Impacts of an Intervention to Reduce Sedentary Behaviour on Measures of Obesity in Primary School Children: A Cluster Controlled Study

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Potential conflicts: Dr Mike Loosemore developed the Active Movement programme. He is the co-owner of the company that own the rights to the Active Movement programme.

Abstract

Background

Sedentary behaviour in children is an independent risk factor for poor health. *Active Movement* is a multicomponent school-based intervention intended to reduce sedentary behaviour and integrate low level activity into normal school routine. We sought to assess its impact on Waist to Height Ratio (WTHR, a measure of obesity), in primary school children from a low socioeconomic area in the UK.

Methods

A cluster-controlled study was performed. Participants were recruited (n=214) from three-year groups (age 5-6 years, 9-10 years and 10-11 years; years) in each of two schools. In the intervention school, *Active Movement* was introduced (n=140). Another school acted as a control (n=74). Participants were studied at both sites over one academic year (September 2016 and July 2017). The primary outcome measure was WTHR, the secondary outcome being behaviour change (physical activity) measured by self-reported questionnaire.

Results

WTHR fell significantly in the intervention school compared to the control (9.1% vs. 3.2% decrease $P<0.0001$) the effect was consistent across all year groups ($p=0.006$, $p<0.001$ and $p<0.001$ for years 1, 5 and 6 respectively). Self-reported physical activity increased in the intervention school (95% CI) = 0.62 (0.36,0.88) $p<0.0001$) but not in the control school (95% CI) = 0.17 (-0.15, 0.49), $p=0.28$).

Conclusions

The introduction of *Active Movement* - a simple, cheap behavioural intervention - appears to improve physical activity levels and reduce obesity in schoolchildren in a deprived area of London. Further studies are required to confirm these findings and, if successful, to improve the intervention and its impacts.

Background

The National Child Measurement Program (NCMP) studied over one million children in England. The proportion of primary school children who were overweight or obese in 2016-17 rose from 22.6% in year 1 (aged 5-6 years) to 34.2% in year 6 (aged 10-11 years)[1]. The 2016-17 NCMP also showed that obesity is strongly associated with social deprivation: 12.7% of children starting school in the most deprived areas were obese, double the rate found in those living in the least deprived areas (5.8%). By year 6, the rates were 26.3% vs 11.4 % respectively. This deprivation gap has increased over the last ten years[2]. Such childhood obesity increases the risk of cardiovascular [3-5] and metabolic disease in adulthood, [6 7] is associated with reduced academic performance[8 9], hyperlipidaemia, hypertension, insulin resistance, poor pulmonary function[10], poor psychological and emotional health, poor sleep and bullying[11]. Children with obesity tend to become adults with obesity[3]. The World Health Organisation thus refers to childhood obesity as '*one of the most serious public health challenges of the 21st century*'[12].

Sedentary behaviour is defined as any waking behaviour characterised by an energy expenditure of ≤1.5 metabolic equivalents (METs), whilst in a sitting, reclining or lying position[13]. Data from 10 countries show that children 2-5 years were spending 34-94% of the day sedentary in 2013[14]. In England the total daily sedentary time, assessed by accelerometer, increased with age from 6-7 hours per day at age 4-7 years to 8-9 hours per day at age 12-15[15]. UK schoolchildren spend 65% of their school hours sedentary[16 17]. Reflecting the findings for obesity, the most deprived socio-economic populations also have the highest sedentary behaviour rates[16 18] . Children in the lowest quartile of household income are about twice as sedentary as children in the highest quartile of household income.[16]

Both reduced levels of physical activity[7] and sedentary behaviour[8 19 20 21 22] contribute to a lower metabolic rate, when at rest, which drives childhood obesity and its related cardio-metabolic disease, all-cause mortality and both psychological and physiological problems[23-25]. Such negative health impacts appear independent of those that result from low physical activity levels[20 26]. As a result, there has been a call to target sedentary behaviour as well as increasing physical activity in order to combat the 'obesity epidemic'[27]. Such action in childhood may benefit adult health, given that such behaviour carries over into adulthood[28]

Ideally, such interventions should be cheap, easy to deploy and cost-effective. The *Active Movement* intervention was designed to reduce sedentary behaviour and to integrate low level activity into the daily routine of primary school children through a multicomponent behavioural change model. We performed a cluster control study to assess its effect on WTHR, seeking confirmation of impact through assessment of self-reported reduction in sedentary behaviour.

Methods

Study Design

A cluster-controlled trial of pupils from 2 primary schools was conducted over 1 school year from September 2016 to July 2017. Ethical approval for the study was obtained from the University College London Research Ethics Committee (application reference 722/002).

Participants

Two state primary schools within 0.5 miles of one another in the London borough of Haringey were recruited for the study. The children of one school were used as the control and of the other as the intervention group. Both schools were from a Lower Layer Super Output Area, defined in the England Indices of Deprivation 2015 as those in the 5-10% most socio-economically deprived areas in the country[29]. The ethnic mix of both schools was highly diverse with children from 27 different countries represented as well as mixed race children, the majority coming from black and Asian backgrounds. The racial mix in both schools was similar.

Procedures

Information sheets were provided to the head teachers, parents and pupils. Written consent was obtained from both head teachers. Parents could withdraw consent for their child from taking part. Only 1 childs' parents withdrew consent. Baseline data was collected at the beginning of the school term in September 2016 (Control n=80, Intervention n=146) and post-intervention measures (Control n=74, Intervention n=140) were collected after one school year. This included a behavioural questionnaire, height and waist circumference. For the measurements, subjects wore school uniforms (jumpers and shoes removed). Height was measured to the nearest 0.5cm with a wall mounted stadiometer ruler (ADE, Hamburg Germany). Waist circumference was measured to the nearest 0.5cm with an anthropometric tape measure (NCD medical Ltd. Ireland) taken at the umbilicus through one layer of clothing in a relaxed standing position. All measurements were taken by trained researchers who were UK Disclosure and Barring service cleared. Where possible, a researcher of the same gender conducted the anthropometry and always in the presence of at least 2 researchers and a school teacher. The PAQ-C questionnaires[30] were handed out pre and post intervention during class time by the usual classroom teacher, for the children to complete.

Intervention

The 'Active Movement' programme is designed to integrate non-sedentary behaviour and low-level activity into the child's normal school routine[31] without disrupting the curriculum. The intervention was led by the teaching staff. The aim was to educate the children in the positive aspects of a healthy lifestyle and positively influence sedentary behaviours from an early age before negative habits can develop. This is achieved by introducing standing and low-level movement during normal classroom teaching and throughout all aspects of the school life and at home. This was achieved through a poster campaign around the school and 'homework' for the children. Examples of changes in the teaching practice would be standing to answer questions instead of raising hands, homework to encourage parents to stand during advertisement breaks while watching television.

Teachers received a formal one-hour training session at the start of the intervention, followed up by a forum at mid-intervention. During these sessions, teachers were educated on the harm attributed to sedentary behaviours and the benefits of reducing this. Teachers were given ideas on how they could integrate non-sedentary and low-level movement into their classrooms and encouraged to create their own ideas.

At the launch, the lead researchers took a children's assembly to introduce the programme and held a parent briefing session. To support these changes, promotional and educational material were placed around the school to inspire and motivate the children. This was supported by holiday homework, activities and challenges. Parents were informed of the progress of the programme through 6 newsletters through the academic year.

Outcome measures

The primary outcome measure was the WTHR, this is recommended as the most accurate measure of obesity in children[32]. The secondary outcome measure was the change in self-reported physical activity, derived through completion of the Physical Activity Questionnaire-Children (PAQ-C)[30]. The questionnaire was designed to assess children's physical activity levels for the proceeding 7 days. Wording was modified from the original, for use in UK English speaking schools (appendix 1). The PAQ-C questionnaire was designed to provide a general measure of PA for children aged 8-14. Each item on the questionnaire can be scored out of 5, with the mean of the 9 questions used as a summary activity score, ranging from 1-5.

Statistical analysis

WTHR values were log transformed before analysis to obtain a normal distribution and values were summarised as geometric mean and approximate SD. Within school changes in values were assessed using paired t-tests, and differences in mean changes between schools by unpaired t-test**.** Within subject mean changes were transformed back to obtain a percentage change. B coefficients and standard errors for school were obtained to show the size of the difference in mean change (for $\log_e$ WTHR) between the two schools. As using ratios in regression models can lead to spurious results, the result was validated using a regression model with change in log circumference as the dependent variable and baseline circumference, baseline and change in height, and school as dependent variables[33].

As the schools differed significantly in baseline WTHR, a sensitivity analysis was conducted. Pupils from the control school were matched 1:1 with pupils from the intervention school using nearest neighbour matching, based on their WTHR. Changes were compared between control pupils and matching intervention pupils using a paired t-test.

Activity score: Activity score was calculated as described in the PAQ-C manual[30]. Each item on the questionnaire was scored on a 5-point scale and the mean of the 9 items was calculated for use as a summary activity score with values ranging from 1 to 5. Scores were approximately normally distributed. Within school changes in activity score were assessed using paired t-tests and differences in mean changes between schools by unpaired t-test. In addition, analysis of covariance models were fitted with change in score as the dependent variable and baseline activity score as a covariate to account for any baseline differences in activity level between schools. B coefficients and standard errors for school were obtained to show the size of the difference in mean change between the two schools.

As only one school received each intervention it was not possible to look at variability between schools for the same intervention or to separate the intervention effects from any other changes that may have occurred within the schools.

Results

A total of 226 children (n=80 controls and n=146 intervention) were recruited to the study in September 2016. Follow up occurred in July 2017. Attrition was low, with only 12 children not recording baseline and end of intervention results - 6 participants from each group (n=74 controls and n=140 intervention). This left complete data for 214 participants. No adverse events were recorded from the study.

Waist to Height Ratio

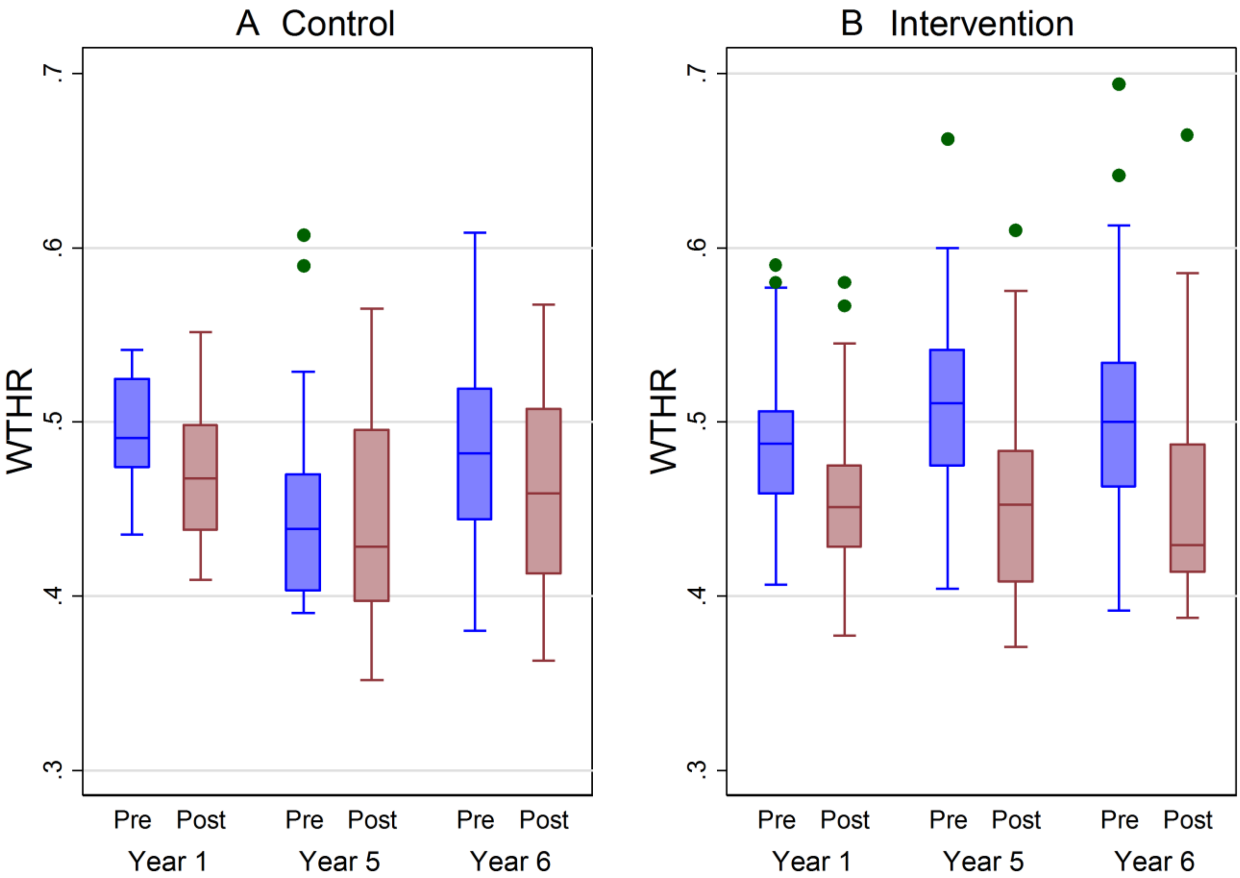
WTHR results for the combined year groups are shown in table 1. WTHR decreased significantly in both schools (9.1% intervention, $p<0.0001$ and 3.2% control, $p<0.0001$). The decrease was significantly greater for the intervention school (b (se) = -0.063 (0.010), $p<0.0001$). The validation regression model using change in log circumference as the dependent variable gave an almost identical effect size and p values (b (se) = -0.064(0.010), $p<0.001$).

Table 1 WTHR by Time and school: Combined data from all age groups.

WTHR	Control N=74	Intervention N=140	P value (Between schools)
Pre (Mean SD)	0.473 (0.053)	0.498 (0.051)	0.001
Post (Mean, SD)	0.458 (0.112)	0.453 (0.051)	0.45
% Change (95% CI)	-3.2% (-4.6, -1.7)	-9.1% (-10.2, -8.1)	B* (se) =-0.063 (0.010) P<0.0001
P value (within schools)	P<0.0001	P<0.0001	

*B is the difference in mean change ($\log_e$ scale) between schools.

Results stratified by year group are shown in figure 1. The effect of the intervention did not differ by year (treatment by year interaction $p=0.61$), with intervention effect sizes (SE) of -0.047 (0.017) $p=0.006$, -0.092 (0.017) $p<0.001$ and -0.060 (0.016) $p<0.001$ for years 1, 5 and 6 respectively.



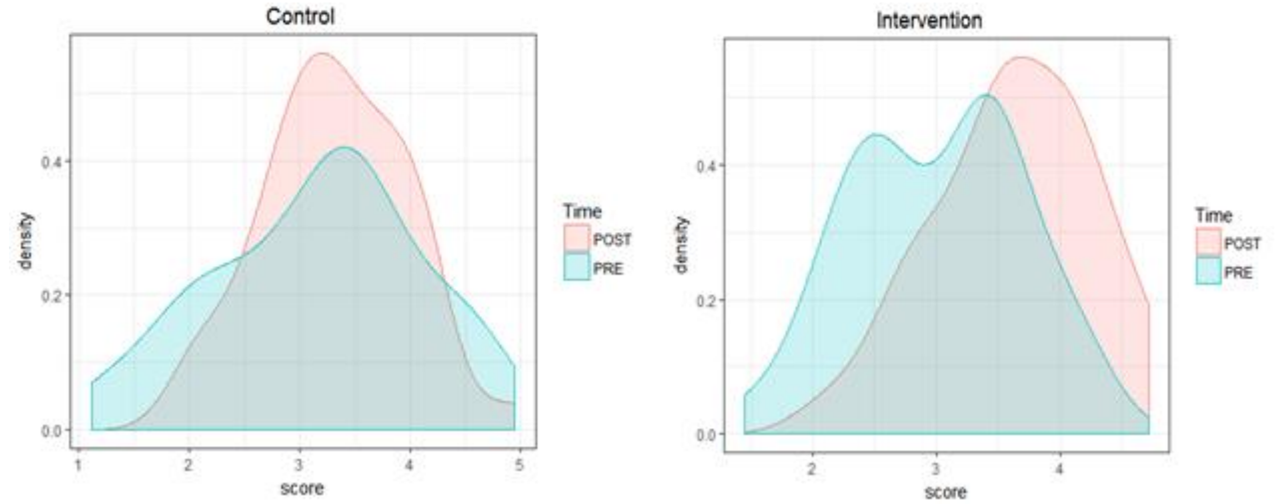
Sensitivity analysis using pupils matched according to baseline WTHR confirmed the significant differences in change between schools overall and in years 5 and 6 (table 2), with overall decreases of 8.3% in the intervention school compared to 3.5% for the control school.

Table 2: Sensitivity analysis: Change in WTHR by school for matched data.

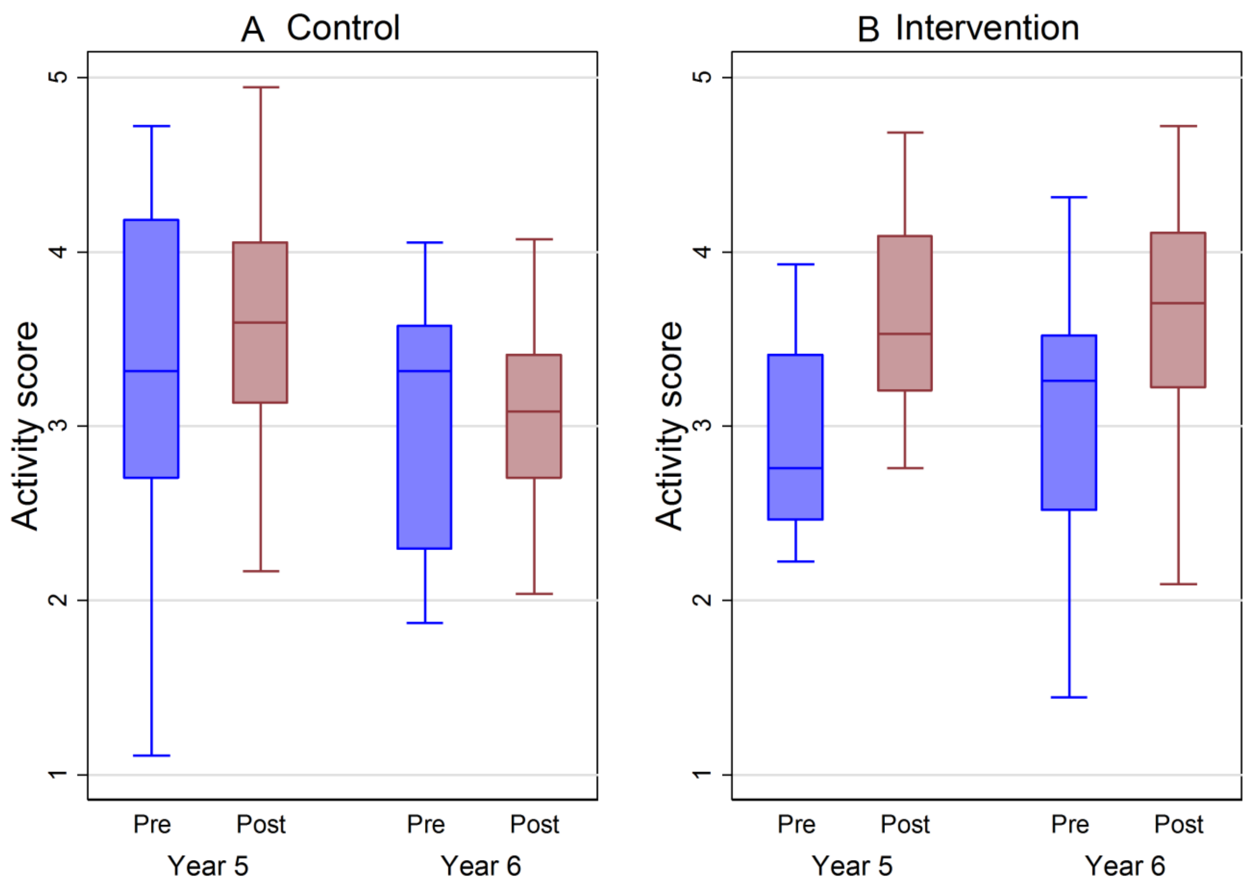
OVERALL	Control	Intervention	Difference (SE) P value
% Change (95% CI)	-3.5% (-5.0, -1.9) N=74	-8.3% (-9.7, -6.8) N=74	-0.051(0.011) P<0.001
YEAR 1			
% Change (95% CI)	-4.7% (-7.3, -2.0) N=24	-6.3% (-8.1, 4.5) N=24	-0.017 (0.018) P=0.35
YEAR 5			
% Change (95% CI)	-1.7% (-4.6,1.3) N-23	-10.8% (-13.1,-8.5) N=23	-0.097 (0.018) P<0.001
YEAR 6			
% Change (95% CI)	-3.8% (-6.3, -1.3) N=27	-7.8% (-10.7, 4.7) N=27	-0.042(0.019) P=0.036

Activity Questionnaire Score

Self-reported activity levels for the combined year groups are shown in table 3. Activity increased significantly in the intervention school ($p<0.0001$) with no significant change in the control school ($p=0.28$). The difference between the schools in the change in activity score was significant (B (se) 0.45 (0.20), $p=0.03$). This difference remained significant after adjusting for baseline activity levels and year (B (se) = 0.36 (0.14), $p=0.01$). The shift in the distributions of activity score before and after intervention are shown in figure 2.



Results stratified by year group are shown in figure 3. The effect of the intervention did not differ by year (treatment by year interaction $p=0.61$), with intervention effect sizes (SE) of 0.42 (0.30) for year 5, and 0.52 (0.28) for year 6.



The control group showed significant increases in only two questionnaire items – walking and PA at lunch. The intervention school showed significant increases in all items except PA at break, PA in the evening and PA at the weekend.

Table 4: Change in individual activity score items

	Control		Intervention		P value
Item	**Change (se)**	**P value**	**Change (se)**	**P value**	**Intervention vs. control**
Walking	0.95 (0.28)	P=0.002	1.64 (0.27)	P<0.0001	P=0.08
PE	0.42 (0.25)	P=0.11	0.51 (0.18)	P=0.008	P=0.77
PA break	0.33 (0.30)	P=0.27	0.16 (0.25)	P=0.53	P=0.65
PA lunch	0.64 (0.21)	P=0.02	0.66 (0.33)	P=0.05	P=0.97
PA after school	0.13 (0.29)	P=0.66	0.51 (0.24)	P=0.04	P=0.31
PA evening	-0.44 (0.28)	P=0.13	0.18 (0.22)	P=0.41	P=0.09
PA weekend	-0.36 (0.27)	P=0.20	-0.03 (0.26)	P=0.92	P=0.38
Last 7 days	-0.18 (0.24)	P=0.47	0.97 (0.26)	P=0.0006	P=0.002
PA per day	-0.01 (0.22(	P=0.95	0.97 (0.19)	P<0.0001	P=0.001

Discussion

We have shown that a simple and cheap intervention targeting sedentary behaviour in children aged 5-11 is effective in reducing WTHR, a marker of children with obesity. WTHR fell by 3.2% in the control group but by three times as much (9.1%) in the intervention group (P<0.0001). This effect was independent of age group. Confidence in this finding comes from matched analysis, with controls in each age group matched 1:1 with the intervention pupils using 'nearest neighbour matching', based on their baseline: WHTR fell by 3.5 in the control vs 8.3% in the intervention groups, p < 0.0001. Matched analysis by year group again showed a greater reduction in years 5 and 6 (P<0.001), but not in year 1 (p=0.35) a result which might relate in part to powering (there were only 48 individuals in this group, 24 and 24 in control and intervention groups respectively). Confidence is further enhanced by the finding that self-reported physical activity increased significantly in the intervention school (p<0.0001) but not in the control school (p=0.28).

As far as measurements of obesity are concerned, programmes which deliver exercise within lessons all report small effect size[34-38]. Active Movement, on the other hand, had very dramatic impact: it reduced WTHR, a marker of obesity, by an (absolute) 5.9% more than the baseline reduction seen in the control group.

Unlike other interventions that have shown an increase in activity[39] or improved fitness by introducing specific bouts of exercise into lessons[35 36 38 40-49]. The aim of *Active Movement* is to make movement part of the way the class is taught. This can be achieved in many different ways depending on the teacher's approach. The whole of the school is involved with information posters and events highlighting the need to be non-sedentary. This message is taken home to the parents in the form of homework. The objective of *Active Movement* is to change behaviour. We believe this intervention is effective because the activity is not an 'add on' but integrated into the lesson and ultimately, the lives of the children.

The social ecological theory of change underpins many study designs in this field and is important as it explains that a combination of individual, environmental and policy change are required to sustain a positive health behaviour[8]. The *Active Movement* intervention changed environment and policy at school, and, by providing homework and education through newsletters changed the individual child's home environment, re-enforcing the positive intervention effect with possible benefits provided to members of the family. Research shows that behaviours at this age are continued into adulthood and that children with obesity tend to become adults with obesity[28].

Strengths and Limitations

The design of the intervention was individualised to the school and meant that it could be easily implemented with low financial cost and disruption and yet is easily adaptable to be expanded across other schools. There was a large study sample which was adequately powered to detect changes previously reported to be sufficient for population health benefit[50]. There was also low attrition in this study with only 12 of the 226 children dropping out (5.3%).

It is possible that some demographic or sociological factors differed between schools. However, in this cluster control trial, schools were in close proximity and were as similar in social and racial demographics and urban environment. The control school had a similar proportion of children eligible for Pupil Premium (a government extra funding programme for disadvantaged children) compared with the intervention school (31% vs 37%).

One weakness of our study is that we only used one measure of adiposity- WTHR. However, this measure is robust, and considered the best estimate of body composition and a better marker for various cardiovascular risk factors in both children and adults than BMI[32 51], as well as being a useful global screening tool for cardiovascular risk[52].

We did not objectively measure physical activity but relied on self-reported questionnaire. This questionnaire was only carried out in year 5 and year 6 as it was too complex to be understood by year 1. Further studies might seek to obtain objective activity measures such that the driver for the change in adiposity (exercise vs nutrition) might be assessed.

One limitation was the lack of randomisation to intervention or control group. The nature of the cluster-controlled study also meant that blinding of participants was also not possible which can also increase risk of bias. In the control group 80 children were recruited versus 146 children in the intervention school – due to the difficulty in persuading a school to be a control arm of a study where no benefit to children would be gained. Groups were samples of convenience and clustered into nests which meant that they were not matched, this being reflected in the statistically significant difference in baseline measures, this risk of bias was acknowledged and addressed in statistical analysis.

Researchers were not blinded, and this could increase risk of outcome data bias. The fidelity of the programme was monitored with a programme of weekly emails to teachers and regular visits maintain contact and momentum of the campaign. Despite all teachers receiving the same training at baseline and students receiving the same educational material, the intervention fidelity within different classes was not measured and therefore intervention dose is difficult to establish.

We cannot discount impacts of unmeasured interventions in the schools. However, it appears that any such changes may actually have mitigated against our finding, leading to our underestimating the impact of the intervention: the control school implemented their own health promoting initiatives, including 'the daily mile'[53], during the study period, an interventions that could not be controlled due to ethical constraints.

The effects of growth and change in body morphology were unlikely to have contributed, given that the same effect was seen across all age groups, and that the scale of change differed between intervention and control schools. Finally, the changes in obesity were matched by reported changes in physical activity, in keeping with the expected effect of the intervention.

Conclusion

A simple and cheap intervention to encourage less sedentary time in primary schools was associate with both increased exercise and a significant reduction in obesity. Further studies are required to confirm and extend these findings in different regions and across different demographic groups and might also assess the long-term impacts of the intervention.

References

1. Statistics Team ND. National Child Measurement Programme: England, 2016/17 In: NHS, ed. England: NHS Digital, 2017.
2. Statistics N. National Child Measurement Programme: England, 2016/17 School year. 2017
3. Singh AS, Mulder C, Twisk JW, et al. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev* 2008;9(5):474-88. doi: 10.1111/j.1467-789X.2008.00475.x [published Online First: 2008/03/12]
4. Lloyd LJ, Langley-Evans SC, McMullen S. Childhood obesity and adult cardiovascular disease risk: a systematic review. *Int J Obes (Lond)* 2010;34(1):18-28. doi: 10.1038/ijo.2009.61
5. Nishtar S, Gluckman P, Armstrong T. Ending childhood obesity: a time for action. *Lancet* 2016;387(10021):825-7. doi: 10.1016/S0140-6736(16)00140-9 [published Online First: 2016/01/30]
6. Freedman DS, Mei Z, Srinivasan SR, et al. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. *J Pediatr* 2007;150(1):12-17 e2. doi: 10.1016/j.jpeds.2006.08.042
7. Hills AP, Andersen LB, Byrne NM. Physical activity and obesity in children. *Br J Sports Med* 2011;45(11):866-70. doi: 10.1136/bjsports-2011-090199
8. Hegarty LM, Mair JL, Kirby K, et al. School-based Interventions to Reduce Sedentary Behaviour in Children: A Systematic Review. *Aims Public Health* 2016;3(3):520-41. doi: 10.3934/publichealth.2016.3.520
9. Raine L, Drollette E, Kao SC, et al. The Associations between Adiposity, Cognitive Function, and Achievement in Children. *Med Sci Sports Exerc* 2018 doi: 10.1249/MSS.0000000000001650 [published Online First: 2018/05/05]
10. Oude Luttikhuis H, Baur L, Jansen H, et al. Interventions for treating obesity in children. *Cochrane Db Syst Rev* 2009(1) doi: ARTN CD001872 10.1002/14651858.CD001872.pub2
11. England PH. Childhood Obesity: applying All Our Health. In: England Ph, ed. Online: Public Health England, 2015.
12. Health OW. Global strategy on diet, physical activity and health.
13. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act* 2017;14(1):75. doi: 10.1186/s12966-017-0525-8
14. Hnatiuk JA, Salmon J, Hinkley T, et al. A review of preschool children's physical activity and sedentary time using objective measures. *Am J Prev Med* 2014;47(4):487-97. doi: 10.1016/j.amepre.2014.05.042 [published Online First: 2014/08/03]
15. Craig RM, Jennifer; Hirani, Vasant. Health survey for England 2008, physical activity and fitness; summary of key findings. Health and Social Care Information Centre2009:1-21.
16. Team LS. National Child Measurement Programme: England 2014/15 school year. In: Centre HSCI, ed.: NHS Digital, 2015.
17. van Stralen MM, Yildirim M, Wulp A, et al. Measured sedentary time and physical activity during the school day of European 10- to 12-year-old children: the ENERGY project. *J Sci Med Sport* 2014;17(2):201-6. doi: 10.1016/j.jsams.2013.04.019
18. Davies EJG, J.R.F., & Edwards, K.L. . Physical activity and sedentary behaviour in 12-13 year old children, stratified by sex, school type and residential deprivation score. *J Phy Edu Res* 2016;3(III):13-28.
19. Carson V, Hunter S, Kuzik N, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Appl Physiol Nutr Metab* 2016;41(6 Suppl 3):S240-65. doi: 10.1139/apnm-2015-0630
20. Tremblay MS, LeBlanc AG, Kho ME, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *Int J Behav Nutr Phys Act* 2011;8:98. doi: 10.1186/1479-5868-8-98
21. Biddle SJH, Bengoechea EG, Wiesner G. Sedentary behaviour and adiposity in youth: a systematic review of reviews and analysis of causality. *Int J Behav Nutr Phys Act* 2017;14 doi: ARTN 4310.1186/s12966-017-0497-8
22. Katzmarzyk PT, Barreira TV, Broyles ST, et al. Physical Activity, Sedentary Time, and Obesity in an International Sample of Children. *Med Sci Sports Exerc* 2015;47(10):2062-9. doi: 10.1249/MSS.0000000000000649

23. Suchert V, Hanewinkel R, Isensee B. Sedentary behavior and indicators of mental health in school-aged children and adolescents: A systematic review. *Prev Med* 2015;76:48-57. doi: 10.1016/j.ypmed.2015.03.026 [published Online First: 2015/04/22]
24. Wu X, Bastian K, Ohinmaa A, et al. Influence of physical activity, sedentary behavior, and diet quality in childhood on the incidence of internalizing and externalizing disorders during adolescence: a population-based cohort study. *Ann Epidemiol* 2018;28(2):86-94. doi: 10.1016/j.annepidem.2017.12.002 [published Online First: 2018/02/15]
25. Regier DA, Kuhl EA, Kupfer DJ. The DSM-5: Classification and criteria changes. *World Psychiatry* 2013;12(2):92-8. doi: 10.1002/wps.20050 [published Online First: 2013/06/06]
26. Saunders TJ, Chaput JP, Tremblay MS. Sedentary Behaviour as an Emerging Risk Factor for Cardiometabolic Diseases in Children and Youth. *Can J Diabetes* 2014;38(1):53-61. doi: 10.1016/j.jcjd.2013.08.266
27. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med* 2015;162(2):123-32. doi: 10.7326/M14-1651 [published Online First: 2015/01/20]
28. Biddle SJ, Pearson N, Ross GM, et al. Tracking of sedentary behaviours of young people: a systematic review. *Prev Med* 2010;51(5):345-51. doi: 10.1016/j.ypmed.2010.07.018 [published Online First: 2010/08/05]
29. Council H. Index of Multiple Deprivation 2015 2015 [Available from: http://www.haringey.gov.uk/social-care-and-health/health/joint-strategic-needs-assessment/other-factors-affecting-health/deprivation accessed 25 July 2017.
30. Kowalski K CP, Donen R. The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual 2004 [Available from: https://www.prismsports.org/UserFiles/file/PAQ_manual_ScoringandPDF.pdf.
31. Movement A. 2018 [Available from: https://activemovementschools.co.uk/.
32. Yoo EG. Waist-to-height ratio as a screening tool for obesity and cardiometabolic risk. *Korean J Pediatr* 2016;59(11):425-31. doi: 10.3345/kjp.2016.59.11.425
33. Tu YK, Clerehugh V, Gilthorpe MS. Ratio variables in regression analysis can give rise to spurious results: illustration from two studies in periodontology. *J Dent* 2004;32(2):143-51. [published Online First: 2004/01/30]
34. Vetter M, O'Connor H, O'Dwyer N, et al. Learning "Math on the Move": Effectiveness of a Combined Numeracy and Physical Activity Program for Primary School Children. *J Phys Act Health* 2018;15(7):492-98. doi: 10.1123/jpah.2017-0234 [published Online First: 2018/03/28]
35. Liu A, Hu X, Ma G, et al. Evaluation of a classroom-based physical activity promoting programme. *Obes Rev* 2008;9 Suppl 1:130-4. doi: 10.1111/j.1467-789X.2007.00454.x [published Online First: 2008/03/01]
36. Kibbe DL, Hackett J, Hurley M, et al. Ten Years of TAKE 10!((R)): Integrating physical activity with academic concepts in elementary school classrooms. *Prev Med* 2011;52 Suppl 1:S43-50. doi: 10.1016/j.ypmed.2011.01.025 [published Online First: 2011/02/02]
37. 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(4):336-41. doi: 10.1016/j.ypmed.2009.07.022 [published Online First: 2009/08/12]
38. Donnelly JE, Lambourne K. Classroom-based physical activity, cognition, and academic achievement. *Prev Med* 2011;52 Suppl 1:S36-42. doi: 10.1016/j.ypmed.2011.01.021 [published Online First: 2011/02/02]
39. Bartholomew JB, Jowers EM, Roberts G, et al. Active Learning Increases Children's Physical Activity across Demographic Subgroups. *Transl J Am Coll Sports Med* 2018;3(1):1-9. doi: 10.1249/TJX.0000000000000051 [published Online First: 2018/05/19]
40. de Greeff JW, Hartman E, Mullender-Wijnsma MJ, et al. Long-term effects of physically active academic lessons on physical fitness and executive functions in primary school children. *Health Educ Res* 2016;31(2):185-94. doi: 10.1093/her/cyv102 [published Online First: 2016/01/31]
41. Donnelly JE, Hillman CH, Greene JL, et al. Physical activity and academic achievement across the curriculum: Results from a 3-year cluster-randomized trial. *Prev Med* 2017;99:140-45. doi: 10.1016/j.ypmed.2017.02.006 [published Online First: 2017/02/15]
42. Mahar MT, Murphy SK, Rowe DA, et al. Effects of a classroom-based program on physical activity and on-task behavior. *Med Sci Sports Exerc* 2006;38(12):2086-94. doi: 10.1249/01.mss.0000235359.16685.a3 [published Online First: 2006/12/06]

43. Martin R, Murtagh EM. Effect of Active Lessons on Physical Activity, Academic, and Health Outcomes: A Systematic Review. *Res Q Exerc Sport* 2017;88(2):149-68. doi: 10.1080/02701367.2017.1294244 [published Online First: 2017/03/23]
44. Mullender-Wijnsma MJ, Hartman E, de Greeff JW, et al. Improving academic performance of school-age children by physical activity in the classroom: 1-year program evaluation. *J Sch Health* 2015;85(6):365-71. doi: 10.1111/josh.12259 [published Online First: 2015/04/17]
45. Mullender-Wijnsma MJ, Hartman E, de Greeff JW, et al. Physically Active Math and Language Lessons Improve Academic Achievement: A Cluster Randomized Controlled Trial. *Pediatrics* 2016;137(3):e20152743. doi: 10.1542/peds.2015-2743 [published Online First: 2016/02/26]
46. Norris E, Dunsmuir S, Duke-Williams O, et al. Physically Active Lessons Improve Lesson Activity and On-Task Behavior: A Cluster-Randomized Controlled Trial of the "Virtual Traveller" Intervention. *Health Educ Behav* 2018;45(6):945-56. doi: 10.1177/1090198118762106 [published Online First: 2018/03/23]
47. Reed JA, Einstein G, Hahn E, et al. Examining the impact of integrating physical activity on fluid intelligence and academic performance in an elementary school setting: a preliminary investigation. *J Phys Act Health* 2010;7(3):343-51. [published Online First: 2010/06/17]
48. 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;91:322-28. doi: 10.1016/j.ypmed.2016.09.005 [published Online First: 2016/09/11]
49. Riley N, Lubans DR, Holmes K, et al. Findings From the EASY Minds Cluster Randomized Controlled Trial: Evaluation of a Physical Activity Integration Program for Mathematics in Primary Schools. *J Phys Act Health* 2016;13(2):198-206. doi: 10.1123/jpah.2015-0046 [published Online First: 2015/06/25]
50. Fairclough SJ, Hackett AF, Davies IG, et al. Promoting healthy weight in primary school children through physical activity and nutrition education: a pragmatic evaluation of the CHANGE! randomised intervention study. *BMC Public Health* 2013;13:626. doi: 10.1186/1471-2458-13-626
51. Lee CM, Huxley RR, Wildman RP, et al. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. *J Clin Epidemiol* 2008;61(7):646-53. doi: 10.1016/j.jclinepi.2007.08.012
52. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. *Nutr Res Rev* 2010;23(2):247-69. doi: 10.1017/S0954422410000144
53. Foundation DM. The Daily Mile [Available from: https://thedailymile.co.uk/.