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; Neeper 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; Neeper et al.). Exercise also enhances the level of key nerve transmitters that improve mood, energy level, and motivation (Meeusen, Watson, Hasegawa, Roelands, & Piancinti, 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 leaning (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 (Tomporowski, 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-