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### Physically active academic lessons

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# CHAPTER 3

The relationship between  
socioeconomic status and  
executive functions:  
Is there a mediating role  
of physical fitness?<sup>3</sup>

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**ABSTRACT**

Children with a social disadvantage are at risk for a low physical fitness and seem to underperform on executive functions in comparison with children without a social disadvantage. The first aim was to investigate the direct relations between social disadvantage, physical fitness and executive functions in primary school children. The second aim was to examine whether physical fitness mediates the relationship between social disadvantage and executive functions. Data on 431 children were collected. Children were categorized as socially disadvantaged children (SDC) or children without a social disadvantage (non-SDC) according to the parental education level (91 SDC, 340 non-SDC, age =  $8.2 \pm 0.7$ , mean  $\pm$  SD). Physical fitness was evaluated with five items of the Eurofit, measuring muscular and cardiovascular fitness. Executive functions were evaluated with the Stroop (inhibition), Digit and Visual span backward (verbal and visual working memory) and M-WCST (cognitive flexibility). Results showed that SDC scored significantly lower on cognitive flexibility [ $\eta_p^2 = 0.015$ ], compared with non-SDC. No differences were found between SDC and non-SDC on physical fitness. Regression analysis showed a small positive relation between aerobic capacity and cognitive flexibility [ $\beta = 0.16$ ]. Results from the mediation analysis showed that physical fitness did not mediate the relationship between social disadvantage and executive functions. Increasing cardiovascular fitness in both SDC as well as non-SDC might be beneficial for cognitive tasks that require cognitive flexibility.

## INTRODUCTION

The importance of executive functions for children has recently received increased interest, given the crucial role in mental health, and the positive relation with academic performance (Diamond, 2013; St Clair-Thompson & Gathercole, 2006). Much of the development of executive functions and the underlying neural circuitry in the prefrontal cortex occurs during childhood (ages 6-12), making it sensitive for environmental experiences of the child (Best et al., 2009). Executive functions consist of distinct, yet related domains, including at least: (a) inhibition, the ability to deliberately suppress an automatic, dominant or prepotent response, (b) working memory, the ability of updating and monitoring information and (c) cognitive flexibility, the ability to change between mental sets or tasks (Miyake et al., 2000). Maintaining or improving physical fitness through regular exercise might be one of the key experiences that positively influences the developmental trajectory of executive functions (Stroth et al., 2009). This is supported by an increasing number of studies which report a general benefit of physical fitness on cognition, with most of the evidence found for executive functions (also called executive control or cognitive control) in adult studies (Colcombe & Kramer, 2003). The relationship between physical fitness and executive functions in children is less well understood.

Possible relations between physical fitness and executive functions could especially be of importance in children with a low socioeconomic status (Socially Disadvantaged Children; SDC), as it is well-documented that SDC are at risk for a low physical fitness (Duncan et al., 1994; Poulton et al., 2002) and score low on executive functions (Ardila et al., 2005; Noble et al., 2007; Waber et al., 2006). Waber et al. (2006) studied 9-12 year old SDC and compared several neurocognitive functions with their norm scores. It was found that more errors were made on tests measuring executive functions, such as working memory and planning. A cross-sectional study, in which the correlations between degree of social disadvantage and eight different executive function tasks were investigated in 5- to 14-year-old children, found a significant positive correlation between 0.20 and 0.46 on most tasks (six out of eight) (Ardila et al., 2005). Several studies have argued that a poor physical health is one of the possible mediators that might explain the relationship between socioeconomic status and general well-being (Bradley & Corwyn, 2002; Noble et al., 2007). Similarly, it can be argued that physical fitness might mediate the association between social disadvantage and executive functions.

Physical fitness, in part genetically determined, but also highly influenced by environmental factors, is defined as the capacity to perform physical activity (Ortega et al., 2008). Physical fitness includes at least two main domains: (a) cardiovascular fitness, the capacity of the cardiovascular and respiratory system to perform prolonged strenuous exercise, and (b) muscular fitness, the capacity of the muscles to perform work against a resistance. Although research is limited, in two cross-sectional studies the relationship between physical fitness and executive functions in primary school children (6-12 years) has been examined. Results showed a small positive relation between cardiovascular fitness and an inhibition task, explaining between 5 - 9% of the variance (Buck et al., 2008). In the second study, children scoring relatively high

on cardiovascular fitness also scored relatively high on a working memory task, indicating a moderate positive relation between physical fitness and working memory [ $\eta^2 = 0.11$ ](Chaddock et al., 2011). In both studies, cardiovascular fitness was used as a measure of physical fitness, as well as only one domain of executive functions, limiting the evidence for a general relationship between physical fitness and executive functions.

Chronic exercise aimed at improving physical fitness will lead to physiological changes in the brain, which might have long term positive effects on executive functions (Stroth et al., 2009). For example, concentration levels of growth factors responsible for synaptic plasticity and neurogenesis are increased (Dishman et al., 2006). Cross-sectional studies investigating the event-related potentials offer a further understanding of the underlying mechanisms involved in the possible relation between physical fitness and executive functions. The event-related potentials reflect the voltage pattern of a neuroelectric signal occurring before or during stimulus or response. Especially the P3 component, which occurs directly after a stimulus, gives information on how the brain processes a stimulus response task. The amplitude of the P3 component represents the amount of allocated attention during the task, while the latency has been related with stimulus processing speed (Polich & Kok, 1995). A higher cardiovascular fitness was strongly related with a higher P3 amplitude [ $\eta^2 = 0.17$ ] and a faster P3 latency [ $\eta^2 = 0.17$ ] during a working memory task (Hillman et al., 2005). During an inhibition task, a moderate relationship was found between cardiovascular fitness and a higher P3 amplitude [ $\eta^2 = 0.12$ ], while no relation was found between cardiovascular fitness and P3 latency (Hillman et al., 2009). Despite small differences between the results of working memory and inhibition, these findings suggest a positive relation between cardiovascular fitness and multiple domains of executive functions.

To summarize, along with the clear evidence of the relationship between social disadvantage and executive functions, physical fitness might also be related with executive functions, with moderate results coming from inhibition and working memory. The aim of the present study was therefore to investigate the direct relations between social disadvantage, physical fitness and executive functions in primary school children. The second aim was to examine whether physical fitness mediates the relations between social disadvantage and executive functions.

## METHODS

### Participants

Data was obtained from 507 second and third graders (394 non-SDC and 113 SDC) across twelve different primary schools in the Northern part of the Netherlands (mean age =  $8.1 \pm 0.7$ ). Of these children, 431 were included and 76 were excluded (18%) because of absence at the time of testing (Table 3.1). Children of which both parents, or the person(s) responsible for daily care, completed less than three years of secondary education were classified as SDC ( $n = 91$ ) (Ministry of Education, Culture and Science, 2006). The other children were classified as non-SDC ( $n = 340$ ). Information of the classification (SDC or non-SDC) was retrieved from the personal school file of each child. SDC and non-SDC were comparable on all descriptive characteristics, apart from age. SDC were significantly older compared with the non-SDC [ $t = -2.9, p = 0.003$ ]. The current study was conducted with prior approval of the institutional Ethics Committee of the Center for Human Movement Sciences of the University Medical Center Groningen, University of Groningen and informed consent was obtained for all children.

**Table 3.1 Descriptive characteristics of the included study population.**

	SDC (n = 91)	non-SDC (n = 340)	<i>p</i> value
Age, years (SD)	8.4 (0.7)	8.1 (0.7)	0.003 <sup>a</sup>
BMI, kg/m <sup>2</sup> (SD)	17.1 (2.8)	16.9 (2.7)	0.493 <sup>a</sup>
- Normal weight, n (%) <sup>c</sup>	68 (75)	263 (77)	0.727 <sup>b</sup>
- Overweight, n (%) <sup>c</sup>	17 (19)	52 (15)	
- Obesity, n (%) <sup>c</sup>	6 (7)	25 (7)	
Sex, n boys (%)	41 (45)	149 (44)	0.905 <sup>b</sup>
Grade			
- Second, n (%)	44 (48)	175 (52)	0.638 <sup>b</sup>
- Third, n (%)	47 (52)	165 (48)	

SD = Standard deviation, SDC = socially disadvantaged children, Non-SDC = children without a social disadvantage.

<sup>a</sup>Independent t-test. <sup>b</sup>Non-parametric Chi-square test. <sup>c</sup>According to the reference values by Cole et al. (2012).

### Physical fitness

Physical fitness was evaluated with five items of the Eurofit physical fitness test battery (Adam et al., 1988). The selected items were standing broad jump (SBJ, explosive strength, in cm), sit-ups in 30 s (SUP, muscular endurance, in number of completed sit-ups) and handgrip strength (HG, static strength, in kg) for measuring muscular fitness. The 10 × 5 m shuttle run (10 × 5 m

SR, speed-coordination, in s) and the 20 m endurance shuttle run (20 m SR, aerobic capacity, in number of stages) were administered for measuring cardiovascular fitness. The standardized and validated Eurofit test battery has been designed for assessment of health-related fitness in both children as well as adults (Adam et al., 1988). The test-retest reliability [ $r$  varied from 0.62 to 0.97] and construct validity of the five items are adequate for children (van Mechelen et al., 1991). The five items were assessed during two regular scheduled physical education lessons. During one lesson, the SBJ, SUP, HG and  $10 \times 5$  m SR were assessed in a circuit form. During the other physical education lesson, the 20 m SR was assessed and BMI was obtained through height and weight measures. Two trials were given for the SBJ, HG and  $10 \times 5$  m SR with the best performance used for further analysis. One trial was given for the SUP and 20 m SR. Instructed researchers administered the test battery to ensure consistency in the test administration.

## **Executive functions**

### *Inhibition*

Inhibition was measured using the Golden Stroop test (Strauss et al., 2006). Children are asked to read aloud 100 color words printed in black ink (word card), to name the colors of 100 solid squares (color card), and to name the colors of 100 incongruent color words (color-word card) as fast as possible. In all three conditions, children are asked to name as many items as they can in 45 seconds. The color-word condition requires the greatest amount of inhibitory control because the child has to read aloud the color of the word and suppress the automatic response of reading the word. An interference score was computed by subtracting the number of correctly named colors in the color-word condition from the number of correctly named colors in the color condition. The score ranges from 0 to 100. The test re-test reliabilities of the word condition, color condition and color-word condition can be considered good [respectively 0.88, 0.82 and 0.73] (Jensen, 1965).

### *Working memory*

The Digit span backward and the Visual span backward, both part of the Wechsler Memory Scale Revised (Wechsler, 1987), were used for measuring respectively verbal and spatial working memory. During the Digit span task the child was asked to recall a sequence of spoken digits in reverse order. The instructor gave the child one practice trial in order to ensure that the child understood the test. The number of digits in each span increases from two to eight, with three sequences in each span. The test stops when the child fails to recall two of the three sequences in a span. The score is the total number of correctly recalled sequences and ranges from 0 to 21. The Visual span task consists of a card containing eight printed squares. The child was asked to repeat tapping sequences in reverse order that increases from two to seven squares, with two sequences in each span. Again, the instructor gave one practice trial in order to ensure that the child understood the test. The test stops when the child fails to recall both sequences in a span. The score is the total number of correctly tapped sequences and ranges from 0 to 12. The test re-test reliability coefficients for the Digit span backward [ $r = 0.82$ ] and the Visual span backward [ $r = 0.75$ ] indicate that both tests are reliable within children. Factor analysis on a standardized sample showed high factor loadings on general working memory for the Digit span backward

[loading = 0.75] and the Visual span backward [loading = 0.65], indicating that both tests are a valid measure for working memory (Wechsler, 1987).

### *Cognitive flexibility*

Cognitive flexibility was measured using the modified Wisconsin card sorting test (M-WCST). The M-WCST consists of four stimulus cards and 48 response cards. Each card contains figures that vary in form (triangle, cross, circle or star), number (one, two, three or four) and color (yellow, red, green, or blue). The examiner places the four stimulus cards in a row in front of the child and instructs the child to match each response card with one of the four stimulus cards. The child is told whether the card is sorted right or wrong. After six consecutive correct responses the sorting category is changed and the examiner instructs the child to find another rule. The test ends after six categories are correctly sorted or after all 48 cards are sorted. A categorizing efficiency was calculated by scoring six points for every completed category and awarding one point for each of the 48 cards not used (Cianchetti et al., 2007). The categorizing efficiency ranges from 0 to 48. The M-WCST is particularly suitable for children, because it takes less time to administer and is less stressful compared with the original WCST (Cianchetti et al., 2007). Although currently no reliability and validity scores are present in children, moderate test-retest reliability correlations were found within adults [0.56 and 0.64 for number of categories and perseverative error respectively] (Lineweaver et al., 1999; Schretlen, 2010). The M-WCST has a strong correlation with part B of the Trail Making Test [ $r = -0.52$ ], which is considered a reliable test measuring cognitive flexibility (Schretlen, 2010). Children were tested individually by instructed researchers in a quiet room at the start of the school year, approximately two weeks before measuring physical fitness.

### **Statistical analysis**

To investigate the relations between social disadvantage and executive functions, while accounting for the family wise error between the four items of executive functions, a MANCOVA was calculated and univariate analyses were obtained, with scores on the Stroop interference, Digit span backward, Visual span backward and M-WCST as dependent variables; social disadvantage (coded as 0 = non-SDC, 1 = SDC) as the independent variable; age as a covariate. Age was included as a covariate because the SDC were significantly older. To investigate the relations between social disadvantage and physical fitness, a second MANCOVA was conducted with scores on SBJ (cm), SUP (n), HG (kg), 10 × 5 m SR (s) and 20 m SR (stage) as dependent variables; social disadvantage as independent variable; age as a covariate. Effect sizes were calculated using the partial eta squared ( $\eta_p^2$ ), which represents the strength of the association between the independent variable and the dependent variable. A  $\eta_p^2$  below 0.06 is considered small, 0.07 - 0.14 medium and above 0.14 strong (Stevens, 1996).

The mediation bootstrapping approach was used to investigate the relationship between physical fitness and executive functions and to test the mediation effect of physical fitness, as suggested by Preacher and Hayes (Preacher & Hayes, 2008). The mediation approach makes a distinction between direct effect, indirect effect and total effect. The total effect in the current



study is the prediction of executive functions from social disadvantage. The indirect effect is the prediction of executive functions from social disadvantage through physical fitness. The direct effect is the prediction of executive functions from social disadvantage, after taking account of the mediation effect of physical fitness (i.e. total effect = direct effect + indirect effect). The mediation approach tests whether the total effect of social disadvantage on executive functions is significantly reduced after the addition of physical fitness to the model. For the mediation approach, social disadvantage was used as the independent variable; SBJ, SUP, HG, 10 × 5 m SR and 20 m SR as proposed mediators; age as covariate and Stroop interference as dependent variable. Similar statistical analyses were conducted with Digit span backward, Visual span backward and M-WCST as dependent variables. 95% Confidence intervals (*CI*) were calculated for the indirect effect of the domains of physical fitness using 5000 bootstrap samples. If zero was not between the lower and upper bound of the *CI*, significance was adopted. A more detailed discussion on bootstrapping can be found elsewhere (Shrout & Bolger, 2002). Effect sizes were calculated using Cohen's  $f^2$ . An  $f^2$  below 0.39 is considered small, 0.40 - 0.59 medium and above 0.59 strong (Cohen, 1988).

Bonferroni adjusted *p*-values were used for univariate and mediation analyses, indicating that statistical significance was adopted when  $p < 0.013$  ( $p < 0.05$  divided through 4) (Field, 2005). Statistical significance for all other tests was adopted when  $p < 0.05$ . All calculations were performed using SPSS v.20.0 software for Windows.

## RESULTS

### Social disadvantage and executive functions

Table 3.2 shows the estimated mean scores for SDC and non-SDC on executive functions after controlling for age. Univariate analyses showed that SDC, compared with non-SDC, scored significantly lower on the M-WCST [ $F(1,430) = 6.6, p = 0.010, \eta_p^2 = 0.015$ ], but no significant differences were found for Stroop interference [ $F(1,430) = 0.8, p = 0.383$ ], Digit span backward [ $F(1,430) = 2.9, p = 0.091$ ], or Visual span backward [ $F(1,430) = 4.0, p = 0.047$ ]. All effect sizes were small.

### Social disadvantage and physical fitness

Univariate analyses showed no significant differences between SDC and non-SDC for SBJ [ $F(1,430) = 0.1, p = 0.810$ ], SUP [ $F(1,430) = 0.1, p = 0.715$ ], HG [ $F(1,430) = 2.0, p = 0.158$ ], 10 × 5 m SR [ $F(1,430) = 2.2, p = 0.141$ ] or 20 m SR [ $F(1,430) = 0.4, p = 0.520$ ] (Table 3.2).

**Table 3.2 Comparison of the SDC and non-SDC on the estimated mean score and standard errors (SE) of executive functions and physical fitness, while controlling for age.**

	SDC (n = 91) Mean (SE)	non-SDC (n = 340) Mean (SE)	<i>p</i> value <sup>c</sup>
<b>Executive functions:</b>			
Stroop interference <sup>a</sup> , score	17.1 (0.8)	17.9 (0.4)	0.383
Digit span backward <sup>b</sup> , correct items	4.8 (0.2)	5.1 (0.1)	0.091
Visual span backward <sup>b</sup> , correct items	5.3 (0.2)	5.7 (0.1)	0.047
M-WCST <sup>b</sup> , category efficiency score	18.6 (1.2)	22.0 (11.8)	0.010
<b>Physical fitness:</b>			
SBJ <sup>b</sup> , cm	124.9 (1.1)	124.3 (1.1)	0.810
SUP <sup>b</sup> , n	15.4 (0.4)	15.3 (0.2)	0.715
HG <sup>b</sup> , kg	13.9 (0.3)	13.4 (0.2)	0.158
10 × 5 m SR <sup>a</sup> , s	24.9 (0.3)	24.4 (0.1)	0.141
20 m SR <sup>a</sup> , stages	3.9 (0.2)	4.1 (0.1)	0.520

SDC = socially disadvantaged children, Non-SDC = children without a social disadvantage, M-WCST = modified Wisconsin card sorting test, SBJ = standing broad jump, SUP = sit-ups, HG = handgrip strength, 10 × 5 m SR = 10 × 5 m shuttle run, 20 m SR = 20 m shuttle run. <sup>a</sup>The better the performance, the lower the score. <sup>b</sup>The better the performance, the higher the score. <sup>c</sup>ANCOVA (statistically adjusted for age).

## Physical fitness and executive functions

The results obtained from the mediation approach showed that the 20 m SR was positively related with the M-WCST [ $\beta = 0.16, p = 0.004$ ], indicating that a higher score on the 20 m SR is related with a higher score on the M-WCST. The total model explained 6% of the variance [ $r^2 = 0.058$ ]. No significant relations were found between the domains of physical fitness and the Stroop interference, Digit span backward and Visual span backward (Table 3.3).

### Physical fitness as a mediator

The mediation approach showed that the total estimated effect of social disadvantage on executive functions was significantly negative for the M-WCST [ $\beta = -0.30, p = 0.010$ ] (Table 3). No significant total estimated effect of social disadvantage was found for the Stroop interference [ $\beta = -0.10, p = 0.383$ ], Digit span backward [ $\beta = -0.20, p = 0.091$ ], or Visual span backward [ $\beta = -0.23, p = 0.047$ ]. The direct estimated effects of social disadvantage on Stroop interference [ $\beta = -0.08, p = 0.490$ ], Digit span backward [ $\beta = -0.18, p = 0.126$ ], Visual span backward [ $\beta = -0.21, p = 0.070$ ], and M-WCST [ $\beta = -0.29, p = 0.015$ ], were non-significant. The results showed that the estimated effects of social disadvantage for executive functions through physical fitness (indirect effect) were not significant for Stroop interference, Digit span backward, Visual span backward and M-WCST. This indicates physical fitness did not mediate the relationship between social disadvantage and executive functions.

**Table 3.3 Regression analysis predicting the performance of executive functions with the domains of physical fitness and social disadvantage while controlling for gender and age: standardized regression coefficients ( $\beta$ ) and standard errors (SE).**

	Stroop interference		Digit span backward		Visual span backward		M-WCST	
	$\beta$ (SE)	<i>p</i> value	$\beta$ (SE)	<i>p</i> value	$\beta$ (SE)	<i>p</i> value	$\beta$ (SE)	<i>p</i> value
<b>Control variable:</b>								
Age	0.10 (0.08)	0.178	0.14 (0.08)	0.072	0.20 (0.07)	0.007	0.17 (0.07)	0.020
<b>Mediators:</b>								
SBJ	0.04 (0.06)	0.567	0.14 (0.06)	0.016	-0.04 (0.06)	0.515	-0.02 (0.06)	0.770
SUP	-0.03 (0.06)	0.555	-0.10 (0.06)	0.071	0.00 (0.06)	0.972	-0.03 (0.06)	0.543
HG	-0.04 (0.06)	0.552	-0.09 (0.06)	0.129	0.03 (0.06)	0.625	0.06 (0.06)	0.319
10x5m SR	-0.08 (0.06)	0.202	0.00 (0.06)	0.976	-0.12 (0.06)	0.054	-0.06 (0.06)	0.314
20m SR	0.02 (0.06)	0.700	0.08 (0.06)	0.178	0.04 (0.06)	0.486	0.16 (0.06)	0.004
<b>Independent variable:</b>								
Social disadvantage (T <sup>a</sup> )	-0.10 (0.12)	0.383	-0.20 (0.12)	0.091	-0.23 (0.12)	0.047	-0.30 (0.12)	0.010
Social disadvantage (D <sup>a</sup> )	-0.08 (0.12)	0.490	-0.18 (0.12)	0.126	-0.21 (0.12)	0.070	-0.29 (0.12)	0.015
<b>Bootstrapping mediation:</b>								
	95%-CI		95%-CI		95%-CI		95%-CI	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
SBJ	-0.012	0.028	-0.029	0.051	-0.030	0.012	-0.022	0.013
SUP	-0.035	0.009	-0.045	0.020	-0.016	0.018	-0.030	0.010
HG	-0.041	0.007	-0.058	0.003	-0.010	0.039	-0.006	0.046
10x5m SR	-0.061	0.004	-0.022	0.032	-0.083	0.003	-0.064	0.006
20m SR	-0.032	0.008	-0.055	0.008	-0.037	0.007	-0.065	0.022

Social disadvantage: 0 = non-SDC, 1 = SDC. M-WCST = modified Wisconsin card sorting test, SBJ = standing broad jump, SUP = sit-ups, HG = handgrip strength, 10x5m SR = 10x5m shuttle run, 20m SR = 20m shuttle run.

<sup>a</sup>The effect of social disadvantage on executive functions, without (T; total effect) and with (D; direct effect) including the mediation effect of physical fitness.

## DISCUSSION

The current study found that SDC scored lower on cognitive flexibility compared with non-SDC, that no differences were found between SDC and non-SDC on physical fitness and that aerobic capacity was positively related with cognitive flexibility. Although physical fitness did not mediate the relationship between social disadvantage and executive functions, aerobic capacity and social disadvantage were significant predictors for cognitive flexibility in primary school children.

According to the authors knowledge, this is the first study that examined the relationship between cardiovascular fitness and executive functions in children using multiple domains of executive functions in the same study. Based on the current findings, it can be concluded that aerobic capacity is related with cognitive flexibility. The finding that cardiovascular fitness is not related with inhibition and verbal working memory is in contrast with previous literature, which stated that a general rather than a selective relationship exists between cardiovascular fitness and executive functions (Hillman et al., 2009). In addition, previous literature reported a relationship between cardiovascular fitness and both working memory and inhibition (Chaddock et al., 2011; Dishman et al., 2006). Earlier studies including both children and adults argued that the relationship between cardiovascular fitness and executive functions is explained by the increase of both gray and white matter in the prefrontal brain areas (Colcombe et al., 2006; Madsen et al., 2010). Although this might explain that cardiovascular fitness is related with executive functions rather than other cognitive functions, it remains unclear why the current study found a relationship only with cognitive flexibility. Future research is therefore needed to better understand the complex relationship between cardiovascular fitness and executive functions.

The results also showed that aerobic capacity, but not muscular fitness was related with cognitive flexibility. Few studies focused on the relationship between muscular fitness and executive functions. While possible different mechanisms might be present between children and adults, muscular fitness training in adults increases concentration levels of neurotransmitters, such as the insulin-like growth factor I, which promotes neuronal survival, differentiation and growth (Liu-Ambrose & Donaldson, 2009). A meta-analytic study showed that combined muscular and cardiovascular training resulted in a larger improvement of executive functions [ $ES = 0.59$ ], compared with cardiovascular training only [ $ES = 0.41$ ] in older adults (Poulton et al., 2002). However, since muscular training is thought to merely prevent a cognitive decline in older adults (Liu-Ambrose & Donaldson, 2009), the improvement in executive functions might not be as effective within primary school children. This is supported by a study investigating the relationship between physical fitness and academic performance, using cardiovascular and muscular domains. It was found that the relationship between physical fitness and academic performance in third and fifth grade children was present for cardiovascular and not for muscular fitness (Castelli et al., 2007).

Several limitations of the current study should be noted to provide a basis for further exploration. Although the current mediating variable analysis provides estimates of causal pathways, randomized controlled intervention studies are needed to provide insight into the actual causal effects of physical fitness on executive functions. Second, a binary classification of socioeconomic status is commonly used in literature (Chomitz et al., 2008), however, different results might have been observed when using a more continuous classification. The SDC classification is a standardized system in the Netherlands, used for the weighted student funding as a means of financing primary schools. The advantage of using such classification is that it can be obtained from the personal school file of the school administration record system without data loss. A more detailed discussion of the weighted student funding and the policy that introduced this classification can be found elsewhere (Driessen & Dekkers, 2008). We did not have access to more detailed socioeconomic data. The relative large sample of children, the multiple domains of physical fitness and executive functions, and the direct testing of the mediation effect using the bootstrapping approach are notable strengths of this study.

The current study showed that social disadvantage and aerobic capacity were related with cognitive flexibility; children with a social disadvantage or lower aerobic capacity scored lower on cognitive flexibility. Physical fitness did not mediate the relationship between social disadvantage and executive functions in children. Finding no relation between social disadvantage and physical fitness makes it likely that the lower performance on cognitive flexibility shown by SDC is explained by other factors, but does not take away the importance of cardiovascular fitness in executive functioning in children. Increasing cardiovascular fitness in both SDC as well as non-SDC might be beneficial for cognitive tasks that require cognitive flexibility.

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