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Targeting the mind and body: Recommendations for future research to improve children's executive functions

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Review Article

Abstract

Children's executive functions (EFs)--the cognitive processing underlying controlled, goal-oriented cognition and behavior--have been shown to be important predictors of future physical, mental, and social wellbeing. Thus, developmental researchers are keen to uncover effective methods to improve children's EFs. While much of the focus in the past decade has been on direct cognitive and behavioral interventions to improve children's EFs, another line of research--typically undertaken in medical schools and in departments of kinesiology--has examined physical health interventions as a way to indirectly improve children's EFs. This commentary suggests that there is promising evidence that physical activity-based interventions to increase children's fitness also enhance children's EFs. There is ample need for additional studies to firmly establish this effect, and to determine the degree to which intervention effects transfer from laboratory EF assessments to 'real-world' functioning. Finally, there is intriguing evidence from animal models that interventions that combine physical and cognitive training have robust positive impacts on brain health. To translate these findings to humans, there is a need for collaborations between developmental psychologists and physical health experts in order to design interventions that simultaneously target children's physical and cognitive health.

Key Words:
Executive functions; intervention; physical health; physical exercise; transfer effects.

Resumen

Mente y cuerpo: Recomendaciones para futuras investigaciones orientadas a mejorar las funciones ejecutivas de niños: Las funciones ejecutivas (EFs) en niños, es decir aquellas operaciones que subyacen a todo procesamiento cognitivo y conductual orientados a un fin, han demostrado ser predictores importantes del bienestar físico, mental y social. Por tal razón, los investigadores del desarrollo están abocados a descubrir métodos eficaces para mejorarlas. Si bien gran parte de la atención en la última década se ha centrado en las intervenciones cognitivas y conductuales directas, otra línea de investigación realizada en general en escuelas de medicina y kinesiología, ha examinado las intervenciones en la salud física como una forma indirecta para mejorar las EFs en niños. El presente comentario sugiere que hay evidencia prometedora de que las intervenciones basadas en actividades físicas para mejorar el estado físico de los niños también podrían mejorar sus EFs. En tal sentido, en la actualidad hay una gran necesidad de realizar estudios adicionales para establecer firmemente este efecto y para determinar el grado de transferencia de los efectos de intervenciones de laboratorio al funcionamiento en el "mundo real". Por último, existe evidencia interesante proveniente de estudios realizados con modelos animales en los que intervenciones que combinan componentes cognitivos y físicos tienen impactos positivos sólidos sobre la salud del cerebro. Para traducir estos resultados a modelos con seres humanos, resulta necesaria la colaboración entre psicólogos del desarrollo y expertos en salud física para diseñar intervenciones orientadas simultáneamente a la salud física y cognitiva de los niños.

Palabras Claves:
Funciones ejecutivas, intervención, salud física, ejercicio físico, efectos de transferencia.

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Executive functions (EFs) –i.e., those cognitive processes important for directing cognition in a goal-oriented manner and for self-control (Banich, 2009) – are of great interest among developmental researchers. This interest is driven in part by the unique ability of EFs to predict various future outcomes of importance, from academic achievement (Duckworth & Seligman, 2005) to socio-economic attainment and physical health status in adulthood (Moffitt et al., 2011). With these important future consequences in mind, research has sought to design and test interventions to promote children's EFs. The hope is that early intervention to improve EFs will have enduring and far-reaching effects on the child's wellbeing. Research has shown that children's EFs can be enhanced through a variety of methods, for example, through adaptive computerized activities that target fundamental aspects of EF (Goldin et al., 2014), through family-based training of parents and children (Neville et al., 2013), and through mindfulness training to promote children's awareness and self-control (Flook et al., 2010).

While much of the focus among developmental psychologists has been on interventions to *directly* alter the cognitive processes and behaviors related to EFs, others in the scientific community have begun to explore interventions to promote EFs *indirectly* by first promoting children's physical health. This latter body of research is inspired in part by two findings. First, across the globe, including in developing countries, childhood obesity rates have increased as a result of decreased physical activity and increased energy consumption (Gupta, Goel, Shah, & Misra, 2012). In turn, children are becoming less physically fit, and disturbingly, the prevalence of cardiometabolic abnormalities --including Type II Diabetes, once described as "adult-onset diabetes"-- has increased among children (D'Adamo & Caprio, 2011). Thus, there is a need to design and implement interventions to promote sustainable changes in children's dietary and physical activity habits. Second, research has discovered that children's physical and cognitive health is interconnected. Indeed, there appears to be a bidirectional link between EF and obesity among children (Liang, Matheson, Kaye, & Boutelle, 2014). On the one hand, obesity is a risk factor for deficits in EF. Engaging in excessive sedentary activity and eating a poor diet might have deleterious effects on the brain, including the prefrontal cortex, which in turn, could result in suboptimal executive functioning. On the other hand, deficits in EF are a risk factor for obesity-related behaviors. EFs are important for avoiding temptations and for delaying gratification, two behaviors which might play an important role in maintaining a healthy lifestyle that includes routine physical activity and a diet containing nutrient-dense, low calorie foods (Best et al., 2012). Thus, there is the exciting possibility that by improving children's EF, their health-related choices also will be improved (Verbeken, Braet, Goossens, & van der Oord, 2013).

With these issues in mind, researchers have begun to target children's physical health as a way to indirectly improve their cognitive functioning. Encouragingly, two randomized controlled trials have shown that engaging children in regular physical activity improves their EFs (Davis et al., 2011; Hillman et al., 2014). Both studies also showed that brain functionality was altered as a result of physical activity, including in areas of the prefrontal cortex (see also Krafft et al., 2013). Physical activity alters various aspects of neurophysiology, including cerebral blood flow, circulation of neurotransmitters, and regulation of proteins important for neural growth and survival—all of which could benefit children's EFs (Best, 2010). Additionally, the study by Davis and colleagues (2011) showed that physical activity improved children's mathematics achievement, despite no explicit mathematics instruction. An intriguing possibility is that the effects on EFs transferred to the real-world domain of academic achievement, an idea that has been supported recently by direct EF interventions (Goldin et al., 2014; Neville et al., 2013).

This promising early evidence should open the door to several lines of inquiry related to physical health-based interventions to improve children's EFs. First, continued evidence from randomized controlled trials is needed to firmly establish that physical activity can reliably improve children's EF. Among other parameters, these studies need to determine the necessary duration (how many weeks or months does the physical activity program need to last?), intensity (how vigorous does the exercise need to be?) and content (should the exercises be primarily aerobic in nature? are group-based exercises better

than individual ones?) to achieve meaningful change. Moreover, these studies should include real-word outcomes (e.g., academic achievement, health behavior) to delineate the extent to which these effects transfer. Although improving EFs is interesting in its own right, a more desirably outcome is to show that performance in the real world (rather than just in the laboratory) is enhanced.

Second, the effects of nutrition-based interventions on children's EFs are unknown. It is plausible that improving children's diet to include more nutrient-dense foods and to reduce high fat, high calorie foods would improve brain and cognitive health (Khan et al., 2015). A program that combines diet and physical activity might have stronger effects than programs that target only one or the other, a proposition that has recently been supported in obese older adults (Napoli et al., 2014). Such a program may be especially useful among children who have already gained excess weight and who may benefit from a more intensive program that improves diet and physical activity together (Wilfley, Vannucci, & White, 2010).

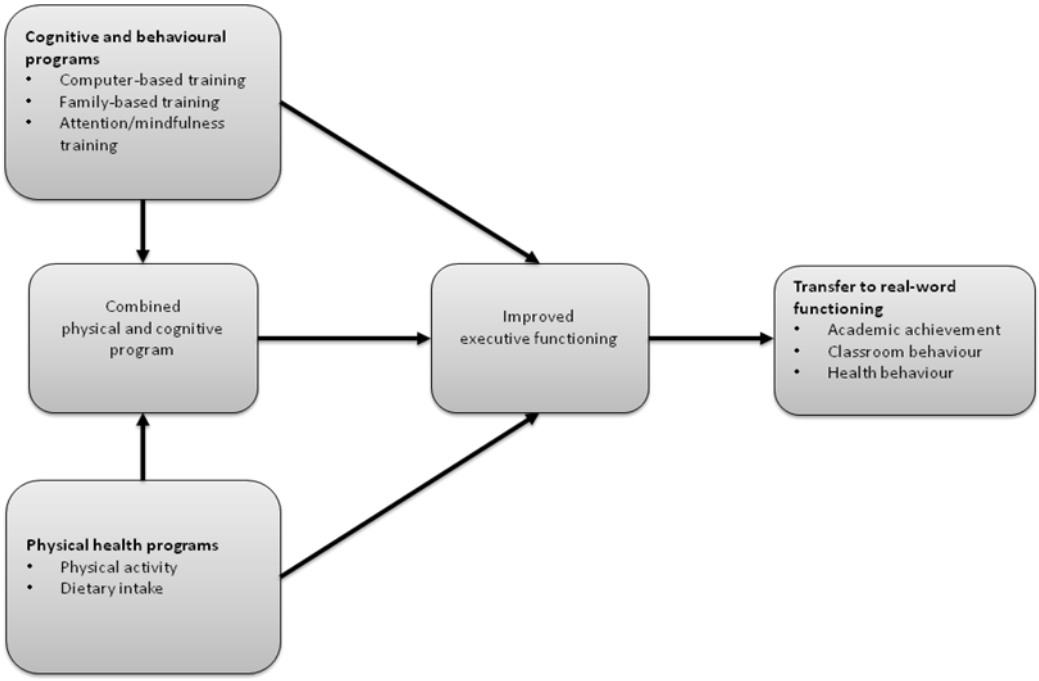

Figure 1. Guide for future research to assess whether physical- and cognitive/behavioral-based interventions impact children's executive functions.

Third, perhaps the most efficacious programs will intervene to promote cognitive and physical health simultaneously. This idea is undergirded by over a decade of animal research, which has suggested that physical exercise combined with effortful learning results in more robust growth and survival or neurons in the rodent brain than either physical exercise or effortful learning in isolation (Shors, Olson, Bates, Selby, & Alderman, 2014). Researchers are now beginning to translate these findings into interventions to promote cognitive health in humans. To date, the focus has been on testing these combined cognitive and physical interventions on older adults to slow down cognitive aging (e.g., Barnes et al., 2013); however, these basic science findings should also be translated into programs to promote EF development in children. For example, a program could include several hours per week of specific EF training (e.g., via adaptive computerized games, social activities with peers, or family-based training to promote parenting practices to elicit children's self-regulation) together with several hours per week of age-appropriate physical activities (e.g., team-based sports). Figure 1 provides a guide for future research to assess whether physical and cognitive interventions positively impact children's EFs, and then, whether those effects transfer to real-world domains of functioning. What is particularly exciting about this area of intervention research is the opportunity for cognitive developmental researchers

to collaborate closely with physical activity researchers, childhood obesity researchers, dieticians, and other medical researchers to design interventions that target children's mind and body.

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