Physically Active Math and Language Lessons Improve Academic Achievement: A Cluster Randomized Controlled Trial

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abstract

OBJECTIVES: Using physical activity in the teaching of academic lessons is a new way of learning. The aim of this study was to investigate the effects of an innovative physically active academic intervention ("Fit & Vaardig op School" [F&V]) on academic achievement of children.

METHODS: Using physical activity to teach math and spelling lessons was studied in a cluster-randomized controlled trial. Participants were 499 children (mean age 8.1 years) from second- and third-grade classes of 12 elementary schools. At each school, a second- and third-grade class were randomly assigned to the intervention or control group. The intervention group participated in F&V lessons for 2 years, 22 weeks per year, 3 times a week. The control group participated in regular classroom lessons. Children's academic achievement was measured before the intervention started and after the first and second intervention years. Academic achievement was measured by 2 mathematics tests (speed and general math skills) and 2 language tests (reading and spelling).

RESULTS: After 2 years, multilevel analysis showed that children in the intervention group had significantly greater gains in mathematics speed test ($P < .001$; effect size [ES] 0.51), general mathematics ($P < .001$; ES 0.42), and spelling ($P < .001$; ES 0.45) scores. This equates to 4 months more learning gains in comparison with the control group. No differences were found on the reading test.

CONCLUSIONS: Physically active academic lessons significantly improved mathematics and spelling performance of elementary school children and are therefore a promising new way of teaching.

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Ms Mullender-Wijnsma contributed to the design of study and drafted the initial manuscript; Ms Mullender-Wijnsma and Mr de Greeff acquired the data; Drs Hartman, Doolaard, Bosker, and Visscher and Mr de Greeff participated in the design and critically reviewed the manuscript; and all authors analyzed the data and approved the manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT: Physically active academic interventions have been shown to positively affect children's academic engagement in the short term, but few studies have assessed the effects of prolonged physically active academic interventions on academic achievement.

WHAT THIS STUDY ADDS: This randomized controlled trial demonstrates the effects of a 2-year physically active academic intervention, in which physical exercise was specifically used when teaching math and language, on children's math and language achievement.

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The development of new ways of teaching and learning to foster children's academic achievement is an important issue in educational sciences. Recently, programs have been developed that incorporate physical activity into the teaching of academic lesson content.[1–7] The majority of the studies focused on short-term, immediate effects and showed that children's academic engagement,[1,4,5] academic motivation,[6] and executive functioning[7] were enhanced shortly after physically active academic lessons. Effects of prolonged intervention periods are largely unknown. A 4-month intervention that integrated physical activity into academic lessons positively influenced the fluid intelligence of children, but no effects were found on language arts, math, and science.[8] In another study, positive effects of the 3-year Physical Activity Across the Curriculum project (PAAC) were found on academic achievement: math, reading, and spelling scores improved.[2,3] Although it was an elegant study, the aim of PAAC was not to improve academic achievement, but to promote physical activity and reduce obesity rates. PAAC coupled academic areas including math, history, geography, language, science, and health with moderate to vigorous physical activity for 90 min per week. Because math and language skills play a key role in children's educational career and are of great importance for their social and occupational functioning in daily life,[9] physical activity should specifically be incorporated when teaching math and language to optimally improve those skills. We recently developed "Fit & Vaardig op School" (Fit and Academically Proficient at School [F&V]), a new series of lessons in which physical exercise is specifically used when teaching math and language in Dutch elementary schools. An initial 1-year pilot study to improve the program supported the feasibility of the intervention and indicated that F&V lessons may positively affect reading and math outcomes.[10]

The F&V intervention is designed to increase academic achievement. During F&V lessons and traditional classroom lessons, similar academic goals are pursued. The difference is that the goals are achieved by different ways of teaching and learning.[10] Integrating physical exercise into visual and auditory academic lesson content may have several benefits. First, sensorimotor information obtained by the body (for example, through physical activity) appears to be an effective aid to learning during childhood.[11] Second, it has been found that moderate to vigorous physical activity that immediately increases activity in the brain may enhance attention,[12,13] and this might cause enhanced academic engagement after physically active academic lessons.[4,5,14] Because academic engagement is a key predictor of academic achievement,[15] it seems likely that more time on task during regular lessons (after a physically active academic lesson) might improve academic achievement in the long term. Furthermore, a longer period of regular moderate to vigorous physical activity might cause the brain to change morphologically (develop new cells and blood vessels) and functionally (affect brain cognitive performance).[12,16] A study with 7- to 9-year-old children found that functional changes to the brain occurred in children who participated in a 9-month afterschool physical activity program: the children showed improved brain indices of executive control.[17]

Building on the results of the initial 1-year F&V pilot study,[10] we designed a 2-year cluster-randomized controlled trial to further investigate the effects of the F&V program on the reading, spelling, and math performance of children. We expected that the intervention would improve children's academic achievement. Because the main focus of the F&V lessons was on math and language, we specifically expected math and language skills to be improved by the intervention.

METHODS

Participants

The study was conducted within 5 elementary school boards in the northern Netherlands (46 schools). To be included, schools were required to be mainstream schools, and only second- and third-grade classes were eligible to participate. Twelve of the 46 schools agreed to participate. At each school, a second- and third-grade class were randomly assigned to the intervention (n = 249) or the control group (n = 250). Randomization was performed by the Netherlands Central Plan Bureau for Economic Policy. School principals, teachers, parents, children, and researchers were unaware of upcoming assignments. At schools where the second-grade class had been assigned to the intervention, the third-grade class served as control, and vice versa. Written informed consent was obtained from the school principals of the participating schools. The parents/legal guardians were informed before the start of the intervention and were given the option to withdraw their permission for their child to participate at any time. All procedures were approved by the ethics committee of the Center for Human Movement Sciences of the University Medical Center Groningen/University of Groningen.

Sample Size Determination

Based on findings from the PAAC study,[2,3] an effect size of 0.44 was assumed (J.E. Donnelly and J.L. Greene, personal communication). The power analysis resulted in a total sample of ≥20 classes, with

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25 children per class (power 0.8, 1-tailed, $\alpha = 0.05$).[18]

Intervention

We developed a manual of physically active math and language lessons (F&V lessons). The difficulty of the teaching material was based on the math and language curriculum of second- and third-grade classes in the Netherlands. The lessons were aimed at young schoolchildren because these children were found to be more affected by classroom-based physical activity interventions than older children.[19] The intervention lessons were taught in the classroom during 2 school years, 22 weeks per year, 3 times a week for 20 to 30 min. In each lesson, 10 to 15 min were spent on math activities and 10 to 15 min on language activities. The main focus was on constant practice and repetition. For example, the children jumped on the spot 8 times to solve the multiplication sum "2 × 4." Each lesson was supported by a presentation on the interactive whiteboard. The physical exercises were aimed at moderate to vigorous intensity.[10]

Measures

Academic achievement was measured by 2 language tests (reading and spelling) and 2 math tests (speed and general math skills). Children's (technical) reading ability was determined using the One-Minute Test, which entails the children reading aloud as many words as possible within a minute; this is then repeated with a different set of words. The total number of words read correctly determines the score (from 0 to 232). Test-retest reliability ($r = 0.89$ to 0.92) and construct validity ($r = 0.78$ to 0.86) of the One-Minute Test for reading are good.[20]

The Speed Test–Arithmetic assesses math speed performance. The children have to solve problems as quickly as possible. The test contains 5 rows of arithmetic sums. The children compute as many sums as possible per row within 1 min. The score is calculated as the total number of tasks solved; the maximum score is 200. Standardization was done on a sample of 4804 elementary schoolchildren from 54 schools in the Netherlands.[21]

In addition, ability scores on spelling and math were retrieved from a child academic monitoring system (CAMS). This standardized and norm-referenced test battery is administered twice a year by the majority of the elementary schools in the Netherlands. The spelling test has 2 parts. During the first part, the teacher reads out a sentence and repeats a certain word from it; the children then have to write that word correctly. The second part consists of individually identifying misspelled words. The reliability ($r = 0.90$ to 0.93), construct, and content validity of the spelling test were good.[22] The math test is an individual task that involves number sense, arithmetic, algebra, geometry, time and money, and knowledge of ratios and fractions. In second and third grades, the test sets great store on solving arithmetic problems; from fourth grade onward, the attention shifts to algebra and knowledge of ratios and fractions.[23] The reliability ($r = 0.93$ to 0.96), construct, and content validity of the math test were good.[24]

Procedure

Children's academic achievement was measured before the start of the intervention (T0) at the end of the previous school year (CAMS) and at the beginning of the new school year (One-Minute Test and Speed Test–Arithmetic), after the first intervention year (8 months to 1 year after T0 [T1]), and after the second intervention year (1 year after T1 [T2]). Test administrators were trained to familiarize them with the One-Minute Test and the Speed Test–Arithmetic. These pretests were individually administered at the schools within 3 weeks. The test administration in the intervention and control groups was done under the same conditions. After the first and second intervention year, the children were posttested in a similar way as the pretesting.

In both intervention years, the intervention group participated in the F&V lessons for 22 weeks, whereas the control group received regular sedentary classroom lessons. The total instruction time was the same in the intervention and control groups. Six qualified elementary school teachers were hired to teach the F&V lessons in the first year. A 1-day training program was provided before the start of the intervention. The teachers learned to work with the lesson material and gave a trial lesson on a school that was not participating in the study. In the second year, the lessons were taught by the regular classroom teachers; all teachers had undergone 1 day of training beforehand. At the start, halfway through, and at the end of the intervention they received coaching in the classroom. Blinding of children and teachers to group assignment was not possible, as the intervention included physically active academic lessons.

Statistical Analyses

The descriptive statistics were calculated using the Statistical Package for the Social Sciences (version 22.0), with significance level set at 0.05. Baseline differences between intervention and control group were examined by using independent t test or χ^2 test.

To take account of the variability between schools, we used repeated-measures multilevel modeling (MLwiN 2.29) to analyze the effects of the intervention on academic achievement. Multilevel models were calculated for each academic achievement posttest, with time

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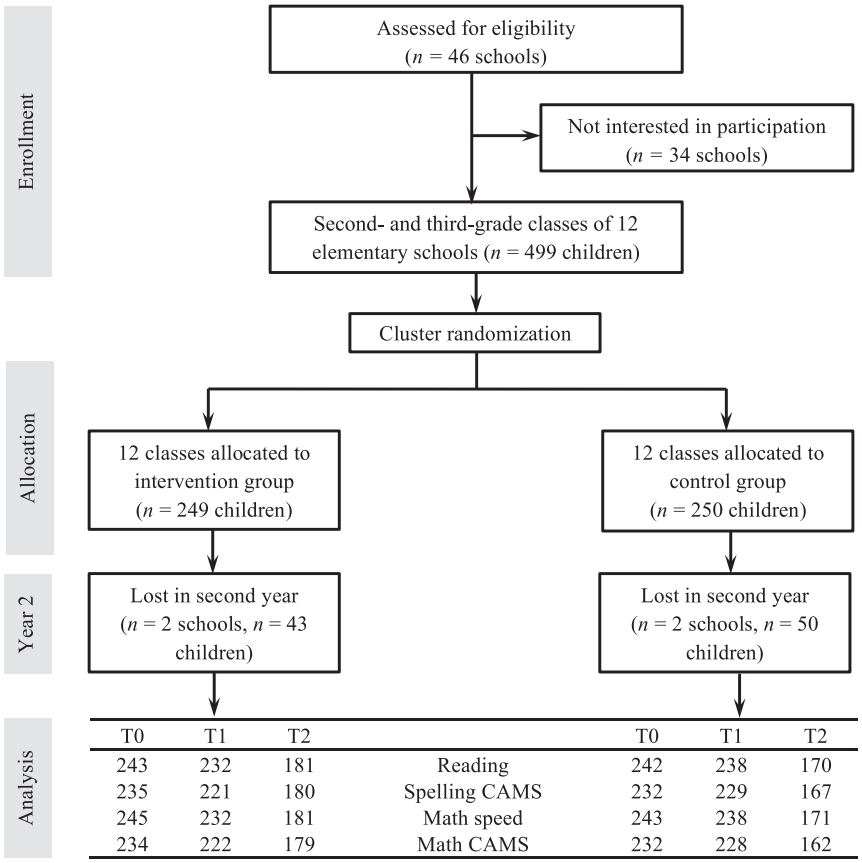


FIGURE 1
Flow of schools and students from enrollment, allocation, and analysis.

TABLE 1 Pretest Characteristics, by Condition

Characteristic	Control	F&V	*P*
n	250	249	
Age, y	8.2 (0.74)	8.0 (0.72)	.026[a]
Male gender	110 (22)	116 (23)	.562[b]
Second grade	116 (23)	141 (28)	.022[b]

Values are expressed as mean (SD) or n (%).
[a] Independent *t* test.
[b] χ^2 test.

(T0, T1, T2) as level 1 U, children as level 2 U, and schools as level 3 U. Explanatory variables for the score on each academic achievement test included grade, gender, and time (model 1). To assess the effect of the intervention on academic achievement, we used condition (intervention or control) and the interaction between condition and time as predictors (model 2). To account for multiple testing, we used a Bonferroni correction, resulting in a significance level of 0.0063. Effect sizes (ESs) were calculated as (estimated intervention effect)/$\sqrt{}$(variance at student level).[25] Interpretation of ES was done to determine the learning gains of the intervention group compared with the control group. First, to determine the academic progress that the children would normally make in a school year (12 months, during which children attend school for about 10 months), the academic progress of the children in the control group in the second intervention year (from T1 to T2) was calculated as (estimated score T2 – estimated score T1)/$\sqrt{}$(variance at student level). Second, by dividing ES by (academic progress of the control group) and multiplying this by 10 (months of education per year), the

TABLE 2 Scores on Academic Achievement Tests

Group	T0		T1[a]		T2[b]	
	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*
Reading						
Intervention	80.73 (29.95)	243	102.62 (28.89)	232	125.34 (26.01)	181
Control	80.81 (31.29)	242	103.45 (29.05)	238	124.82 (30.93)	170
Spelling CAMS						
Intervention	117.85 (7.40)	235	126.86 (7.90)	221	135.12 (8.72)	180
Control	118.84 (7.98)	232	127.16 (9.09)	229	133.49 (9.07)	167
Math speed						
Intervention	38.82 (17.49)	245	60.44 (22.51)	232	83.81 (28.16)	181
Control	42.05 (18.70)	243	61.01 (23.53)	238	78.35 (26.59)	171
Math CAMS						
Intervention	48.03 (19.16)	234	69.58 (16.78)	222	82.36 (15.85)	179
Control	53.94 (18.14)	232	68.65 (17.63)	228	82.83 (16.68)	162

[a] The children in the intervention group who were not retained in the study did not differ from the children in the control group who were not retained in the study (age, grade, gender, condition, and pretest scores).
[b] Of the children who were not retained in the study at the math CAMS test, there were significantly fewer third-grade children in the intervention group than the control group ($\chi^2 = 5.31$, $P = .02$). No other differences were found between the children in the intervention group who were not retained in the study and the children in the control group who were not retained in the study (age, grade, gender, condition, and pretest scores).

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TABLE 3 Multilevel Regression Coefficient (*B*) for Each Factor Predicting the Domains of Academic Achievement in Reading and Spelling CAMS

Factor	Reading						Spelling CAMS					
	Model 1			Model 2			Model 1			Model 2		
	B	SE	*P*	*B*	SE	*P*	*B*	SE	*P*	*B*	SE	*P*
Fixed effects												
Random intercept	68.156	1.918	—	66.889	2.304	—	114.590	0.587	—	114.520	0.683	—
Third grade[a]	25.922	2.280	<.001*	26.194	2.289	<.001*	8.662	0.575	<.001*	8.767	0.576	<.001*
Male[b]	0.319	2.288	.889	0.251	2.286	.912	−1.265	0.579	.029	−1.284	0.577	.027
T1[c]	21.718	0.655	<.001*	21.715	0.922	<.001*	8.750	0.275	<.001*	8.327	0.383	<.001*
T2[c]	41.850	0.731	<.001*	41.157	1.046	<.001*	15.852	0.304	<.001*	14.512	0.431	<.001*
Intervention group[d]	—	—	—	2.328	2.395	.332	—	—	—	0.055	0.647	.932
Intervention × T1	—	—	—	0.005	1.310	1.000	—	—	—	0.852	0.544	.118
Intervention × T2	—	—	—	1.341	1.462	.360	—	—	—	2.590	0.599	<.001*
Random effects												
Variance schools	0.000	0.000	1.000	0.000	0.000	1.000	1.138	0.872	.193	1.139	0.870	.191
Variance students	604.324	40.951	<.001*	602.685	40.851	<.001*	33.055	2.604	<.001*	32.939	2.586	<.001*
Variance time	99.529	4.949	<.001*	99.395	4.941	<.001*	16.685	0.848	<.001*	16.293	0.828	<.001*
Deviance	11 106.946	—	—	11 104.552	—	—	8028.608	—	—	8006.816	—	—

—, not relevant to the model.
[a] Reference category: second grade.
[b] Reference category: female.
[c] Reference category: T0.
[d] Reference category: control group.
* Significant ($P < .00625$) regression coefficient.

number of months learning gains of the intervention group after 2 intervention years was obtained.

RESULTS

Figure 1 shows that of the initial 499 children (mean age 8.1 ± 0.7 years) of 12 elementary schools, 249 children were assigned to the intervention and 250 children to the control group. Two schools dropped out in the second intervention year: 1 because of long-term absence of the teacher and the other because it was closed down. At T0, 466 to 488 children were measured, at T1, 453 to 475 children, and at T2, 341 to 352 children. Common reasons for not completing the tests were absence from school or leaving to attend another school.

The number of boys was similar in the control and intervention groups. However, the children in the control group were significantly older than the children in the intervention group ($t = -2.2$, $P = .03$), as significantly more children in the control group were in third grade ($\chi^2 = 5.2$, $P = .02$) (Table 1). Table 2 presents the mean scores of children who took the academic achievement tests per measurement moment.

The results of the multilevel analysis can be found in Tables 3 and 4. At T0, only the math CAMS score of the intervention group was significantly lower than that of the control group ($t = -2.77$; $P = .005$) (model 2). The results further revealed no significant effect of the intervention on reading scores after 1 year ($t = 0.00$; $P = 1.00$; ES = 0.00, 95% confidence interval (CI) −0.10 to 0.10) or after 2 years ($t = 0.76$; $P = .45$; ES = 0.05, 95% CI −0.06 to 0.17) (Fig 2A). The results of the spelling test revealed no significant effect after 1 intervention year ($t = 1.57$; $P = .12$; ES = 0.15, 95% CI −0.04 to 0.33). However, after the second year, there was a significant effect of the intervention

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TABLE 4 Multilevel Regression Coefficient (*B*) for Each Factor Predicting the Domains of Academic Achievement in Math Speed and Math CAMS

	Math Speed						Math CAMS					
	Model 1			Model 2			Model 1			Model 2		
	B	SE	*P*	*B*	SE	*P*	*B*	SE	*P*	*B*	SE	*P*
Fixed effects												
Random intercept	27.565	1.681	—	28.194	1.899	—	40.589	1.382	—	42.514	1.562	—
Third grade[a]	24.209	1.531	<.001*	24.425	1.533	<.001*	16.586	1.242	<.001*	16.615	1.247	<.001*
Male[b]	3.379	1.544	.029	3.332	1.538	.031	5.251	1.251	<.001*	5.201	1.248	<.001*
T1[c]	20.054	0.665	<.001*	18.455	0.921	<.001*	18.034	0.542	<.001*	14.740	0.745	<.001*
T2[c]	39.924	0.741	<.001*	35.876	1.041	<.001*	30.391	0.601	<.001*	27.712	0.846	<.001*
Intervention group[d]	—	—	—	−1.445	1.688	.392	—	—	—	−3.801	1.372	.005*
Intervention × T1	—	—	—	3.196	1.308	.015	—	—	—	6.622	1.056	<.001*
Intervention × T2	—	—	—	7.912	1.454	<.001*	—	—	—	5.252	1.171	<.001*
Random effects												
Variance schools	13.083	8.246	.113	12.739	8.082	.116	9.174	5.657	.106	8.919	5.545	.109
Variance students	245.041	18.503	<.001*	244.099	18.353	<.001*	158.390	12.062	<.001*	159.079	12.014	<.001*
Variance time	103.236	5.117	<.001*	99.959	4.954	<.001*	64.414	3.286	<.001*	61.177	3.121	<.001*
Deviance	10 778.213	—	—	10 747.902	—	—	9776.413	—	—	9734.880	—	—

—, not relevant to the model.
[a] Reference category: second grade.
[b] Reference category: female.
[c] Reference category: T0.
[d] Reference category: control group.
* Significant (*P* < .00625) regression coefficient.

on the spelling scores ($t = 4.32$; $P < .001$; ES = 0.45, 95% CI 0.25 to 0.66) (Fig 2B). This equates to 4 months (0.45/1.08 × 10 = 4.17) more learning gains after 2 intervention years in comparison with the control group. In the math speed test, the children in the intervention group showed no significant improvement after 1 intervention year ($t = 2.44$; $P = .02$; ES = 0.20, 95% CI 0.04 to 0.37), but after the second year they showed significantly greater improvement in comparison with the control group ($t = 5.44$; $P < .001$; ES = 0.51, 95% CI 0.32 to 0.69) (Fig 2C). This equates to >4 months (0.51/1.12 × 10 = 4.55) more learning gains after 2 intervention years in comparison with the control group. Last, the results of the math CAMS test revealed that the scores of the children in the intervention group had improved significantly more than those of the control group after 1 year ($t = 6.27$; $P < .001$; ES = 0.53, 95% CI 0.36 to 0.69) and also after 2 years ($t = 4.49$; $P < .001$; ES = 0.42, 95% CI 0.23 to 0.60). The greatest improvement was after 1 year, and there was a retention of this effect after 2 years (Fig 2D). After 2 intervention years, 4 months (0.42/1.03 × 10 = 4.08) more learning gains were made by the intervention group compared with the control group.

DISCUSSION

The results add to those from the PAAC study, in which various existing academic lessons were coupled with physical activity to promote physical activity: that study showed that physically active academic lessons improved children's academic achievement.[2,3] Our study goes beyond this finding by demonstrating that a new physically active series of lessons specifically aimed at improving

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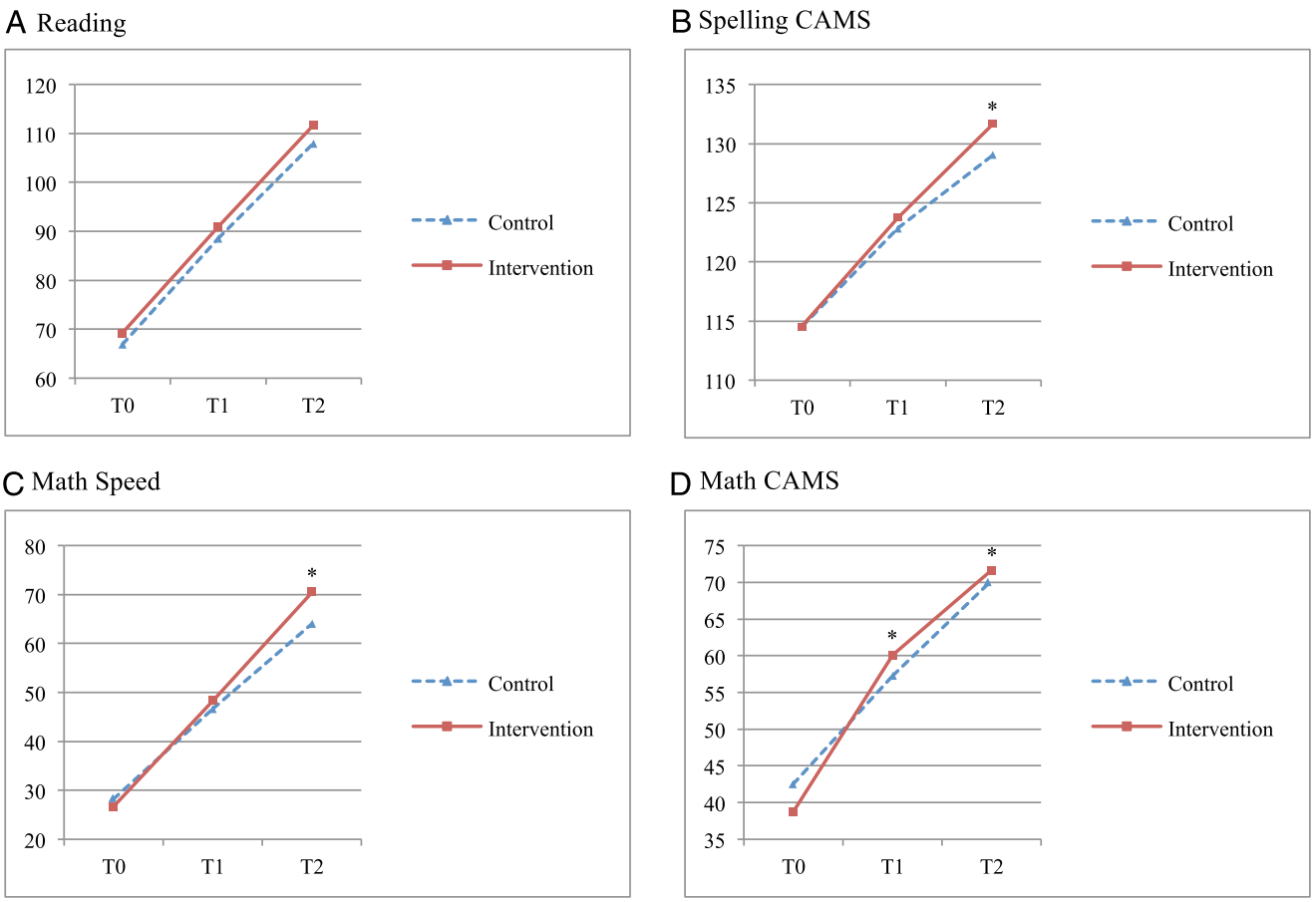


FIGURE 2

Predicted mean scores (based on the second model of the multilevel analysis) on the reading (A), spelling CAMS (B), math speed (C) and math CAMS (D) tests per measurement moment (T0, T1, T2). *Significantly greater improvement of the intervention group in comparison with the control group ($P < .00625$).

math and language improves the math and language achievement of elementary schoolchildren. Because the school curriculum is comparable on most Dutch elementary schools, the findings of our study can be generalized to other Dutch elementary schools. Generalizing results to other economically developed countries seems warranted, as similar findings were obtained in the PAAC study.

The F&V intervention improved performance on math and spelling but not on reading. This discrepancy might be caused by the content of the intervention program and the academic tests. The F&V program mainly focused on repetition of concepts that children had learned in earlier classes and memorization of these concepts. More concretely, the main focus was on solving arithmetic problems and the spelling of words and less on reading speed.[10] The focus of the math speed test lies on solving arithmetic problems. In second and third grades, the math CAMS test also focuses on solving arithmetic.[23] The spelling CAMS measures children's spelling level, and the reading test is about reading as many words as possible within a minute. This could mean that the intervention was particularly effective for improving the academic skills practiced during F&V lessons.

The effects of the intervention on academic achievement might be the result of a combination of mechanisms. One might be the effect of moderate to vigorous physical activity on the brain[12,13,16,17] and on academic engagement.[4,5,14] It is also possible that the innovative teaching method may be effective because brain and body work in conjunction and because our cognitive knowledge is rooted in bodily awareness.[11,26] This would apply to children in particular, because all knowledge initially stems from sensory stimulation and motor processes.[27] Further research with more than one intervention group and a control group is needed to find out why using physical exercise in teaching academic content is effective in improving children's academic achievement.

In previous research, it has been shown that children exercised at

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moderate to vigorous intensity for 64% of the duration of the F&V lessons.[10] Extra physical activity during academic lessons may contribute positively to children's overall health, prevent children from being overweight, and help in reaching the recommended 60 minutes of daily moderate to vigorous physical activity.[2,28,29] Future research is needed to further investigate whether the lessons contribute to children's health.

Some limitations to the findings should also be noted. First, enhanced academic performance after the first intervention year might be possible due to the presence of specially trained intervention teachers. This was obviated by training regular classroom teachers to teach the F&V lessons in the second year. Second, the CAMS was administered by the schools itself. Although this test administration is practice as usual, this could have influenced the results. Strengths of this study were the design (cluster-randomized controlled trial) and the large sample size. Furthermore, the novel contribution of this study is showing that specifically integrating physical activity into math and language lessons is sufficient to improve important academic skills.

CONCLUSIONS

Participation in the F&V physically active math and language intervention positively contributed to math and spelling performance of elementary school children. After 2 intervention years, they gained 4 more months in spelling and math achievement compared with control children. The findings suggest that physically active academic lessons should be part of the school curriculum because it is an innovative and effective way for teachers to improve children's academic achievement. Physical activity should specifically be integrated into math and language lessons to optimally improve those important skills.

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ABBREVIATIONS

CAMS: child academic monitoring system
CI: confidence interval
ES: effect size
F&V: Fit and Academically Proficient at School
PAAC: Physical Activity Across the Curriculum

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