

University of Groningen

Physically active learning

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Document Version

Publisher's PDF, also known as Version of record

Publication date:

2017

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Wijnsma, M. (2017). *Physically active learning: the effect of physically active math and language lessons on children's academic achievement*. [Thesis fully internal (DIV), University of Groningen]. Rijksuniversiteit Groningen.

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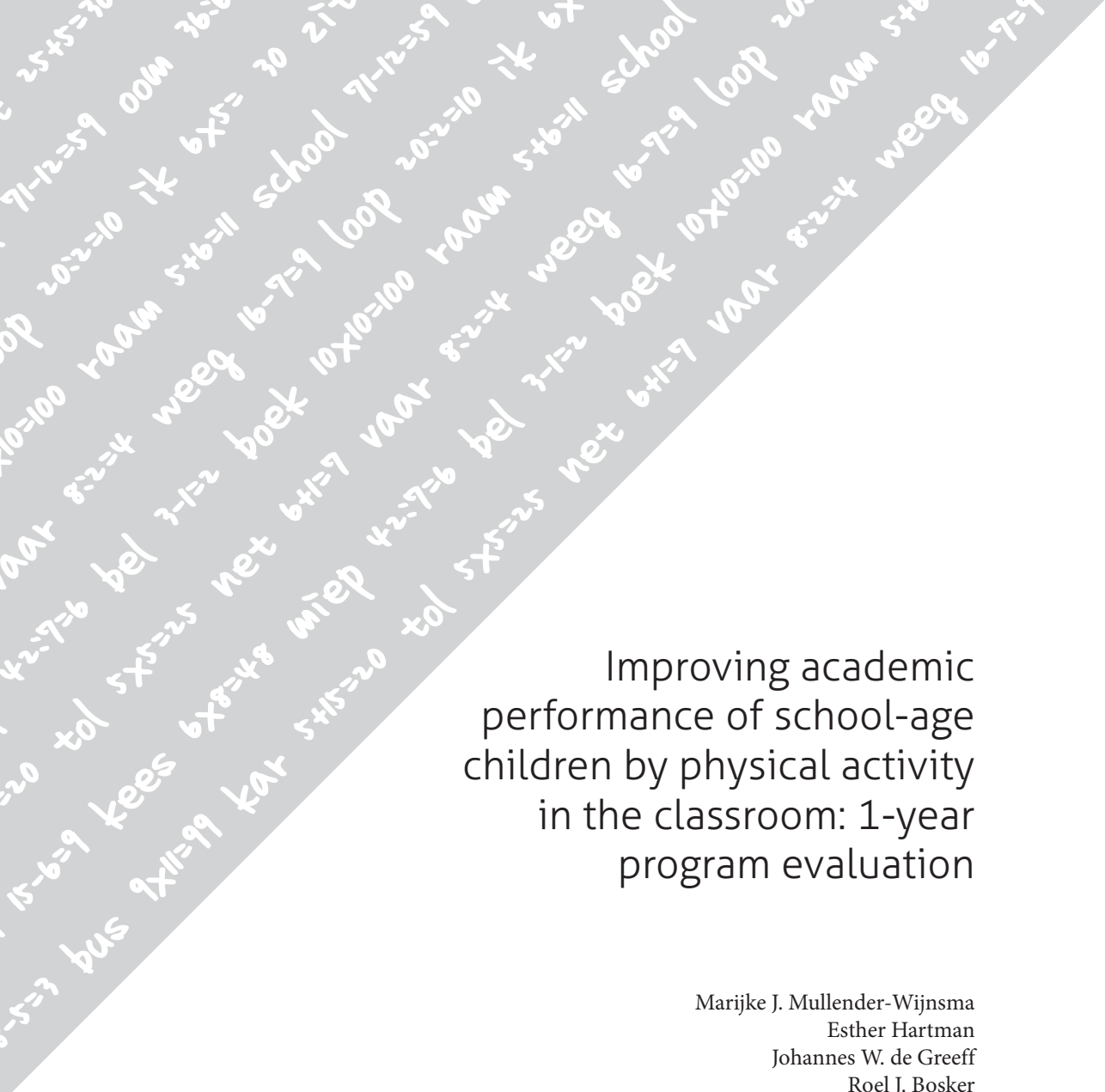
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Improving academic
performance of school-age
children by physical activity
in the classroom: 1-year
program evaluation

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ABSTRACT

Background An intervention was designed that combined physical activity with learning activities. It was based upon evidence for positive effects of moderate to vigorous physical activity (MVPA) on academic achievement. The aim of this study was to describe the program implementation and effects on academic achievement after one year.

Methods Second- and third-grade classes of six elementary schools were included in the study. The intervention group participated in physically active academic lessons and the control group in regular classroom lessons. Implementation measures were obtained and the children were pretested and posttested on mathematics and reading.

Results Teacher observations and self-reports indicated that the lessons were implemented as planned. Classroom observations showed that children's on-task behavior during the lessons was above 70%. On the basis of heart rate measures, on average 64% of the lesson time was spent in MVPA. Post-test mathematics and reading scores of third-grade children who participated in the intervention were significantly higher in comparison with control children. Post-test mathematics scores of second-grade children in the intervention condition were significantly lower in comparison with control children.

Conclusions The intervention program was successfully implemented and the lessons contributed to the academic outcomes of third-grade children.

INTRODUCTION

There is currently a lot of interest in the relationship between children's physical activity and their academic performance. Studies addressing the association between physical activity and academic performance in children and adolescents, reveal that physical activity is either positively related to academic performance or that there is no relationship between these two domains. The literature further suggests that extra time for school-based physical activity is not likely to hinder children's academic performance.¹⁻⁴ In addition, a review concluded that more research is necessary to make defensible claims for the educational benefits of physical activity.⁵ Educational benefits of physical activity can be derived from the theory of brain-based learning. This theory, in part, suggests that moderate to vigorous physical activity (MVPA) stimulates the brain in a positive way.⁶ In the short term, physical activity stimulates immediate chemical changes in the brain that increases attention and may enhance cognitive performance.⁷ For example, larger P3 amplitude of the event-related brain potentials, which is thought to represent processes involved in dividing attention and activating the working memory, were found after moderate intensive acute exercise.⁸ In the long term, regular MVPA could lead to morphological changes (angiogenesis, neurogenesis and synaptogenesis) in brain regions that are important for learning.^{7,9} Researchers showed that an intensive exercise program for overweight children led to positive effects on math achievement, planning skills, and to increased activity in the prefrontal cortex of the brain, which plays an important role in cognitive control.¹⁰ Another study found that the aerobic fitness of children was positively related to the P3 amplitude.¹¹ These findings suggest that physical activity and physical fitness may in the short and the long term positively affect important brain areas that stimulate cognition of children and could be a motive to enhance school-based physical activity.

School-based physical activity is often associated with physical education. But physical activity breaks inside the classroom may also have academic benefits.^{1,12} More specifically, these physical activity breaks can be combined with learning activities. Combining learning with physical activity is an easy way to invest in both academic exercise and physical activity. The combination saves time because teachers do not have to choose between academic instruction and (extra) physical education. Moreover, a study reported that an interaction between aerobic physical activity and cognitive engagement may have a stronger effect on cognitive functioning.⁷ An overview of the impact of ten years of TAKE10!, a program for elementary school children that introduces physical activity into learning activities,

showed that this school-based physical activity program can be implemented with success in elementary classrooms. The results showed that teacher and child acceptance was high, that the children participated in MVPA during the TAKE 10! activities, and that children's academic outcomes might improve.¹³ The intensity level of the TAKE10! lessons was measured using accelerometers and pedometers and of moderate to vigorous intensity throughout the duration of the lessons.¹⁴ An evaluation study of an intervention to promote physical activity called Physical Activity Across the Curriculum (PAAC), confirmed a good acceptance of physically active academic classroom lessons among teachers and children. Regular classroom teachers delivered existing academic lessons using MVPA. After one year of implementation it appeared that the lessons were rated as enjoyable (93%) and that the children showed significantly greater levels of physical activity compared with children in control schools. The participation of the teachers in the training session was high and they incorporated the lessons several times a week (47 to 65 minutes a week). The majority of the teachers (66%) believed the children performed the lessons with a moderate intensity.¹⁵

To date, a small number of studies have examined the effect of the combination of academic lessons with physical activity in the classroom.¹² Within these studies the distinction between short-term and long-term effects can be made. Short-term effects are effects that occur during or immediately after a physical activity break, such as changes in children's in-school physical activity, academic motivation, and time-on-task. Children's time-on-task is a predictor of academic success.¹⁶ After physically active academic classroom lessons an improvement in on-task behavior and increased in-school physical activity was observed.¹⁷⁻¹⁹ Long-term effects of PAAC were evaluated after three intervention years. The main goal of PAAC was to reduce gains in body mass index (BMI). The participation in the PAAC lessons led to less increase in BMI and an intriguing outcome was that math, spelling and reading scores of elementary school children significantly improved by attending the PAAC lessons.²⁰

In sum, combining learning activities with physical activity may lead to favorable academic outcomes as well as health improvements. Building on this, we developed a school-based intervention that combines physical activity and learning. The PAAC intervention,²¹ containing PAAC and TAKE10! lessons, inspired us to develop 'Fit en Vaardig op school' (F&V, Fit and academically proficient at school). The main goal of F&V is improving academic outcomes, secondary goals focus on an increase in executive functioning, physical fitness, and physical activity. F&V is a two-year elementary school-based intervention program, preceded by a one-year study to improve the program. The program evaluation

of the intervention in the one-year study is described in this paper. The first aim was to describe the implementation of the F&V program. Because different F&V programs were developed for second- and third-grade classes, implementation differences between the two grades also were explored. The second aim was to investigate the effects of the program on mathematics and reading outcomes after one year. It was hypothesized that children in the intervention group performed better on a mathematics and reading test after the intervention in comparison with the control group. Evaluating the implementation and effects of the F&V intervention is important to improve the intervention and to prevent the absence of positive intervention effects on the long term due to bad implementation and intervention flaws.²²

METHODS

Participants

A total of 228 children (mean age, 8.1; 122 boys and 106 girls) from second- or third-grades of six elementary schools were recruited from the Northern Netherlands. A quasi-experimental design with a control group was used. Every school participated with a second- and third-grade class. Three second-grade classes participated in the F&V intervention ($n = 58$). The other three second-grade classes formed the control group ($n = 62$). In the schools where grade two participated in the intervention, grade three formed the control group ($n = 52$) and in the schools where grade two formed the control group, grade three participated in the intervention ($n = 56$). Informed consent was obtained for all children and the ethic committee of the Center of Human Movement Sciences of the University Medical Center Groningen/University of Groningen gave ethics approval for the intervention.

Intervention

The researchers developed 63 physically active academic classroom lessons for second- and third-grade. During each F&V lesson 10 to 15 minutes were spent on solving math problems followed by 10 to 15 minutes on solving language problems. The level of the teaching material was based on the math and language curriculum of second- and third-grade classes in the Netherlands. The main focus was on repetition and memorization of reinforced concepts that children learned in an earlier class. The physical exercises were of moderate to vigorous intensity but relatively easy to perform. At the start of each lesson the

children stood behind or beside their school desk. During the lessons specific exercises or basic exercises were performed. The specific exercises were performed when the children answered a question. For example, words had to be spelled by jumping in place for every mentioned letter. The basic exercises were performed during the remaining part of the lesson, for example marching, jogging or hopping in place. The interactive whiteboard played an important role in the F&V lessons. Every lesson was supported by a presentation on the board whereupon the mathematical and language tasks became visible.

Instruments

To obtain information that will guide program improvement, evaluation activities were undertaken. An important aim was to determine the degree of conformity between the program as implemented and the program's design. Several components that are considered to be important for evaluation of program implementation were taken into account: reach, dose delivered, dose received, and fidelity (quality of implementation).^{22,23} Teacher observations assessed dose delivered and fidelity. Teacher self-reports were used to measure reach, dose delivered, and fidelity. On-task observations and heart rate measures were performed in the children to determine dose received and fidelity.

Teacher observations in the classroom were performed to assess the teacher implementation of instructional practices. These were open observations by the researchers who developed the program during several intervention lessons. Feedback was provided about the duration of the lessons, lesson intensity, classroom management, and use of the lesson content.

After every lesson the teachers reported in teacher self-reports if the lesson was implemented as planned by describing which part of the lesson content was used, skipped or changed. They also provided advice to improve the lesson by answering the open question 'what would you do differently next time?'

To assess the on-task behavior of the children during the F&V lessons two observers performed on-task observations. They observed six children at a time, every child was observed for five seconds before moving on to another child. When all six children were observed once, they started with the first child again. It was observed whether or not the children showed on-task behavior related to the lesson content and on-task behavior related to the movements. The observers watched if the children were attentive to the teacher or the lesson content that was displayed on the interactive whiteboard and if the children were making

the movements they were supposed to do. In addition, within the movement observations it was observed whether the basic exercise (on-task), the specific exercise (on-task) or no/other exercise (off-task) was performed. Only single behaviors were noted, when the observers saw a child perform two or more behaviors during the five seconds observation time, no behavior was recorded. The inter-rater reliabilities of the observations were of substantial agreement and ranged from $\kappa = 0.73$ through $\kappa = 0.78$.^{24,25}

The intensity of the F&V lessons was determined by heart rate measurements with team heart rate monitors. The monitors averaged and stored heart rate every second throughout the lessons.²⁶ Prior to the F&V intervention a maximal endurance test (20m shuttle run test) was performed during a physical education class. This test consisted of running back and forward over 20 meter at an increasing speed.²⁷ The maximum heart rate (HRmax) of the children was determined by the maximum heart rate recorded during the shuttle run test.

After one year, academic outcomes of the children were evaluated by measuring mathematics and reading skills. Mathematics was assessed by performance on the Tempo-Test-Rekenen (Speed-Test-Arithmetic), in which the children solved arithmetic problems as quickly as possible. The score was calculated as the total number of tasks solved, the maximal score was 200. Standardization has been done on a sample of 4804 elementary schoolchildren of 54 different schools in the Netherlands.²⁸

Reading ability was assessed by performance on the Eén-Minut-Test (One-Minute test), in which the children had to read out loud as many words as possible. After one minute, the test was repeated with a different set of words. The score was calculated as the total number of words read correctly and ranges from 0 to 232. The test has been developed for measuring technical reading skills in children from second- to sixth-grade. Test-retest reliability (r varied from 0.89 to 0.92) and construct validity (r varied from 0.78 to 0.86) of the One-Minute reading test are good.²⁹

Procedure

Two intervention teachers, who were proponents of the F&V program, were hired to teach the F&V lessons three times a week, for 21 weeks, at three schools each. A one-day training was provided before the start of the intervention by the researchers who developed the program. The teachers were informed about the theoretical background of the intervention and the importance of the moderate to vigorous intensity of the lessons. Furthermore, they

learned to work with the F&V lesson material (manual, lesson content, and interactive whiteboard). After the training the teachers had to give a trial lesson on a school that was not participating in the study. The researchers observed this lesson and the teachers were provided with feedback. One week after the training session the F&V intervention started. During the course of the intervention each teacher was observed six times. In addition, after every lesson the intervention teachers filled out the teacher self-report.

The on-task behavior was observed during one F&V lesson of a subsample of 55 children. At every school two observers observed 6 to 14 children. A subsample of 82 children wore heart rate meters during one F&V lesson. From the data the percentage of time in a certain heart rate zone (0–60%, 60–90% and 90–100% of HRmax) was calculated. Exercising between 60–90% of HRmax was considered as MVPA.^{30,31} All children were pretested and posttested on mathematics and reading. Due to absence from school, 14 children were not present during all pre- and post-test. Of the initial 228 children, 214 children remained.

Data analysis

From the teacher self-reports the percentage of presented lesson content and the percentage of canceled lessons were calculated. Time-on-task differences between second- and third-grade classes related to the lesson content (paying attention or not) and related to the movements (exercising or not) were analyzed with the Mann-Whitney U test. This test was used because the data were not normally distributed. The percentage of MVPA per child per lesson was calculated by dividing the lesson time spent in 60 to 90% of HRmax with the total lesson time. Intensity differences between second- and third-grade children were tested with the independent samples t-test.

The effect of the F&V intervention on academic achievement was analyzed with two analyses of covariances (ANCOVAs) on the post-test mathematics and reading scores, controlling for pretest and grade differences. In case of significant interactions between grade and condition, separate ANCOVAs were conducted per grade. All statistical analyses were performed using SPSS software (version 20.0; IBM, Armonk, NY) and statistical significance was set at 0.05.

RESULTS

Teacher observations

The six observations during the intervention period showed that the intervention teachers implemented the lessons as planned. The lesson time was always at or near the intended 20–30 minutes and the physical activity during the lessons was adequate. Furthermore, in unexpected situations, for example when a task appeared to be too difficult, the intervention teachers were able to make quick adjustments to the lessons.

Teacher self-report

Owing to holiday and excursions on average 3.7% of the lessons were canceled, which means that two lessons were canceled and in total 61 lessons were taught at each school. To make sure all lesson content was addressed, the content of the canceled lessons was always shortly discussed in the next lesson. The intervention teachers reported that of the 61 lessons taught, on average 98% of the lesson content was discussed. The skipped lesson content was mainly left out because a lesson would otherwise take more than 30 minutes. Besides implementing the lessons as they were on paper, the teachers often added extra content to the lessons, for example additional questions were asked.

In order to improve the intervention, the intervention teachers provided advice after every given lesson regarding the movements, the difficulty level of the lesson content and the duration of the lessons. First, the teachers pointed out that some movements did not fit within specific lessons. These movements were too intensive, not intensive enough, too difficult or too easy. Second, they indicated that the difficulty of mainly the mathematics lesson content was occasionally too high. It was experienced that intensive movements and difficult sums did not go together. Finally, they made clear that the duration of the lessons varied and that the mathematics part of the lessons often lasted longer than the language part of the lessons.

Time-on-task

The children were on-task related to the lesson content for on average 72% of the time. The on-task behavior of the children related to the movements was on average 73%. Table 2.1 shows that second-grade children spent less time on the specific exercise in comparison

Table 2.1 Comparison between second- and third-grade on the activity of the children in percentages (with SD)

Activity	grade 2 (n = 25)	grade 3 (n = 30)	p-value ^a
Basic exercise (on-task)	41.0 (19.4)	40.0 (16.5)	0.84
Specific exercise (on-task)	28.2 (11.4)	35.6 (12.2)	0.03
No/other exercise (off-task)	30.8 (20.8)	24.5 (19.2)	0.25

^aIndependent samples t-test.

Table 2.2 Comparison between second- and third-grade on the average time in percentages (with SD) in a heart rate zone, in percentage of HRmax

Heart rate zone	grade 2 (n = 40)	grade 3 (n = 42)	p-value ^a
0–60%	29.0 (24.0)	42.3 (31.1)	0.03
60–90% (MVPA)	70.4 (24.0)	57.1 (30.5)	0.03
90–100%	0.6 (2.9)	0.5 (2.2)	0.87

^aIndependent samples t-test.

with the third-grade children ($t = -2.3$, $p < 0.05$). No differences between grades were found for the time spent on basic exercise and no/other exercise.

Intensity level

Table 2.2 shows the percentage of time in which the children performed physical activity in a certain heart rate zone. MVPA was performed for on average 64% of the lesson time (about 16 minutes of a 25-minute lesson). Second-grade children exercised significantly more time in MVPA during the F&V lessons in comparison with third-grade children ($t = 2.18$, $p < 0.05$).

Academic achievement

The results of the ANCOVAs, controlling for pretest and grade differences, revealed no significant main effects, but a significant interaction between condition and grade with respect to the post-test mathematics ($F(1, 209) = 26.48$, $p < 0.05$) as well as the post-test reading ($F(1, 208) = 5.41$, $p < 0.05$).

It can be seen in Table 2.3 that the third-grade children in the intervention group scored significantly higher on both mathematics ($F(1,99) = 11.72$, $p < 0.05$) and reading ($F(1,98)$

Table 2.3 Comparison between intervention and control group on the estimated mean score of mathematics and reading, while controlling for pretest scores

		Intervention group Estimated means (SE; n)	Control group Estimated means (SE; n)	p-value ^a
Mathematic	Grade 2	51.6 (1.3; 54)	57.8 (1.2; 58)	0.00
	Grade 3	78.8 (1.6; 53)	70.6 (1.7; 49)	0.00
Reading	Grade 2	95.8 (1.6; 54)	97.7 (1.6; 58)	0.40
	Grade 3	116.9 (1.3; 52)	111.8 (1.4; 49)	0.01

^aANCOVA.

= 6.97, $p < 0.05$) in comparison with the third-grade children in the control group. On the other hand, the second-grade children in the intervention group scored significantly lower on mathematics in comparison with the second-grade children in the control group ($F(1,109) = 12.40$, $p < 0.05$). No differences were found on the reading test in second grade ($F(1,109) = 0.72$, $p = 0.40$).

DISCUSSION

F&V combines physical activity with mathematics and language activities. The focus of the pilot study was on program evaluation; the program implementation and the program outcomes were evaluated. The teacher self-reports showed that the lessons could be implemented as planned by trained intervention teachers in the school curriculum of Dutch elementary school children. Hardly any lessons were canceled (3.7%) and almost all planned lesson content was discussed (98%). Implementation results of the PAAC intervention showed that teachers incorporated the lessons for 47 to 65 minutes a week and did not reach the intended 90 minutes of physical activity in the class.¹⁵ The high teacher engagement rates in our study are probably due to the fact that the teachers were specially hired for the intervention. However, these rates also indicate high engagement of the participating schools and the regular classroom teachers because the lessons had to be given during regular class time and be incorporated into the existing curriculum.

It appeared from time-on-task observations during the intervention lessons that the on-task behavior of the children related to the lesson content and the movements was above 70%. Similar percentages of on-task behavior during regular sedentary classroom lessons were found.¹⁶ But in other studies, percentages above 80% of on-task behavior during regular classroom lessons have also been shown.^{18,32} Nevertheless, the percentages found in this

study seem to be quite high taken in mind that the lessons, in which the children had to perform mathematics and language activities while moving, were different from regular classroom lessons.

Heart rate monitoring results showed that the children were moderate to vigorous physically active for on average 64% of the lesson time. To the authors' knowledge, our study is the first that measured the intensity of physically active academic lessons with heart rate monitoring. Other classroom based physical activity interventions measured the intensity of the lessons using pedometers, accelerometers, and indirect calorimeters. These studies found an increase of daily in school activity and indicated that the intensity of the lessons was mainly MVPA.^{14,17,19,33} In addition, during Dutch physical education it was found that 47% was of the lesson time was spent in moderate to vigorous intensity.³⁴ In comparison with physical education, the F&V lessons can promote a meaningful increase in energy expenditure.

The results of the academic tests indicated that the third-grade children who participated in the F&V intervention scored higher on both mathematics and reading in comparison with the control group. In contrast, the mathematic outcomes in second-grade indicated a lower score in the intervention group in comparison with the control group and no differences were found on the reading test. The results in third-grade are in accordance with the results of Donnelly et al.²⁰ who found a significant improvement of physically active academic lessons on mathematics, spelling, and reading. The contrary effect in second-grade may be partly explained by the difference in MVPA. Second-grade children participated in MVPA significantly more than third-grade children. In a study among second- and fifth-grade children dual task differences between grades were investigated. It was found that fifth-grade children had the ability to differentially control and allocate their attention, where second- grade children did not.³⁵ Maybe third-grade children who participated in this study had the ability to focus their attention more on the academic content, whereas second-grade children focused on both tasks (physical activity and academic content) evenly. This is in accordance with the on-task observations that showed that third-grade children performed more specific exercises than second-grade children. Which means that third-grade children spent more time answering questions by performing exercises in comparison with second-grade children. Future research is necessary to examine if combining MVPA with academic content is only successful from a certain age, and to examine if MVPA during physically active academic lessons is indeed an important prerequisite to improve the academic achievement of children.

On the basis of all evaluation outcomes the intervention will be improved. The lessons will be adapted on the basis of the intervention teacher's advice. The type of movements, the difficulty, and the duration of the lessons will be adjusted. By improving these aspects we expect that the on-task behavior of the children during the F&V lessons will increase. Future studies will examine the effects of the improved intervention on academic outcomes and fitness in a two-year randomized control trial.

Limitations

The on-task observations and the heart rate measures rely on data from one lesson per school. On-task behavior and intensity of the lesson can differ per lesson because of differences in lesson content and children's motivation. However, at every participating school a different lesson was observed so the data collected still gives an overall picture of the lessons.

A fairly small number of classes participated in this study, six second-grade classes and six third-grade classes of six elementary schools. In the next two intervention years a randomized controlled trial will be conducted on 12 other elementary schools to investigate intervention effects further.

CONCLUSIONS

This study shows that the F&V intervention program can be implemented with success in elementary classrooms. The physically active academic lessons improved the academic achievement of third-grade children. On the basis of program evaluation outcomes the intervention will be improved and in future studies effects of the improved intervention will be investigated.

IMPLICATIONS FOR SCHOOL HEALTH

There is growing evidence that children's physical activity in clearly defined contexts (such as physical education and organized sports) is declining.³⁶ It is important to increase children's physical activity to do something about the worldwide increase of the prevalence of overweight in school-age children.³⁷ Because most children are enrolled in school, school is ideally suited for physical activity interventions. This study made clear that physically active academic lessons do not come at the expense of academic lesson time and still

contribute to the amount of MVPA in children. The extra physical activity may help to reach the recommended 60 minutes of physical activity a day, to prevent an increase in BMI and to enhance the overall health.^{20,38,39} Additionally, this study indicated that physically active academic lessons may be effective in improving academic achievement.

Our findings suggest that school administrators should consider to integrate physically active academic lessons into their school curriculum. Physical exercises can be added to existing academic lessons wherein the emphasis is on repetition or memorization. Integration of physically active academic lessons in the school curriculum may be an innovative way to increase the amount of health-related physical activity as well as academic achievement.

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