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Effects of physical activity on schoolchildren's academic performance: The Active Smarter Kids (ASK) cluster-randomized controlled trial☆

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A B S T R A C T

Objective. To investigate the effect of a seven-month, school-based cluster-randomized controlled trial on academic performance in 10-year-old children.

Methods. In total, 1129 fifth-grade children from 57 elementary schools in Sogn og Fjordane County, Norway, were cluster-randomized by school either to the intervention group or to the control group. The children in the 28 intervention schools participated in a physical activity intervention between November 2014 and June 2015 consisting of three components: 1) 90 min/week of physically active educational lessons mainly carried out in the school playground; 2) 5 min/day of physical activity breaks during classroom lessons; 3) 10 min/day physical activity homework. Academic performance in numeracy, reading and English was measured using standardized Norwegian national tests. Physical activity was measured objectively by accelerometry.

Results. We found no effect of the intervention on academic performance in primary analyses (standardized difference 0.01–0.06, $p > 0.358$). Subgroup analyses, however, revealed a favorable intervention effect for those who performed the poorest at baseline (lowest tertile) for numeracy ($p = 0.005$ for the subgroup $*$ group interaction), compared to controls (standardized difference 0.62, 95% CI 0.19–1.07).

Conclusions. This large, rigorously conducted cluster RCT in 10-year-old children supports the notion that there is still inadequate evidence to conclude that increased physical activity in school enhances academic achievement in all children. Still, combining physical activity and learning seems a viable model to stimulate learning in those academically weakest schoolchildren.

1. Introduction

Exploring new teaching and learning methods to improve children's academic performance is important. Physical activity (PA) may be an effective strategy affecting positively academic performance, and school-based studies investigating the effect of increased PA on academic performance have steadily increased in number the last decade. It is suggested that beneficial effects of PA on academic performance are due to improved cognitive functions, such as attention, concentration and working memory (Trudeau and Shephard, 2008; Tomporowski et al., 2008; Bailey et al., 2009; Rasberry et al., 2011; Fedewa and Ahn, 2011; Singh et al., 2012; Norris et al., 2015; Mura et al., 2015; Donnelly et al.,

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2016). Results are mixed and range from a positive effect to none on academic performance. Most consistent is the observation that increases in school-time PA apparently do not affect pupils' academic performance negatively. However, most previous studies are hampered by several limiting factors, including a lack of randomization, low statistical power and subjective measurement of PA. Therefore, the evidence base regarding whether increases in school-time PA affect academic performance is limited. Extending this knowledge is important for curricula developments and to inform future interventions. We therefore assessed the effect of a seven-month, school-based PA intervention (i.e., Active Smarter Kids, ASK) on academic performance on a large sample of 10-year-old children in Norwegian elementary schools. In addition, we determined the effects of sex, socioeconomic position, and baseline level of academic performance on the relation between participation in the intervention and academic performance.

2. Methods

The intervention was conducted within a socio-ecological conceptual framework that recognizes that PA behaviors have multiple levels of influence (McLeroy et al., 1988). Our procedures and methods conform to ethical guidelines defined by the World Medical Association's Declaration of Helsinki and subsequent revisions (WMA, 1964). The Regional Committee for Medical Research Ethics approved the study protocol. We obtained written consent from each child's parents or legal guardian and from school authorities prior to all testing. The study is registered in Clinicaltrials.gov ID nr: NCT02132494. We previously published a detailed description of the study (Resaland et al., 2015), but provide a brief overview below.

2.1. Design and participants

ASK was a seven-month cluster-randomized controlled trial (cluster RCT) with a random allocation at the school level using a 1:1 ratio. Such randomization eliminated the possibility of contamination between pupils in the same school. Sixty schools were approached and 57 schools (1129 children) agreed to participate (recruitment success of 95% of schools, 94% of children) (Fig. 1). Inclusion criteria were: i) schools had ≥7 pupils in fifth grade; ii) pupils were able to participate in daily PA and physical education (PE); and iii) pupils were able to complete

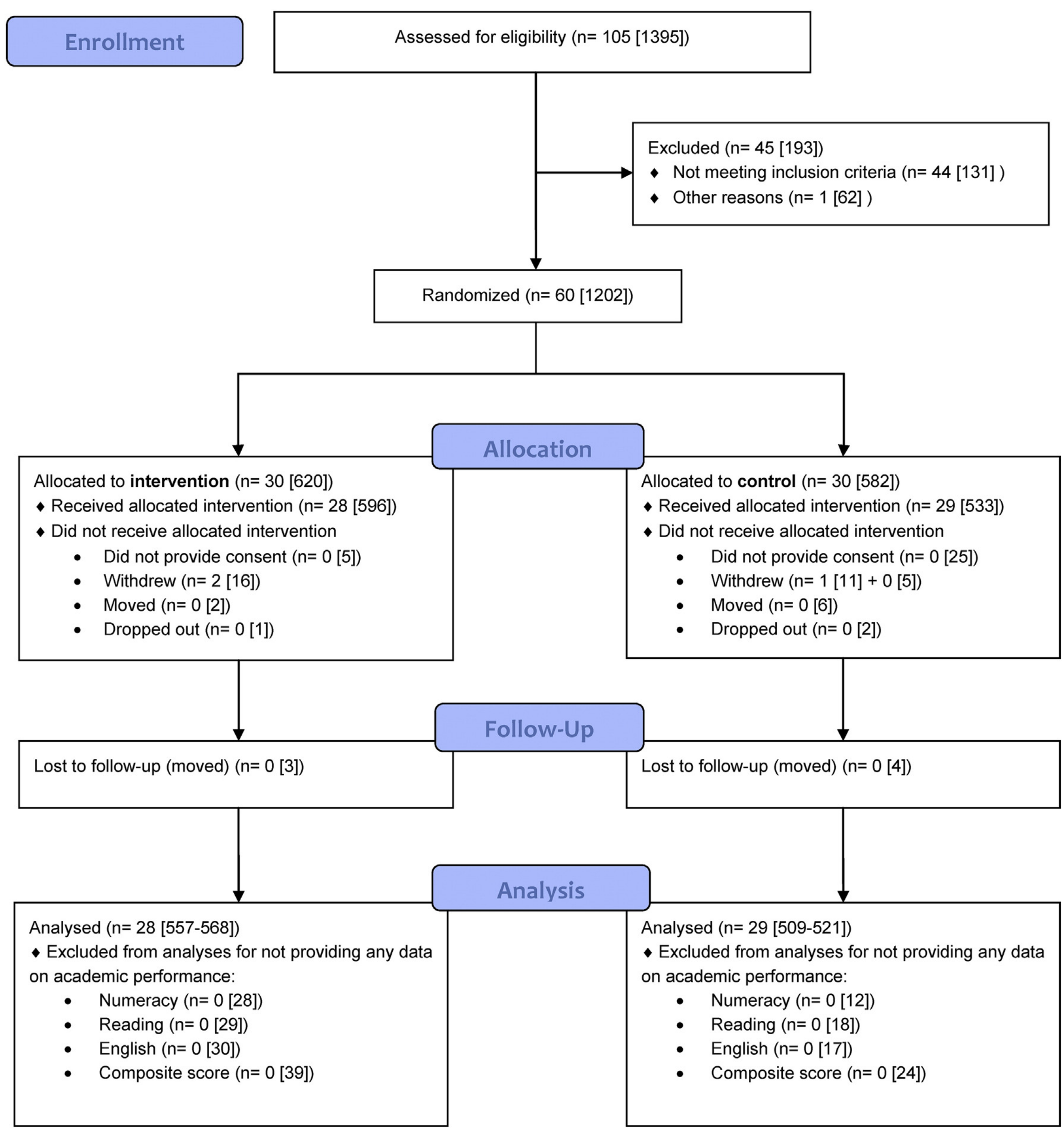

Fig. 1. The consort flow diagram. Flow of schools and children through the study. All numbers are schools [children].

academic performance tests. Children were 10.2 years old (standard deviation ± 0.3) and attending fifth-grade classes in Sogn og Fjordane County, Norway. The ASK study was designed to detect an effect size of 0.35 between two groups for change in academic performance (Resaland et al., 2015).

2.2. Teacher training

Fifth-grade classroom teachers in the intervention schools (I-schools) delivered the intervention. To support and qualify teachers to conduct the intervention, we arranged three comprehensive pre-intervention seminars and two regional refreshing sessions during the intervention period. We also gave support via email and telephone to teachers in I-schools. A password-protected homepage (http://www.askstudy.no) further provided teachers in I-schools with information, videos and content for approximately 100 PA lessons. All lessons on the homepage were developed in collaboration with I-schools in Sogn og Fjordane County. Finally, we provided all I-schools with equipment (e.g., laminating machines and accessories, mathematics bingo tiles, cones) necessary to support the intervention.

2.3. The intervention

The intervention comprised three components aimed at providing children with the opportunity to engage in 165 min of PA/week more than the control group did: i) physically active lessons for 90 min/week, conducted in the playground; physically active educational lessons were delivered in three core subjects – Norwegian (30 min/week), mathematics (30 min/week) and English (30 min/week); ii) PA physical activity breaks (5 min/day) implemented in the classroom during academic lessons; and iii) PA homework (10 min/day) prepared by teachers. In addition, pupils attending I-schools participated in the curriculum-prescribed 90 min/week of PE and the curriculum-prescribed 45 min/week of PA. Thus, PA (165 min/week) and PE/PA (135 min/week) components provided children opportunities to engage in school-based physical activities 300 min/week. The intervention was established as part of the mandatory school curriculum for all pupils attending I-schools. Control schools (C-schools) were asked to provide the "normal practice" school curriculum, including usual amounts of PA/PE, being approximately 135 min/week.

The intervention was designed so activities could be varied and enjoyable for the children. We emphasized to I-school teachers that activities were intended for all children, including those neither particularly fit nor enthusiastic about PA. Teachers were encouraged to motivate children during active lessons, in order to stimulate their positive feelings and attitudes towards PA. We adopted a self-determination perspective, providing teachers with choices and options, and ASK teachers could draw upon a pool of physical activities, developed pre-intervention by the teachers themselves in co-operation with ASK's study group. The intervention was designed so approximately 25% of daily PA was of vigorous intensity, defined as "children sweating and being out of breath." Teachers achieved the vigorous-PA-intensity component through selecting a variety of high-intensity activities such as running, relay racing, obstacle courses and various forms of high-activity play.

2.4. Outcome measures

Children were assessed at baseline (Time (T)1) and follow-up (T2, after 7 months) as described below.

2.4.1. Academic performance

Academic performance in numeracy (often referred to as mathematics in the literature), reading and English was measured using standardized Norwegian national tests designed and administered by The Norwegian Directorate for Education and Training (NDET) (The Norwegian Directorate for Education and Training, 2015). Most (~95%) fifth-grade pupils in Norway completed these tests during autumn 2014. The numeracy test measured pupils' ability to understand numbers and measurements, and measured their skills in statistics. The reading test measured pupils' ability in basic Norwegian reading skills such as finding information in a text, interpreting and understanding the text, and reflecting on and considering its form and content. The English test measured pupils' ability to find information and understand the main content and some details in simple texts (The Norwegian Directorate for Education and Training, 2015). The three academic performance tests were conducted to map whether a pupil's achievements were in accordance with national curricular goals. The score was standardized to a mean of 50 scale points, with a standard deviation of 10 (Norwegian Ministry of Education, 2013). The three different tests were administered on three different days at both baseline and follow-up. The numeracy test was computer-based, while the other two were paper and pencil tests. Pupils had 60 min to complete the English test and 90 min to complete the other two. These tests are extensively verified for validity and reliability by NDET (The Norwegian Directorate for Education and Training, n.d.) and aligned with competencies demanded from all schools by the national curriculum. Numeracy, reading and English tests were analyzed individually and individual scores were used to derive a composite score, being the total score of the three test scores.

2.4.2. Physical activity

Physical activity was measured using triaxial accelerometry (ActiGraph GT3X+, LLC, Pensacola, Florida, USA). Children were instructed to wear the accelerometer on the right hip throughout seven consecutive days, except during water-based activities or while sleeping. Our criterion for a valid day was a wear time of ≥480 min/day accumulated between 06:00 and 24:00; a wear time of ≥180 min/day accumulated between 09:00 and 14:00 was a criterion for a valid school day. Periods of ≥20 min of zero counts were defined as non-wear time (Esliger et al., 2005). Totals of ≥4 (out of 7) days and ≥3 (out of 5) school days were applied as valid measurements. All analyses were based on accumulated data using a 10-s epoch. Outcomes for PA levels were i) total PA (counts/min), ii) sedentary time (SED), iii) light-intensity PA (LPA) and iv) moderate-to-vigorous intensity PA (MVPA)(min/day). Additionally, we reported the proportion of children who achieved the guideline PA level (a minimum mean of 60 min/day of MVPA). We adopted previously applied and established cut points (Evenson et al., 2008; Trost et al., 2011). We analyzed all accelerometry data using Kinesoft analytical software ("http://kinesoft.org/"). The collection of baseline accelerometer data (April–June 2014) was conducted before the intervention started. The post-test collection of accelerometer data (April–June 2015) took place before the post-test collection of academic performance data.

2.4.3. Adherence to protocol

Schools received a questionnaire every month to assess adherence to the intervention protocol, where teachers reported duration (min/week) and intensity of pupils' PA.

Intensity was reported on a scale from 1 to 3 where 1 = low-intensity activity, 2 = moderate-intensity activity and 3 = vigorous-intensity activity for all three intervention components (PA educational lessons, PA break and PA homework) and for compulsory PE and PA lessons.

2.4.4. Anthropometry

Body mass (weight; 0.1 kg) was measured using an electronic scale (Seca 899, SECA GmbH, Hamburg, Germany). Stature (height; 0.1 cm) was measured with a portable Seca 217 (SECA GmbH, Hamburg, Germany).

2.4.5. Demographic characteristics

We obtained self-reported educational level from parents/guardians to assess socio-economic status. Parental education was categorized into three levels using the highest educational level obtained by the mother or father: i) upper or lower secondary school, ii) university < four years and iii) university ≥ four years.

2.5. Statistics

We report descriptive statistics as means and standard deviations (SD). We tested differences between groups on categorical baseline variables using generalized estimating equations with school as a cluster variable. All other analyses were performed using a mixed-effect model with school as a random effect. The intervention effect was analyzed using an intention-to-treat analysis. We included all children from whom we obtained baseline or final measures of academic performance. Missing data were imputed from relevant variables by means of multiple imputations using a Markov Chain Monte Carlo procedure with 20 iterations; we assumed data were missing at random. To analyze the effect of the prescribed contrast between groups, we also performed secondary (per protocol) analyses comparing I-schools that reported performing ≥80% of prescribed PA with C-schools performing ≤120% of curriculum-prescribed PA (i.e. ≤162 min PA and PE/week) (efficacy). Effect estimates were derived from testing the main effect of group on change in academic performance (dependent variable), while including baseline scores for independent variables as covariates. We tested the between-group difference in change in PA (T2-T1) using minutes per day spent in SED, LPA and MVPA, including baseline scores and change in wear time as covariates. All effect estimates are reported as regression coefficients (β) and 95% confidence intervals (95% CI), along with *p*-values and the intraclass correlation coefficient (ICC) for the cluster effect of schools.

To further explore PA's effect on change in academic performance, we conducted association analyses across all 57 schools without respect to group allocation. Independent variables were PA reports from teachers and change in all accelerometry-derived PA outcomes (individual and aggregated data, i.e., mean change in PA over time for each school).

We performed subgroup analyses to assess the moderating effect of several variables on the intervention's effect on academic performance. Moderating effects for change in academic performance (dependent variable) were determined by testing a categorical subgroup ∗ group interaction, after controlling for main effects of group and subgroup. Variables in the model were academic performance (at T1; tertiles), sex, socioeconomic status and baseline school-time PA and total PA level (total PA (counts/min; tertiles), SED (%) and MVPA (%)). For moderators other than academic performance, baseline academic performance was a covariate in the model.

Outcomes and analyses were determined a priori (Resaland et al., 2015). All analyses were performed using IBM SPSS v. 23 (IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp., USA) or later versions. A two-sided p-value ≤ 0.05 is considered statistically significant.

3. Results

We could not acquire academic performance data from some children and therefore excluded them from analyses for numeracy (n = 40), for reading and English (n = 47), and the composite score (n = 63) (~4% of total; see Fig. 1). Seven children dropped out during follow-up.

Table 1 shows children's baseline characteristics by group. There were no differences between I-schools and C-schools for any variables.

Table 1
Children's demographic and anthropometric characteristics, physical activity levels and academic performance at baseline. Mean (SD). Children not providing valid data did not differ between the intervention and the control group.

	n	Intervention	n	Control
Demographics				
Age (years)	596	10.2 (0.3)	533	10.2 (0.3)
Sex (% girls/boys)	596	47/53	533	49/51
Parents' education level (%)	578		491	
Upper secondary school		30.8		34.8
University <4 years		30.8		28.9
University ≥4 years		38.4		36.3
Anthropometry	578		517	
Body mass (kg)		36.9 (8.0)		37.2 (8.1)
Height (cm)		142.6 (6.8)		142.8 (6.8)
BMI (kg/m^2)		18.0 (3.0)		18.1 (3.0)
Overweight/obese (%)		17.4/3.5		17.8/3.8
Physical activity full day	564		496	
Total PA (cpm)		740 (300)		721 (263)
SED (min/day)		468 (57)		465 (62)
MVPA (min/day)		77 (28)		73 (24)
Achieving guideline PA level (%)		67		64
Physical activity at school	566		497	
Total PA (cpm)		650 (184)		639 (192)
SED (min/day)		178 (19)		179 (20)
MVPA (min/day)		29 (11)		28 (10)
Academic performance				
Numeracy (points)	564	51.1 (9.8)	516	51.4 (9.2)
Reading Norwegian (points)	560	49.2 (10.0)	506	49.7 (9.4)
English (points)	555	49.0 (9.6)	507	49.8 (10.0)
Composite score (z-score)	545	-0.02 (1.02)	502	0.02 (0.98)

BMI = body mass index; SED = sedentary time; MVPA = moderate-to-vigorous intensity physical activity.

During school hours, 946 children had valid accelerometry data for T2-T1; 908 children had valid data during the full day. There were no significant differences between groups for change in PA either during school hours (p ≥ 0.399) or during the full day (p ≥ 0.370) (Table 2). The same findings extend to the subgroup that achieved a significant intervention effect on numeracy (p ≥ 0.142, n = 288–309).

Total PA levels reported by I-schools and C-schools over the intervention period were 288 (21) and 157 (35) min/week, respectively. Thus, differences between schools (131 min/week), according to teacher reports, were 20% less than prescribed, but clearly greater than those differences indicated by accelerometry. Sensitivity analyses using stricter wear time criteria did not change any findings.

We found no significant effect of the intervention on any academic performance measure in the intention-to-treat analyses (Fig. 2). Effect sizes were very small across all outcomes (0.01–0.06 SD units).

To test for possible moderating effects of changes in academic performance, we tested group ∗ subgroup interactions for academic performance at T1, sex, socioeconomic position and PA at T1. We found a significant effect of the intervention on numeracy by tertile (subgroup ∗ group p = 0.005). The specific subgroup effects were 2.39 (95% CI 0.72–4.06) points for the lowest tertile, −0.04 (−1.54–1.47) points for the middle tertile, and −0.23 (−1.63–1.17) points for the highest tertile. The standardized effect size was 0.25 (95% CI 0.08–0.43) SDs when considering the whole group SD (9.5 points), and 0.63 (0.19–1.07) SDs when I-school children in the lowest tertile were compared to their C-school counterparts (SD 3.8 points). No other interactions for baseline values reached statistical significance (p = 0.298 for Reading, p = 0.087 for English and p = 0.115 for the composite score).

Sex was the only moderator that reached statistical significance for the change in academic performance. Boys demonstrated a positive trend (mean difference [95% CI] 0.44 [−1.00–1.87] points) and girls a negative trend (−1.33 [−2.78–0.10] points) in Reading (p for interaction = 0.032). We observed the same trend for numeracy (boys: 0.97 [−0.33–2.26]; girls −0.01 [−1.31–1.29]). However the group ∗ sex interaction for numeracy was not statistically significant (p = 0.096). Sex-

Table 2
Mean baseline, follow-up and group (intervention–control) differences (95% confidence intervals) in change in PA during school hours and during full days.

	Intervention group		Control group		Group difference
	Baseline	Follow-up	Baseline	Follow-up	
School hours					
n	508		438		
Total PA (cpm)	654 (638–670)	658 (641–676)	647 (629–664)	626 (608–644)	13.5 (−36.9–64.0)
SED (min/day)	178 (177–180)	179 (177–180)	179 (177–181)	182 (180–183)	−1.0 (−5.2–3.2)
LPA (min/day)	85 (84–86)	82 (81–83)	83 (82–85)	82 (80–83)	0.9 (−1.2–3.0)
MVPA (min/day)	30 (29–30)	30 (29–31)	29 (28–30)	29 (28–30)	0.1 (−3.0–3.2)
Full day					
n	497		411		
Total PA (cpm)	750 (723–776)	628 (610–645)	732 (707–758)	612 (593–630)	−2.1 (−47.5–43.2)
SED (min/day)	469 (464–474)	496 (491–500)	466 (461–472)	495 (490–501)	3.4 (−4.2–11.0)
LPA (min/day)	236 (233–240)	220 (217–223)	233 (229–236)	222 (219–225)	−1.1 (−5.2–2.8)
MVPA (min/day)	78 (75–80)	68 (66–70)	74 (72–77)	66 (64–68)	−1.1 (−6.1–4.0)

PA = physical activity; cpm = counts per minute; SED = sedentary time; LPA = light physical activity; MVPA = moderate-to-vigorous intensity physical activity.

specific patterns were less pronounced for English ($p = 0.477$) and for the composite score ($p = 0.192$).

We provide results from the per protocol analyses (Table 3), comparing I-schools that according to self-reports completed ≥80% of the prescribed PA (27 schools, 574 children included; 1 school, 22 children excluded) with C-schools that reported ≤120% of recommended PA (16 schools, 324 children included; 13 schools, 209 children excluded). Compared to the intention-to-treat analyses, the per protocol analyses showed that the intervention's effect decreased for all measures, except for English, where the effect became statistically significant (mean difference 0.13 [0.01–0.26] SDs).

Post hoc analyses across groups showed no significant associations between reported PA levels from each school and change in any academic performance variable ($p > 0.116$). These results agree with the non-significant associations observed between change in academic performance and change in PA (accelerometry; whole day and during school time) according to individual ($p > 0.058$) and aggregated data (mean change in PA for each school; $p > 0.129$) (sample sizes: PA during the whole day: n = 793–865 children across the outcome variables; school-time PA: n = 821–899 children across the outcome variables).

4. Discussion

We did not detect any significant effect of the intervention on numeracy, reading, English or the academic composite score. However, the intervention significantly affected numeracy in children in the lowest tertile of the numeracy score at baseline.

We observed no significant difference between I-schools and C-schools in pupils' PA or SED measured objectively using accelerometers. An important reason for this seems to be high levels of PA in the control group, something which is not uncommon in PA intervention trials (Waters et al., 2012). As our premise was that PA would cause a change in academic performance, this is likely to be the main reason we were unable to detect measurable benefits between I-schools and C-schools in pupils' academic performance. Yet, teacher-reports of PA indicated high adherence to the intervention and a clear contrast between the groups. These contrasting results between subjective and objective measures of PA might be partly expected as over reporting of PA is common by self-report measures. In addition, some of the activities performed by the I-schools (e.g., activities focusing on motor skills as throwing, catching, balance or muscular strength) might be underestimated by the objective measurement. Still, the present study can be viewed as a study of the effect of PA without academic content vs. PA with academic content. The issue regarding PA type with or without academic content has yet to be addressed, and is of great interest to the field.

The observed significant effect on numeracy for children in the lowest tertile of numeracy performance at baseline may be more a result of how PA was integrated into the curriculum rather than a result of the amount of PA (i.e., the dose). The "physically active educational lessons" were a cornerstone and a novel part of the intervention, where curricular content that involved solving problems or addressing questions was embedded within physical activities. This approach to learning may have affected those who were less literate in numeracy. Although this

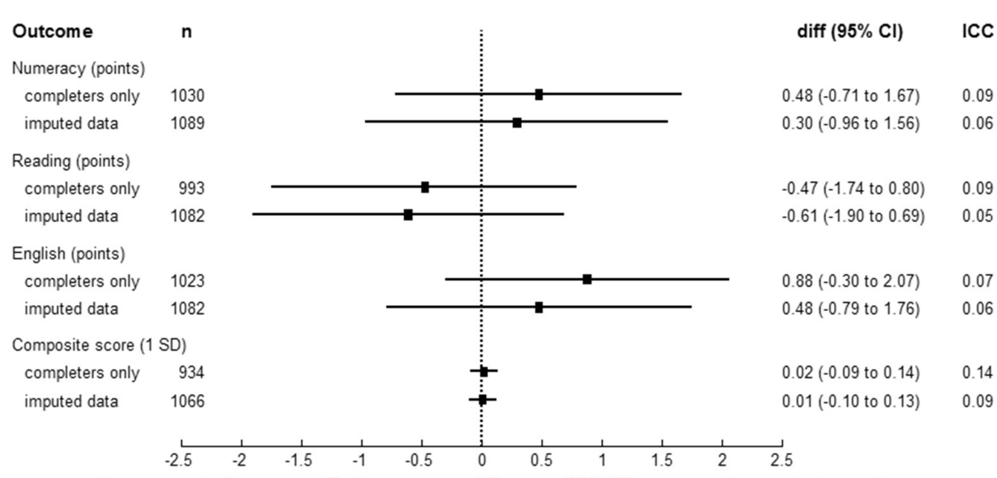

Fig. 2. The intervention's effect (intention-to-treat analyses): completers only vs. imputed data (all children with pre- or post-data for a given variable). The composite score is expressed as the standardized mean of standardized individual scores. 95% CI = 95% confidence interval; ICC = intraclass correlation coefficient; SD = standard deviation.

Table 3
The intervention's effect (per protocol analyses).

	n	Group difference (95% CI)	p	ICC
Numeracy	822	0.18 (−1.09–1.45)	0.777	0.07
Reading Norwegian	805	−0.30 (−1.54–0.94)	0.626	0.04
English	821	1.39 (0.08–2.70)	0.039	0.05
Composite score	767	0.05 (−0.07–0.16)	0.415	0.09

is speculation, it may be that those children who performed most poorly at baseline in numeracy responded best to this combined approach – rather than simply to an increased amount of PA. This approach to learning may be more appealing to those children who performed most poorly at baseline in numeracy. It also allows teachers to use different didactic methods, which may be important because of pupils' different learning strategies (Dunn and Dunn, 1993; Gardner, 2011). In addition, it seems that the perception that PA "steals" time away from traditional subjects in school can be overcome by using an approach that effectively combines PA and academic learning.

Mullender-Wijnsma et al. (2016) carried out a two-year cluster RCT including 499 s- and third-graders from the Netherlands, investigating the effects of an innovative physically active academic intervention called Fit & Vaardig op School (F&V) on academic achievement of children. Their multilevel analysis showed that children in the intervention group had significantly greater gains in mathematics and spelling scores after two years. However, the results revealed that the intervention had no significant effect on a number of variables after only one school year. The non-significant intervention effect observed in our study and the two-year length of the F&V study suggest that the ASK intervention may have been of insufficient length to yield benefits in academic performance in students at the group level similar to those in Mullender-Wijnsma et al. (2016). This notion is supported by the Physical Activity Across the Curriculum (PAAC) (Donnelly et al., 2009), a three-year cluster RCT that found that mathematics, spelling and reading improved significantly in the intervention group as compared to the control group after three years.

Our objectively measured PA data suggested that participants, in both I-schools and C-schools, were on average more active than a population-based national sample of Norwegian 10-year-olds (Anon., 2012) and European and US counterparts (Cooper et al., 2015). Therefore, the high level of PA at baseline for our group of pupils may have resulted in a limited potential to intervene, and ceiling effects may have influenced our results. Yet, contrary to this hypothesis, we found no interaction effect of baseline PA for change in academic performance.

Is there a negative trade-off between having active, healthy students and having better academic performance? The mounting evidence suggests there is not. Several studies have demonstrated that increased time allocated to school-time PA did not detract from academic performance (Singh et al., 2012; Norris et al., 2015; Ahamed et al., 2007). Given the documented health benefits children derive from increased PA levels (Strong et al., 2005; Janssen and LeBlanc, 2010; Dobbins et al., 2013) and the number of hours that children spend in school, educating "healthier" children seems a justifiable use of valuable school time. There is little evidence that eliminating subjects (such as PE) to allow for more classroom-based "academic" learning is associated with better academic performance (Hillman et al., 2008). Furthermore, increasing time allocated to theoretical subjects (without more effective methods or better-quality teaching) does not translate into better test scores (Committee et al., 2013). Thus, given the varied nature of how children learn, it is reasonable that practical didactical approaches that incorporate physically active educational lessons and short physical activity breaks during classroom lessons for children may be a feasible and simple approach to improving academic performance for some, if not all, children.

Study strengths included the cluster RCT design, large sample size and high attrition, and objective measurements of PA. Regarding limitations, our objectively measured PA data suggested that within our sample the amount of PA was high across intervention and control groups at baseline and follow-up, indicating the existence of ceiling effects.

The present study was carried out in one Norwegian county, and one should therefore be careful when generalizing the results.

5. Conclusion

We designed a multi-component model of school-based PA that teachers were able to deliver effectively and we conducted a rigorous seven-month cluster RCT on the effects of this school-based PA program on an academic performance, with the largest sample to date of 10-year-old elementary schoolchildren.

We found no significant overall effect of the intervention on academic performance. However, there was a significant effect on numeracy among the children who initially performed the poorest (in the lower-third tertile of numeracy). Our study therefore adds to a growing body of evidence that PA may be one way of improving academic performance in numeracy in some children (i.e., in those whose performance in numeracy is lowest). Thus, integrating PA and numeracy seems a viable model to stimulate learning in some schoolchildren. However, this study also supports the notion that there is still inadequate evidence to conclude that increased time in school PA or PE enhances academic achievement in children throughout the population (Keeley and Fox, 2009; Howie and Pate, 2012).

Competing interests

WvM is director-shareholder of VU University Medical Center spin-off company Evalua Nederland B.V. ("http://www.evalua.nl") and non-executive board member of ArboUnie B.V. (www.arbounie.nl). Both companies are active in the Dutch occupational healthcare market.

Abbreviations

ASK	active smarter kids
cluster RCT	cluster randomized controlled trial
cm	centimeter
C-schools	control schools
CV	coefficient of variation
ICC	intraclass correlation coefficient
I-schools	intervention schools
kg	kilogram
LPA	light-intensity physical activity
MVPA	moderate-to-vigorous intensity physical activity
PA	physical activity
PE	physical education
SED	sedentary time

Transparency document

The Transparency document associated with this article can be found, in online version.

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