

Justifying Physical Education Based on Neuroscience Evidence

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Recent discoveries strengthen the connection between physical activity and cognitive function.

The effects of exercise on human function are complex and diverse, and numerous organs and tissues appear to respond to exercise stimulus. Epidemiological data reveal that regular exercise reduces the incidence of the leading causes of mortality, such as heart disease, type 2 diabetes, several types of cancer, and obesity (Bize, Johnson, & Plotnikoff, 2007; Kelley, Kelley, & Franklin, 2006). It is therefore not surprising that research indicates that exercise also profoundly benefits brain function (Cotman & Engesser-Cesar, 2002; Kelley et al., 2006; Neeper, Gomez-Pinilla, & Cotman, 1996; Puetz, 2006; Russo-Neustadt, Beard, Huang, & Cotman, 2000). Studies indicate that exercise promotes brain growth, including the production of new neurons and increased intersynaptic connections (Cotman & Engesser-Cesar; Neeper et al.). Knowledge of the effects of exercise on brain function is highly pertinent to physical educators and exercise professionals. This information has become part of the knowledge base of their profession and should be included in the professional training of teacher candidates and exercise science majors. Education of the American public, including those who make critical decisions regarding curriculum and budget allocation, is also necessary. The purpose of this article is to review the basic scientific findings and to suggest how this information might be used to defend the role of physical education in schools.

Being Physically Active in an Information Society

American society pays lip service to the concept that the human organism operates as an integrated whole, but reductions in the time allocated for physical education in schools imply a continuation of the traditional Western schism of mind and body. In reality, Westerners often relegate things physical to a lower status than things mental, and the notion that human activities may be categorized as physical or mental clearly conveys a dualistic or separatist view. The fact that mandatory physical education classes have been eliminated in many school districts across the nation (Landers & Kretchmar, 2008; Lowry, Wechsler, Kahn, & Collins, 2007) suggests a lack of understanding among school administrators and the American public of the connection between the physical and the mental. The physical education profession needs to strengthen its efforts to educate the public on the unique value of physical activity and physical education in the physical and mental growth and development of children and adolescents.

Research supporting the value of physical activity for improved health in children and adolescents abounds (Berg & Sady, 1983; McKenzie et al., 1996; Sallis & McKenzie, 1998; Stone, McKenzie, Welk, & Booth, 1998; U.S. Department of Health and Human Services [USDHHS], 2000). Furthermore, physical education is believed to be an effective means of increasing physical activity among youths (Centers for Disease

Control and Prevention [CDC], 2001a; Kahn et al., 2002). For these reasons, numerous professional organizations and agencies, including the American Heart Association (2002), American College of Sports Medicine (1988), American Academy of Pediatrics (2000), CDC (1997), and USDHHS (2000) have endorsed quality daily physical education for all students. Such support would not exist without there being a considerable weight of evidence. Physical education can be an effective means of improving attitudes about physical activity and of providing time during the school day to help youths to meet recommended exercise guidelines.

Further education of the American public is needed regarding the benefits of physical activity and physical education on overall health, emotions, and intellectual capacity. It seems logical for physical educators and other exercise professionals first to become familiar with the important research findings about the effects of exercise on the brain and cognitive function. This information may give professionals a better understanding of the mechanisms by which exercise might enhance learning and emotional state. By being better informed, professionals may exert greater influence on students, parents, and those who make curriculum and budgetary decisions that affect school programs (e.g., principals, school board members).

Current knowledge about how exercise affects brain function suggests that physical education should be an important part of the curriculum in all schools. However, this starkly contrasts with the actual allocation of funds in school budgets, which is typically much smaller for physical education than for other subjects, as if it were of lesser educational value than core subjects. The percentage of schools that require physical education classes decreases progressively from elementary school through high school (CDC, 2001b).

A Biological Basis for Exercise Effects on the Brain

Researchers in neuroscience use noninvasive techniques, such as magnetic resonance imaging (MRI) and positive emission tomography (PET), to examine anatomical and physiological changes in the brain produced by exercise. Years ago, methods to examine changes in brain structure and function were quite limited. New techniques, however, have "opened the door" to findings that indicate that the brain is conditioned as a result of regular exercise. Studies using animals indicate that even several days of running increases production of a protein in the nerve cell or neuron called brain-derived neurotrophic factor (BDNF; Cotman & Engesser-Cesar, 2002; Neepor et al., 1996). This protein enhances the growth and repair of synapses and neurons, which, in turn, appear to improve cognitive function (Cotman & Engesser-Cesar; Neepor et al.). Exercise also enhances the level of key nerve transmitters that improve mood, energy level, and motivation (Meeusen, Watson, Hasegawa, Roelands, & Piacinti, 2006). Several of these transmitters are also believed to combat depression (Russo-Neustadt et al., 2000).

Animal studies indicate that areas of the brain involved

in learning, such as the hippocampus, experience changes such as increased BDNF, production of new neurons, and increased number and quality of intersynaptic connections between neurons as a result of exercise (Cotman & Engesser-Cesar, 2002; Widenfalk, Olsen, & Thoren, 1999). These alterations in the brain show how exercise might improve cognitive function.

A short-term increase in BDNF in the synapses of areas in the brain occurs within several days of beginning an exercise regimen. This has been demonstrated in the hippocampus of rats within three days of daily running on an exercise wheel (Gomez-Pinilla, Ying, Opazo, Roy, & Edgerton, 2001). Exercised animals that have demonstrated increased BDNF learn a maze task more quickly than animals living in a standard cage (Kitamura, Mishnia, & Suguyama, 2003). A hormone called insulin-like growth factor (IGF-1), which is secreted from skeletal muscle during exercise, passes into the brain where it acts as a growth enhancer (Anderson, Alcantara, & Greenough, 1996). Likewise, the development of new capillaries (i.e., angiogenesis) occurs in the hippocampus after exercise (Gomez-Pinilla, Dao, & So, 1997). The IGF-1 may work in concert with BDNF to repair nerve cells, improve the number of connections with other nerve cells, and enhance the growth of new neurons and capillaries to nourish new cells. It is not surprising that these alterations occur in the sensory and motor cortex regions because of their extensive activation during physical activity. However, it is noteworthy that the same changes occur in the hippocampus, a critical region of the brain intimately involved in memory and learning (Cotman & Engesser-Cesar, 2002).

In humans, three weeks of repetitive finger-movement training appears to enlarge the primary cortex (Karni et al., 1995), and five days of piano practice was found to increase the hand area of the activated motor cortex (Pascual-Leone et al., 1995). Animal studies indicated that activities that involved climbing and balance resulted in greater production of BDNF than running (Anderson et al., 1996; Swain et al., 2003). These findings suggest that more complex motor activities than running might be especially advantageous for brain development and cognitive function. While studies on humans are needed to test this hypothesis, Ratey (2008) suggested that sports and games that require high coordination skills, as well as cognitive action to guide strategy during play, may be especially valuable for brain development. Ratey proposed that the wide variety of motor patterns and continual tactical adjustments needed in most sports and games may activate more regions of the brain than aerobic activities that are motorically less complicated and less varied.

The conclusion of a review paper in the exercise literature indicated that bouts of physical activity act in a way similar to psychostimulant drugs by facilitating attention (Tomprowski, 2003). The effect appears to facilitate learning by raising the energy level and improving the ability to focus on a learning task. The effects of neurotransmitters may explain in part why acute exercise has been shown to improve cognitive function in adults (Brisswater, Col-



Substantial evidence suggests that exercise helps to maintain cognitive function in older adults.

lardeau, & Arcelin, 2002; Tomporowski) and children (Caterino & Polak, 1999; McNaughton & Gabbard, 1993), which suggests that exercising before studying may enhance learning. As a result of these collective physiological effects of exercise on the brain, it appears that additional studies are needed on humans to determine possible benefits on a broad range of cognitive functions. However, the evidence thus far is encouraging.

Cognitive Effects of Exercise

Being able to document anatomical and physiological alterations in the brain of animals as a consequence of exercise provides a basis to believe that the same might occur in humans. Although further research is needed to support this contention, there is already considerable evidence that exercise improves or helps to maintain cognitive function in older persons, who have been the target of much of the research. This is true particularly in terms of enhancing “executive control,” which relates to memory, planning, considering alternatives, and making decisions. These functions deteriorate with age, but exercise has exerted a fairly strong protective function across studies (Colcombe & Kramer,

2003). For example, seniors ages 60 to 75 years old who participated in a walking group showed improved cognitive function in measures such as executive control, while a comparison group that used stretching exercises failed to show improvements (Kramer et al., 1999). Evidence also suggests that regular exercise may have protective effects on the brain, as demonstrated by a reduced incidence of Alzheimer’s disease (Friedland et al., 2001; Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001).

If beneficial effects are seen in older persons, one might suspect an even greater effect in children because of their rapid overall physical growth. Studies in children indicate that increased physical activity improves academic performance (Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983; Shephard, 1997). The effect of physical education programs on academic performance has not been as widely studied, but some work has suggested that academic performance improves when more time is spent in physical education and less time in the classroom (Sallis & McKenzie, 1999; Shephard). A review of the literature by Shephard emphasized three longitudinal studies conducted in Canada, France, and Australia. The longitudinal design and large sample sizes in these studies strengthen their potential application. The results are meaningful for school administrators because they suggest that time allocated to physical education, while reducing classroom time for other subjects, does not necessarily reduce academic performance. A recent review of the literature published in the *Journal of Physical Education, Recreation & Dance* (Smith & Lounsbury, 2009) points out the difficulties associated with assessing the effect of physical education on academic achievement because of the variety in designs used in different studies. Study designs vary in terms of curriculum, measure of academic achievement, teacher quality, previous learning, being experimental or nonexperimental, and so on. Nonetheless, it was concluded that daily quality physical education appears to increase the rate of learning and is positively related to academic achievement, and that allocating time to physical education does not detract from academic achievement. The studies also indicated that allocating less time for physical education and more time for core subjects during the school day does not guarantee improved academic performance.

Behavioral and Emotional Effects of Exercise

The broad anatomical and physiological effects of exercise suggest that exercise may be useful as a means of treating conditions such as attention deficit/hyperactivity disorder, depression, fatigue, and stress. These conditions seem common in modern life and in school-age children and limit the quality of education and life in general. For example, fatigue is reported in about 20 percent of the adult population in the United States (Puetz, 2006). Across a number of epidemiological studies, physical activity has been found to provide a strong and consistent improvement in fatigue. Furthermore, a dose-response relationship exists, such that exercise of higher intensity or longer duration provides more

relief from fatigue than lesser amounts (Puetz).

Exercise also positively influences depression in clinical and healthy populations (Cotman & Egesser-Cesar, 2002). In one study, when exercise was combined with antidepressants, BDNF was increased after only two days and the symptoms associated with depression were reduced. In comparison, antidepressants alone often take weeks to become effective (Russo-Neustadt et al., 2000). Consequently, exercise appears to reduce the time needed for antidepressants to improve the clinical symptoms of depression. Sudden termination of regular exercise, such as occurs when an athlete is injured, reduces BDNF levels and may explain the accompanying depression that typically occurs (Widenfalk, Olson, & Thoren, 1999).

Physical Activity and the Feeling of Reward

Considerable research suggests that the rising rates of depression may be closely linked to the reduction in physical activity opportunities in modern life (Robins et al., 1984; Seligman, 1990). The effort-based rewards theory (Lambert, 2006) holds that the evolution of interconnected brain structures called the "nucleus accumbens-striatum-cortex circuitry" enhanced the ability of humans to work industriously for long periods while meeting the basic needs of survival to obtain food, water, and shelter. Most of the symptoms of depression used for diagnosis are associated with the nucleus accumbens (American Psychiatric Association, 2000). This structure and its neural circuitry release neurochemicals believed to provide a sense of reward, pleasure, and achievement from having met the demands of physical effort.

The World Health Organization estimates that 25 percent of all health care visits across the globe are for mental illness and that the incidence is rapidly rising (Parker, Gladstone, & Chee, 2001). In comparison with earlier generations, modern life has become highly sedentary. For example, the Old Order Amish, who have maintained a simpler lifestyle including hours of physical labor each day, expend approximately six times the energy of modern office workers (Bassett, Schneider, & Huntington, 2004). Lambert (2006) stated that after 100,000 generations of humans being hunters-gatherers and 500 generations as agriculturalists, only 10 generations of humans have existed since the beginning of the industrial age. He contended that the human brain, because it evolved over many more years while humans were highly physically active, adapted in a manner that promoted physical activity. Part of this neurological adaptation included the development of neural interconnections between portions of the brain that regulate physical activity and emotions. This neurological circuit produces hormones and neurotransmitters that produce feelings of pleasure and reward as a result of doing meaningful work. Lambert suggests that the nucleus accumbens, located between the striatum (or motor system) and the limbic system (which regulates emotions), is anatomically located in a logical spot to link physical activity and emotional state. Other research also supports the important role of the nucleus accumbens on mental



Complex motor behaviors involving strategy, such as basketball, may be particularly valuable for brain development.

state (Greenfield, 1991; Mingote, Weber, Ishiwari, Correa, & Salamone, 2005).

The effort-based reward theory and its neurological underpinnings have interesting implications for the role of physical education in today's society. Daily physical education may be a means of improving the emotional state of students and consequently facilitate learning. This hypothesis is supported in part by the generally positive effects seen in studies examining the influence of physical activity and physical education on student academic performance (Dwyer et al., 1983; Shephard, 1997). Physical education can potentially enhance physical skills, which may encourage more physical activity outside of school and in later years. Learning physical skills and deriving the positive feelings attained through physical effort may improve the emotional state of the learner and enhance readiness to learn.

An Anthropological View

The effort-based reward theory (Lambert, 2006) is largely based on the link between physical activity and the evolution of the human brain. A similar explanation was provided by Ratey (2008). He stated that our ancestors were hunters and gatherers who *had* to move; those who did not or could not move were undoubtedly less likely to survive. While hunting and gathering for prolonged periods, the brain, muscles, heart, and other supporting physiological systems were continuously stimulated. Sensory input from the eyes, ears, muscles, and joints provided continual stimuli to numerous regions of the brain for collation, interpretation, and decision making. Thus, the hunter might stop to examine the tracks or droppings of game, alter the course of travel, and continue the vigilance to spot game. The hunter needed perseverance and determination to continue for long periods, which required serotonin, dopamine, and norepinephrine. The "gatherer" may have been similarly stimulated while

searching for wild fruits, nuts, and herbs. The brain activation while pursuing these tasks would be continual and extensive from a neurological standpoint. It is not surprising then that such activities were likely to be potent factors in the brain development of humans. The neurotransmitters and hormones that enhance mental and physical energy and overall cognitive function were activated as humans moved for hours each day. The brain would thus have received daily stimulation in order to optimize the capacity to adapt and survive. Consequently, much of human brain development may have occurred in response to movement, and humans today likely still possess the same capacity (Ratey, 2008).

A Call to Action

The evidence supporting physical education as a basic part of K-12 education is increasingly based on neuroscience. Furthermore, the research findings across numerous studies are consistent in demonstrating that exercise facilitates learning (Landers & Arent, 2007; Sibley & Etnier, 2003). The time seems ripe for physical educators to broadcast this knowledge to the American public, other professionals, and school administrators. In recent decades, AAHPERD has done an admirable job in collaborating with groups such as the American Medical Association, American Heart Association, and the American College of Sports Medicine. These groups all have the common goal of improving the health status of Americans, but today we also need to garner the support of professional educational organizations that include school administrators and school board members, who directly influence curriculum and state achievement tests.

Landers and Kretchmar (2008) suggested that school administrators and school board members place lesser value on physical education because its content is not assessed in any state's achievement tests. Because school administrators are under more scrutiny in recent years to provide quantitative evidence, more time and dollars are allocated to subjects that are assessed on state achievement tests. The recent No Child Left Behind legislation has even further encouraged an increased emphasis on achievement tests. In the past, much of the rationale for defending the role of physical education in the overall curriculum was based on the fitness and health benefits associated with exercise. However, though health and fitness are critically important, they are not directly assessed in state tests and hence are not strongly supported in the curriculum. Educating school administrators and school boards on the scientific evidence regarding the effects of exercise on the brain and learning may be more likely to prompt their support. This line of reasoning suggests that state achievement tests at some point should include content from physical education. This content would surely include health and fitness benefits, but also the neurological effects and impact of physical activity on learning and emotional health.

It may have been too idealistic to think that the health and fitness evidence would be enough to defend the physical education curriculum, and now fewer and fewer

schools provide daily quality physical education (Landers & Kretchmar, 2008; Lowry et al., 2001) in spite of the strong evidence about health. A rationale based more extensively on exercise as a means of enhancing learning and emotional state may be more likely to elicit the attention and support of school administrators.

The importance of developing strong advocacy messages was also emphasized by Smith and Lounsbery (2009), who argued that school administrators demand data-based evidence. They presented research-based evidence on academic performance that can be used to defend physical education and physical activity. While the evidence that physical education enhances academic performance is mostly positive in the article, additional research is certainly needed. Future research by physical educators should consider using state exam scores as an outcome measure, because these data are of particular interest to school administrators.

In conclusion, research from the neurosciences appears to offer additional evidence that strengthens the case for daily physical education in K-12 education. In the author's opinion, this evidence is relatively unknown by school administrators and the general public, and it therefore needs to be better publicized. Perhaps the era of physical education being a "supplement" to other "academic" areas could be a thing of the past. With effective and widespread publicity of evidence-based information, we might be on the threshold of a new era of physical education, one in which it is treated as a vital rather than a minor component in education.

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viduals would be able to repeatedly reinforce Janet through praise, with comments such as, "You're a great teacher, and we know you're willing to do whatever it takes to make all students successful." They might also say something to the effect of "All of the extra time and planning you put into your classes really pays off. Each child always seems to have so much fun in your physical education class!" Similarly, Janet should try to avoid any negative influences surrounding her. She should also interact with fellow physical educators who include students with significant disabilities in their programs on a regular basis. Talking to colleagues is a great way to get new ideas for the classroom, see what others are doing, and verbalize concerns and possible problems that could arise. Janet should also go directly to the students' special education teachers to learn what they have found works or does not work with the students. Special educators can provide detailed, pertinent information because they work with the students on a daily basis and typically know them well.

Finally, Janet's physiological state could also affect her self-efficacy. To ensure that she maintains a strongly perceived self-efficacy, Janet should remain calm, relaxed, and as stress-free as possible. This could be achieved through using effective time-management strategies, planning ahead, seeking new ideas, and using resources via the Internet, books, and inservice trainings. Janet should also eat a well-balanced diet, exercise regularly, and make time to do things she enjoys. Basically, if the teacher is well maintained, this will carry over into the class.

Summary

Why does Serena Williams win so many tennis tournaments? She clearly has the talent, but she also has a level of self-confidence that cannot be matched by her peers. She believes in herself and knows she is going to succeed. This idea of self-confidence leading to success is also true for physical educators like Janet. Physical educators who truly believe they can include children with disabilities in their general physical education programs will find a way to be successful. Unfortunately, due to a lack of coursework and limited experiences, many physical educators do not have confidence in their ability to do so. This article has suggested an application of Bandura's social cognitive theory to GPE teachers who are faced with including students with disabilities. In particular, the four sources of information—enactive mastery experiences, vicarious experiences, verbal/social persuasion, and physiological states—can help physical educators develop more self confidence in their abilities to include students with disabilities (Bandura, 1986, 1997). No doubt Janet and other general physical educators who use this information can improve their self-confidence with regard to including students with disabilities in their physical education classes.

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