

The Relationship of Health Behaviors to Childhood Cognition and Brain Health

Charles H. Hillman Naiman A. Khan Shih-Chun Kao

Department of Kinesiology and Community Health, University of Illinois at Urbana-Champaign, Urbana, Ill., USA

Key Words

Fitness · Physical activity · Obesity · Adiposity · Executive control · Cognitive control · Academic performance · Scholastic achievement

Abstract

Background: Physical activity and aerobic fitness have been shown to have positive implications for children's cognitive performance and brain structure and function. In addition, emerging evidence suggests that excess body mass is related to decreased cognitive performance and differential brain structure and function. Recently, several randomized controlled trials have provided causal evidence for the beneficial effects of daily physical activity on cognition and its neural underpinnings. However, the data linking excess body mass to compromised cognitive function are largely correlational since trials that manipulate body mass to determine changes in brain and cognition remain sparse. Such studies are sorely needed to provide strong evidence for the relation of childhood health behaviors to not only physical, but brain health as well. **Summary:** This manuscript provides a brief review of the current literature on physical activity and excess body mass on brain structure, brain function, and an aspect of cognition known as executive control, which refers to cognitive processes involved in the intentional component of environmental interaction. Generally, the

findings indicate that daily physical activity or higher aerobic fitness is related to greater volume and integrity of brain structure, efficient and effective brain function, and superior executive control. Alternatively, excess body mass is related to decreased integrity of brain structure, less effective brain function, and poorer executive control. **Key Messages:** The findings have considerable implications for lifespan health and effective functioning, and demonstrate that childhood health behaviors have implications not only for cognitive and brain health but also for scholastic performance and educational attainment.

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It has been well established that health behaviors impact physical health and function across the lifespan. For example, a greater consumption of calorically dense foods and a physically inactive lifestyle have been related to adiposity and metabolic diseases [1–3]. However, comparatively little is known about the relationship of health behaviors to cognitive and brain health, particularly during preadolescence, a period characterized by rapid brain growth and plasticity. The influence of health behaviors on childhood brain plasticity and cognitive performance

is especially interesting because evidence indicates that specific behaviors are linked to cognitive and brain outcomes across the lifespan [4]. This review describes the relationship of physical activity (PA) and excess body mass to measures of brain and cognition among children.

Physical Activity

Recently, considerable efforts have been aimed at the benefits of PA (or aerobic fitness) on brain structure and function, and cognition with the purpose of determining how these health factors promote effective functioning within the context of scholastic achievement and learning. Aerobic fitness has been correlated with better performance on tasks assessing cognition and memory as well as the volumes of specific brain structures, such as the basal ganglia [5] and hippocampus [6], with higher-fit children demonstrating larger volumes and superior performance. Other research has imaged white matter tracts connecting prefrontal cortex with other brain regions, and found that children who were more fit [7] or received daily PA had greater structural integrity following the intervention [8], with intervention compliance (i.e., attendance) related to increased white matter integrity [9].

Comparatively, greater efforts have been aimed at the study of PA and brain function. Specifically, neuroimaging tools, including event-related brain potentials and functional magnetic resonance imaging (fMRI), have provided evidence for the relation of PA or fitness to differential brain function, most notably during cognitive tasks that modulate executive control requirements (i.e., the ability to orchestrate thoughts and actions to meet internal goals). In addition to the correlational evidence, a growing number of randomized controlled trials have been conducted, which are consonant with demonstrating a beneficial effect of physical activity intervention on aspects of brain and cognition.

Several published reports from the FITKids trial have indicated that brain function, using event-related potentials, is enhanced following a 9-month PA intervention provided as an afterschool program following each school day [10–11]. Changes in brain function were accompanied by selective improvements in performance during tasks requiring greater executive control. A dose-response relationship was also noted such that greater attendance in the program was related to greater changes in brain function. Lastly, fMRI findings among a subset of FITKids study participants ($n = 23$) demonstrated decreased activation in the right anterior prefrontal cortex

following the intervention, which was accompanied by improvements in behavioral performance on the executive control task; this effect was not mirrored by control group participants [12]. Importantly, the decreased activation in the prefrontal cortex and improved behavioral performance exhibited by children assigned to the PA intervention did not differ from a group of young adults, who served as a reference point for mature or optimal brain function.

Two separate clinical trials in overweight children corroborated the beneficial effect of PA on brain and cognition using fMRI and measures of executive control [13–14]. Specifically, children assigned to an exercise intervention exhibited increased activation in the prefrontal cortex and decreased activation in the parietal cortex from baseline to post-testing during tasks that modulated executive control demands. Further, mathematical achievement was enhanced in children assigned to the exercise intervention (in a dose-response fashion) relative to those assigned to the control condition [13]. Collectively, although the literature-base is emerging, the findings indicate that PA (and aerobic fitness) is positively related to the volume and integrity of specific brain structures, the optimization of brain function, and better cognitive performance during tasks that place greater demand upon executive control. Such findings indicate that PA builds not only physical health but also brain health in specific regions that support executive control function.

Body Mass

By comparison, the understanding of the relation of body mass to brain and cognition during childhood has recently emerged, as only a handful of papers have been published to date. Neuroimaging research has mainly focused on brain function with only a single instance of brain structure reported. Specifically, event-related brain potential studies have uncovered differences in attention [15], inhibition [16], and conflict monitoring [17] during tasks that manipulate executive control, such that healthy-weight children exhibit larger and more effective patterns of neuroelectric activation relative to overweight/obese children. These findings were accompanied by differences in task performance, with healthy-weight children outperforming overweight/obese children, particularly on tasks that require greater amounts of executive control. Importantly, the behavioral findings noted in studies of brain function sit within a larger literature that has

identified differential performance associated with body mass across tasks of general mental ability [18], hippocampal-dependent memory [19], executive control [20–21], and scholastic achievement [20].

Further, emerging evidence suggests that metabolic or disease risk may contribute to the observed differences in brain and cognition between healthy-weight and overweight/obese children. Specifically, Scudder et al. [21] investigated children at risk for metabolic syndrome and found that those with at least one risk factor exhibited poorer executive control compared to their counterparts without any risk factors. Other findings [22] have observed obesity-related differences in brain structure, indicating that adolescents with metabolic syndrome exhibited smaller hippocampal volume and decreased white matter integrity relative to adolescents without risk factors for metabolic syndrome. Importantly, these group differences in brain structure were accompanied by behavioral differences, as adolescents with metabolic syndrome demonstrated poorer attention, executive control, and scholastic achievement [22]. Collectively, these findings point to a detrimental relationship between excess body mass and cognitive and brain health during childhood, indicating that metabolic syndrome or its constituent risk factors may play a mechanistic role in the underlying alterations in brain and behavior.

Summary

Together, this review highlights the relationship of PA and body mass to brain and cognition during childhood, and more generally, describes the importance of

health behaviors for maintaining not only physical health but brain health as well. Such findings point to the importance of adopting a healthy lifestyle to promote increased cognitive functioning during development and the promotion of effective functioning across the lifespan. Given that the brain endures considerable growth during maturation, the influence of lifestyle factors to support plasticity is especially important during this period of the lifespan, as it appears that a healthful lifestyle stands to provide a basis for lifelong brain health. Such a conclusion should not be surprising, given the noted effects of a physically inactive lifestyle on physical health and function across the lifespan. Nevertheless, greater research efforts are needed to conduct the necessary randomized controlled trials to better inform the scientific community and develop a ‘best practice’ approach for those working with children to develop lifelong health and function. Given the implications of these findings for scholastic success, and the fact that the vast majority of children attend public schools, such a setting may be ideal for implementing interventions to increase the adoption of health behaviors among children.

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Disclosure Statement

The authors have no conflicts of interest to disclose.

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