Obesity Facts

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Decreasing Sedentary Time during Lessons Reduces Obesity in Primary School Children: The Active Movement Study

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Abstract
Introduction: School-based exercise interventions targeted at reducing obesity are often successful in the short term, but they are resource-heavy and do not always lead to long-lasting behaviour changes. This study investigated the effect of reducing sedentary time, rather than increasing exercise, on physical activity (PA) behaviours and obesity in primary school children. ***Methods:*** Thirty UK state primary schools participated in this cluster-controlled intervention study (IDACI score = 0.15 ± 0.07, free school meals = 26 ± 9%). Twenty-six intervention and 4 control schools (intervention = 3,529, control = 308 children) completed the Physical Activity Questionnaire for Children (PAQ-C) in terms 1 and 3. Three intervention and 3 control schools (intervention = 219, control = 152 children) also measured waist-to-height ratio (WTHR). The Active Movement Intervention is a school-based programme which integrates non-sedentary behaviours such as standing and walking in the classroom. Data were analysed via ANCOVAs and multiple linear regressions. ***Results:*** WTHR was reduced by 8% in the intervention group only ($F(2, 285) = 11.387$, $p < 0.001$), and sport participation increased by 10% in the intervention group only ($F(1, 232) = 6.982$, $p = 0.008$). Other PAQ-C measures increased significantly in the intervention group, but there was no group*time interaction. Changes in PAQ-C did not predict reductions in WTHR. Instead, the amount of change in WTHR was predicted by intervention group and by baseline WTHR of the pupil, where children with higher baseline WTHR showed greater reductions ($F(2, 365) = 77.21$, $p < 0.001$, $R^2 = 0.30$). Socio-economic status (SES), age, or gender did not mediate any of the changes in the PAQ-C or WTHR. ***Conclusion:*** Reducing sedentary behaviours during school time can be an effective obesity reduction strategy for primary school children who are overweight. The lack of demographic effects suggests that this method can be effective regardless of the school's SES, pupil age, or gender.

Introduction

Childhood obesity continues to grow as an international concern. The World Health Organisation refers to it as "one of the most serious public health challenges of the 21st century" [1]. School-based interventions have attempted to tackle childhood obesity through multi-

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component approaches, with varied results. This study evaluated the effects of a novel intervention, built on recommendations from previous literature, on reducing childhood obesity in primary school children.

In England, the National Child Measurement Programme (NCMP) reported that the proportion of primary school children who were overweight or obese in 2016–17 rose from 22.6% to 34.2% [2]. Childhood obesity increases the risk of cardiovascular [3, 4] and metabolic disease in adulthood [5, 6], is associated with reduced academic performance [7, 8], hyperlipidaemia, hypertension, insulin resistance, poor pulmonary function [9], poor psychological and emotional health [10]. Sedentary behaviour is one of the main risk factors for childhood obesity and associated cardio-metabolic disease [11–13]. It is also arguably one of the easier factors to address with minimal resources. Children in the UK spend around 7 h per day sedentary [14]. This increases with age [15], tracking into teenage and adult years [16]. Sedentary children are more likely to be overweight [17] and have a higher risk of becoming overweight or obese adults [18], highlighting the importance of early intervention.

School environments present an opportunity to implement risk reduction measures throughout development. Classroom time accounts for 64% of a child's sedentary time during a school day and likely constitutes the largest portion of sitting time throughout their entire day [19]. Most studies have focused on delivering sport and exercise interventions during school break hours, when children are already most active [19, 20], with largely inconclusive findings. In a meta-analysis of 30 studies, Metcalf et al. [21] reported significant but negligible effects of exercise interventions on physical activity (PA) in children, with a pooled effect of increasing walking or running by only 4 min per day. Love et al. [22] analysed pooled actigraphy data from 17 school-based trials, concluding that the exercise interventions were not effective at increasing moderate to vigorous physical activity (MVPA) levels in children. A review of 57 studies concluded that multi-component interventions with theoretical frameworks are most effective in increasing activity levels in adolescents, but not in primary school children [23]. Importantly, school-based interventions appear more effective at increasing activity levels during school hours than prompting behaviour change outside school [24].

While most interventions focus on increasing exercise time, behaviour change theories suggest that reducing sedentary behaviours might be a more successful first step towards active lifestyles [25]. Wendel et al. [26] showed a reduction in BMI in primary school children following the introduction of standing desks, while Epstein et al. [27] reported that reducing sedentary behaviours was more effective than increasing exercise in reducing obesity rates in children.

Several factors may contribute to the success of school-based interventions. Love et al. [28] pointed out that many studies fail to investigate the effect of deprivation on intervention success, calling for authors to account for the effects of SES in their analyses. Logistical implementation issues are commonly reported barriers for school-based interventions, as complex, multilevel approaches adding new activities to the school day can generate high additional workload for schools with saturated curricula and limited resources. In a re-evaluation of the JUMP-in project, which adopted a multilevel approach, de Meij et al. [29] called for simple guidelines, clear communication and feedback, and step-wise implementation for multimodal approaches.

In summary, the existing literature indicates that exercise-based interventions are not always effective in producing long-lasting increases in PA behaviours that sedentary time is a strong predictor of childhood obesity and that classroom time constitutes a significant proportion of children's sedentary time. In addition, infrastructure investments are not always effective [30], highly structured and multi-component interventions are rarely feasible for school staff [29], cost and complexity may constitute a barrier for implementation in deprived settings [28], and interventions in primary schools appear to be the most challenging [23].

The Active Movement Programme was developed to attempt to overcome these challenges. It targets a reduction in sedentary behaviour rather than a direct increase in exercise, with simple instructions and low resources. The aim of this study was to investigate the effects of reducing sedentary behaviour during lessons on abdominal obesity and PA behaviours in primary school children in a range of socio-economic settings.

Materials and Methods

Study Design

Thirty state primary schools across different boroughs in London, UK, and surrounding boroughs in South England took part in the study. A cluster-controlled trial was performed across the schools between 2017–18 and 2018–2019, and then in 2021–22. Twenty-six schools, recruited from local councils, expressed interest to take part in the intervention. Control schools were recruited by identifying schools with similar demographics to intervention schools based on postcode and invited to act as test-retest controls: four schools agreed to take

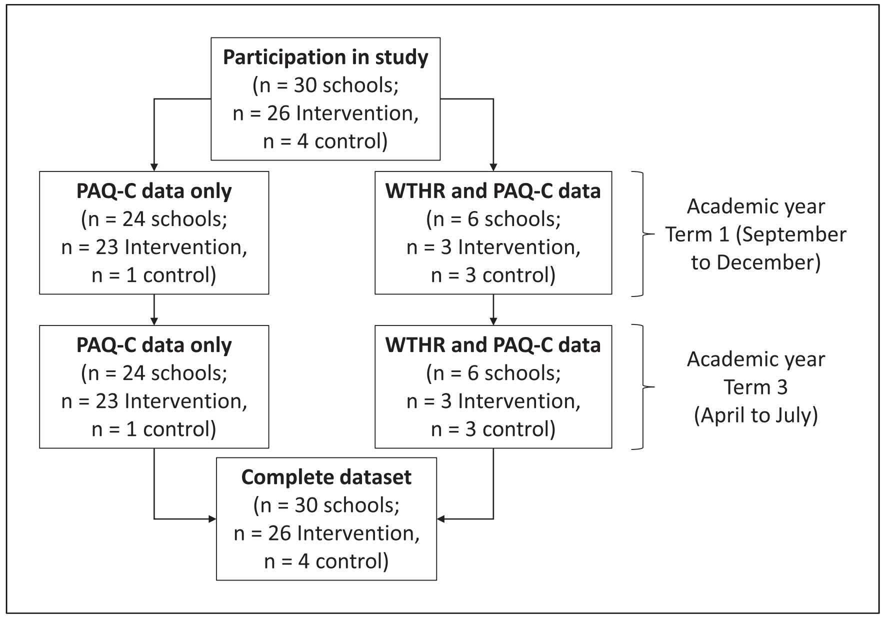

Fig. 1. Flowchart depicting the study methodology, including data collection for the Physical Activity Questionnaire for Children (PAQ-C) and waist-to-height ratio (WTHR).

part. Responses to the Physical Activity Questionnaire for Children (PAQ-C) for all thirty schools and waist-to-height ratio (WTHR) for six schools were recorded in term 1 and term 3 of the academic year (Fig. 1). Ethical approval was granted by the University College London Research Ethics Committee (722/002) in line with the Declaration of Helsinki. Written informed consent was obtained from head teachers and parents of participating schools. Verbal assent was also obtained from all participating pupils prior to data collection. In addition, throughout data collection, researchers repeatedly confirmed to participants that they could skip any element of data collection or stop participating in the study at any point.

Intervention

The Active Movement Programme was designed to integrate non-sedentary behaviour and low-level activity into a child's normal school routine without disrupting the curriculum. The intervention was led by school teaching staff after receiving instruction from researchers. The aim of the programme was to reduce time spent sedentary during lessons, using this change to educate children on the positive aspects of a healthy lifestyle. This was achieved by introducing standing and low-level movement during normal classroom teaching, for example, standing when answering questions. To encourage children to remain active throughout school life and at home, posters were placed around the school with activity ideas, and "activity homework" was recommended, such as encouraging parents to stand during TV advert breaks.

Teachers received a formal 1-h training session at the start of the intervention and a mid-intervention forum. During these sessions, teachers were educated on the harm attributed to sedentary behaviours and the benefits of reducing them. Teachers were given ideas on how to integrate non-sedentary and low-level movement into classrooms and encouraged to create their own ideas. At the programme launch, the lead researchers used a school assembly to introduce the programme to children and held a parent briefing session. Parents were informed of the progress of the programme through 6 newsletters during the academic year.

PAQ-C

Pre-intervention measures were gathered from children in years 3–6 in September–October of term 1, and post-intervention measures were gathered in term 3 in July. To measure self-reported activity levels, schools were sent an online link to the PAQ-C [31], which children completed on school library computers during school hours. The PAQ-C questionnaire was designed to provide a general measure of PA levels over the proceeding 7 days, for ages 8–14. Wording was modified from the original, for use in UK English-speaking schools.

Each item is scored out of 5, and the mean of the 9 questions is used as a summary activity score ranging from 1–5. Question 1 asks about participation in individual activities (walking, skipping, running, cycling, swimming, football, badminton, hockey, skateboarding, other sports). Answers to all activities except walking and skipping were averaged to give a variable representing "Sport Participation." To obtain sub-components of PA scores from the questionnaire, a factor analysis was conducted on pre-intervention responses to questions 2–9 using a polychoric correlation and applying a Varimax (orthogonal) rotation with weighted least squares estimation. The analysis yielded two factors explaining 52% of the variance (Table 1). Factor 1, labelled "Breaktime Activity," explained 17% of the variance and was computed as Q3 * 0.76 + Q4 * 0.74. Factor 2, labelled "Outside School Activity," explained 34% of the variance and was computed as Q5 * 0.76 + Q6 * 0.81 + Q7 * 0.71 + Q8 * 0.56 + Q9 * 0.57. Question 2 was analysed separately as "PE attitudes." Factor loadings obtained from pre-intervention responses were applied to the entire pre- and post-sample to compute activity factors.

Table 1. Factor analysis output for the Physical Activity Questionnaire for Children (PAC-Q)

	Loadings		Communality
	factor 1: breaktime activity	factor 2: outside school activity	
Q2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)?	0.21	0.32	1.1
Q3. In the last 7 days, what did you do most of the time at breaktime?	0.76	0.15	1.0
Q4. In the last 7 days, what did you normally do at lunch (besides eating lunch)?	0.74	0.11	1.0
Q5. In the last 7 days, on how many days right after school, did you do sports, dance, or play games in which you were very active?	0.08	0.76	1.0
Q6. In the last 7 days, on how many evenings did you do sports, dance, or play games in which you were very active?	0.07	0.81	1.0
Q7. On the last weekend, how many times did you do sports, dance, or play games in which you were very active?	0.11	0.71	1.0
Q8. Which one of the following describes you best for the last 7 days?	0.20	0.56	1.3
Q9. * Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week, Monday to Sunday	0.20	0.57	1.2

*Q9 was scored as the average of the responses given for each of the 7 days of the week.

Weight-to-Height Ratio

Measurements were taken by researchers at the schools from children in years 1–6. Height was measured without shoes, using a wall-mounted stadiometer ruler (ADE, Hamburg, Germany). Waist circumference was measured with an anthropometric tape measure (NCD Medical Ltd., Ireland) taken at the umbilicus over one layer of clothing in a relaxed standing position. Measurements were taken over one layer of clothing (shirt, but not jumper) to ensure child safeguarding throughout the study. With school uniforms being largely consistent across UK schools, it was deemed that any impact on measurements caused by the layer of clothing would be stable across the entire sample, therefore mitigating the overall influence on results. WTHR was calculated by dividing waist circumference by height. WTHR was chosen due to being recommended as the more accurate measure of obesity in children, compared to BMI [32].

Socio-Economic Status

SES was measured using the Income Deprivation Affecting Children Index (IDACI) score, calculated using each school's postcode [33]. The IDACI score measures the proportion of all children aged 0–15 living in income-deprived families in an area. The more deprived the area, the higher the score [34]. The range of scores in the UK at the time of the study was 0.004–0.898. The percentage of children signed up for free school meals (FSM) at each school was obtained from the "Get Information About Schools" Register, a government register of all schools and colleges in England and Wales [35].

Data Analysis

Statistical analyses were conducted on R studio (version 4.2.3). Data normality was tested via a Shapiro-Wilk test. Questionnaire data resulted not normally distributed, but physical data were normally distributed. Attempts to normalise the data through transformations were not successful; therefore, the original data were used in analyses. Group differences between term 1 and term 3 results were first assessed via a two-way ANOVA. Pairwise t tests with Bonferroni correction were conducted as post hoc on the WTHR data, while for the questionnaire data, post hoc paired and unpaired Wilcoxon tests were conducted to check for differences between terms within subjects and between groups (intervention, gender). Multiple linear regressions were used to identify factors determining pre-post changes in WTHR. The impact of SES on the intervention was tested by including SES variables as covariates in ANCOVAs and in multiple regressions. The alpha level was set at 0.05.

Results

Demographics

All schools completed the intervention and allowed researchers to collect term 1 and term 3 data. From the 30 participating schools, 8,203 children completed the term 1 PAQ-C responses and 5,649 submitted term 3

Table 2. Demographic overview of number of children included in the study with matched pre- and post-data

	Schools, *n*	Children, *n*				% FSM (mean±SD)	IDACI score (mean±SD)
		total	boys	girls	NA[a]		
PAQ-C							
Intervention	26	3,529	1,591	1,662	276	26.6±9.2***	0.147±0.065
Control	4	308	117	151	40	24.8 + 8.9	0.209±0.064***
WTHR							
Intervention	3	219	111	105	3	27.4±9.3	0.104±0.074
Control	3	152	51	61	40	27.6±7.2	0.223±0.064***

The mean %FSM and IDACI scores were calculated by child. [a]NA = the children preferred not to disclose their gender. ***Significant difference between intervention and control group ($p < 0.001$).

responses, but only 3,837 could be matched by pupil in both terms, meaning that data from 6,178 responses were unfortunately not useable for test-retest analyses. Only the 3,837 matched responses were included in the analysis. Six of these schools also consented to gathering WTHR. 529 children were measured in term 1, but only 378 in term 3, of which 371 were matched. Group and gender details are included in Table 2. UK IDACI scores ranged from 0.004 to 0.29 (where a higher score indicates greater deprivation), with an average score across the study of 0.15 ± 0.07. The mean IDACI score for all London boroughs in 2019 was 0.179, placing 11 of the 30 schools above the London average IDACI [34]. FSM uptake ranged from 1 to 47% per school, with an average of 26 ± 9%. In 2019, 17.2% of children in London were eligible for FSM, placing 21 of the 30 schools above the London average [36].

Waist-to-Height Ratio

WTHR was significantly reduced in the intervention group but not in the control group. There was a Group*Time interaction ($F(2,285) = 11.387$, $p < 0.001$) in the change in WTHR, where only the intervention group showed a significant reduction ($p < 0.001$) (shown in Fig. 2a). There was no gender difference in WTHR at any time point or between groups, no Group*Time*Gender interaction and no Group*Time*School Year interaction, indicating that age and gender did not affect changes in WTHR in this study. There was also no effect of SES on changes in WTHR, neither by %FSM nor IDACI score.

A sub-analysis by school indicated that 2 of the 3 intervention schools significantly lowered WTHR ($p <$ 0.001) while one did not. There was no significant difference in WTHR change between the 3 control schools. Of the 3 intervention schools, the two that showed a decrease had 100% compliance (defined as the same children attending measurements pre- and post-intervention), while the school that did not had 83% compliance.

PAQ-C

PAQ-C responses suggest that children attending intervention schools increased their activity levels in term 3; however, this increase was only statistically different for Sport Participation (Table 3). There was a time effect on both the Overall Score and Outside School Activity score, which only increased significantly in the intervention group ($p < 0.001$). There was no Group*Time interaction for either of these. There was a Group*Time interaction ($F(1,232) = 6.982$, $p = 0.008$) for Sport Participation, where the intervention group increased ($p < 0.001$) and the control group did not ($p = 0.276$). However, the control schools also reported lower participation than the intervention schools at both time points ($p < 0.001$), indicating that control schools started at a lower baseline participation in sport, which may have affected results. Both the intervention and control schools increased activity during PE in term 3 ($p < 0.001$; $p = 0.020$), with no difference between groups.

General trends suggest that the intervention group increased activity levels in term 3, while the control group did not. However, only Sport Participation showed a significant Group*Time interaction. These findings might be confounded by the smaller sample size in the control group, and therefore the null hypothesis cannot be rejected.

Overall, there was a significant correlation between IDACI score and %FSM ($R = 0.62$, $p <0.001$). Therefore, a composite score of SES was created by summing the z-scores of each index. To determine whether deprivation

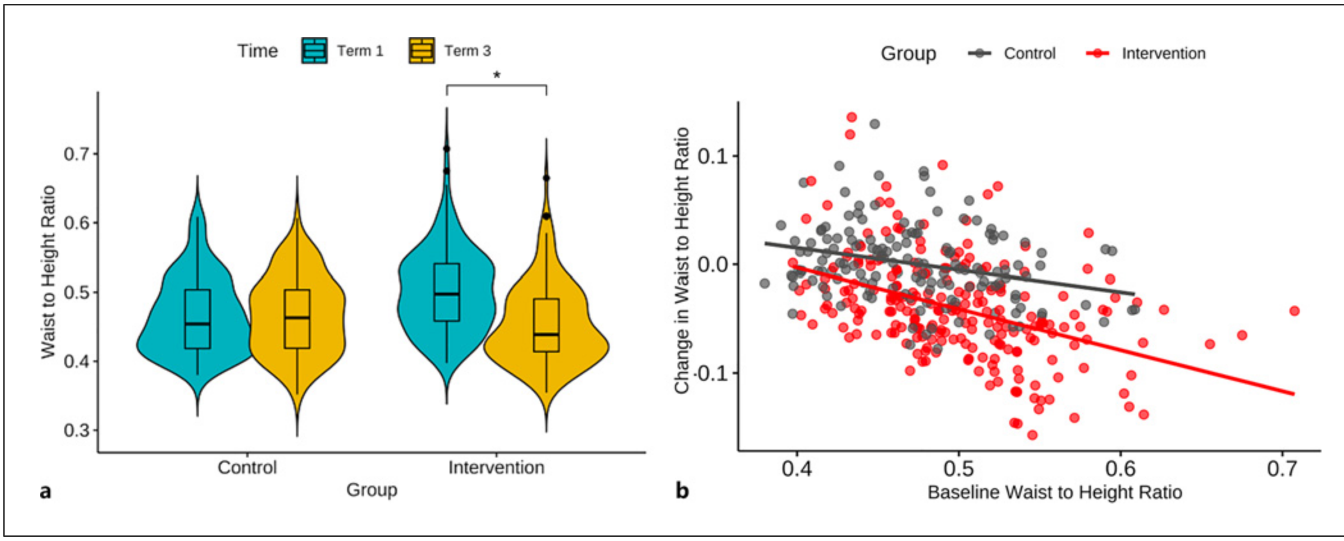

Fig. 2. a Pre- and post-WTHR for control and intervention schools (n = 371) *Significant reduction in WTHR in the intervention school only (p < 0.001). **b** Relationship between the change in WTHR and starting WTHR per child (R-sq = 0.30, p < 0.001).

Table 3. Mean ± SD pre- and post-PAQ-C outcome scores and WTHR measurements for the intervention (INT) and control (CTRL) groups

	n	Group	Pre	Post	Time (*p* value)	Group*time (*p* value)
Overall score (scale 1 – 5)	3,529 308	INT* CTRL	3.4±0.8 3.3±0.8	3.6±0.8*** 3.4±0.7	<0.001	
PE (scale 1 – 5)	3,529 308	INT CTRL	4.0±1.0 4.0±1.2	4.1±0.9*** 4.2±0.8*	<0.001 0.020	
Breaktime (scale 1.0 – 7.5)	3,529 308	INT CTRL	5.7±1.7 5.5±1.7	5.7±1.7 5.6±1.5		
Outside school (scale 2 – 18)	3,529 308	INT CTRL	10.7±3.4 10.8±3.2	11.4±3.3*** 11.2±3.1	<0.001	
Sport participation (scale 8 – 40)	3,529 308	INT*** CTRL	14.1±3.8 11.9±3.8	15.5±5.9*** 11.6±5.9	<0.001	0.009
WTHR	219 152	INT CTRL	0.50±0.05 0.47±0.05	0.46±0.05*** 0.48±0.05	<0.001	<0.001

*p < 0.05, ***p < 0.001.

impacted the outcome of the intervention, this SES score was used as a covariate in the ANCOVAs and in regression models to predict change in activity scores between terms. Including SES in the ANCOVAs did not change the outputs of any activity factor score. SES was also not significant in any regression model, where changes in activity factor scores were not predicted by SES.

PAQ-C Scores and Demographics

There was a gender difference in PAQ-C scores (shown in Fig. 3), where boys scored higher than girls on both time points for Overall Score (p < 0.001) and Breaktime Activity (p <0.001) in the entire sample and for Sport Participation (p < 0.001) in the intervention group only. There was no gender difference for PE and activity outside school in either group at either time point. It is

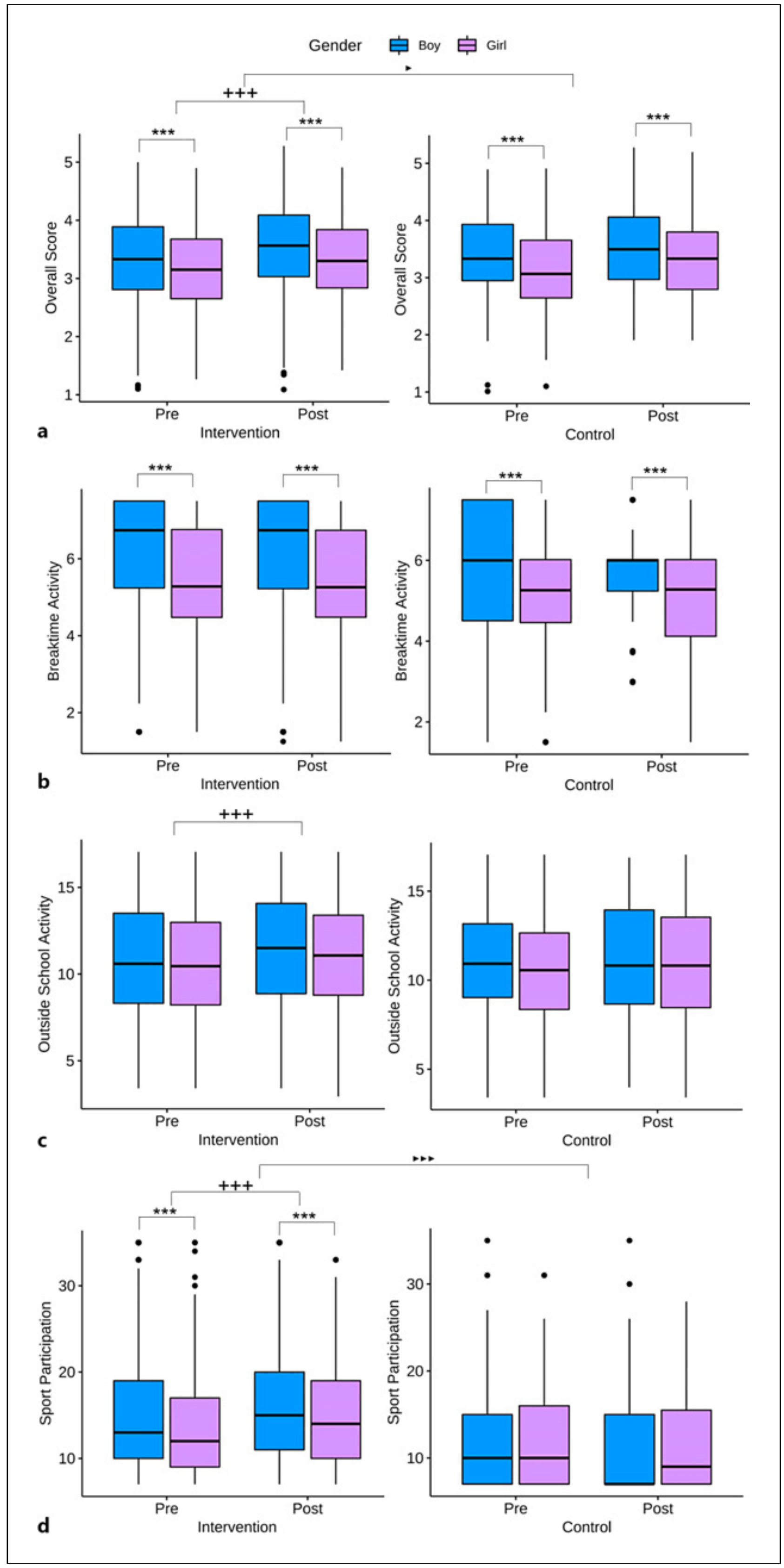

Fig. 3. Pre- and post-intervention activity scores separated by intervention group and by gender for overall score (**a**), breaktime activity (**b**), outside school activity (**c**), sport participation (**d**) (n = 3,837). ***Significant difference between genders ($p < 0.001$). +++ Significant difference between time points ($p < 0.001$). ▸▸▸Significant difference between groups: ▸($p < 0.1$), ▸▸▸($p < 0.001$).

important to note that there were neither Time*Gender nor Group*Time*Gender interactions for any variables; boys and girls reported equal changes within intervention groups when changes did occur. Therefore, boys generally scored higher than girls on the PAQ-C, but gender did not influence the magnitude of changes between terms. The largest gender differences in activity factors occurred during Breaktime Activity, where boys were more active than girls in both intervention groups, and scores remained consistent in both terms (shown in Fig. 3b). School year was not a significant determinant in pre-post changes between intervention groups.

WTHR, PAQ-C, Gender, and SES

There was no relationship between baseline WTHR and overall score on the PAQ-C. A multiple linear regression by backward elimination was run on the change in WTHR, using change in activity levels, SES, age, and gender as predictors in the full model; only baseline WTHR and intervention group remained significant in the model ($F(2, 365) = 77.21$, $p < 0.001$, $R^2 = 0.30$). The reduction in WTHR was predicted by 0.14–0.31 * Baseline WTHR - 0.03 * Group, where the intervention group was coded = 1. Therefore, changes in WTHR were not predicted by changes in reported PA levels, nor were they influenced by SES as measured by the school's IDACI score or %FSM. Instead, children who had a higher WTHR at baseline and took part in the intervention were the ones who lost most weight (shown in Fig. 2b), regardless of the school's SES, their age, or gender.

Discussion

The main finding of this study indicates that reducing sedentary time during school hours can reduce WTHR in children who are overweight. These changes were not related to changes in self-reported levels of PA and were not affected by age, gender, or school SES. They were however dependent on baseline WTHR, indicating that this type of intervention can be effective in targeting children with higher levels of abdominal obesity. Some changes in PA were reported, particularly in sport participation, but it is not clear if these were directly related to the intervention itself. While there were gender differences in self-reported activity levels, gender did not impact changes in activity levels between terms.

Changes in WTHR

WTHR was significantly reduced in the intervention schools, with greater decreases in children who started the intervention with a higher WTHR. The overall mean reduction in WTHR was 8% after circa 6 months across the entire cohort, which is of strong clinical significance and impact, especially considering the nature of intervention which did not include moderate or vigorous activities. This reflects findings from previous studies which also reported weight loss in children following a reduction in sedentary time [26, 27] and adds to the body of research supporting a reduction in sedentary time, rather than an increase in physical activity, as an effective obesity reduction strategy [25]. Prolonged low-intensity aerobic exercise is known to maximise lipid oxidation and has been demonstrated to promote long-term weight loss over a period of 1–3 years more effectively than dieting in adults [37]. While exercise time or intensity was not objectively measured in this study, these promising results suggest that arbitrarily increasing low-level activity such as standing and walking during school time might be enough to contribute to an increase in daily metabolic expenditure, thereby promoting weight loss through a sustainable strategy, irrespective of moderate to vigorous activity time. Particularly as classroom time constitutes the largest portion of children's sedentary time throughout the day [19], these results suggest that targeting these hours when children are typically inactive seems to be an effective strategy for promoting weight reduction in overweight children. Further research should explore the relationships between total daily light activity and weight loss in children through objective measures such as accelerometery.

It should be noted that only 2 of the 3 intervention schools showed a significant reduction in WTHR. Numerous reasons could explain the difference in effectiveness between schools, from demographics to engagement. The school that did no't show any change was the least deprived of the three and did not have a lower starting WTHR than the two other schools, discounting SES or obesity prevalence as reasons for not showing a change. However, it was also the only school that participated in the intervention after the COVID-19 pandemic (academic year 2021–22, compared to 2017–18 and 2018–19 for the other two intervention schools, respectively). Various restrictions still in place in the UK may have impacted the effectiveness of the intervention. Decreased PA was extensively reported in children during the pandemic [38], with a staggering increase of 22–66% screen time reported in some studies [39]. While schools continued to operate throughout the 2021–22 academic year, sequelae of the pandemic may have included increased sedentary behaviour and screen time at home, as well as reduced access to PA in and out of school due to ongoing restrictions and social distancing throughout the winter. This could have affected change in WTHR.

Physical Activity

A meta-analysis of accelerometery data by Love et al. [22] reported that, despite trends of increased PA in children following school-based exercise interventions, the pooled effect was not significant in increasing objectively measured levels of PA in children. The present study did not target an increase in MVPA but focused instead on reducing sedentary time (increasing light activity). Results from the self-reported PAQ-C scores reflect Love's findings; there was an increase in PA levels in term 3 in the intervention group in nearly all activity factors but these changes did not differ statistically between intervention groups. Only increase in Sport Participation showed an interaction between intervention groups. However, responses on Sport Participation were not comparable at baseline so the control children might not have shown a change due to already being less engaged in sport in term 1. Importantly, the average IDACI score in control schools was significantly higher than intervention schools, indicating that these children resided in more deprived areas and therefore might have had less access to organised sport than their counterparts in the intervention group. A larger sample of control schools, with matched IDACI, is needed to corroborate these findings.

It is possible that encouraging children to become more active pushed them to become more involved in sports outside of school hours. It is also possible that children engage more in structured activities in term 3 when the weather improves and more outdoor activities may be offered in the UK. Eime et al. [40] reported that 31–45% of Year 7–13 children see cold weather as a barrier to PA. However, the authors could not find any literature on sport participation by season and recommend further investigating whether seasonality impacts children's access to and willingness to participate in PA. Understanding seasonal changes in PA engagement could help design more effective interventions targeted at improving physical and mental wellbeing in children and adolescents.

Gender Differences

It has been largely established in the literature that girls are generally less active than boys and that this difference increases with age [41]. Despite the differences in activity levels found in this study, where girls scored lower than boys on a few activity factors, there was no gender difference in score changes between terms. This reflects Love et al.'s [22] meta-analysis, who also reported no differential effects by gender in objectively measured changes in PA.

The main gender difference observed in this study was a lower Breaktime Activity level in girls across terms 1 and 3 in both groups. This is consistent with existing literature, where objective actigraphy studies have shown that girls are more sedentary than boys during school breaktimes, and boys engage in MVPA significantly more than girls during these times [19, 20, 30]. However, despite the gender difference in the amount of activity, both boys and girls spend the majority of their breaktime being active [20]. It is therefore unsurprising that an intervention to reduce sedentary behaviour in this study did not impact activity levels during breaktime, when children are naturally most active.

In contrast, this study did not find a gender difference in activity levels outside of school. In the intervention group, boys and girls reported equal increases in activity outside of school in term 3. There is a dearth of objective research on activity levels outside of school hours in children, with conflicting findings. Beighle et al. [20] report greater activity levels in boys in 170 primary school children, but Bailey et al. [19] report no gender differences in 135 middle school children. The current study included more than 3,000 primary school children. Despite questionnaire-based measures being subject to recall bias, the consistency in gender differences across terms suggests that at least the repeatability of self-perceptions could be considered reliable.

In this study, girls scored lower on participation in sport. It should be noted that the list of activities provided in the questionnaire may be biased towards being more appealing to boys (e.g., football, hockey, skateboarding, but not dance, gymnastics, or volleyball) [42]. That girls scored equally on PA for Outside School Activity, but lower on Sport Participation, raises the question of whether currently used questionnaires are inclusive and account for gender preferences in activity type, or whether girls may have different perceptions of what it means to be "active." Further research should investigate differences in sport preferences and perceptions of "being active" between genders. It is nonetheless interesting that girls in the current study reported being equally active to boys outside of school hours, and both genders increased equally in their participation on both scores in term 3.

Socio-Economic Status

Despite a rich body of literature indicating that socio-economic deprivation is strongly and complexly associated with poorer access to PA [43] and higher obesity rates [44] in childhood, few studies on school-based interventions have addressed the impact of SES on intervention outcomes [28]. The present study included schools from a range of SES backgrounds, with schools located in areas that included between 1 and 29% of children residing in income-deprived families and with a FSM uptake of 1–49%. Despite the wide range in statuses included in the analysis, school SES did not impact either WTHR or PAQ-C outcomes of this intervention. This suggests that an intervention targeting a reduction in sedentary time during school hours, without the need for materials or costly resources, can be effective in reducing obesity regardless of SES.

Study Strengths and Limitations

It is a strong message that low-intensity activity with low metabolic expenditure such as that implemented in the current study can reduce WTHR. These results are especially impactful considering the minimal resources required to implement the Active Movement Programme in schools. Teacher training consisted only of 1 h prior to the programme and a mid-intervention forum. Other required resources were minimal (placing posters around schools, a school assembly and parent briefing session lead by researchers). With intervention complexity previously identified as a key barrier to success [29], the Active Movement Programme overcomes this issue. Indeed, the Active Movement Programme appears to represent an easy to implement and resource efficient solution to a major and growing public health concern.

The main limitation of this study was the small sample of control schools for the PAQ-C. Despite best efforts, it was challenging to engage schools in data collection without providing an intervention. Using self-reported PA levels was a limitation as this is highly subject to recall bias and particularly challenging to collect accurately in children. Salmon et al. [45] found that studies with objective measures reported a higher success at increasing PA (64%) than questionnaire-based studies (38%), suggesting that the inaccuracy of self-reported measures, especially in children, may contribute to poor quality data [46]. In addition, the questionnaire covered activity levels during breaks and outside of school but not during classroom time, which was the main focus of the intervention. Identifying whether children perceived changes in classroom time activity, or objectively measuring sedentary time using accelerometers, might have provided further clarity on the drivers underlying the reduction in WTHR.

SES measures included in the analysis refer to the school and not the pupil. SES is complex and multifactorial, difficult to measure without a comprehensive picture of household income, location and parental education per child. In this study, SES was determined at school level using the IDACI score of the school's postcode and %FSM uptake of the school. While FSM is considered a good generic indicator of broad SES, the complexities of socio-economic disadvantage and determinants of FSM eligibility make it a coarse and relatively inaccurate measure of deprivation itself [47–49]. Within a group of eligible families, parents from higher educational backgrounds on the income threshold are more likely to take up the subsidy, while parents from the lowest SES backgrounds or immigrant communities may not be aware of the opportunity, therefore missing out on FSM for their child [48]. This group of pupils has been referred to as the "super deprived" [49]. The FSM score in this study was not based on eligibility but on percentage of pupils with FSM in each school, therefore may not accurately represent their SES. Therefore, the SES measure used in this study should be interpreted as an indicator of the probability of each child coming from a low-income family.

School engagement has been varied both in implementing the intervention and in collecting data. School-based interventions present limitations, with highly structured and multi-component interventions notoriously challenging for schools to follow and presenting barriers to implementation and replication [29]. Strength of the current intervention was the low requirement for resources and structure, with teachers given ideas on how to make classroom activities less sedentary without a rigid structure to follow. However, this is also a limitation of the study as the activities could not be controlled.

Recommendations

These results suggest the strong potential that low-cost and low-resource interventions may have on reducing child obesity, particularly in low-income settings. While it is extremely important that children engage in vigorous exercise for their physical and cognitive development, much of the literature highlights the challenges related to the sustainability and logistics of sport or exercise-based interventions. This paper provides promising evidence that a long-term (6+ months) school-based intervention aimed specifically at reducing sedentary time may be effective at promoting weight loss in primary school children. Considering that classroom time constitutes the most sedentary period of a child's day [19], schools may wish to implement creative ways of embedding movement during lessons in order to support healthy child development. This may be especially true where extensive physical activities outside the classroom are restricted. Future research should also consider investigating the impact of similar programmes on child mental wellbeing, behaviour, and cognition during study hours.

Governing bodies and authorities could perhaps consider implementing policies that support the reduction of sedentary time at school. This could be achieved, for example, by providing support for schools to implement similar programmes, or by creating schemes that help schools develop and measure the impact of such interventions through measurable outcomes. If further research were to identify the optimal levels of physical activity required to help reduce obesity, as well as to maximise academic achievement and mental wellbeing, this might lead to more specific evidence-based guidelines about minimum requirements of physical activity time per school day, and the form they could take. After all, healthy minds, through healthy bodies, are likely to learn better.

Conclusion

The main finding of this study indicates that a school-based intervention that targets a reduction of sedentary time during classroom hours can significantly reduce WTHR, particularly in children with a higher starting WTHR. More importantly, gender, age, and SES did not impact the effectiveness of the intervention, and the reduction in WTHR could not be explained by self-reported changes in PA levels during break or outside of school. Therefore, reducing sedentary time during classroom hours can reduce obesity in primary school children independently of their demographic background. These results provide a promising avenue for the implementation of cost-effective and low-resource interventions to help tackle the important and worsening global concern that is childhood obesity.

Statement of Ethics

This study protocol was reviewed and approved by University College London Research Ethics Committee, approval number 722/002, in line with the Declaration of Helsinki. Written informed consent was obtained from head teachers and parents of pupils at participating schools.

Conflict of Interest Statement

Professor Mike Loosemore and Peter Savage co-created Active Movement. The remaining authors have no conflicts of interest to declare.

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Author Contributions

F.R., P.W.B., and M.L. designed the study. P.S. designed and delivered the intervention and managed the data collection. F.R. and E.W. collected the data. F.R., P.W.B., and N.S. analysed the data and wrote the manuscript. All authors reviewed and contributed to the final draft of the manuscript.

Data Availability Statement

The raw data supporting the findings in this article are not publicly available due to privacy reasons but are available from the corresponding author upon reasonable request.

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