

English abstract

Title

Count on your body - The effect of classroom-based physical activity on academic achievement in math

Background

As a cornerstone in the development of modern society, the educational system receives continuous attention from policy-makers, educators and citizens. In general, the intention is to optimize educational programs so that children can learn the academic skills that will enable them to improve the future for their societies and families. Prioritizing within the educational system has typically been based on a dualistic perception where mind and body are two separate systems and are composed of entirely different material.

Maximum academic achievement is thus reached by focusing the mind and minimizing disturbance from the body. Based on this point of view, educational reforms have emphasized longer school days with more time devoted to academic instruction and less time for physical activity (PA), e.g. in the form of physical education classes. However, research originating from a neurophysiologic perspective has found positive associations between general PA level or aerobic fitness and both educational outcomes and cognitive performance as well as brain function. Furthermore, research based on the theory of embodiment has shown improved understanding and memory of academic content learned with the body involved. PA as an integrated part of academic teaching may thus be a promising initiative, and reduction of PA does not help to enhance children's academic achievement.

Despite increasing evidence for an association between PA or fitness and cognitive performance, few high-quality longitudinal studies have examined the effect of PA on academic performance (rather than cognitive control or other educational outcomes). Furthermore, to the best of our knowledge, only three studies have assessed academic outcomes following the integration of PA into the classroom.

Aims

The aim of the thesis was to investigate the effect of integrating classroom-based, task-relevant physical activity in math lessons on math achievement, executive functions, aerobic fitness, and body mass index in elementary school children. We also objectively measured the physical activity levels of the intervention group and the control group receiving standard academic lessons.

Methods

The study was designed as a school-based, cluster-randomized controlled trial targeting schoolchildren in 1st grade, and was carried out between August 2012 and June 2013. Eligible schools in two municipalities in the Region of Southern Denmark were invited to participate in the study. After stratification by municipality, twelve schools were randomized to either intervention group or control group, comprising a total of 505 children (7.2 ± 0.3 years). The intervention lasted one school year (9 months) and was a classroom-based PA program that involved integration of PA related to the academic content into the math lessons delivered by the schools' math teachers.

The primary study outcome was change in math achievement, measured by a 45-minute standardized math test, and the impact was evaluated by the Cohens-d effect size.

Secondary outcomes were change in:

- Executive functions assessed as reaction time and accuracy in a modified Eriksen flanker task
- Aerobic fitness assessed as distance run in the Andersen 20m intermittent shuttle-run test
- Body composition assessed as Body Mass Index
- Teacher perception of classroom-based PA assessed by qualitative semi-structured interviews

Intervention compliance was assessed via objectively measured PA recorded by accelerometry during one week prior to baseline and follow-up measurements as well as retrospective teacher SMS questionnaires distributed after each school day in four separate weeks over the school year.

The normal physical education program differed between the two municipalities, with children receiving either 270 or 90 minutes of physical education (PE) per week. This difference was accounted for by stratifying the randomization by municipality and furthermore provided an opportunity to investigate the impact of the PA stimulus as a general task-irrelevant vs. a task-relevant stimulus. Thus post-hoc analysis was conducted examining the intervention effect on math achievement in four sub-groups including: i) Control ii) Extra PE iii) Active Math and iv) Active Math + Extra PE. It should be noted that the post-hoc analysis was underpowered and did not include randomization, so the results should be interpreted with caution.

Overall changes and sex-specific changes were assessed in a mixed models analysis.

Results

At baseline, the intervention and control groups were similar in regard to math score, executive functions, total PA and total time spent on medium to vigorous PA (MVPA). However, the control group was taller ($p<0.001$), more physically active during math lessons ($p<0.001$), and spent more time on MVPA during math lessons ($p<0.001$) as well as during school hours ($p<0.001$) compared to the intervention group. During the intervention period, the active math group had significantly higher physical activity level (117.0 counts/min, 95% CI 3.7; 230.2, $p=0.04$) and time spent on MVPA (3.1% of time registered, 95% CI 1.2; 5.1, $p=0.002$) during math lessons compared to the control group. Mean response rate on teacher SMS questionnaires was $55.9 \pm 32.5\%$, with responding teachers reporting initiation of PA in 70% of all math lessons. Approximately one-third of these lessons were reported to contain over 10 minutes of MVPA.

The 9-month active math intervention had a significant effect on the primary outcome of math achievement, with the intervention group improving their math score by 1.2 points (95% CI 0.4; 1.9, $p=0.002$) more than the control group. Expressed in percentage terms, the control and intervention groups improved their math scores by 22.6% and 30.5% respectively, corresponding to a change difference of 39%. The Cohen d effect size for group differences in the change in math scores was $d=0.38$.

Regarding secondary outcomes, a significantly smaller increase in body mass index (-0.3 kg/m^2 95%CI -0.5 ; -0.04 , $p=0.02$) was observed in the intervention group compared to controls, as well as a significant gender interaction term for accuracy on incongruent trial in the modified Flanker task ($p=0.03$). Aerobic fitness was not affected. Post-hoc analysis indicated that math achievement was not significantly affected by task-irrelevant Extra PE, whereas active math elevated math score significantly compared to controls. In addition, a combination of active math and extra PE appeared to be the most beneficial and increased math score significantly compared to controls ($p<0.001$) and to extra PE ($p=0.008$). Sex-specific post-hoc analysis indicated that boys and girls responded differently, and significant improvement in math score compared to controls was only observed in

boys.

The qualitative investigation suggested that the perception of the legitimacy of physical activity in academic lessons was deeply embedded in the individual teacher's educational beliefs and experiences. Creating opportunities for teachers to acquire planning skills and experience with this new approach to academic lessons as well as to develop a perception of the body as essential for learning and cognition appear critical for the success of the suggested initiatives.

Conclusions and perspectives

This thesis brings novel evidence of central importance in the pursuit for improved education for primary school children. Taken together, these results confirm the positive effects of involving the body in learning academic content through physically active academic lessons on a daily basis in the elementary school classroom. This means that we may need to reconsider cognition as well as the current approach in educational systems to acknowledge the body as a mediator for learning and understanding. If replicated, these findings should be taken into account in policy-making and educational planning so that physical activity can be justified, supported, and integrated into a modern educational system. It is possible that we could achieve higher academic standards for our children in elementary school and give them an even better basis for their future.

Further research should address how factors such as type, quality, intensity, and duration of physical activity can influence the learning outcome in math and other academic areas, and external validity should be prioritized to facilitate operationalization of research in schools. The teacher as mediator of physically active academic lessons will be of central importance, and a key aspect will be the role and motivation of teachers in such initiatives. Future interventions in this area must therefore be developed in collaboration with teachers and the school environment.