness. That is, more neurons were active during the task of determining if the image was a cat or dog. Additionally, higher fit individuals had faster response times, they were able to process the information with greater speed. This may be explained by an increase in neural connections. ‘‘Fitness may be associated with increasing neuroelectric activation related to the allocation of attention and working memory resources’’ (p.1972). This phenomenon would help explain how students who have higher levels of aerobic fitness have the possibility to put more material in their working memory.

Scholarly Limitations

The nationally representative study conducted by Carlson et al. (2008) had multiple possible sources of bias. For instance, the participants were more likely to have higher socio-

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[9] Mitochondria produce energy in the form of Adenosine Triphosphate, which is needed in practically all cells.

[10] AVo2 max test is an excellent indicator of aerobic fitness, which measures the maximal consumption of oxygen.

economic status when compared with the average American. This could be a possible bias of the study because higher socioeconomic status has often been associated with higher academic achievement. Furthermore, the amount of time spent in physical education was assessed by teachers and not the researchers. This procedure might be responsible for altering the actual time students spent exercising. On the other hand, the research was conducted with a very large database, which ultimately reduces the biases. Taking into consideration socioeconomic status must be a hard ordeal since another research study exhibited the same limitation (Coe, et al., 2006). Castelli, Hillman, Buck, & Erwin (2007), on the other hand, established that "children who displayed higher levels of physical fitness were more likely to have higher standardized test scores in reading and mathematics, regardless of […] variables such as age, sex, school characteristics (i.e., school effectiveness), and poverty index"(p. 248). Such findings eliminate the possibility that the positive correlation between exercise and academic performance is only due to SES.

Other studies such as Shephard's (1996) empirical study might have had a cohort effect[11]. Still, the chances of having had a cohort effect were fairly slim, since both groups were only separated from one year and not much change in healthy lifestyles occurred between 1995 and 1996. According to some researchers, physical activity and academic achievement had a slight negative relationship (Tremblay, et al., 2000).

Conclusion

Most research that I have encountered suggested either a positive or neutral correlation between physical education and physical activity and greater academic achievement. In light of such research, I suggest that school administrators reconsider the elimination of physical

[11] A cohort effect exists when a variable causes the data obtained from one certain cohort (group of individuals born at the same time) to be different from another cohort. For example, the cohort who grew up with computers has on average greater technological capabilities than the group who was born with typewriters.

education classes as a means to raise academic performance. A better solution would be to integrate the psychomotor and cognitive domain within every classroom. Doing so would most likely increase creativity and productivity. A physical education teacher succeeded in integrating academic material within his physical education class (Vail, 2006). His revolutionary idea combined mathematical problem-solving and rock-climbing. As students progressed through the strengthening activity, they also enjoyed mental challenges (Vail, 2006). Similarly, homeroom elementary teachers should strive to integrate physical activity in their daily schedules. For example, they could create an activity in which children respond to questions by finding clues around the classroom.

Through the examination of scientific articles, such as Shephard's (1996) Trois-Rivières experiment, which demonstrated that the cohorts of students with more physical education showed greater overall academic achievement, the relationship between physical activity and cognitive benefits is more clearly validated. Furthermore, by including various mechanisms that attempt to explain how increasing the amount of physical education leads to gains in academic achievement, I have provided multiple reasons for being active. It is therefore crucial that school administrators increase or at least maintain the amount of physical education that students obtain. In regards to future research, conducting experimental studies may be beneficial in discovering if the relationship between physical education and academic achievement is a causal one. Since previous studies tend to focus on discovering a correlation between physical activity and academic achievement, an empirical study would be more accurate in determining if an increase in physical education provides greater academic achievement.

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