



Skill-related physical fitness versus aerobic fitness as a predictor of executive functioning in children with intellectual disabilities or borderline intellectual functioning



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ARTICLE INFO

Article history:

Received 21 March 2016

Received in revised form 15 January 2017

Accepted 2 March 2017

Available online 10 March 2017

Number of reviews completed is 2

Keywords:

Intellectual disability

Borderline intellectual functioning

Aerobic fitness

Skill-related physical fitness

Executive functioning

ABSTRACT

Children with intellectual disabilities (ID) or borderline intellectual disabilities (BIF) often demonstrate impairments in executive functioning (EF). Studies in typically developing children show that aerobic fitness (AF) is positively related with EF. Skill-related physical fitness (SF) might, however, be a stronger predictor of EF than AF, as cognitive challenges are inherent in application of these skills. In this study, AF and SF were examined *simultaneously* in relationship with domains of EF in children with ID or BIF. Seventy-three children (age range 8–11; 51 boys) with ID (IQ range 56–79) or BIF (IQ range 71–79) were measured annually over a period of 4 years on AF (20-m endurance shuttle run test) and SF (plate tapping and 10 × 5 m run). EF was measured with the Stroop Color-Word test (inhibition), Trailmaking and Fluency test (cognitive flexibility), Self-ordered pointing task (working memory) and the Tower of London (planning). Multilevel models showed that SF was significantly associated with inhibition and both measures of cognitive flexibility, but in the same models no significant associations between AF and EF were found. In addition, age was significantly related to working memory and cognitive flexibility, favouring the older children. In children with ID or BIF, SF is of greater importance than AF in relationship with core domains of EF.

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What this paper adds?

For the first time aerobic fitness and skill-related physical fitness were examined *simultaneously* in relationship with a wide range of EF domains (inhibition, cognitive flexibility, working memory and planning) in 8–11-year old children with ID or BIF. In this longitudinal study, the children were measured annually over a period of 4 years. Multilevel models were used in order to give insight into possible developmental changes per EF measure with increasing age. Next, multilevel modelling was used to examine the unique contributions of aerobic fitness and skill-related physical fitness to EF. The results showed a unique relationship between skill-related physical fitness and inhibition and cognitive flexibility. No significant associations between aerobic fitness and EF were found. Age was significantly related to working memory and cognitive

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flexibility, favouring the older children. In children with ID or BIF skill-related physical fitness is of greater importance in relationship with domains of EF than aerobic fitness.

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1. Introduction

Children with intellectual disabilities (ID) demonstrate impairments in executive functioning (EF; Hartman, Houwen, Scherder, & Visscher, 2010; Kirk, Gray, Riby, & Cornish, 2015; Sgaramella, Carrieri, & Barone, 2012), which incorporates a collection of inter-related higher-cognitive processes responsible for purposeful, goal-directed behavior (Anderson, 2002). EF is an important predictor of academic achievement (Bull, Andrews, Espy, & Wiebe, 2008; Van der Niet, Hartman, Smith, & Visscher, 2014) and social functioning (Diamond, 2013). Core executive functions are cognitive flexibility, inhibition, and working memory which can be seen as relatively lower-level executive functions, compared to more complex executive functions like planning (Miyake et al., 2000; Diamond, 2013). In general, development of EF is characterized by an accelerated development between 5 and 10 years with a continued development into adolescence (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Anderson, 2002). However, the developmental trajectories of the specific EF processes reflect the differences in complexity: inhibition shows the largest improvements in the preschool years, and less change later on. Working memory and cognitive flexibility improve mostly after preschool years, whereas in planning the largest improvements can be seen in late childhood and adolescence (Best, Miller, & Jones, 2009).

An interesting question is whether or not decreased levels of physical fitness are related to EF in children with intellectual disabilities. Children with ID have demonstrated lower aerobic fitness levels than typically developing children (Hartman, Smith, Westendorp, & Visscher, 2015). Studies in typically developing children have shown that aerobic fitness was positively related to aspects of EF, such as inhibition, cognitive flexibility, and planning (Buck, Hillman, & Castelli, 2008; Hillman, Buck, Themanson, Pontifex, & Castelli, 2009; Van der Niet et al., 2014). Fewer studies in individuals with cognitive impairments have been conducted. A positive relationship between physical exercise and inhibitory control has been found in individuals with Down Syndrome (Chen & Ringenbach, 2016). A possible theory explaining the link between aerobic fitness and EF is the cardiovascular fitness hypothesis, which states that aerobic exercise might induce short and long term changes in brain regions critical to learning and memory, as a result of increased cerebral blood flow (Etnier et al., 1997). In addition, aerobic exercise resulted in increased levels of neurotransmitters like brain-derived neurotrophic factor (BDNF) and other growth factors, that promote neurogenesis and synaptic plasticity (Hötting & Röder, 2013). Recently, it has been shown that aerobic fitness was positively associated with differences in regional brain function and brain structure in children (Chaddock, Pontifex, Hillman, & Kramer, 2011). Furthermore aerobic fitness was related to increased white matter integrity in children, which may result in faster neural conduction between brain regions important for cognitive control (Chaddock-Heyman et al., 2014). Although in typically developing children, positive relationships have been found between aerobic fitness and executive functions, in children with ID no clear evidence is available for a wide range of executive functions.

Besides the links that have been found between aerobic fitness and EF, skill-related physical fitness might be a predictor of EF, and an even stronger predictor than aerobic fitness. It has been hypothesized that, besides the aerobic mechanisms, learning and developmental mechanisms play an important role, as skill-related movements provide learning experiences that aid cognitive development (Sibley & Etnier, 2003). Skill-related physical fitness consists of those components of physical fitness that have a relationship with enhanced performance in sports and motor skills, and important aspects are coordination and agility (Corbin, Pangrazi, & Franks, 2000). Coordination is the ability to use the senses, such as sight and hearing, together with body parts in performing motor tasks smoothly and accurately. Agility is the ability to rapidly change the position of the entire body in space with speed and accuracy (Corbin et al., 2000). Several brain structures play a pivotal role in both skill-related movements and EF. There are important striatal pathways between the cerebellum and dorso-lateral prefrontal cortex, brain regions that are critical for complex movements as well as complex cognitive performance (e.g. EF) (Diamond, 2000; Koziol et al., 2014). Pesce (2012) argued that qualitative demands inherent in movement tasks could be important in the relationship with cognition (e.g. EF), but these aspects are largely under-investigated. Many forms of exercise include cognitively demanding physical activities such as employing competitive strategies, anticipating the behavior of teammates or opponents, and dealing with changing task demands (Best, 2010). In typically developing children a review showed the strongest relationships between complex motor skills and higher order cognitive skills (Van der Fels et al., 2015). In individuals with cognitive impairments, i.e. adolescents with Down Syndrome, a positive relationship has been found between manual dexterity and planning ability (Holzapfel et al., 2015).

In children with ID not only are levels of skill-related physical fitness lower than in typically developing children (Hartman et al., 2015), but also performance of gross motor skills (i.e. locomotor and object control skills) is impaired (Hartman et al., 2010; Vuijk, Hartman, Scherder, & Visscher, 2010; Westendorp, Houwen, Hartman, & Visscher, 2011). A positive relationship has already been found between gross motor skills and planning in children with ID (Hartman et al., 2010) and between gross motor skills and cognitive flexibility in children with Down Syndrome (Schott & Holfelder, 2015). We hypothesize that skill-related physical fitness components, resulting in smoothly and accurately performed motor tasks, are also positively related to EF in children with ID.

As children with ID have low levels of aerobic and skill-related physical fitness, as well as EF, we need to investigate whether skill-related physical fitness is related to EF in a different way compared to aerobic fitness. We need to fully

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