Imaging the Effects of Physical Exercise on Brain Function

Summary:
Physical exercise promotes a vast range of psychophysiological effects, among these mood elevation, stress reduction, anxiolysis, and modulation of pain perception. Exercise is also known to improve learning and memory, and recent research indicates neuroprotective mechanisms along with changes in brain structure and function. Further studies in humans, using event-related potentials and functional magnetic resonance imaging (fMRI), have shown how aerobic exercise influences cognitive processes, with the extant literature indicating overall facilitation of cognition with selectively greater improvement for tasks requiring extensive frontal lobe involvement, such as those collectively termed “executive control”. Ligand activation studies in human athletes using positron emission tomography (PET) have been conducted to unravel endogenous transmitter release induced by strenuous exercise, both in the dopaminergic and the opioidergic system. Future work is forthcoming to investigate the neuronal and neurochemical mechanisms associated with exercise as a “therapeutic intervention” in clinical conditions, for instance in depression or drug abuse.

Neuroimaging provides an unprecedented means for studying the effects of physical exercise on brain function. The aim of this symposium is, therefore, to highlight the current evidence from both, human and non-human animal work on the body-brain interactions promoted by physical exercise.

Speakers:

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“Mechanisms Associated with the Influence of Exercise on Cognitive Function”
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New advances in animals and humans studies show the powerful action of exercise and lifestyle on modulating brain plasticity and cognitive function. Now we know that exercise has the capacity to modulate molecular systems that are critical for neuronal function and plasticity, and can determine the resistance of neurons to insults associated with aging, injury, and neurodegenerative diseases. In particular, Gomez-Pinilla will discuss physiological mechanisms by which exercise impacts cognitive function by interacting with molecular systems that modulate synaptic plasticity. An important attribute of exercise is its aptitude to enhance levels of brain derived neurotrophic factor (BDNF) in brain regions critical for learning and memory such as the hippocampus. BDNF has a remarkable capacity for supporting cognitive function in the CNS through its diverse actions on axonal and dendritic remodeling, synaptogenesis, and synaptic efficacy. New evidence indicates that the supporting role of BDNF on cognition is associated with its ability to interface energy metabolism and synaptic plasticity. Now we know that an increase in oxidative stress, a consequence of aberrant energy metabolism, results in a decrease in BDNF levels. BDNF appears to be a positive regulator of energy expenditure as the peripheral or central administration of BDNF reduces body weight and improves glucose control in rodents. Exercise is intrinsically associated with energy such that it is not surprising that energy metabolism can be an intermediate step for the effects of exercise on the brain. It is noteworthy that the association between energy metabolism, synaptic plasticity, and cognition may provide molecular basis for functional imaging directed to understand cognitive function. In addition, some of the brain effects of exercise at the molecular level are shared with those of other aspects of lifestyle such as nutritional factors. New evidence indicates that omega-3 fatty acid supplementation enhances the
effects of exercise on synaptic plasticity and learning and memory. Accordingly, the combined actions of diet and exercise provide for a way to counteract cognitive deficits, and may alleviate dysfunction resultant from brain insults, aging, and genetically linked disorders (supported by NIH/NINDS award NS50465).

References


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As children advance through the stages of development they move from inefficient cognitive functioning due to immaturity of various brain structures, to more complex, well-organized cognition. Children often exhibit ineffective performance across a variety of tasks involving attention, cognition, and memory. In schools, cognitive processes such as these are measured via standardized test scores and academic grades. In the laboratory, these processes are examined through measures of cognitive control, which refers to a subset of goal-directed processes involved in the selection, scheduling, and coordination of the computational processes responsible for perception, memory, and action. The study of exercise and fitness influences on cognition has increased in interest over recent years due to the growing public health burden of inactivity among America’s youth. Research has indicated that increased exercise participation is associated with improvements in both general and selective aspects of cognition, with the strongest relationship observed for tasks requiring extensive cognitive control. Given that cognitive control is involved in computational processes such as reading and mathematical problem-solving, exercise may serve to increase academic performance. Accordingly, the purpose of this presentation is to describe the research examining the relationship between exercise and various aspects of cognition (both in the laboratory and in the schools) in children. The overall goal of this line of research is to determine behaviors that improve cognition, maximize health and well-being, and promote the effective functioning of individuals as they progress through the lifespan.


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The presentation will discuss the scientific literature on the relationship between physical activity and exercise and cognition and brain function of older adults. Several literatures will be critically reviewed including prospective epidemiological studies which ask whether physical activity can serve to
maintain cognition or delay the onset of age-associated neurodegenerative disorders such as Alzheimer's disease. Cross-sectional studies of the relationship between exercise and cognitive and brain function will also be reviewed as will the smaller, but critically important, randomized exercise training interventions which examine whether relatively short-term exercise training programs can enhance cognition and positively influence brain structure and function. The presentation will conclude with a discussion of the gaps in the extant literature and prescriptions for future studies of exercise and other non-pharmacological interventions to enhance cognitive and brain function of older adults.


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Frequently encountered psychophysical phenomena associated with physical exercise such as raised mood and modulation of pain perception have suggested that central opioidergic effects play a key role. However, due to technical and ethical constraints, the so-called “endorphin hypothesis” of raised mood in runners was hitherto based entirely upon indirect measures such as elevated endorphin levels in peripheral blood after exercise. Which brain areas are involved and how specific neurotransmitter effects in dedicated brain areas are linked to behavior, remained an open question. The presentation will discuss ligand displacement work using PET and the non-selective opioidergic ligand 6-O-(2-[18F]fluoroethyl)-6-O-desmethyldiprenorphine ([18F]FDPN) to test for central opioidergic release (Spilker et al., 2004) after 120 min of outdoor running (Boecker et al., 2008a; Boecker et al., 2008b). Our findings in 10 athletes demonstrate changes in opioidergic binding linked to affective modulation. After demonstrating these central effects in the opioidergic system, research has been undertaken with fMRI to study the effects of aerobic exercise on heat pain processing.

