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Six physical education lessons a week can reduce cardiovascular risk in school children aged 6-13 years: a longitudinal study

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Abstract
Aims: Cardiovascular disease (CVD) originates during childhood and adolescence. Schools are potentially effective settings for early public health prevention strategies. The aim of this study was to evaluate the effect of six physical education (PE) lessons on children's CVD risk.
Methods: This longitudinal study in 10 public schools (1218 children, aged 6-13 years), 6 intervention and 4 control schools evaluates a natural experiment, where intervention schools tripled PE to six lessons per week compared to the mandatory two PE lessons in the control schools. Baseline (2008) and two year follow up measures were anthropometrics, aerobic fitness, blood pressure and blood samples providing lipids and measures for insulin resistance. Based on these variables, a composite risk score was calculated and used for further analysis. Multivariate multilevel mixed effect regression models were used to estimate effect of intervention taking the hierarchical structure of data into account. Individual, class and school were considered random effects. Intra class correlation (ICC) was calculated.
Results: Intervention significantly lowered mean of composite risk score with 0.17 SD (95%CI: -0.34 to -0.01). Six PE lessons per week had a beneficial effect on triglycerides (TG) levels (-0.18 SD, 95%CI: -0.36 to 0.00), systolic blood pressure (SBP) (-0.22 SD, 95%CI: -0.42 to -0.02) and insulin resistance (HOMA-IR)(-0.17 SD, 95%CI: -0.34 to 0.01)
Conclusion: Six PE lessons at school can reduce children's CVD risk measured as a composite risk score. The changes in risk score are considered substantial in the perspective of public health strategy for preventing CVD in later life.
Keywords: School-based intervention, metabolic health, CVD risks, children, prevention, public health.

Six physical Education Lessons a Week can reduce cardiovascular risk in School Children aged 6-13 years: a longitudinal Study

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Introduction

Although cardio vascular disease (CVD) is normally not expressed before adulthood, the natural history of CVD risk starts already in childhood [1-3], and CVD risk factors has been shown to track from childhood into adolescence and adulthood [4, 5]. Therefore, early and effective prevention of the risk factors leading to CVD is important [4, 6].
Primary schools have been pointed out to be potentially effective arenas for preventive strategies and promotion of healthy lifestyle [7]. School-based intervention studies have been conducted during the last two decades mainly focusing on increasing physical activity levels and preventing obesity. Recently studies have also focused on intervention effects on CVD risk factors [8-15]. However, design and methods of these studies differ and results are not univocal. In conclusion, the findings in these studies support that school-based intervention can affect and prevent some CVD risk factors in children, but more research is required regarding duration and volume of interventions in large-scale cohorts with long term follow up.
This study is part of the CHAMPS study-DK [16]. The objective of the present study was to evaluate the effect of four extra, adding up to six, PE lessons per week, on cardiovascular risk factors in children aged 6-13 years. The primary outcome was a composite risk score, and secondarily single risk factors included in the composite risk score.

Methods

Design

The CHAMPS study-DK is a longitudinal study and can be described as a quasi-experimental study evaluating a natural experiment[17] including 10 public schools – 6 intervention and 4 control schools. Public schools in Denmark are non fee-paying state schools funded from taxes and organized from local authorities in the municipality. Children attend school from the age of 6 (pre-school) to the age of 16 or 17 (9^{th} or 10^{th} grade). The study has been described in detail elsewhere [16]. Briefly, all 19 primary schools in the municipality of Svendborg, Denmark, were invited to participate in the project as sports (intervention) schools. Ten of the 19 schools agreed to be sports schools, but only six schools were willing to prioritize the financing of the extra PE lessons. The municipality was asked to obtain matched control schools amongst the 13 schools doing "business as usual". The six intervention schools and the four control schools were matched according to school size, urban/rural area and socio-economic position. In this way there were n=773 and n=734 children in interventions and control group respectively, as possible participants. Parents and children were unaware of the initiation of this project until two months before the following school year, thereby avoiding parents influencing school choice [16]. All children and parents from the 10 participating schools received information about the study through school meetings and written information. Parents signed informed consent forms for joining the project. Participation was at any time voluntary. Permission to conduct The CHAMPS study–DK was granted by the Regional Scientific Ethical Committee (Region of Southern Denmark) (Project number: S-20080047).

The school-based PE program - Intervention

The school leaders and PE teachers at the intervention schools were invited to design the set-up for an optimal PE intervention. The six intervention schools chose to implement four additional PE lessons per week to their usual PE program (resulting in a minimum of 4.5 hours PE per week divided over at least three sessions of at least 60 minutes). Furthermore, all PE teachers were educated in specific age-related training principles, developed by Team Denmark, focusing on children's physical, physiological, mental and social development to enhance and optimize motor sport skills[18]. Control schools continued their regular PE curriculum with two PE lessons/week resulting in 1.5 hours/week[16], which is mandatory in Denmark at a national level.

Participants

A total of 1507 children attending pre-school to the 4th grade in 2008 were invited to participate in the CHAMPS study-DK and 1218 children (age 8.4, range 5.4-11.6 years) and their parents accepted.

All measurements were carried out by trained staff at the children's schools from late August to early October in 2008 and 2010. Only children with complete data at both time points were included in the analysis of the composite risk score. The number of participants included in the analyses on single risk factors varied according to completeness of data (Figure 1).

Anthropometrics

Weight was measured to the nearest 0.1 kg on an electronic scale (Tanita BWB-800S, Tanita Corporation, Tokyo, Japan) with the children wearing shorts and t-shirts. Height was measured to the nearest 0.5 centimeter (cm) using a portable stadiometer (SECA 214, Seca Corporation, Hanover, MD). Both anthropometrics were conducted barefooted. Body mass index (BMI) was calculated as [weight (kg)/height^2 (m)].

Waist circumference (WC) was measured to the nearest 0.5 cm at umbilicus level after a gentle expiration. Two measurements were undertaken and a consecutive third measure performed if the difference between the first two measurements exceeded 1 cm. An average of the two nearest measurements were calculated and used in the analysis.

Pubertal stage

Puberty was self-assessed. The Tanner pubertal stages self-assessment questionnaire used in this study consisted of drawings of the 5 Tanner stages [19, 20]. Explanatory text in Danish supported the self-assessment. Due to very few above Tanner Stage 2 (less than 2%) puberty was dichotomized into pre-pubertal (Tanner Stage 1) and pubertal (Tanner Stages 2-5) for the analyses.

Blood pressure

Blood pressure was recorded with a suitable cuff size on the left arm using an automated blood pressure monitor (Welch Allyn®, Vital Signs Monitor, 300 Series with FlexiPort™ Blood Pressure). The child was resting in the sitting position for 5 minutes before monitoring. The five subsequent values were recorded with 1-minute intervals or until the last three values had become stable. Mean of the three last recordings of systolic blood pressure (SBP) was used in the analyses.

Blood samples

Fasting blood samples were obtained between 8.00 and 10.00 in the morning of testing. Samples were kept on ice and handed in to the laboratory within 4 hours and kept at -80 degrees Celsius until analyzed. TC, TG, HDL-C and glucose were analyzed by quantitative determination using enzymatic, colorimatic method on Roche/Hitachi cobas c systems. Insulin was analyzed using solid phase enzyme-labeled chemiluminescent immunometric assay.

Total Cholesterol:HDL-C ratio (TC:HDL) was calculated. A Homeostasis Assessment Model (HOMA-IR) score was calculated from insulin (μU/ml) x glucose (mmol/l)/22.5 as described by Matthews et al [21]. HOMA-IR is reliable as a measure of insulin resistance in large scale and general populations [22, 23].

Cardiorespiratory fitness (CRF)

CRF level was assessed by the Andersen test, a 10 minutes intermittent running test validated against directly measured maximal oxygen uptake [24]. The total distance measured in meters was the test result. Validity and reliability of this field test was tested on a sub-sample within the study sample [25].

Composite risk score

A composite risk score was created for analysis by summing z scores for logHOMA-IR, SBP, logWC, logTC:HDL and logTG and subtracting fitness level. A low value of composite-risk score is considered healthier than high values of composite-risk score.

Statistical Analysis

To estimate the effect of the extra PE lessons, multivariate multilevel mixed effect regression analysis using hierarchical models were used based on the intention to treat principle. Individual, class and school were considered random effects. Intra class correlation (ICC) was calculated to compare the variation between school and school classes as a fraction of the total variance. Analyses were adjusted for baseline values of outcome, age, gender and puberty (and height when WC was the outcome variable). Effect modification by gender, age, puberty and above/below the median in composite-risk score at baseline was explored by adding an interaction term between the moderator and school type (intervention versus control). If the p value of interaction term was <0.10, subgroup analyses were performed.

Multilevel regressions were performed on all covariate values at baseline to test significance of difference between children intervention and control groups, and between children with complete data sets and those with missing data or lost to follow up.

WC, HOMA-IR, TC:HDL ratio and TG, but not CRF and SBP, were slightly skewed, and therefore log transformed before used as single risk outcome variable and before z scores were made for the composite risk score.

Sensitivity analysis were performed imputing missing values on the outcomes and covariates (n=140-450) using chained equations ("mi impute chained" in STATA) including all other covariates (respective outcome at baseline, age, gender, pubertal status, school type) and random effects (indicators for school class and school)[26]. Beta coefficients and standard errors (SE) were obtained based on 20 imputed datasets.

All analyses were carried out in STATA (version12.1) with $\alpha=0.05$ (two-sided).

Results

Out of 1507 invited children from the 10 public schools 1218 (81%), 697 out of 773 (90%) from intervention schools and 521 out of 734 (71%) from control schools gave written consent (Figure 1). At baseline, 907 (75 %) of all participants had measurements of all single CVD risk factors and 878 (73 %) at follow up. In total, 712 (59 %) had complete data on the main outcome at both time points (see figure 1). Participant's characteristics are presented in Table 1.
At baseline, the group of children included in the analysis, mean age 8.5 (range 5.7 to 11.4) were taller, had lower BMI and a higher proportion were pubertal compared to children not having complete data for composite risk score at both time points, see Table1. Children with non-complete data had significantly worse baseline values of TG, TC/HDL, WC and CRF, but not composite risk score, SBP, HOMA- IR, compared to children with complete data (in sample). There were no differences in any baseline values between children at sports schools and control schools in the sample, see Table 1. Sensitivity analysis imputing missing values in a multiple imputation did not change estimates of association for any of the CVD risk scores (estimates available in supplementary Table 1).

Composite risk score changed significantly more in favor of children attending intervention schools compared to children attending control schools (β-0.17 SD, CI 95%:-0.34 to - 0.01, ICC 0.15). SBP and logTG changed significantly more in intervention schools compared to control schools (β-0.22 SD, CI 95%; -0.42 to -0.02, ICC 0.13) (β -0.18 SD, CI 95%; -0.36 to 0.00; ICC 0.12) respectively. Also changes in logHOMA-IR were in favor of the children attending intervention schools, but were border line significant (β -0.17 SD, CI 95%;-0.34 to 0.01; ICC 0.09). The ICC's reported are estimate for the fraction (%) of the variation explained by class clusters. School clusters, as random effects, did not explain a significant fraction of the variation. The difference in changes between intervention and control for TC: HDL, WC and CRF were small and insignificant. An overview of the adjusted effect estimates on z scores is displayed in Figure 2.
No effect modification by age, gender or puberty was found. Interaction for those above versus below the median of composite risk score was significant (β -0.29 SD, CI 95%: -0.5 to -0.07, p=0.008). Difference in changes between the children with a composite risk score above the median showed that those "at risk" had a significant greater benefit of intervention compared to the children with the least favorable risk score at control schools (β -0.32 SD, CI 95%; -0.19 to -0.01, ICC 0.10) and also compared to children not at risk (below the median). An illustration of the differences in changes in z scores of composite risk score is presented in Figure 3.

Discussion

This quasi-experimental study evaluating a natural experiment showed that six PE lessons per week significantly changed children's composite CVD risk score in favor of the children attending intervention schools. These results, proving considerable effect sizes for the whole sample and an even higher effect size for the children with the poorest risk score, suggest that a simple and relatively easily adaptable intervention potentially could affect future public health if sustained.

Other school-based interventions aiming at reducing CVD risk factors in childhood have observed divergent effects. Two studies, comparable to the CHAMPS study-DK, used a risk score similar to the one we used. Bugge et al [8] used a composite risk score constructed from sex specific sum of z-scores for SBP, TG, TC:HDL, HOMA-IR and CRF but added the sum of four skinfolds instead of WC. No significant effect on a composite risk score as a result of a three-year intervention program with four PE lessons per week was observed, suggesting that doubling the amount of PE lessons might not be enough to reduce CVD risk factors. Kriemler et al [13] used, as a secondary outcome, a sum of z scores of TG, inverted HDL cholesterol, glucose, mean blood pressure and WC and found a significant reduction in CVD risk factors after one year of intervention with five PE lessons per week and additional physical activity homework. Results of these two comparable studies support the hypothesis that in order to reach an effect of extra PE in a healthy pediatric population, the magnitude of the intervention must approximate 5-6 PE lessons per week or one hour per day. This speculation is supported by the study of Resaland et al[9] who found significant reductions in single CVD risk factors (blood pressure, VO^2peak, TG, and TC:HDL) after two years of intervention with 60 minutes of PE per day by trained teachers. In contrast to our findings, Resaland and Kriemler observed significantly increased levels of CRF, which is considered a strong predictor of CVD risk [27]. The results of three school based intervention studies with no significant effect on CVD risk [10, 14, 15] support the idea that a certain volume and intensity is needed in order for an intervention effect to occur, since the intervention program in all of these studies were either of short duration (8 weeks) or small volume (revising existing PE lessons).

The analysis on the single risk factors included in the composite risk score in our study suggest that the major contribution to decreased risk was due to considerable changes in SBP, HOMA-IR and TG and less due to changes in TC:HDL, WC and CRF.

The absence of any effect observed on CRF and WC in the present study is somewhat surprising, as these factors are thought to be essential to the underlying cause of the multifactorial development of a poor risk profile. Intervention effect on CRF has substantially been shown in other school based studies [7]. An effect on WC could have been expected as we have previously shown that the intervention had preventing effect on the prevalence of overweight and obesity as well as a decreasing effect on total body fat percentage (unpublished data). One explanation for the lack of observed effect on these outcomes in our study could be that the majority of Danish schoolchildren are normal weight and in general have healthy CRF levels, and consequently a change in mean values are not likely to reach significance. Another plausible explanation could be that the primary focus in the intervention program was to ensure joy of moving and playing by enhancing age related motor skills. Consequently, we speculate that the intensity level in the PE lessons might not have been enough to improve CRF levels. Furthermore the impact of intervention on change in physical activity levels is not yet evaluated in the project, therefore a compensation of the increased PA at school in leisure time PA, cannot be rejected.

A borderline significant effect on logHOMA-IR was observed in this study. Children attending intervention schools decreased their score 9% more than children at control schools. The most comparable studies to the CHAMPS study-DK regarding volume and duration of the intervention program [8, 9] showed no significant effect on HOMA-IR except for boys in the CoSCIS study [8]. In the study by Resaland et al [9], introducing 60 min of PE per day, no effect on HOMA-IR was observed despite a significant increase in cardiorespiratory CRF in the intervention group. This is in contrast to our findings where no intervention effect was observed on CRF, even though an effect on HOMA-IR was observed.

Our result on TG is supported by two other school-based studies [9, 13] with similar effect sizes, but not in the CoSCIS [8]. The difference in change of the logTG equals a 7% greater improvement in TG values in the intervention group compared to the control group (in which TG values actually rose). The clinical relevance of this change is difficult to estimate, but it equals a beneficial change of -0.18 SD compared to the control group.

The observed results on SBP in our study are supported by the studies of Resaland et al [9] and McMurray et al. [11]. Bugge et al [8] found only an effect for boys and Kriemler et al [13] found no effect on blood pressure despite a significant effect observed on physical activity and CRF levels.

The size of effect on SBP β-1.72 mmHg (equaling β - 0.22 SD) will, if sustained until adulthood, have a considerable impact on future public health since as little as a 2mmHg downward shift in the blood pressure distribution of the general population could result in an annual reduction in stroke, coronary heart disease, and all-cause mortality of about 6%, 4% and 3%, respectively [28].

As a primary outcome we chose a composite risk score. Clustering of risk factors occurs in children, and a composite risk score is a better measure of CVD risk than single risk factors [29, 30]. The single risk factors were not weighted in the calculation of the summed composite risk score in the present study. Therefore, the score might not capture the true picture of clinically "at risk", however little is known as to whether single risk factors should be weighted differently or not.

Strength and limitations

Since participants' persistence and adherence to measurements is crucial for high validity of research results, the high number of participants at follow up in the present study is regarded as strength of the study.

Given the nature of a natural experiment, the researchers had no influence or control regarding the content and intensity of the PE lessons besides the anticipation, that the teachers followed the age-related concept. It is of great importance in the scope of public health, that intervention and the observed results are not dependent on researchers or experts set up of intervention and therefore considered directly transferable into the daily praxis in other school settings and at relatively low costs. Furthermore compliance to intervention is considered high as none of the participating schools reported any issues on accomplishing the mandatory extra PE lessons. The municipality of Svendborg has subsequently sustained the four extra PE lessons and expanded the concept of sports schools to more classes (pre-school to 7th grade) making health promotion and prevention a part of the public school agenda.

It is a limitation to this study that the quality of the PE lessons was not monitored as part of the research project and that intervention and control schools were matched, not randomized, which would have eliminated the risk of confounding. The cohort consisted of a majority of healthy, normal weight Caucasian children; hence generalizability of our results might be limited to other ethnic groups. Pubertal status was assessed by self-reported using the Tanner Scale, and though this method is validated in adolescents [19] we cannot ensure that their pubertal stage is not over- or underestimated, and it was surprising that more boys at baseline reported being pubertal (> Tanner stage 1) than girls. Finally, the high attrition rate may have further affected the generalizability of our findings, but since associations in imputed and not-imputed samples were fairly similar we have confidence that the results are not explained by selection bias.

In summary, the CHAMPS study-DK shows that mandatory PE intervention with six lessons per week in public schools can reduce CVD risk factors in children. The size of effect observed in this healthy pediatric cohort, with larger effect in the subgroup with the poorest composite risk score, which encompasses the children in need of prevention, emphasizes the potential for school based intervention programs to be an important strategy for primary prevention in public health. "Future research in school-based interventions could profitably focus on implementation of effective interventions – focusing on frequency, intensity, duration and adherence to constitute sufficient quality of mandatory PE lessons."

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Author contributions

HK had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors contributed to important parts of the process: Study concept and design: HK, NW, LBA. Acquisition of data: HK, MH, NC. Analysis and interpretation of data: HK, NW, LBA. Drafting of the manuscript: HK. Critical revision of the manuscript for important intellectual content: HK, NC, NW, MH, LBA. Statistical analysis: HK, LBA, NW. Obtained funding: NW, LBA.

Declaration of Conflicting interests

The Authors declare that there is no conflict of interests

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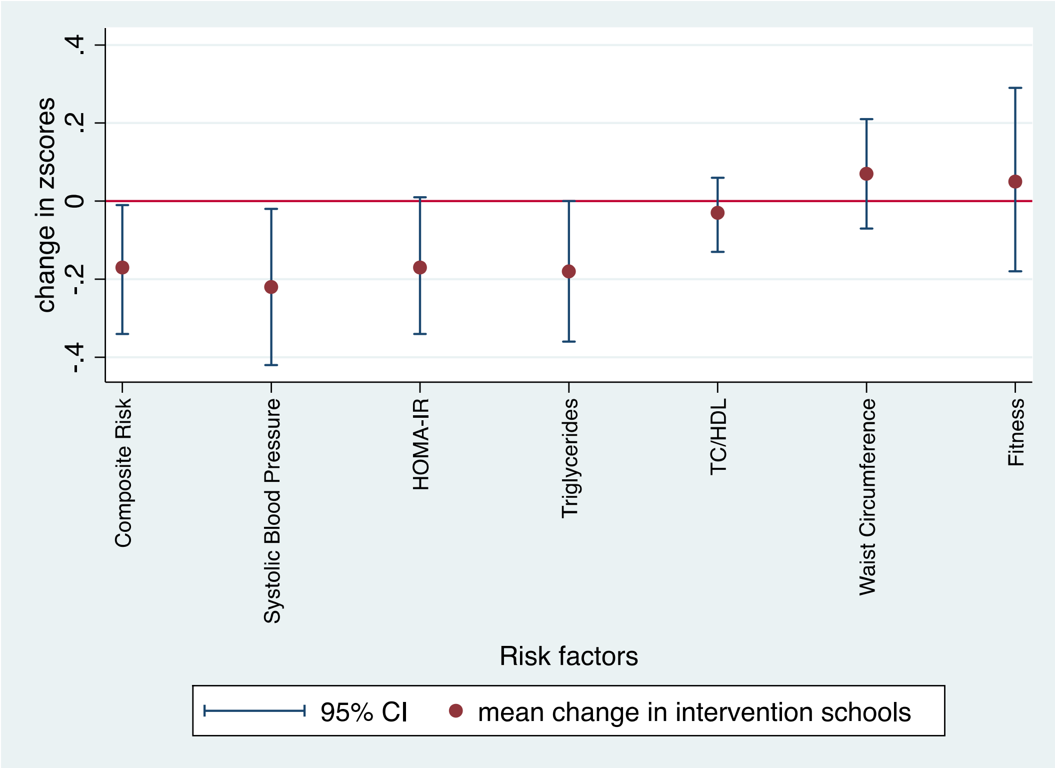
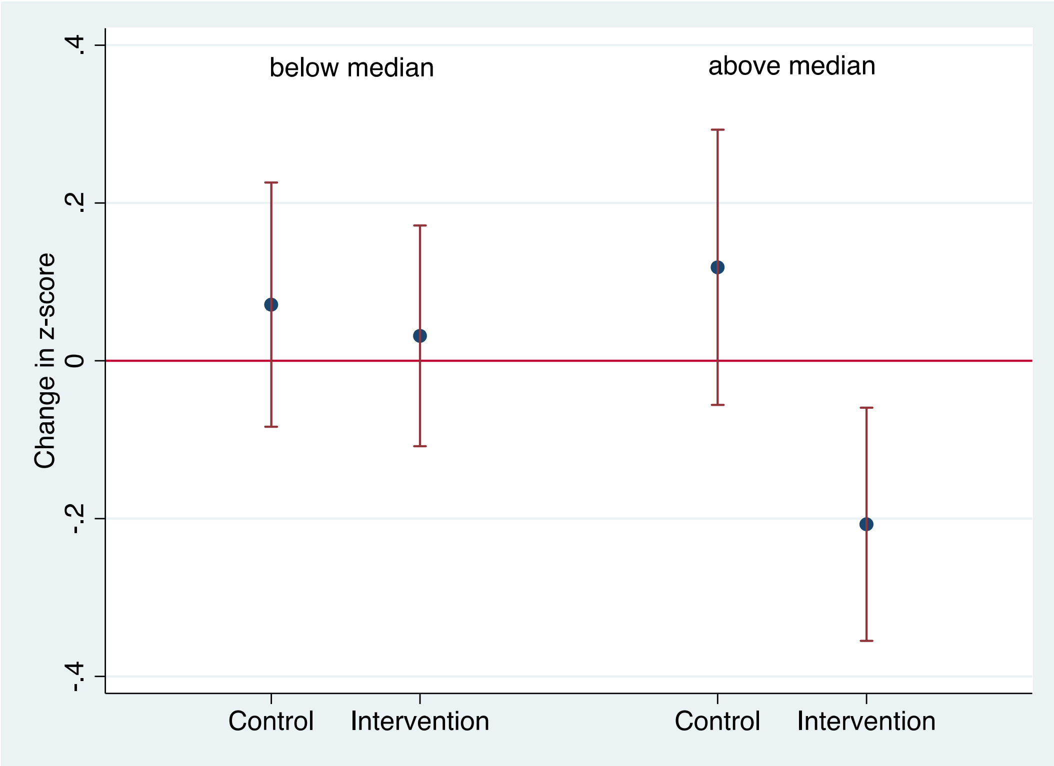
Figure 2: Difference in change in composite and single risk scores between intervention and control schools during two school years (expressed in z scores)



Estimates adjusted for age, puberty, gender and baseline values

Figure 3:

Difference in changes in risk scores between children with a composite risk score above or below the median at intervention and control schools.



Circles representing mean. Vertical bars representing 95% CI.

Estimates adjusted for age, puberty, gender and baseline values