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Exploring the relations among physical fitness, executive functioning, and low academic achievement



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ABSTRACT

Physical fitness seems to be related to academic performance, at least when taking the role of executive functioning into account. This assumption is highly relevant for the vulnerable population of low academic achievers because their academic performance might benefit from enhanced physical fitness. The current study examined whether physical fitness and executive functioning are independent predictors of low mathematics and spelling achievement or whether the relation between physical fitness and low achievement is mediated by specific executive functions. In total, 477 students from second- and third-grade classes of 12 primary schools were classified as either low or average-to-high achievers in mathematics and spelling based on their scores on standardized achievement tests. Multilevel structural equation models were built with direct paths between physical fitness and academic achievement and added indirect paths via components of executive functioning: inhibition, verbal working memory, visuospatial working memory, and shifting. Physical fitness was only indirectly related to low achievement via specific executive functions, depending on the academic domain involved. Verbal working memory was a mediator between physical fitness and low achievement in both domains, whereas visuospatial working memory had a mediating role only in mathematics. Physical fitness interventions aiming to improve low academic achievement, thus, could potentially be successful. The mediating effect of executive functioning suggests that these improvements in academic

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achievement will be preceded by enhanced executive functions, either verbal working memory (in spelling) or both verbal and visuospatial working memory (in mathematics).

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Introduction

There is accumulating evidence for relations between the physical and the cognitive domains. Children with higher levels of physical fitness perform better cognitively, as shown by their academic abilities in mathematics, reading, and language (Fedewa & Ahn, 2011; Santana et al., 2017). Physical fitness can be defined as a set of characteristics used to perform physical activities (Ortega, Ruiz, Castillo, & Sjöström, 2008). It entails the full range of physical capacities and can be subdivided into various components such as aerobic fitness, muscular strength, and skill-related fitness. The relation between physical fitness and academic achievement seems to be especially strong in the domain of mathematics (Chaddock-Heyman et al., 2015; Chomitz et al., 2008; Lambourne et al., 2013), although relations have also been found for reading (e.g., Chomitz et al., 2008) and spelling (Pindus et al., 2016).

Interestingly, physical fitness has been related not only to academic achievement but also to other cognitive functions such as executive functioning (see Chaddock, Pontifex, Hillman, & Kramer, 2011). Executive functions are a subset of higher-order cognitive functions that are involved in organizing and controlling goal-directed behavior (Diamond, 2013). Three core executive functions are generally distinguished: inhibition, shifting, and working memory (Miyake et al., 2000). Inhibition is defined as the ability to withhold dominant automatic behaviors that are irrelevant for the task at hand. Shifting, or task switching, refers to the ability to shift attention forward and backward among multiple tasks in order to easily adapt to changing situations. Verbal and visuospatial working memory are required for the monitoring and coding of incoming information in order to revise and replace information that is no longer relevant by new, more useful information. Well-developed executive functions are a prerequisite for good academic performance. Reading, spelling, and mathematics are complex skills that rely heavily on the ability to inhibit automatic behavior, to shift between strategies, and to update working memory (Best, Miller, & Naglieri, 2011).

Several explanations have been proposed to account for the relationship between physical activity and executive functioning. In general, these mechanisms can be categorized into two broad categories: physiological mechanisms and learning/developmental mechanisms. According to physiological mechanisms, aerobic activity at a moderate-to-vigorous intensity level leads to an upregulation of several growth factors (e.g., brain-derived neurotrophic factor) and monoamines (dopamine, epinephrine, and norepinephrine), resulting in short- and long-term changes in the structure and functioning of brain regions that are responsible for learning (Best, 2010). Learning/developmental mechanisms explain the relation between physical activity and cognition by referring to the learning experiences that take place while being physically active, which have beneficial effects on cognitive development as well. In this sense, it is not the physical exertion per se that is important but rather the cognitive engagement during physical activity and the cognitive demands inherent in motor skill learning and coordination of complex movements (Sibley & Etnier, 2003). It has been suggested that both mechanisms are complementary, meaning that a combination of moderate-to-vigorous physical activity and cognitive-demanding activities will have the strongest effects on executive functioning (Kempermann et al., 2010).

Because executive functions are essential cognitive skills for good academic performance, and because physical fitness seems to be related to both executive functioning and academic achievement, it can be hypothesized that the relation between physical fitness and academic achievement goes via executive functioning (Howie & Pate, 2012). A study by van der Niet, Hartman, Smith, and Visscher (2014) provided the first support for the mediating effect of executive functioning by reporting that the direct relation between physical fitness and academic achievement disappeared once executive

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