Physically active academic lessons

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CHAPTER 4

Effect of physically active academic lessons on body mass index and physical fitness in primary school children[4]

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ABSTRACT

Background: Preventing overweight and improving physical fitness in primary school children is a worldwide challenge, and physically active intervention programs usually come with the cost of academic instruction time. This study aimed to investigate effects of physically active academic lessons on body mass index (BMI) and physical fitness in primary school children. Methods: Dutch children attending second- or third-grade class from 12 primary schools [N = 376, 8.1 ± 0.7 years] were randomly assigned to a 22-week intervention program or to the control group. In addition to measuring BMI before and after the intervention, physical fitness was measured with 5 items of the Eurofit test battery, measuring cardiovascular and muscular fitness. Results: Multilevel analysis showed a significant interaction effect between condition (intervention vs control) and grade [$B = -0.47$, $p < 0.05$]. For third-grade children, BMI of the intervention group did not change significantly during the intervention period, whereas a significant increase was found in the control group. No significant main or interaction effects were found for cardiovascular or muscular fitness. Conclusions: The current physically active academic lessons had positive effects on BMI in third-grade children, but had no effects on cardiovascular and muscular fitness.

INTRODUCTION

Overweight and obesity in primary school children are an important risk factor for numerous health problems, including a cluster of cardiometabolic risk factors such as hypertension, insulin resistance, and increased levels of blood lipids (Bailey et al., 2012; Boddy et al., 2014). It is known that many of these risk factors persist into adulthood (Singh et al., 2008) and that physical inactivity in children contributes to the development of overweight and obesity (Dobbins et al., 2013). Nevertheless, primary school children in the Netherlands still spend the majority of their school time (66%) in sedentary activities and less than 5% in moderate to vigorous activities (van Stralen et al., 2014). The school setting is an important environment to promote physical activity and prevent overweight and obesity, because children spend a large part of their day in the school environment (Pate et al., 2006). In addition, physical activity in schools is associated with a higher on-task behavior (Mahar et al., 2006) and could also positively influence academic performance (Erwin et al., 2012).

Preventing overweight by improving children's body composition, as measured by body mass index (BMI), has proven to be difficult in school-based interventions (Demetriou & Höner, 2012; Harris et al., 2009). A meta-analysis that included randomized controlled trials and controlled clinical trials found no significant effect of a variety of physical activity interventions designed to improve BMI in children (Harris et al., 2009). A possible explanation for this finding is that the intensity of the physical activity was insufficient or that there may have been small effects in overweight children, but this effect is not likely to be found when studying the entire study population (Harris et al., 2009).

Regular physical activity in at least moderate to vigorous physical activity (MVPA) results in an improvement of cardiovascular fitness (Kristensen et al., 2010), which is an important predictor of physical health in children (Ortega et al., 2008). Six out of 11 intervention programs aiming to improve cardiovascular fitness through MVPA were effective according to a systematic review including controlled and randomized controlled trials within the school setting (Kriemler et al., 2011). Although a general relationship between MVPA and cardiovascular fitness in children is weak to moderate (Kristensen et al., 2010; Strong et al., 2005), moderate to strong associations were found in children with initially low levels of physical activity [$\beta = 0.63$] (Kristensen et al., 2010). This suggests that intervention programs might especially be effective in increasing the level of cardiovascular fitness in children with relatively low levels of physical activity or fitness.

The focus of intervention programs is often limited to cardiovascular fitness, with less or no attention focused on muscular fitness (Kriemler et al., 2011). Including muscular fitness as one of the outcome measures is nevertheless recommended (Janssen & LeBlanc, 2010), given that an inverse association has been found between muscular fitness and metabolic risk factors, independent of cardiovascular fitness (Smith et al., 2014; Steene-Johannessen et al., 2009). Nevertheless, only 2 out of 11 intervention programs included muscular fitness (Kriemler et al., 2011). One study was unable to find a significant improvement in muscular fitness, while still finding an improvement in cardiovascular fitness (Sollerhed & Ejlertsson, 2008). The other study did not find an improvement in both domains of physical fitness (Verstraete et al., 2007). Given the competing curriculum demands and the high pressure on teachers to increase the academic performance (Erwin et al., 2012), programs that focus on improving physical fitness usually come with the cost of academic instruction time, making it difficult to implement. A more promising strategy is to include physical activity during learning activities in the classroom (Donnelly et al., 2009; Riley et al., 2014). Being physically active during a time in which the children are normally required to sit still may lead to a decrease in BMI and improvements in muscular and cardiovascular fitness. Previous literature has shown that after 8 months of physically active academic lessons (based on TAKE 10!), the BMI of 6- to 12-year-old girls who participated in the daily 10-minute intervention program significantly decreased (-0.47 kg/m^2), compared to girls in the control group (0.66 kg/m^2) (Liu et al., 2007). Another study has shown that similar physically active academic lessons significantly slowed the increasing rate of BMI (1.8 percentile increase of BMI for the intervention group vs 2.4 percentile increase for the control group) and showed significant positive results on reading, mathematics, and spelling (Donnelly et al., 2009). Effects on physical fitness were not included, and therefore, unknown at this point. Granted the inverse association with health and psychological risks, and the positive association with academic performance, effects on physical fitness are an important outcome measure for physically active academic lessons (Janssen & LeBlanc, 2010; Pate et al., 2006).

The aim of this study was to investigate effects of physically active academic lessons on BMI and physical fitness in primary school children in the Netherlands. It was hypothesized that being physically active during these lessons would decrease BMI and increase physical fitness. In addition, it was expected that possible effects are larger for children with an initially higher BMI and lower levels of physical fitness. This study is part of the project ‘‘Fit en Vaardig op school’’ (fit and academically proficient at school; F&V), which is a randomized controlled trial including a school-based intervention program for primary school children with the primary aim to improve academic performance. The intervention program contains lessons that include simple, individual physical exercises during routine learning activities such as mathematics, spelling, and reading tasks in the classroom (Mullender-Wijnsma et al., 2015).

METHODS

Participants

Data were obtained from 388 children across 12 different schools in the Northern part of the Netherlands. From every school, the second- or third-grade class was randomly assigned to the intervention group. Randomization was performed by the national Bureau for Economic Policy Analysis that was not involved in the study. The class that was not assigned to the intervention group formed the control group. Ten outliers and 2 children who attended less than 80% of the intervention lessons were excluded from further analyses. The final study sample consisted of 6 second and 6 third-grade classes in the intervention group (n = 181), and 6 second- and 6 third-grade classes in the control group (n = 195). The descriptive characteristics of the study population are shown in Table 4.1. No differences were found between the control and the intervention group, apart from age and grade. A higher percentage of third-grade children were included in the control group [B = -0.11, $t(371)$ = 2.20, $p < 0.05$] and because of this, the control group was significantly older compared to the intervention group [B = -0.23, $t(371)$ = 3.14, $p < 0.05$]. No significant age differences between the control and intervention group were found when investigating the second- [B = -0.09, $t(185)$ = 1.05, p = 0.297] and third-grade children [B = -0.13; $t(181)$ = 1.27; p = 0.080] separately. Informed consent was obtained for all children.

Table 4.1 Baseline characteristics of children in the intervention and control group.

	Control (n = 195)	Intervention (n = 181)	p value[a]
Age (yr)	8.2 ± 0.8	8.0 ± 0.7	0.002
Height (cm)	132.5 ± 6.9	131.5 ± 6.6	0.145
Weight (kg)	29.6 ± 6.1	29.2 ± 5.8	0.480
Overweight	31 (16)	34 (19)	0.726
Obesity	10 (5)	9 (5)	
Grade			
Second	88 (45)	102 (56)	0.029
Third	107 (55)	79 (44)	
Sex			
Girls	115 (59)	100 (55)	0.518
Boys	80 (41)	81 (45)	

Values are mean ± SD for continuous or n (%) for overweight, obesity, grade and sex.
n = number of participants.
[a]Multilevel regression analysis to account for clustered data.

Instruments

Children were weighed to the nearest 0.1 kg (Model Clara 803, Seca, Chino, CA) and standing height was measured to the nearest cm using a portable stadiometer (Model Seca 220, Seca). Body mass index was calculated as weight (kg)/height (m^2). Overweight and obesity were defined according to the reference values for BMI in children (Cole et al., 2000). Physical fitness was evaluated with 5 items of the Eurofit physical fitness test battery (Adam et al., 1988). The standardized and validated Eurofit test battery has been designed for assessment of health-related fitness in both children as well as adults (van Mechelen et al., 1991). The selected items were 10 × 5 m shuttle run (10 × 5 m SR, speed-coordination, in seconds, s) and the 20 m endurance shuttle run (20 m SR, cardiorespiratory endurance, in number of completed stages) for measuring cardiovascular fitness. The 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) were administered for measuring muscular fitness. The test-retest reliability (*r* varied from 0.62 to 0.97) and construct validity of the 5 items are adequate for children (van Mechelen et al., 1991).

Procedure

F&V is a 2-year cluster-randomized controlled trial of a school-based intervention program, focusing on integrating physical activity into the routine academic lessons such as mathematics, spelling, and reading tasks in the regular education classroom. For example, the children had to solve a mathematical problem by giving the answer with the correct number of jumps (2 times 3 is 6 jumps). Learning activities were matched with the regular learning activities, resulting in a different program for second- and third-grade children. The physical exercises were aimed to be of moderate to vigorous intensity, yet relatively easy to perform. Results of an implementation study showed that the MVPA engagement, measured during the lessons with heart rate monitors, was on average 64% of the time (around 16 minutes of MVPA) (Mullender-Wijnsma et al., 2015). Six substitute teachers, who were hired and trained to deliver the intervention lessons, took over the control of the classroom from the regular teacher during the lessons, which was delivered 3 times a week, 30 minutes each time for 22 weeks. During each lesson, 10-15 minutes were spent on solving math problems followed by 10- 15 minutes on solving language problems. A detailed description of the intervention and its implementation has been described elsewhere (Mullender-Wijnsma et al., 2015). The physical fitness test battery was assessed during 2 regularly scheduled physical education classes at the start of the school year (pretest) and directly after the intervention period of 22 weeks (posttest). The 10 × 5 m SR, SBJ, SUP, and HG were assessed in a circuit form during one physical education class. The children were familiarized with the tests and were given one trial for the SUP and 2 trials for the 10 × 5 m SR, SBJ, and HG. The best performance was used for further analysis. During another class, the 20 m SR was assessed and BMI was obtained through height and weight measures. One trial was given for the 20 m SR. Height and weight were measured while the children were wearing gym clothes without shoes. Instructed researchers administered the test battery following the standardized protocol (van Mechelen et al., 1991) to ensure consistency in the test administration.

Data analysis

Multilevel regression analyses were conducted for descriptive analyses and to assess the possible differences between the control and intervention group before the intervention, for second- and third-grade children separately. A random intercept was considered for each child (level 1) and for each school (level 2), to account for the common experience the children share within each school. The outcome measures of the pretest, BMI (kg/m^2), SBJ (cm), SUP (n), HG (kg), 10 × 5 m SR (s), and 20 m SR (stage), were used as the dependent variables and condition (intervention or control) as the independent variable. To assess the possible differences between the intervention and control group after the intervention, multilevel regression analyses were conducted. A random intercept was considered for each child (level 1) and for each school (level 2). The outcome measure of the posttest (BMI, SBJ, SUP, HG, 10 × 5 m SR, or 20 m SR) was treated as dependent variable and condition as an independent variable (condition model). Sex, age, grade, and the corresponding scores of the pretest were treated as covariates. To investigate whether there were different intervention effects for second-grade compared to third-grade children, the inclusion of the interaction between condition and grade was considered as an additional independent variable (condition × grade model). In the third and final model (condition × baseline model), the inclusion of the interaction between condition and pretest score was considered to investigate whether the possible effect of the intervention depended on the pretest scores. The model fit was evaluated by comparing the deviance of the covariates model, which included only the covariates, with the final model (Snijders & Bosker, 2011). Statistical significance was adopted for all tests when $p < 0.05$. All statistical analyses were conducted using MLwiN (version 2.29).

RESULTS

Table 4.2 shows the mean scores of the pretest for BMI and the domains of physical fitness. Within second-grade children and within third-grade children, no significant differences were found between the control and intervention group. This indicates that for BMI and for the domains of physical fitness, the control group did not differ from intervention group before the intervention.

Table 4.2 Comparison of the pretest scores for BMI and the domains of physical fitness for the control and intervention group.

	Second grade		Third grade	
	Control (n = 88)	Intervention (n = 102)	Control (n = 107)	Intervention (n = 79)
BMI (kg/m^2)	16.3 ± 2.1	16.6 ± 2.4	17.1 ± 2.6	17.0 ± 2.3
SBJ (cm)[a]	117.5 ± 18.1	122.0 ± 18.9	133.5 ± 21.5	127.5 ± 21.1
SUP (number of sit-ups)[a]	14.6 ± 4.4	14.9 ± 3.9	16.2 ± 3.9	15.9 ± 3.9
HG (kg)[a]	12.1 ± 3.1	12.7 ± 2.6	14.7 ± 2.9	14.3 ± 3.4
10 × 5 m SR (seconds)[b]	25.0 ± 3.0	24.9 ± 2.0	23.4 ± 2.1	24.2 ± 3.0
20 m SR (stages)[a]	4.0 ± 2.0	3.8 ± 1.6	4.2 ± 1.9	4.3 ± 1.8

Values are mean ± SD. No significant differences were found between the control and intervention group using multilevel regression analysis to account for clustered data.
n = number of participants, BMI = body mass index, SBJ = standing broad jump, SUP = sit-ups, HG = handgrip strength, 10 × 5 m SR = 10 × 5 m shuttle run, 20 m SR = 20 m endurance shuttle run.
[a]A higher score indicates a better performance. [b]A lower score indicates a better performance.

No significant difference was found between the intervention and control group on BMI posttest scores in the condition model (Table 4.3). Including condition and the interaction between condition and grade significantly improved the covariance model [$\Delta\chi^2(2) = 6.7$, $p < 0.05$]. The significant interaction between condition and grade [$B = -0.47$, $t(369) = 2.03$, $p < 0.05$] indicated that the intervention effect was different for third-grade compared to second-grade children. Figure 4.1 shows the predicted pretest and posttest BMI values based on the condition × grade model. Within the third grade, BMI of children in the control group increased significantly during the intervention period, whereas BMI of children in the intervention group did not change significantly. This interaction effect was not found within second-grade children. Including the interaction between condition and pretest scores did not improve the model, indicating that the intervention effect did not depend on the pretest scores. For the domains of physical fitness, including condition did not improve the model fit. This indicates that no significant differences were found on the posttest scores between the intervention and control group after controlling for sex, age, grade, pretest scores, and accounting for the clustered structure of the data. Including the interaction between condition and grade, or the interaction between condition and pretest scores, did not improve the model indicating that the effects did not depend on grade or pretest scores.

Table 4.3 Multilevel models predicting the posttest scores for BMI and each item of physical fitness, accounting for the clustering of data at school level and controlling for sex, age, grade and the pretest scores.

	BMI			SBJ			SUP			HG			10 × 5 m SR			20 m SR		
	B[a]	SE	p	B[a]	SE	p	B[a]	SE	p	B[a]	SE	p	B[a]	SE	p	B[a]	SE	p
Random intercept	0.04	0.59	.941	39.08	11.89	**.001**	9.56	2.85	**.001**	-1.22	1.64	.460	10.27	1.85	< **.001**	1.13	1.17	.333
Sex[b]	-0.05	0.07	.466	2.04	1.46	.162	0.35	0.35	.313	0.19	0.20	.343	-0.28	0.18	.124	0.56	0.15	< **.001**
Age	0.00	0.08	.053	0.77	1.54	.616	-0.64	0.37	.090	0.68	0.22	**.003**	-0.09	0.19	.632	0.05	0.15	.764
Grade[c]	0.08	0.11	.434	1.90	2.15	.378	1.98	0.52	< **.001**	0.00	0.30	.992	-0.02	0.27	.944	-0.14	0.22	.503
Pretest	0.99	0.02	< **.001**	0.61	0.04	< **.001**	0.72	0.05	< **.001**	0.79	0.04	< **.001**	0.62	0.04	< **.001**	0.66	0.04	< **.001**
Condition[d]	-0.12	0.07	.082	2.55	1.40	.071	0.13	0.34	.712	0.06	0.20	.780	0.13	0.18	.466	0.05	0.14	.742
Deviance Covariance model			771.16			3036.84			1973.35			1561.34			1468.23			1293.30
Deviance Condition model			768.12			3033.57			1973.21			1561.26			1467.70			1293.19

BMI = body mass index, SBJ = standing broad jump, SUP = sit-ups, HG = handgrip strength, 10 × 5 m SR = 10 × 5 m shuttle run, 20 m SR = 20 m endurance shuttle run.
[a]Unstandardized regression coëfficient. [b,c,d]Respectively girls, second grade and control group are coded as 0. Boys, third grade and intervention group are coded as 1.

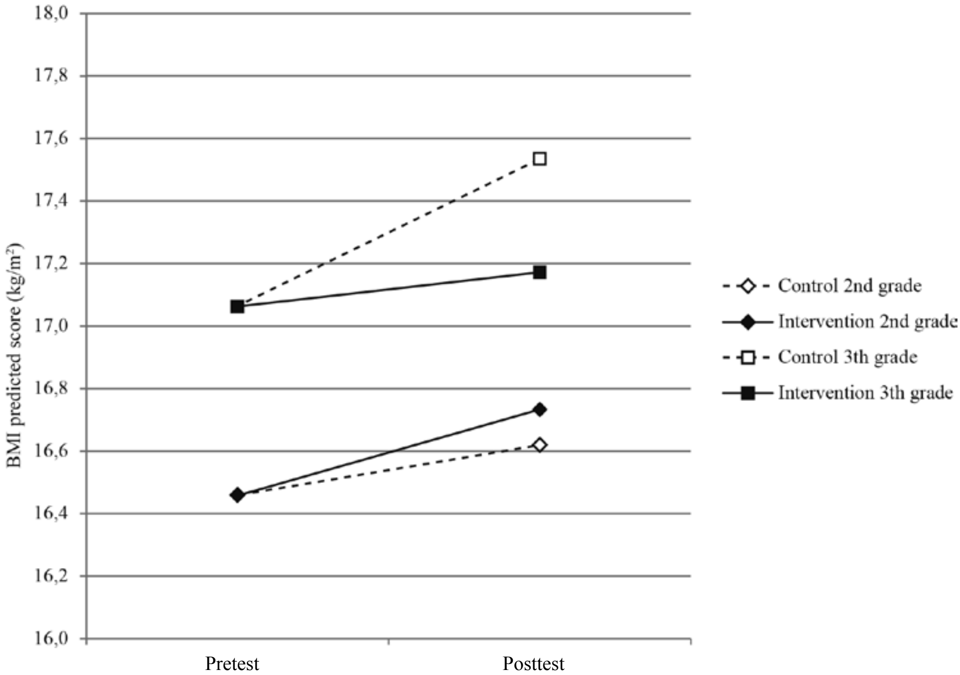

Figure 4.1 Predicted pretest and posttest values for Body Mass Index (BMI) for second- and third-grade children.

DISCUSSION

The aim of this study was to investigate effects of physically active academic lessons on BMI and physical fitness in primary school children. It was hypothesized that possible effects are larger for children with an initially higher BMI and lower levels of physical fitness. The results of this study show that the physically active academic lessons had a significant effect on the BMI of third-grade children. The BMI of the intervention group did not change significantly, whereas a significant increase was found in the control group during the intervention period. No significant effects were found on physical fitness.

Improving BMI through school-based interventions is known to be challenging and intervention studies were mostly unsuccessful (Demetriou & Höner, 2012; Harris et al., 2009). In this study, the BMI of the third-grade children in the intervention group did not change whereas the BMI of the control group increased, indicating that the lessons might prevent overweight and obesity in third-grade children. Previous literature argued that small effects of a subset of children in the intervention could not be noticeable in the assessment of the entire study population (Harris et al., 2009; Magnusson et al., 2012). A secondary aim of this study was therefore to investigate possible effects in children with initially higher BMI; however, no effect for children with initially higher BMI was found. The positive effects on BMI in third-grade children are comparable with the physical activity across the curriculum (PAAC) study, showing a significantly smaller increase in BMI for schools that delivered the lessons more than 75 minutes per week after 3 years (Donnelly et al., 2009). Considering that the current lesson time was close to 75 minutes per week (Mullender-Wijnsma et al., 2015), this study has shown that positive effects on BMI can even be found after an intervention period of 22 weeks.

Physically active academic lessons also have the potential to improve physical fitness (Donnelly et al., 2009), but these effects have not been published in previous studies. This study showed that the intervention had no effect on muscular or cardiovascular fitness. A meta-analysis that investigated the effects of school-based physical activity programs argued that a lack of significant effects could be due to the intensity of the program (Harris et al., 2009). Heart rate monitoring results of the current lessons showed that the MVPA engagement was on average 16 minutes (Mullender-Wijnsma et al., 2015). This duration of MVPA is comparable with the average time spend in MVPA during a physical education lesson in Dutch primary school children, which is around 18 minutes (Slingerland et al., 2011). School-based physical activity programs with comparable intensity and duration had a positive (Kriemler et al., 2010; Sollerhed & Ejlertsson, 2008), or no effect on physical fitness in 6- to 12-year-old children (Boyle-Holmes et al., 2010; Verstraete et al., 2007). It therefore remains unclear which intensity and duration are needed to improve physical fitness in primary school children. Although more intense physical exercises of the lessons might have improved physical fitness, high intensity exercises during physically active academic lessons can have a negative impact on the academic tasks (Kamijo et al., 2004). Nonetheless, because the children are mostly physically inactive during the school time (van Stralen et al., 2014), the lessons likely decreased sedentary time which can have beneficial health effects in children (Verloigne et al., 2012).

Limitations

There are some limitations in this study that should be considered. Although this study controlled for several possible confounders such as sex, age, grade, and school, there are still some potential confounders that may have affected the results. We did not take into account differences in motivation for the exercises or after-school activities. It is therefore unclear whether or not the increase of physical activity during the school time affected the physical activity after school or during the weekends. The primary strengths of this study were the cluster-randomized controlled trial design and the fact that the program was integrated in the school curriculum and directed at all the children in the class, which avoided selection bias in the intervention group.

Conclusions

The physically active academic lessons had positive effects on BMI in third-grade children during a time in which the children normally have to sit quiet, but the lessons did not affect physical fitness. The intensity of the lessons might need to be further increased in order to positively impact BMI and physical fitness in all children.

Implications

Children spend a lot of their school time in sedentary behavior (van Stralen et al., 2014). Reducing the time spend in this behavior and promoting physical activity during school time can have important health benefits. One of the biggest barriers for teachers to promote physical activity in primary schools are their own perceptions toward physical activity and their lack of knowledge about how to improve it (Riley et al., 2014). The current physically active academic lessons provide primary school teachers a novel strategy to integrate physical activity into the routine academic lessons that is both feasible and does not come with the cost of academic instruction time (Mullender-Wijnsma et al., 2015). A potentially important benefit that might lower the barriers for teachers (and school directors) is that physically active academic lessons might not only provide health benefits but might also enhance academic performance (Donnelly & Lambourne, 2011; Erwin et al., 2012; Riley et al., 2014). This study has shown that the current lessons have significant health benefits that are associated with an improved BMI in third-grade children. To improve physical fitness in children, the intensity of physically active academic lessons might need to be higher.

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