Physically active academic lessons

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Publication date:
2016

Citation for published version (APA):
de Greeff, J. W. (2016). *Physically active academic lessons: Effects on physical fitness and executive functions in primary school children*. [Thesis fully internal (DIV), University of Groningen]. Rijksuniversiteit Groningen.

CHAPTER 1

General introduction

A recent study has shown that within the period of 2000 and 2014 the number of Dutch preadolescent children (6-12 years) that achieve the recommended amount of moderate-to-vigorous physical activity (MVPA) is declining, while the time spent in physical inactivity is increasing (Hildebrandt et al., 2015). Physical activity is generally defined as *"any bodily movement produced by skeletal muscles that results in energy expenditure"* (Caspersen et al., 1985, p. 126). The current international physical activity guidelines for youth suggest that all preadolescent children should accumulate 60 minutes of daily MVPA, which refers to activity that is performed at 3.0 or more times the intensity of rest (WHO, 2010). This trend of increased time spend in physical inactivity has been reported in other countries as well (WHO, 2010). Because a physical inactive lifestyle tracks into adulthood (Twisk et al., 2000), it is important to implement and evaluate effective strategies for increasing physical activity in preadolescent children.

It is already known that children that participate in MVPA regularly, improve their physical fitness (Kriemler et al., 2010; Kristensen et al., 2010) and lower their health risk (e.g. obesity and hypertension) (Janssen & LeBlanc, 2010). Physical fitness, considered as a set of subdomains that contribute to the ability to perform physical activity and exercise (Caspersen et al., 1985), is for a large part determined by the physical activity pattern over a recent period (weeks or months). In the current thesis, we have focused on the health-related subdomains of physical fitness: cardiovascular fitness, which is the capacity of the cardiovascular and respiratory system to perform prolonged strenuous exercise; muscular fitness, defined as the capacity of the muscles to perform work against a resistance; and body composition, defined as the relative amount of muscle, fat, bone and other vital parts of the body (Caspersen, 1985).

Lately, there is an increasing scientific interest in the hypothesis that regular MVPA might not only lower childhood health problems (e.g. obesity and hypertension), but might also promote improvements in cognitive functions. This hypothesis is partly supported by an abundant number of cross-sectional studies that demonstrated that improvements in physical fitness is related with improvements in cognitive functions (see Hillman et al., 2011; Tomporowski et al., 2011 for reviews). Interestingly, these cognitive benefits from physical fitness are suggested to be selective or disproportionately larger for executive functions compared with other cognitive functions (Etnier et al., 2006). Executive functions, which are effortful cognitive processes that are necessary for goal directed cognition and behavior (Welsh et al., 2006), have a crucial role in mental health and are closely related with academic performance (Gathercole et al., 2004; St Clair-Thompson & Gathercole, 2006). Executive functions consist of at least three related domains: inhibition, which is the ability to avoid dominant or automatic responses and suppress environmental interference; working memory, which involves temporarily keeping relevant information and further processing this information; and cognitive flexibility, which requires children to switch between multiple tasks (Diamond, 2013; Miyake et al., 2000).

Typical classroom behavior of preadolescent children is mainly sedentary, with current curriculums contributing to around 7-8 hours a day spent in sedentary behavior (Esliger & Hall, 2009). Physical exercise programs that focus on increasing the time spent in MVPA and reducing physical inactivity during the school curriculum usually come with the loss of academic instruction time. Given the competing curriculum demands and the high pressure on improving academic performance (Erwin et al., 2012), implementing a physical exercise program is therefore difficult to realize. Coupling physical and cognitive demands might be an important alternative strategy to enhance physical fitness, executive functions and academic performance. Physically active academic lessons are an innovative strategy that introduces MVPA in the classroom, that do not detract from children's learning and come with the possible cognitive benefits from MVPA (Donnelly & Lambourne, 2011). We therefore designed and implemented an intervention program in which Dutch children are physically active during the regular mathematic and language lessons. Possible benefits of these physically active academic lessons could especially be of importance in children with a low socioeconomic status (SES). A child's SES is a construct that is often conceptualized as the social standing or class of the child's parents or caregivers (Hauser, 1994). The Dutch classification of social disadvantage (a dichotomous variable) is used as a measure of SES in the current thesis. Preadolescent children of which their parents completed less than three years of secondary education are in the Netherlands classified as children with a social disadvantage (SDC) (Ministry of Education, Culture and Science, 2006). It is well-documented that SDC are at risk for a low physical fitness (Duncan et al., 1994; Poulton et al., 2002) and generally score lower on academic performance (Chomitz et al., 2008; Sirin, 2005) compared with children without this social disadvantage (non-SDC) (Chomitz et al., 2008). This so called achievement gap continues through adolescence and adulthood, with large economic and social consequences for the career of SDC during adolescence and adulthood (Bradley & Corwyn, 2002). The first aim of the current thesis was therefore to investigate the relationships between physical fitness, executive functions and academic performance in SDC and non-SDC. Secondly, we investigated the effects of physically active academic lessons on physical fitness and executive functions[1].

[1]This thesis is closely related to another thesis that focuses on the implementation and effects of physically active academic lessons on academic performance (Mullender-Wijnsma, in progress).

THEORETICAL FRAMEWORK

Possible mechanisms underlying the effects of MVPA on cognition

The hypothesized model illustrated in Figure 1.1 provides an overview of the possible effects of regular MVPA on cognition in preadolescent children. Firstly, the model assumes that because of the physically active academic lessons are implemented during a time in which the children normally are required to sit still, the amount of in-school MPVA increases. According to the cardiovascular fitness hypothesis, regular MVPA increases physical fitness, which in turn leads to several structural changes in the brain (Etnier et al., 1997). Although it is originally stated that this applies for cardiovascular fitness, gains in muscular fitness might also lead to structural changes in the brain. It has been shown that muscular fitness training in adults increases concentration levels of neurotransmitters such as the insulin-like growth factor I, which promotes neuronal growth (Liu-Ambrose & Donaldson, 2009). The executive functions hypothesis, originally based on results from adult studies, states that MVPA leads to increased activity in selective parts of the brain structural network and especially improves executive functions (Colcombe & Kramer, 2003). Support for this hypothesis can also be found in studies that focus on preadolescent children. For example, MRI studies with preadolescent children have shown that physical fitness is related with increased volumes of specific regions of the basal ganglia (Chaddock, Erickson, Prakash, VanPatter et al., 2010) and hippocampus (Chaddock, Erickson, Prakash, Kim et al., 2010). There is also growing evidence that even a single bout of MVPA (also referred to as acute MVPA) can cause physiological and neurological responses, such as an improved blood flow in the brain and an enhancement of

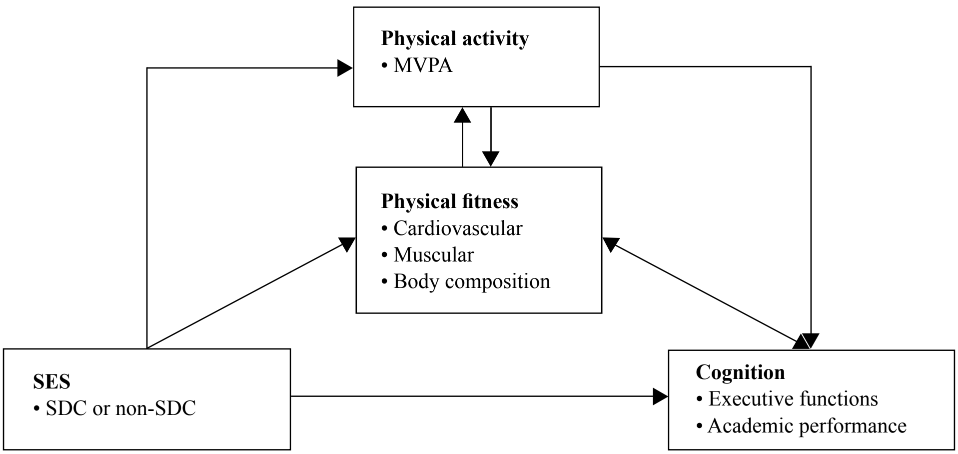

Figure 1.1 Hypothesized model underlying the effects of physical activity on the relation between SES and cognition.
SES: socioeconomic status; SDC: socially disadvantaged children; non-SDC: children without a social disadvantage; MVPA: moderate-to-vigorous physical activity.

the concentration of various neurotransmitters involved in cognitive processes. An example of a neurotransmitter that is positively affected by MVPA is the brain-derived neurotrophic factor (BDNF), of which stimulating neurogenesis and synaptic restauration are one of its roles (Dishman et al., 2006; Winter et al., 2007). Although the effects of these responses typically disappear after a short period (Curlik & Shors, 2013), regularly challenging the brain with physically active academic lessons might, in the long term, result in more structural changes in the brain structural network (Moreau, 2015).

Secondly, the model in Figure 1.1 assumes that there are considerable differences between SDC and non-SDC on cognition that should be taken into account when investigating the effects of physically active academic lessons. For example, if SDC score lower on physical fitness, it is more likely that they will improve on physical fitness, while non-SDC would need a longer period and/or higher intensity in order to improve their physical fitness.

AIMS AND OUTLINE OF THIS THESIS

The main aim of the research described in the current thesis is to study the effects of physically active academic lessons on physical fitness and executive functions in primary school children. We started this research by first investigating the relationships between physical fitness, executive functions and academic performance. These relationships are examined in SDC and non-SDC. Secondly, we investigated the effects of physically active academic lessons on physical fitness and executive functions.

The aim of Chapter 2 is to examine the relationships between physical fitness and academic performance. This chapter gives insight into the differences between SDC and non-SDC on physical fitness and academic performance. In addition, as both physical fitness (cardiovascular fitness and muscular fitness) and academic performance (mathematics, spelling and reading) can be divided in different subdomains, this chapter gives in particular insight into the associations between each subdomain of physical fitness and academic performance. Finally, the chapter examines whether physical fitness is a mediator between SES and academic performance.

In Chapter 3 the relationships between social disadvantage, physical fitness and executive functions are examined. The differences between SDC and non-SDC on executive functions are studied. In addition, it is investigated whether physical fitness indirectly influences the relationship between social disadvantage and executive functions. It was hypothesized that SDC score lower on executive functions compared with non-SDC and that physical fitness was related with executive functions in both SDC and non-SDC. Secondly, it was hypothesized that a lower performance of SDC on executive functions can be partly explained by a lower performance on physical fitness.

Chapter 4 describes the effect of physically active academic lessons on body mass index (BMI) and physical fitness. In a cluster-randomized controlled trial (cluster-RCT), children from twelve primary schools followed a 22-week intervention program in which physical activity was integrated in the mathematics and language lessons. The program was provided three times a week during school time. The control group followed the regular curriculum. The posttest scores on BMI and physical fitness of the intervention group was compared with the scores of the control group, after controlling for pretest differences. The hypothesis was that being physically active during these lessons would decrease BMI and increase physical fitness.

Chapter 5 examined the effects of physically active academic lessons on physical fitness and executive functions after two years. The children that followed the 22-week intervention program in the first year of the cluster-RCT, continued following the physically active academic lessons in the next school year (for a period of another 22 weeks). Baseline and posttest scores after one and after two years of the intervention group are compared with the control group. Finally, in Chapter 6 a summary is provided of the most important findings of the research described in the current thesis. Following this summary, the conclusions, limitations and suggestions for future research are discussed.

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