Influence of a 2- to 6-year physical education intervention on scholastic performance

The CHAMPS study-DK

Bugge, Anna; Möller, Sören; Tarp, Jakob; Hillman, Charles H; Lima, Rodrigo Antunes; Gejl, Anne Kaer; Klakk, Heidi; Wedderkopp, Niels

Published in:
Scandinavian Journal of Medicine & Science in Sports

DOI:
10.1111/sms.12902

Publication date:
2018

Document version:
Final published version

Accepted: 21 April 2017

DOI: 10.1111/sms.12902

ORIGINAL ARTICLE

WILEY

Influence of a 2- to 6-year physical education intervention on scholastic performance: The CHAMPS study-DK

Anna Bugge[1] | **Sören Möller**[2,3] | **Jakob Tarp**[1] | **Charles H. Hillman**[4] | **Rodrigo Antunes Lima**[1,5] | **Anne Kær Gejl**[1] | **Heidi Klakk**[1,6] | **Niels Wedderkopp**[1,7]

[1]Centre of Research in Childhood Health, Institute for Sport Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark

[2]OPEN—Odense Patient data Explorative Network, Odense University Hospital, Odense, Denmark

[3]Department of Clinical Research, University of Southern Denmark, Odense, Denmark

[4]Department of Psychology, Department of Health Sciences, Northeastern University, Boston, MA, USA

[5]CAPES Foundation, Ministry of Education of Brazil, Brasília, DF, Brazil

[6]University College Lillebælt, Odense, Denmark

[7]Sports Medicine Clinic, The Orthopedic Department, Hospital of Lillebaelt Middelfart, Institute of Regional Health Research, University of Southern Denmark, Odense, Denmark

Correspondence
Anna Bugge, Centre of Research in Childhood Health, University of Southern Denmark, Odense M, Denmark.
Email: anbugge@health.sdu.dk

Funding information
The TRYG Foundation; The Nordea Foundation; The IMK Foundation; The Region of Southern Denmark

The aim of this study was to investigate the influence of a school-based intervention with a tripling of physical education (PE) lessons from two (90 minutes) to six lessons per week (270 minutes) on scholastic performance. This study is part of the CHAMPS study-DK, a quasi-experimental study that began in 2008. The intervention group consisted of six schools, and the control group consisted of four matched schools (mean age at baseline=8.4 years, kindergarten class fourth grade). Academic performance was extracted from the national test system from 2010 to 2014 (Math and Danish were measured at third and sixth, and second, fourth and sixth grades, respectively). Participants included 1888 students participating in at least one scholastic performance test. Linear mixed models were applied to test for differences between groups and adjusted for known confounders. No significant differences were observed between groups in the academic performance tests (control group reference); Danish second grade β=−1.34 (95% CI −9.90, 7.22), fourth grade β=0.22 (95% CI −6.12, 6.56), sixth grade β=1.03 (95% CI −5.02, 7.08), and all grades combined β=0.28 (95% CI −5.74, 6.31) and Math third grade β=−2.87 (95% CI −9.65, 3.90), sixth grade β=0.99 (95% CI −7.36, 9.34) and combined β=−1.20 (95% CI −8.10, 5.71). In conclusion, no significant differences were observed between intervention and control schools for scholastic performance. Importantly, there were no negative effects of additional PE on scholastic outcomes, despite more PE and longer school days for intervention children.

KEYWORDS
academic achievement, children, physical activity, school-based intervention, youth

1 | INTRODUCTION

A growing body of evidence demonstrates associations of physical activity (PA) with cognitive and brain health during development.[1] Several reviews have summarized the evidence regarding the relationship between PA, cardiorespiratory fitness, and scholastic performance.[1-4] Virtually all have reported a positive relation of PA to scholastic outcomes or no relationship between these constructs. In the latter case, the findings have been interpreted to suggest that an increase in PA was not detrimental to scholastic performance.[1,5] The mechanisms by which PA and cardiorespiratory fitness affects scholastic performance is a growing area in several different research disciplines, spanning from animals models

of specific brain structures and functions affected by PA,[6-8] to studies of the acute and longer term benefits of PA/cardiorespiratory fitness on child populations,[9,10] and the more socioemotional aspects of conducting PA during the school day that may possibly enhance motivation and joy, which in turn benefit scholastic outcomes.[11] The vast majority of these various research threads point to the beneficial effects of increased PA and higher cardiorespiratory fitness levels on cognitive function and scholastic outcomes. Despite these multiple benefits, there is a growing trend in many countries to decrease opportunities for children and adolescents to be physically active during the school day.[12,13]

Therefore, if a direct relationship between PA and scholastic performance could be demonstrated, it could potentially impact policymakers on national and school district levels, regarding allocation of time devoted to PA during the school day. Unfortunately, to date, most scientific evidence stems from cross-sectional or small-scale studies, as well as from controlled laboratory settings, which limit generalizability to the school setting. School-based studies are needed to assess the influence of PA interventions in "real-world" settings on scholastic outcomes. One intervention strategy to enhance PA in schools is to change the amount or the content of the physical education (PE) lessons. Five previous studies have investigated the effect of either increased or enhanced PE lessons on scholastic performance, but findings were mixed.[14-18] Some of the PE studies demonstrated a positive intervention effect,[15,16] while other indicate mixed[17,18] or null overall effects.[14] Such lack of consensus may stem from differences in design and implementation of the intervention, intervention intensity, diverse baseline, and other characteristics of participants and methods used to assess outcomes. Accordantly, there is a need for additional school-based studies to investigate whether enhanced or improved PE relates to scholastic performance. Specifically, long-term studies over several years are especially warranted. The primary aim of this study was to investigate the influence of a trippling of PE lessons on scholastic performance of school-aged children after 2-6 years of intervention. We hypothesized that the long-term school-based PE intervention in our study would positively influence scholastic performance outcomes relative to those who did not receive the intervention.

2 | METHODS

2.1 | Study design and participants

The current investigation was part of the Childhood Health, Activity, and Motor Performance School Study Denmark (the CHAMPS study-DK). The CHAMPS study-DK is a large-scale, quasi-experimental study based on a natural experiment consisting of one municipality (Svendborg) deciding to implement a tripling of PE lessons in some of its primary schools. The CHAMPS study-DK is described in detail elsewhere[19,20] and only methods pertinent to this study are included here. Data for this study includes baseline demographic data from 2008 (grades kindergarten class through fourth grade) and scholastic performance data from 2010 until 2014 (see below for details). Figure 1 illustrates the flowchart for this investigation. All 19 schools in the municipality of Svendborg were invited to participate in the study. Six schools agreed to become "Sports Schools" (intervention group), receiving six PE lessons per week. Four other schools matched on school size, urban/rural area, and socioeconomic status of the student body, agreed to serve as control schools, receiving the standard two PE lessons per week. All children and parents/legal guardians received information about the study through school meetings and written information. Parents/legal guardians provided written informed consent. The study had an open entry, which meant that new participants were included throughout the study. Participants for this investigation include 1888 students, participating in at least one national test of scholastic performance. Of these, 1045 had baseline measurements in 2008 (see Figure 1). The CHAMPS study-DK was approved by the Regional scientific Ethical Committee (Region of Southern Denmark) (Project number: S-20080047 and S-20140105).

2.1.1 | PE intervention

School principals and teachers were invited to contribute to the design of the intervention. Therefore, the choice of implementing four additional PE lessons per week was based on their recommendations. The four additional lessons supplemented the two mandatory PE lessons resulting in six lessons (minimum of 4.5 hours) of PE per week divided over at least three sessions of at least 60 minutes. Because of the additional PE, children in intervention schools had longer school days compared to control group children. Furthermore, all PE teachers at intervention schools were trained in specific age-related training principles, developed by Team Denmark, the Danish Elite Sport Foundation. These principles focus on children's physical, physiological, mental, and social development to enhance and optimize motor skills.[21] Control schools continued their regular PE curriculum with two PE lessons per week resulting in 1.5 hours/week, which at that time was the mandatory minimum amount of PE stipulated by law in Denmark.

2.2 | Measurements

2.2.1 | Anthropometrics

Body mass was measured to the nearest 0.1 kg on an electronic scale (Tanita BWB-800S; Tanita Corporation, Tokyo, Japan) with children wearing shorts and T-shirts. Stature was measured to the nearest 0.5 cm using a portable stadiometer (SECA 214; Seca Corporation, Hanover, MD, USA).

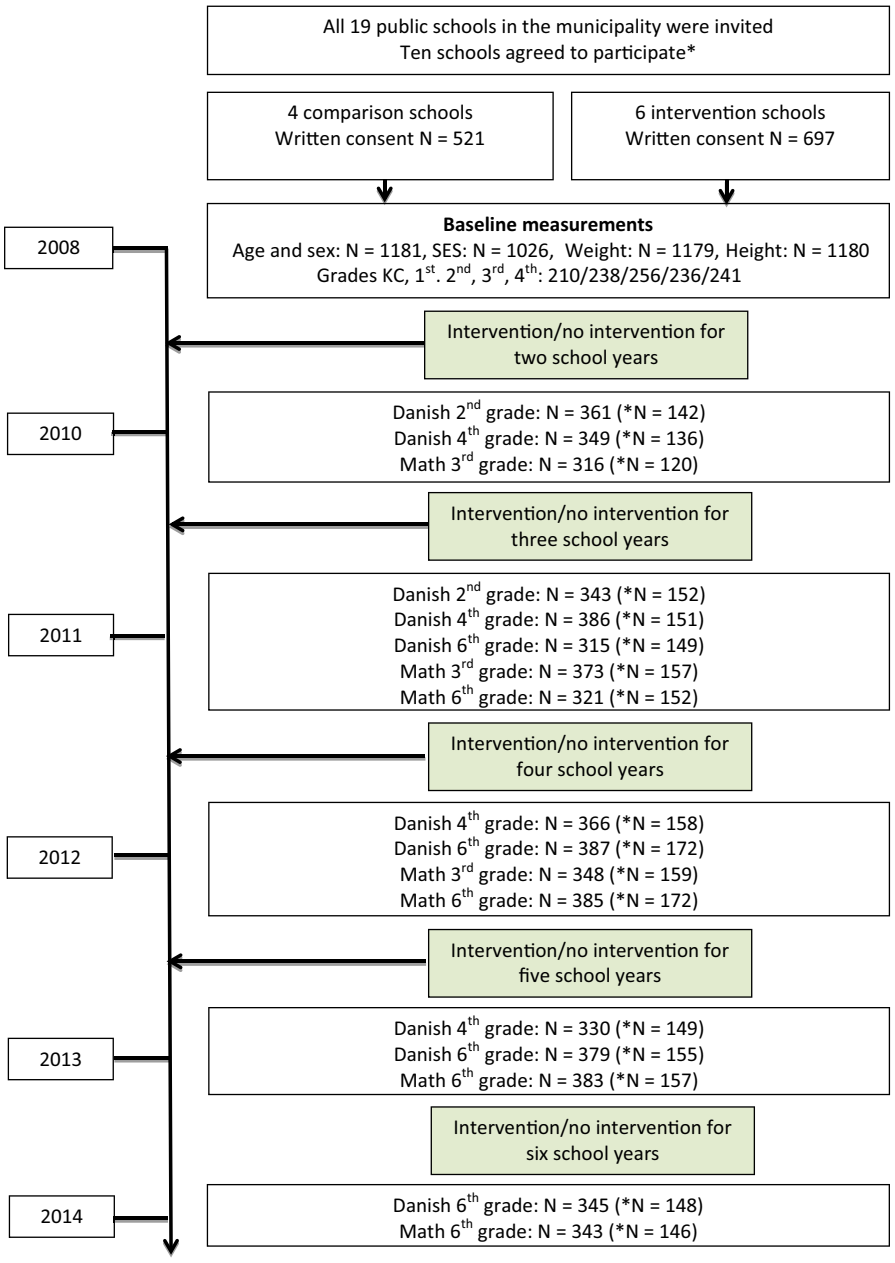

FIGURE 1 The flowchart illustrates the total number of participants and marked with * in the parentheses the number of participants without baseline measurements of body weight and stature in 2008

2.2.2 | Cardiorespiratory fitness

Cardiorespiratory fitness was assessed at baseline by the Andersen test,[22] which is a 10-minute intermittent running test (15 seconds of running, 15 seconds of standing). The test has been validated against direct measures of maximum oxygen uptake in children of different age groups. The total distance in meters was used as test result.

2.2.3 | Academic achievement

Results were extracted from the Danish National Test System, which was implemented nationwide in 2010. The tests are computerized and composed in a progressive manner, depending on the individual child's performance, such that correct answers lead to more difficult subsequent questions, and incorrect answers lead to easier subsequent questions. The final test result is therefore based on the level of difficulty, not the number of correct answers. The tests are divided into three different domains; for Danish: language understanding, decoding, and text comprehension, and for mathematics: algebra, geometry, and basic mathematics skills. No aids are permitted during the tests. The tests are scored on a scale from 0 to 100 in each domain. For this study, the mean of the three domains was used for analyses.

2.2.4 | Socioeconomic status

As an indicator of parental education, the female guardian's highest completed education was obtained from a

questionnaire.[23] The most recent questionnaire completed for each child was used to account for parents still pursuing educational opportunities during the study period. Categories were completion of: (a) 10th grade or less, (b) vocational education, (c) high school education, (d) short tertiary education, (e) bachelor's degree or equivalent, (f) master's degree or higher.

2.3 | Statistical analysis

Differences in baseline values of sex, age, parental education, body mass, and stature between participants in the intervention and control schools, and between boys and girls, were analyzed using linear regression with adjustment for grade for continuous variables and with chi-square tests for categorical variables. To test for differences between school types (intervention/control schools), linear mixed models were applied with each academic test as outcomes and the dichotomized school type as exposure. The models were adjusted with fixed effects for sex, parental education, and age of the student at the date of the specific test. Furthermore, random effects for school and class were included to accommodate the clustering of students within these units. A possible interaction between sex and intervention was investigated. Each of the five tests of scholastic performance (three Danish and two Mathematics) was analyzed separately. Further, two separate composite analyses were carried out for all Danish and for both Math tests. In analyses of the composite scores, a random effect for the individual child was included in the models, which were further adjusted for grade level.

In secondary analyses, the model was adjusted for the number of intervention years. This was applied to account for possible differentiation of intervention effects owing to differences in the length of intervention time (eg, 2-6 years of intervention).

Residuals were checked for normality across all analyses and the intraclass correlation coefficients were calculated for all random effects. Finally, drop-out and drop-in analyses were performed. Logistic regression analyses were performed to investigate if non-participation in the scholastic performance tests among children in the baseline sample was associated with age at baseline, gender, or parental education. To describe drop-in linear mixed models were used to investigate if scholastic performance differed between children in the baseline sample and children included in the study later, adjusting for age at test, gender, parental education, and school type. Furthermore, as a sensitivity analysis, linear mixed models were applied to investigate if scholastic performance of children who had no information on maternal education (and hence were excluded in the main analysis) differed from children with this information (Appendix 1). All analyses were carried out in Stata/SE 14.1 (StataCorp LLC, Texas, USA).

3 | RESULTS

Table 1 presents baseline characteristics for participants included in the study in 2008.

No significant differences were observed between participants from the two school types (intervention/control) at baseline (P's>.05). Boys were older, taller, and had a higher cardiorespiratory fitness compared to girls (P<.001). No other differences were observed between the sexes (P's>.05).

3.1 | Differences between intervention and control schools

Table 2 shows the results from the Danish tests in second, fourth, and sixth grade and for all Danish tests combined. No significant differences were observed between intervention and control groups for any of the Danish tests. Adding the number of years of intervention/no intervention to the model did not alter the findings. Females had significantly better results compared to males in sixth grade and in all Danish tests combined. No interaction between sex and school type (intervention/control) was found and the interaction term was not included in the final model.

Table 3 shows the results from the Mathematics tests in third and sixth grade and both tests combined. No significant differences were observed between intervention and control groups for any of the Mathematic tests. Adding the number of years of intervention/no intervention to the model did not change these findings. Males had significantly better results compared to females in both third and sixth grades and in both tests combined. No interaction between sex and school type (intervention/control) was found, and the interaction term was not included in the final model.

Results on differences between drop-out and drop-in participants, and results on the sensitivity analyses can be seen in Appendix 1. Generally, age and mother's education were associated to drop-out, whereas drop-in was generally not associated to scholastic performance.

4 | DISCUSSION

This is the first Danish long-term school-based intervention study investigating the influence of increased PE on scholastic performance. Scholastic performance was not affected following a PE intervention relative to a control condition after 2-6 years, which is counter to our central hypothesis. However, the intervention also did not relate negatively to scholastic outcomes, indicating that additional time spent in PE does not detract from scholastic performance. Previous reports from this study have found positive intervention effects on body composition and certain metabolic risk factors.[19,24] Further, children in the intervention group had higher PA

TABLE 1 Baseline characteristics of participants by group allocation and sex. Values are mean and SD unless otherwise stated

	Intervention schools		Control schools		*P*-values for difference between school types at baseline	*P*-values for difference between sexes at baseline
	Boys N=306	Girls N=374	Boys N=246	Girls N=255		
Age (years)	8.40 (1.42)	8.29 (1.42)	8.51 (1.45)	8.37 (1.48)	.795	<.001
Body weight in kg	29.41 (6.87)	28.82 (6.21)	29.75 (6.76)	29.42 (7.60)	.539	.133
Stature in cm	133.61 (9.75)	131.50 (9.50)	133.64 (10.29)	131.93 (9.94)	.396	<.001
Aerobic fitness in meters	921.94 (114.41)	868.89 (90.04)	926.64 (108.58)	852.75 (100.11)	.298	<.001
Parental education[a], n (percent reporting in each category)						
Tenth grade or less	18 (6%)	18 (5%)	6 (2%)	10 (4%)	.111	.743
Vocational education	82 (27%)	110 (29%)	66 (27%)	63 (25%)		
High school education	51 (17%)	56 (15%)	40 (16%)	30 (12%)		
Short tertiary education	8 (3%)	20 (5%)	6 (31%)	3 (1%)		
Bachelor or equivalent	88 (29%)	95 (25%)	77 (31%)	76 (30%)		
Master degree or higher education	19 (6%)	19 (5%)	12 (5%)	15 (6%)		
Missing	40 (13%)	56 (15%)	39 (16%)	58 (23%)		
Grade, n (%)						
KC	55 (18%)	70 (19%)	40 (16%)	45 (18%)	.808	.193
First	64 (21%)	77 (28%)	41 (17%)	56 (22%)		
Second	69 (23%)	78 (21%)	68 (28%)	41 (16%)		
Third	59 (19%)	77 (21%)	47 (19%)	53 (21%)		
Fourth	59 (19%)	72 (19%)	50 (20%)	60 (24%)		

KC, Kindergarten class.

[a]Maternal or female guardians highest completed education was used as the parental education indicator.

levels during school hours, but not outside of school; thus, overall PA level did not differ between the two groups.[25] Given these earlier reports, there are reasons to believe that the intervention was delivered as intended and had efficacy for improving health outcomes. Therefore, the lack of positive intervention effects on scholastic performance was probably not due to poor fidelity with the intervention.

4.1 | Comparison with other school-based intervention studies

There are several other plausible explanations for the lack of positive intervention effects on scholastic performance in this study. First, the intervention did not result in changes in the overall PA level[25] or cardiorespiratory fitness.[19] Changes in overall PA and fitness could be one important factor necessary for PE interventions to be successful in influencing scholastic performance. This view is supported by results from both cross-sectional, longitudinal observational studies, and from controlled laboratory experiments (see ref. 1,3, for review). Accordingly, several previous PE intervention studies reported positive effects on both scholastic performance and in PA and/or cardiorespiratory fitness following their PE intervention[16,17] (PA/fitness reported in ref. 26,27). Other studies have not included PA or fitness in their reporting.[15,18] Coe et al.[14] did not find an effect of their PE intervention on scholastic performance, but did observe greater academic test scores for children achieving the recommended goal for vigorous PA compared to children not achieving this goal.[14] The current intervention was a combination of both an increase in the number of, and a focus on, quality in PE. Previous studies have focused on either increasing the number of PE lessons,[14-16] or improving the content of, or the teaching in, PE lessons.[17,18] Evidence is still too sparse to conclude whether enhancing or improving PE lessons or a combination of the two are most effective for enhancing scholastic performance. However, there are reasons to believe that PE interventions should be intensive enough to engender an increase in overall PA or cardiorespiratory fitness level to affect scholastic performance.

Second, the current intervention was not designed specifically to affect scholastic performance, but had the overall aim of improving physical health of the participating children.[20] Conjecture suggests that other interventions, for example, applying PA integrated into academic subjects might affect scholastic performance even without making substantial changes to PA or fitness levels. School-based interventions with this focus have shown promising results,[28,29] but more

TABLE 2 Danish results (mean of three domains; language understanding, decoding and text comprehension). β-values and 95% CI

	2nd grade	4th grade	6th grade	Combined[a]
N	485	996	939	2420[b]
School type (control schools reference)	−1.34 (−9.90, 7.22)	0.22 (−6.12, 6.56)	1.03 (−5.02, 7.08)	0.28 (−5.74, 6.31)
Sex: (female is reference)	−1.15 (−5.34, 3.05)	−2.33 (−5.33, 0.67)	−3.19* (−6.09, −0.30)	−2.94* (−5.40, −0.48)
Test age (years)	0.34 (−5.58, 6.25)	−0.57 (−4.81, 3.66)	−1.59 (−5.76, 2.57)	1.96 (−1.20, 5.13)
SES[c]				
Tenth grade or less	−4.03 (−15.57, 7.52)	−8.30* (−15.79, −0.81)	−5.89 (−13.08, 1.29)	−6.57* (−12.70, −0.43)
Vocational education	(Reference)	(Reference)	(Reference)	(Reference)
High school education	6.94 (−1.04, 14.93)	5.90* (0.81, 11.00)	6.40** (1.83, 10.97)	6.26 ** (2.13, 10.40)
Short tertiary education	6.99 (−0.46, 14.43)	4.25 (−.1.48, 9.97)	7.97** (2.08, 13.86)	6.57** (1.71, 11.44)
Bachelor or equivalent	8.39*** (3.44, 13.34)	10.52*** (6.98, 14.05)	10.55*** (7.08, 14.02)	10.31*** (7.37, 13.25)
Master degree or higher education	13.54** (4.98, 22.09)	19.27*** (13.20, 25.35)	22.44*** (16.74, 28.15)	18.57*** (13.63, 23.51)
ICC: School	0.06 (0.02,0.23)	0.03* (0.01, 0.11)	0.03* (0.01, 0.11)	0.04*** (0.01, 0.10)
ICC: Class	0.11 (0.05, 0.23)	0.09*** (0.05, 0.16)	0.08** (0.04, 0.15)	0.08*** (0.04, 0.14)
ICC: Individual				0.73*** (0.70, 0.75)

ICC, intraclass correlation coefficients (95% CI).

Mixed effects models adjusted for sex, age, and parental education and taking into account the clustering on school and class.

[a]For all years combined also clustered on individual IDs. These analyses are further adjusted for grade.

[b]Note this is the number of observations, not the number of subjects included.

[c]Maternal or female guardians highest completed education was used as the socioeconomic status indicator.

*P<.05, ** P<.01, *** P<=.001.

TABLE 3 Mathematics results (mean of three domains; algebra, geometry and basic mathematics skills). β-values and 95% CI

	3rd grade	6th grade	Combined[a]
N	712	940	1652[b]
School type (control schools reference)	−2.87 (−9.65, 3.90)	0.99 (−7.36, 9.34)	−1.20 (−8.10, 5.71)
Sex (females reference)	4.71** (1.28, 8.15)	3.43* (0.52, 6.34)	4.27*** (1.80, 6.74)
Test age (years)	−0.47 (−5.25, 4.31)	−1.55 (−5.73, 2.62)	−1.00 (−4.41, 2.40)
SES[c]			
10th grade or less	−5.13 (−14.44, 4.17)	−6.39 (−13.89, 0.81)	−6.11 (−12.35, 0.13)
Vocational education	(Reference)	(Reference)	(Reference)
High school education	2.61 (−3.56, 8.79)	4.15 (−0.48, 8.77)	2.99 (−1.15, 7.13)
Short tertiary education	3.50 (−2.72, 9.71)	6.49* (0.54, 12.43)	5.20* (0.33, 10.06)
Bachelor or equivalent	6.85*** (2.86, 10.83)	8.59*** (5.11, 12.07)	7.47*** (4.55, 10.40)
Master degree or higher education	16.36*** (9.50, 23.21)	16.31*** (10.61, 22.00)	14.95*** (10.03, 19.87)
ICC: School	0.03 (0.004, 0.18)	0.07*** (0.03, 0.18)	0.05*** (0.02, 0.14)
ICC: Class	0.12*** (0.07, 0.21)	0.14*** (0.08, 0.24)	0.11*** (0.06, 0.18)
ICC: Individual			0.54*** (0.48, 0.61)

ICC, intraclass correlation coefficients (95% CI).

Mixed effects models adjusted for sex, age, and parental education and clustered on school and class.

[a]For all years combined also clustered on individual IDs. These analyses are further adjusted for grade.

[b]Note this is the number of observations, not the number of subjects included.

[c]Maternal or female guardians highest completed education was used as the socioeconomic status indicator.

*P<.05, **P<.01, ***P<=.001.

studies are needed to advance our understanding in this area. Further, it might be speculated that combining different strategies to enhance PA in schools could have beneficial effects on scholastic performance. However, most studies using a multicomponent approach to increase PA during school hours did not find an effect on scholastic performance.[30-32]

Importantly, the multicomponent studies reporting on PA and fitness have not demonstrated a positive intervention effect on these outcomes.[31,32] One multicomponent study found positive intervention effects on math, but not reading, but PA or fitness levels were not reported.[33] It is therefore not known whether the positive effect on scholastic performance was caused by changes in these outcomes.

In the multicomponent intervention by Resaland et al.[31] the intervention significantly affected numeracy in children in the lowest tertile at baseline. The authors suggested that this finding could be caused by the intervention element consisting of integrating PA in the academic lessons.[31] Future studies should verify this result by investigating how diverse intervention strategies might have differential effects on children differing in academic level, and also in other characteristics, for example, parental education, body composition, metabolic, and mental health. Finally, the extra PE lessons in our study were added to the normal curriculum and resulted in longer school days for the intervention group. This could potentially have led to cognitive fatigue, thereby having a negative effect on learning.[34] However, no such negative results were observed.

Collectively, results from the present study corroborate much of the existing literature to suggest that highly diverse results exist for the effect of school-based PA interventions on scholastic performance. Despite the diverse outcomes in the literature, existing evidence suggests that enhancing PA in school does not come at the cost of scholastic performance, which supports the conclusion in the most recent reviews in this field.[1,5]

4.2 | Strengths and limitations

The strengths of the study include the large sample size, the length of the intervention period (from 2-6 years), and the inclusion of national standardized test results as a measure of academic performance. However, several limitations are noted. Although schools were matched based on size, geographic placement, and socioeconomic status of the student body,[20] the lack of randomization infers that conclusions of a causal nature are inappropriate. Regardless, our conclusions do not differ substantially from other studies using proper randomization.[31,32]

Another limitation is the lack of a baseline measure of scholastic performance, which eliminated the possibility to conduct subgroup analyses based on this variable. This measure was not possible to obtain because the Danish National Test System was not implemented nationwide until 2010. To remedy this issue, we examined whether there were substantial differences between intervention and control schools before the intervention was initiated. There were no significant differences between the two school types in average grade level of the final examinations in Danish and Mathematics in ninth graders between 2006 and 2008 (data not reported). However, since this analysis was performed at the school level, it can only be considered a crude marker of equity. Also, it would be of interest to follow the children after sixth grade, as a PE intervention like the one in our study might affect older age groups differently. Furthermore, we did not collect information on learning difficulties among participants, which could have improved our understanding of potential differences among groups. Lastly, assessments of the quality in the PE lessons during the 6-year intervention were not collected, which could have highlighted the extent to which the concepts of "age-related training" were met.

5 | CONCLUSION AND PERSPECTIVE

In summary, the findings demonstrated that scholastic outcomes were unaffected by a 2- to 6-year PE intervention in the CHAMPS study-DK. There are, however, many known benefits of PA for children's health and development. Previous reports from this study have demonstrated an effect on body composition and metabolic health. However, more research is needed to identify the optimal design and intensity of school-based interventions that simultaneously improve scholastic performance while achieving overall health benefits. It is possible that school-based PA interventions should either be intensive enough to induce improvements in overall PA or fitness level or use approaches to increase PA more closely related to the academic content (eg, integrating PA in the learning subjects).

ACKNOWLEDGEMENTS

This study was supported by The TRYG Foundation, The Nordea Foundation, The IMK Foundation and The Region of Southern Denmark. The authors are thankful to all participating children and their families, school principals and teachers, and politicians and employees in the local authority of Svendborg, and finally to the working groups in the CHAMPS study-DK. The authors declare that they have no competing interests.

REFERENCES

1. Donnelly JE, Hillman CH, Castelli D, et al. Physical activity, fitness, cognitive function, and academic achievement in children: a systematic review. *Med Sci Sports Exerc*. 2016;48:1223-1224.
2. Centers for Disease Control and Prevention (CDC). *The Association Between School Based Physical Activity, Including Physical Education, and Academic Performance*. Atlanta, GA: U.S. Department of Health and Human Services; 2010:1-84.
3. Fedewa AL, Ahn S. The effects of physical activity and physical fitness on children's achievement and cognitive outcomes: a meta-analysis. *Res Q Exerc Sport*. 2011;82:521-535.

4. Singh A, Uijtdewilligen L, Twisk JW, van MW, Chinapaw MJ. Physical activity and performance at school: a systematic review of the literature including a methodological quality assessment. *Arch Pediatr Adolesc Med* 2012;166:49-55.
5. Bangsbo J, Krustrup P, Duda J, et al. The Copenhagen Consensus Conference 2016: children, youth, and physical activity in schools and during leisure time. *Br J Sports Med*. 2016;50:1177-1178.
6. Cotman CW, Berchtold NC. Exercise: a behavioral intervention to enhance brain health and plasticity. *Trends Neurosci*. 2002;25:295-301.
7. Van Prag PH, Kempermann G, Gage FH. Running increases cell proliferation and neurogenesis in the adult mouse dentate gyrus. *Nat Neurosci*. 1999;2:266-270.
8. Voss MW, Vivar C, Kramer AF, van Praag H. Bridging animal and human models of exercise-induced brain plasticity. *Trends Cogn Sci*. 2013;17:525-544.
9. Chaddock L, Erickson KI, Prakash RS, et al. A neuroimaging investigation of the association between aerobic fitness, hippocampal volume, and memory performance in preadolescent children. *Brain Res*. 2010;1358:172-183.
10. Hillman CH, Pontifex MB, Raine LB, Castelli DM, Hall EE, Kramer AF. The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience*. 2009;159:1044-1054.
11. Sibley BA, Etnier JL. The relationship between physical activity and cognition in children: a meta-analysis. *Pediatr Exerc Sci*. 2003;15:243-256.
12. Hills AP, Dengel DR, Lubans DR. Supporting public health priorities: recommendations for physical education and physical activity promotion in schools. *Prog Cardiovasc Dis*. 2015;57:368-374.
13. Institute of Medicine. *Educating the Student Body: Taking Physical Activity and Physical Education to School*. Washington, DC, USA: Institute of Medicine of the National Academies; 2013.
14. Coe DP, Pivarnik JM, Womack CJ, Reeves MJ, Malina RM. Effect of physical education and activity levels on academic achievement in children. *Med Sci Sports Exerc*. 2006;38:1515-1519.
15. Ericsson I, Karlsson MK. Motor skills and school performance in children with daily physical education in school—a 9-year intervention study. *Scand J Med Sci Sports*. 2014;24:273-278.
16. Kall LB, Nilsson M, Linden T. The impact of a physical activity intervention program on academic achievement in a Swedish elementary school setting. *J Sch Health*. 2014;84:473-480.
17. Sallis JF, McKenzie TL, Kolody B, Lewis M, Marshall S, Rosengard P. Effects of health-related physical education on academic achievement: project SPARK. *Res Q Exerc Sport*. 1999;70:127-134.
18. Telford RD, Cunningham RB, Fitzgerald R, et al. Physical education, obesity, and academic achievement: a 2-year longitudinal investigation of Australian elementary school children. *Am J Public Health*. 2012;102:368-374.
19. Klakk H, Andersen LB, Heidemann M, Moller NC, Wedderkopp N. Six physical education lessons a week can reduce cardiovascular risk in school children aged 6-13 years: a longitudinal study. *Scand J Public Health*. 2014;42:128-136.
20. Wedderkopp N, Jespersen E, Franz C, et al. Study protocol. The Childhood Health, Activity, and Motor Performance School Study Denmark (The CHAMPS-study DK). *BMC Pediatr*. 2012;12:128.
21. Bach SG, Eiberg S. *Aldersrelateret træning - Håndbog for 0.-6. klasse [Age Related Training – A Handbook for Pre-School to 6th Grade]*. Brøndby, Denmark: Team Denmark; 2010.
22. Andersen LB, Andersen TE, Andersen E, Anderssen SA. An intermittent running test to estimate maximal oxygen uptake: the Andersen test. *J Sports Med Phys Fitness*. 2008;48:434-437.
23. Marks GN. Are father's or mother's socioeconomic characteristics more important influences on student performance? Recent international evidence *Soc Indic Res*. 2008;85:16.
24. Klakk H, Chinapaw M, Heidemann M, Andersen LB, Wedderkopp N. Effect of four additional physical education lessons on body composition in children aged 8-13 years—a prospective study during two school years. *BMC Pediatr*. 2013;13:170.
25. Moller NC, Tarp J, Kamelarczyk EF, Brond JC, Klakk H, Wedderkopp N. Do extra compulsory physical education lessons mean more physically active children—findings from the childhood health, activity, and motor performance school study Denmark (The CHAMPS-study DK). *Int J Behav Nutr Phys Act*. 2014;11:121.
26. Bunketorp KL, Malmgren H, Olsson E, Linden T, Nilsson M. Effects of a curricular physical activity intervention on children's school performance, wellness, and brain development. *J Sch Health*. 2015;85:704-713.
27. Sallis JF, McKenzie TL, Alcaraz JE, Kolody B, Faucette N, Hovell MF. The effects of a 2-year physical education program (SPARK) on physical activity and fitness in elementary school students. Sports, play and active recreation for kids. *Am J Public Health*. 1997;87:1328-1334.
28. Donnelly JE, Greene JL, Gibson CA, et al. Physical Activity Across the Curriculum (PAAC): a randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary school children. *Prev Med*. 2009;49:336-341.
29. Mullender-Wijnsma MJ, Hartman E, de Greeff JW, Bosker RJ, Doolaard S, Visscher C. Improving academic performance of school-age children by physical activity in the classroom: 1-year program evaluation. *J Sch Health*. 2015;85:365-371.
30. Ahamed Y, Macdonald H, Reed K, Naylor PJ, Liu-Ambrose T, McKay H. School-based physical activity does not compromise children's academic performance. *Med Sci Sports Exerc*. 2007;39:371-376.
31. Resaland GK, Aadland E, Moe VF, et al. Effects of physical activity on schoolchildren's academic performance: The Active Smarter Kids (ASK) cluster-randomized controlled trial. *Prev Med*. 2016;91:322-328.
32. Tarp J, Domazet SL, Froberg K, Hillman CH, Andersen LB, Bugge A. Effectiveness of a school-based physical activity intervention on cognitive performance in Danish adolescents: LCoMotion-Learning, Cognition and Motion—a cluster randomized controlled trial. *PLoS One*. 2016;11:e0158087.
33. Hollar D, Messiah SE, Lopez-Mitnik G, Hollar TL, Almon M, Agatston AS. Effect of a two-year obesity prevention intervention on percentile changes in body mass index and academic performance in low-income elementary school children. *Am J Public Health*. 2010;100:646-653.
34. Sievertsen HH, Gino F, Piovesan M. Cognitive fatigue influences students' performance on standardized tests. *Proc Natl Acad Sci USA*. 2016;113:2621-2624.

How to cite this article: Bugge A, Möller S, Tarp J, et al. Influence of a 2- to 6-year physical education intervention on scholastic performance: The CHAMPS study-DK. *Scand J Med Sci Sports*. 2018;28:228–236. https://doi.org/10.1111/sms.12902

APPENDIX 1

Drop-out and drop-in analyses

Age at baseline was negatively associated with drop-out before tests of Danish in second grade (OR=0.42 *P*=.028) and positively associated with drop-out before Danish test in sixth grade (OR=1.37 *P*<.001), as well as Mathematics in third and sixth grade (OR=1.49 *P*=.006 and OR=1.36 *P*<.001, respectively). Males were more likely to drop-out for Danish in fourth grade (OR=1.70 *P*=.039), but not for the other tests. For Danish in second and fourth grade and Mathematics in third grade "mother's education of tenth grade or less" was positively associated with drop-out (OR=4.80 *P*=.028; OR=2.85 *P*=.017, respectively, OR=3.16 *P*=.014), while the other categories of mother's education were not significantly associated with drop-out compared to vocational education. In the drop-in analysis, no differences in scholastic performance between children included at baseline and children included later were found, apart from slightly higher points (β=3.85 (95% CI: (0.16, 7.54) *P*=.041) in mathematics in sixth grade for children included at baseline. In the sensitivity analysis, a positive association between availability of the maternal/female guardian's education and academic performance was found, so that participants presenting this variable had better scores compared to participants without this variable. This was nonsignificant for Danish second grade (β=3.04 *P*=.227), but significant for Danish in fourth and sixth grade (β=4.80 *P*=.009 and β=4.08 *P*=.022, respectively) and Mathematics in third and sixth grade (β=7.37 *P*<.001 and β=7.03 *P*<.001, respectively).