

# Reducing children's classroom sitting time using sit-to-stand desks: findings from pilot studies in UK and Australian primary schools

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## ABSTRACT

**Background** This research examined the influence of sit-to-stand desks on classroom sitting time in primary school children.

**Methods** Pilot controlled trials with similar intervention strategies were conducted in primary schools in Melbourne, Australia, and Bradford, UK. Sit-to-stand desks replaced all standard desks in the Australian intervention classroom. Six sit-to-stand desks replaced a bank of standard desks in the UK intervention classroom. Children were exposed to the sit-to-stand desks for 9–10 weeks. Control classrooms retained their normal seated desks. Classroom sitting time was measured at baseline and follow-up using the activPAL3 inclinometer.

**Results** Thirty UK and 44 Australian children provided valid activPAL data at baseline and follow-up. The proportion of time spent sitting in class decreased significantly at follow-up in both intervention groups (UK:  $-9.8 \pm 16.5\%$  [ $-52.4 \pm 66.6$  min/day]; Australian:  $-9.4 \pm 10\%$  [ $-43.7 \pm 29.9$  min/day]). No significant changes in classroom sitting time were observed in the UK control group, while a significant reduction was observed in the Australian control group ( $-5.9 \pm 11.7\%$  [ $-28.2 \pm 28.3$  min/day]).

**Conclusions** Irrespective of implementation, incorporating sit-to-stand desks into classrooms appears to be an effective way of reducing classroom sitting in this diverse sample of children. Longer term efficacy trials are needed to determine effects on children's health and learning.

**Keywords** activPAL, ethnic diversity, health, pilot controlled trial, sedentary behaviour, socioeconomic status

## Introduction

In children, adverse associations between sedentary behaviour (sitting) and cardio-metabolic health risk markers (obesity, blood pressure, cholesterol, insulin), fitness, cognitive development and academic achievement have been reported.<sup>1–4</sup>

In adults, sedentary behaviour has been associated with increased risk for numerous chronic conditions, including obesity, cardiovascular disease, some cancers and type 2 diabetes.<sup>5–8</sup> Sedentary behaviour is the most prevalent pastime exhibited by children and adults, accounting for ~65% of waking hours,<sup>9–11</sup> and has been shown to track from childhood into adolescence and adulthood.<sup>12,13</sup> The successful reduction of sedentary behaviours in young people is pertinent

for the primary and secondary prevention of diseases that result from excessive engagement in these behaviours.

The school classroom is conducive to high volumes of sitting, with Australian data showing that 63% of class time per

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school day is spent sedentary.<sup>14</sup> Moreover, children sit for longer during school hours compared with non-school hours on school days.<sup>11,14</sup> Due to the contextually driven nature of sedentary behaviour, interventions in children have begun to target reductions in classroom sitting,<sup>15–21</sup> with initial studies demonstrating the feasibility of incorporating sit-to-stand desks in primary school classrooms.<sup>16,20,22</sup> Evidence suggests that the use of sit-to-stand desks in primary schools is effective in increasing energy expenditure<sup>17,21</sup> and standing and movement during the school day.<sup>18</sup> However, only one study has directly assessed the impact of such interventions on sitting time.<sup>16</sup> Hinckson *et al.*<sup>16</sup> reported a reduction in total daily sitting of ~1 h/day in children exposed to sit-to-stand desks at school; however, the specific changes in classroom sitting time were not reported.

To date, evidence on the use of sit-to-stand desks in the school environment has largely been restricted to USA and New Zealand samples. The generalizability of these studies to other countries is unclear due to differences in educational systems. This paper reports the findings of two controlled intervention pilot studies conducted in the UK and Australia, which adopted similar intervention strategies, to examine the influence of sit-to-stand desks on primary school children's classroom sitting time and total school day sitting.

## Methods

### Participants

#### UK study

Participants were recruited from an ethnically diverse primary school located in the City of Bradford, England. Bradford has high levels of deprivation and childhood morbidity;<sup>23</sup> the school was located in a neighbourhood within the top third for overall deprivation in England. The school contained two classrooms per year group, and in consultation with the Head and Assistant Head Teachers, the Year 5 cohort (9–10 year olds) were selected for participation. Evidence suggests that children in Year 5 upwards are active participants in their own learning, making them an optimal target for classroom interventions that may facilitate learning.<sup>24</sup> Parents/guardians of Year 5 children received a letter explaining the school was replacing some existing desks within one Year 5 classroom with sit-to-stand desks. The study was approved by the Loughborough University Ethical Advisory committee. Parents/guardians provided written informed consent for their children to participate in the intervention evaluation.

#### Australian study

Participants were recruited from a primary school located in a middle-high socioeconomic status (SES) area in Melbourne, Victoria. In consultation with the Principal and senior

teachers, two Year 6 (11–12 year olds) classrooms (out of a possible three) were randomly selected for participation. Parents/guardians of all children from the respective classrooms received a letter explaining that their child's classroom had a 50% chance of receiving a sit-to-stand desk. Parents returned written informed consent for their children to participate in the intervention evaluation. The study was approved by Deakin Human Ethics Advisory Group-Health and the Department of Education and Early Childhood Development.

### Interventions

In both the UK and Australian studies, one classroom was allocated to the intervention condition while the other was assigned to the control (usual care) condition.

#### UK study

The intervention took place during the spring term (January–April 2014). In the intervention classroom, home to 27 students, three standard desks (sitting a total of six children) were replaced with six Ergotron WorkFit-PD sit-to-stand desks (Ergotron Inc., USA, Fig. 1). The teacher rotated the children around the classroom in groups of six according to the specific lesson being taught to ensure that each child was exposed to the sit-to-stand desks once a day for at least 1 h for 9 weeks. The time of day during which each child was exposed to the desks varied over the course of the week and children were informed that they could sit (on stools provided) or stand when using the desks. The intervention teacher received training on desk adjustment. Information on the benefits of reducing sedentary behaviour and classroom sitting time reduction strategies, based on materials adapted from a previous cluster randomized controlled study, were also provided.<sup>15</sup> No environmental or other changes were made to the control classroom (home to 28 students), their teacher continued with normal lesson delivery.

#### Australian study

The intervention took place during the spring term (September–November 2013). In contrast to the UK study, all standard desks were replaced with Ergotron WorkFit-PD sit-to-stand desks providing all 26 children (and the teacher) with their own desk throughout the 10-week school term (Fig. 1). Standard classroom chairs remained at the desks throughout. Children were initially encouraged to stand for at least one 30-min class per day and to increase this gradually over the 10-week intervention. As in the UK study, the intervention teacher received training on desk use and the same classroom sitting time reduction strategies.<sup>15</sup> The control



**Fig. 1** The sit-to-stand desks located in the intervention classrooms of the UK (top panel) and Australian (lower panel) schools.

classroom involved 22 students and had no environmental or other changes, with the teacher continuing their usual lesson delivery.

### Measurements

Identical measurements were taken in both studies at baseline (prior to desk installation) and at 9–10 weeks of follow-up (last 2 weeks of school term). All measurements were undertaken in the schools by trained researchers. Children with parental consent self-reported their age and ethnicity (UK study, e.g. White, Asian) or parent's place of birth (Australian study). Height and weight were directly measured to the nearest 0.1 cm and 0.1 kg, respectively, without shoes, using portable stadiometers (Australian study: Seca model 220; UK study: Leicester Height Measure) and electronic weighing scales (Australian study: Tanita model 1582; UK study: Seca model 887). For both, the average of two measurements was calculated. Children were issued with an activPAL3 accelerometer (PAL Technologies, UK), worn on the thigh for 7 consecutive days, which responds to signals related to gravitational forces

and provides information on thigh inclination.<sup>25</sup> The activPAL is a valid measure of time spent sitting, standing and walking in children.<sup>26</sup> In the UK study, the activPAL was placed within a nitrile sleeve and attached to the leg using a waterproof hypoallergenic medical dressing (BSN Hypafix), enabling participants to wear the device continuously (24 h a day). In the Australian study, the activPAL was placed in an elastic garter and worn on the front of the thigh during all waking hours. Children were asked to complete a daily log book where they reported the times they woke up and went to bed, and any time the activPAL was removed. On Day 8, children returned the activPAL and diary to school where it was collected by a researcher.

### Data management

All activPAL data were downloaded using manufacturer proprietary software (activPAL Professional v.7.2.29) in 15-s epochs and processed using a customized Microsoft Excel macro. The number of minutes that children spent sitting, standing and stepping during waking hours (between 6 am and 10 pm) was obtained for each school day (weekend data were omitted due to low compliance). As applied in accelerometer studies, non-wear time was defined as 60 min of consecutive zero accelerometer counts.<sup>27</sup> To enable the examination of the influence of the sit-to-stand desks on classroom sitting time, time spent sitting, standing and stepping during class time (based on provided school bell times) were extracted from the daily weekday data. Due to the exploratory nature of the study, children were included in the analyses if they had worn the activPAL for at least 8 h on at least 1 weekday at each time point.

### Statistical analyses

Statistical analyses were conducted using SPSS v.22 (SPSS Inc., Chicago, IL, USA). To account for differences in activPAL wear time between baseline and follow-up, and between the intervention and control groups within the UK and Australian studies, the proportions of wear time spent sitting, standing and stepping were calculated for each participant. These data were used in the analyses as opposed to the absolute minute data. The Shapiro–Wilk test confirmed that all data were normally distributed. To examine any differences between the children participating in the two studies, baseline data for the proportion of class time spent sitting, standing and stepping were compared using independent *t*-tests. The proportions of time spent in each behaviour during class time were compared between the baseline and follow-up periods for the intervention and control groups within each study using paired-samples *t*-tests. Differences in the proportion

of time spent sitting, standing and stepping during class time at baseline and follow-up, along with changes in these behaviours, were compared between groups within each study using independent samples *t*-tests. These analyses were repeated for the proportions of time spent in each behaviour on a whole weekday.

## Results

### Participants

#### UK study

Fifty-four children had parental consent to participate in the study, of which 30 (56%; 16 boys, 14 girls; mean [ $\pm$  SD] age:  $10.0 \pm 0.3$  years, BMI:  $18.3 \pm 3.2$  kg/m<sup>2</sup>) provided valid activPAL data at baseline and follow-up. Twenty-three per cent self-reported their ethnicity as White, 63% South Asian and 13% mixed ethnicity. There were no significant differences between the compliant and non-compliant participants in terms of age, BMI, sex proportion or the proportions of participants from each ethnic group ( $P > 0.05$ ).

#### Australian study

Forty-eight children had parental consent, of which 44 (92%; 19 boys, 25 girls; mean [ $\pm$  SD] age:  $11.6 \pm 0.5$  years, BMI:  $19.4 \pm 3.3$  kg/m<sup>2</sup>) provided valid activPAL data at baseline and follow-up. Just over half (54%) of the sample's parents were born in Australia.

### Changes in classroom sitting, standing and stepping time

At baseline, children from both countries spent 5 h/day in the classroom (not including morning recess and lunch). There were no significant differences in classroom sitting time at baseline between the UK ( $200 \pm 48$  min/day, 70% of classroom wear time) and Australian ( $203 \pm 22$  min/day, 69% of classroom wear time) study samples.

Table 1 shows the mean minutes, and the proportion of time spent sitting, standing and stepping during class at baseline and follow-up for the intervention and control participants in the two studies. The proportion of time spent sitting in class decreased significantly at follow-up in both intervention

**Table 1** Sitting, standing and stepping time (mean min/day  $\pm$  SD), along with the proportion of time spent in these behaviours for the UK and Australian sample, measured using the activPAL during class time for the intervention and control groups at baseline and follow-up

	Intervention class				Control class			
	Baseline	Follow-up	Change	Difference (P-value) <sup>a</sup>	Baseline	Follow-up	Change	Difference (P-value) <sup>a</sup>
UK sample	<i>n</i> = 16				<i>n</i> = 14			
Sitting (min)	210.4 $\pm$ 34	158 $\pm$ 49.2	-52.4 $\pm$ 66.6		187.4 $\pm$ 59.1	180.5 $\pm$ 67.5	-6.9 $\pm$ 91	
% of wear time	71.8 $\pm$ 10.6	62 $\pm$ 15.8	-9.8 $\pm$ 16.5	0.03	68.6 $\pm$ 20	65.4 $\pm$ 20.1	-3.2 $\pm$ 30.2	NS
Standing (min)	58.5 $\pm$ 25.1	61.3 $\pm$ 34.3	2.8 $\pm$ 39.6		57.8 $\pm$ 32	57.9 $\pm$ 34.1	0.1 $\pm$ 52.8	
% of wear time	20.1 $\pm$ 8.7	23.5 $\pm$ 12.5	3.4 $\pm$ 14.9	NS	24 $\pm$ 20.8	21.9 $\pm$ 12.8	-2.1 $\pm$ 26.2	NS
Stepping (min)	23.9 $\pm$ 8.1	38 $\pm$ 23.5	14.1 $\pm$ 18.8		20.2 $\pm$ 9.7	33.8 $\pm$ 22.7	13.6 $\pm$ 25.9	
% of wear time	8.2 $\pm$ 2.8	14.5 $\pm$ 7.9	6.3 $\pm$ 6.8	0.002	7.4 $\pm$ 3.6	12.8 $\pm$ 8.2	5.4 $\pm$ 9.1	NS
Steps	1654 $\pm$ 528.9	3024 $\pm$ 2195	1370 $\pm$ 1937	0.013	1425 $\pm$ 663	2588 $\pm$ 1867	1163 $\pm$ 2028	NS
Wear time (min)	292.7 $\pm$ 12.2	257.2 $\pm$ 47.5	-35.5 $\pm$ 50.9	0.014	265.4 $\pm$ 36.2	272.1 $\pm$ 37.3	6.7 $\pm$ 45.2	NS
Australian sample	<i>n</i> = 24				<i>n</i> = 20			
Sitting (min)	201.5 $\pm$ 25.4	157.8 $\pm$ 19.7	-43.7 $\pm$ 29.9		205.3 $\pm$ 18.3	177.1 $\pm$ 22	-28.2 $\pm$ 28.3	
% of wear time	67.9 $\pm$ 8.4	58.5 $\pm$ 8.4	-9.4 $\pm$ 10	<0.001	70.8 $\pm$ 5.8	64.8 $\pm$ 10.8	-5.9 $\pm$ 11.7	0.04
Standing (min)	53.7 $\pm$ 13.3	72 $\pm$ 21.6	18.2 $\pm$ 21.2		43.7 $\pm$ 7.7	58.2 $\pm$ 18.1	14.6 $\pm$ 18.9	
% of wear time	18.1 $\pm$ 4.5	26.4 $\pm$ 7.5	8.3 $\pm$ 7.6	<0.001	15.1 $\pm$ 2.7	20.7 $\pm$ 5.9	5.6 $\pm$ 6.4	0.001
Stepping (min)	41.4 $\pm$ 15.5	41.1 $\pm$ 9.9	-0.3 $\pm$ 15.4		41.1 $\pm$ 11.5	40.9 $\pm$ 16.7	-0.2 $\pm$ 18.1	
% of wear time	14 $\pm$ 5.2	15.1 $\pm$ 3	1.1 $\pm$ 4.9	NS	14.2 $\pm$ 3.9	14.5 $\pm$ 5.6	0.3 $\pm$ 6.2	NS
Steps	3356 $\pm$ 1264	3213 $\pm$ 738	-143 $\pm$ 1245	NS	3318 $\pm$ 932	3209 $\pm$ 1296	-109 $\pm$ 1449	NS
Wear time (min)	296.6 $\pm$ 5.6	270.8 $\pm$ 20.4	-25.8 $\pm$ 22.2	<0.001	290 $\pm$ 7.4	276.1 $\pm$ 28.1	-13.8 $\pm$ 26.4	0.03

NS, not significant.

<sup>a</sup>Due to variations in wear time between the baseline and follow-up measurement periods, comparisons were made between the proportion of wear time spent sitting, standing and stepping, and not for the absolute minute data. The time spent in these behaviours is provided, however, for information.

groups. In the UK intervention group, while there were no significant changes in the proportion of time spent standing in class, there was a significant increase in the proportion of time spent stepping, along with step counts, at follow-up. In the Australian intervention group, a significant increase in the proportion of time spent standing during class was observed, no changes were seen in stepping time. In the UK control group, no significant differences in any behaviour during class time were observed over the intervention period. In the Australian control group, a significant reduction in the proportion of class time spent sitting, and a significant increase in the proportion of class time spent standing was observed.

Within the UK and Australian studies, the intervention and control groups did not differ significantly at baseline in terms of the proportion of class time spent sitting, standing or stepping ( $P > 0.05$ ). In the UK sample, there were no significant differences between the intervention and control groups at follow-up. In the Australian sample, the intervention group spent a significantly lower proportion of time sitting ( $P = 0.03$ ), and a higher proportion of time standing ( $P < 0.01$ ) during class time at follow-up in comparison to the control

group (Table 1). The changes in behaviours over the intervention period did not differ significantly between the intervention and control groups in either country ( $P > 0.05$ ).

### Total weekday sitting, standing and stepping time

At baseline, the UK study sample spent a significantly higher proportion of time sitting in comparison to the Australian study sample on a school day (70% [588 ± 81 min/day] versus 62% [494 ± 81 min/day] of waking time,  $P < 0.001$ ). There were no significant differences in the proportion of time spent standing between the two samples; however, the UK sample spent a significantly lower proportion of time stepping in comparison to the Australian sample (11% [91 ± 32 min/day] versus 17% [138 ± 47 min/day] of waking time,  $P < 0.001$ ).

In the UK study, the proportion of time spent sitting, standing and stepping did not differ significantly between baseline and follow-up when examined over the course of a whole school day for the intervention and control groups ( $P > 0.05$ ) (Table 2). In the Australian study, a significant increase in the proportion of time spent standing on a weekday was observed in the intervention group ( $P < 0.01$ ). No

**Table 2** Sitting, standing and stepping time (mean min/day ± SD), along with the proportion of time spent in these behaviours for the UK and Australian sample, measured using the activPAL on a whole weekday for the intervention and control groups at baseline and follow-up

	Intervention class				Control class			
	Baseline	Follow-up	Change	Difference (P-value) <sup>a</sup>	Baseline	Follow-up	Change	Difference (P-value) <sup>a</sup>
UK sample	<i>n</i> = 16				<i>n</i> = 14			
Sitting (min)	606.5 ± 66.4	525.7 ± 103.7	-80.8 ± 103.4		566.1 ± 92.6	574 ± 180.6	7.9 ± 199	
% of wear time	69.1 ± 8.3	66.8 ± 6.6	-2.3 ± 10.7	NS	71.4 ± 7.6	69.1 ± 14.1	-2.3 ± 16.8	NS
Standing (min)	176.0 ± 62.5	160.1 ± 40	-15.9 ± 76.2		149.2 ± 48.1	151 ± 68.4	1.8 ± 93.4	
% of wear time	19.5 ± 6	20.8 ± 6	1.3 ± 9.1	NS	18.9 ± 5.9	18.8 ± 9	-0.1 ± 12.1	NS
Stepping (min)	102.1 ± 30.2	100.4 ± 45.7	-1.7 ± 48.1		77.4 ± 30.5	95.1 ± 53.9	17.7 ± 59.8	
% of wear time	11.4 ± 2.9	12.5 ± 4.4	1.1 ± 4.7	NS	9.7 ± 3.6	12.1 ± 6.9	2.4 ± 7.4	NS
Steps	7695 ± 2378	7776 ± 3769	81 ± 4223	NS	5974 ± 2307	7295 ± 4309	1321 ± 4712	NS
Wear time (min)	884.4 ± 97.4	785.9 ± 131.1	-98.5 ± 129.9	0.01	792.4 ± 95.3	819.8 ± 131.2	27.4 ± 157.1	NS
Australian sample	<i>n</i> = 24				<i>n</i> = 20			
Sitting (min)	498.2 ± 80.2	429.8 ± 60.4	-68.3 ± 97.2		489.7 ± 84.6	435.5 ± 81.2	-54.2 ± 115.8	
% of wear time	62.1 ± 11	59 ± 5.7	-3.1 ± 11.2	NS	62.4 ± 8.5	62.4 ± 8.6	0 ± 10.6	NS
Standing (min)	172 ± 51.3	185 ± 39.6	13 ± 53.1		152 ± 38	145.5 ± 34.7	-6.5 ± 35.8	
% of wear time	21.3 ± 6.1	25.5 ± 5.5	4.2 ± 7.4	0.01	19.4 ± 4.6	20.7 ± 3.9	1.4 ± 4.4	NS
Stepping (min)	134.4 ± 53.4	113.5 ± 29.9	-20.9 ± 40.2		142.2 ± 39.2	118 ± 44.2	-24.2 ± 50.3	
% of wear time	16.6 ± 6.6	15.5 ± 3.4	-1.1 ± 5.1	NS	18.3 ± 5.1	16.9 ± 6	-1.3 ± 7.7	NS
Steps	11 011 ± 4441	9103 ± 2348	-1908 ± 3268	0.01	11 678 ± 3230	9513 ± 3520	-2165 ± 4238	0.03
Wear time (min)	804.4 ± 49.6	728.2 ± 68.2	-76.2 ± 59	<0.001	783.7 ± 65	698.8 ± 88.1	-84.9 ± 97.4	<0.001

NS, not significant.

<sup>a</sup>Due to variations in wear time between the baseline and follow-up measurement periods, comparisons were made between the proportion of wear time spent sitting, standing and stepping, and not for the absolute minute data. The time spent in these behaviours is provided however for information.

significant changes were seen in any behaviour in the control group ( $P > 0.05$ , Table 2).

## Discussion

### Main finding of this study

This paper reports the findings from two pilot studies conducted in ethnically and socioeconomically diverse samples of primary school children from the UK and Australia, which adopted similar intervention strategies, to examine the influence of sit-to-stand desks on classroom sitting time. Despite differences in desk provision, the intervention groups from both schools exhibited similar significant reductions in the proportion of class time spent sitting. Taken together, these pilot studies add to the limited evidence base on the efficacy of sit-to-stand desks on objectively measured sitting time.<sup>16</sup>

### What is already known on this topic

Sedentary behaviour is the most prevalent health-related behaviour exhibited by children and adults.<sup>9–11</sup> In children, adverse associations between sedentary behaviour and health have been reported.<sup>1–4</sup> While optimum reductions in sedentary time in children need to be established, recent data from adults show that reallocating just 30 min of sedentary time per day to light movement is associated with a 2–4% improvement in cardio-metabolic biomarkers.<sup>28</sup> The school classroom is conducive to high volumes of sitting.<sup>14</sup> Earlier studies have demonstrated the feasibility of incorporating sit-to-stand desks in the classroom environment,<sup>16,20,22</sup> however, specific changes in classroom sitting time have not been reported.

### What this study adds

An important practical and novel finding of this research was that similar changes in classroom sitting time were seen in the UK and Australian studies (9.8% [ $-52$  min/day] and 9.4% [ $-44$  min/day]), despite the differences in desk provision. The similar reductions in classroom sitting between interventions suggest that it may not be necessary to replace all standard desks in a given classroom with sit-to-stand desks and a bank of desks may be sufficient to produce meaningful changes in sedentary behaviour in the classroom. A randomized controlled trial directly comparing these two intervention strategies is required to confirm this finding. Furthermore, the use of the sitting time reduction strategies provided to intervention teachers were not formally evaluated in the present pilot studies, further research will be required to evaluate the effectiveness of sit-to-stand desks on their own and in combination with sitting time reduction strategies.

The interventions appeared to have different effects on classroom non-sedentary time. For example, the UK

intervention group demonstrated a significant increase in the proportion of class time spent stepping, which was coupled by a significant increase in step counts. In contrast, the Australian intervention group displayed a significant increase in the proportion of class time spent standing, with no changes in stepping. These findings could partially be attributed to the fact that the UK sample had to move around the classroom to use the sit-to-stand desks. Installing a bank of sit-to-stand desks and rotating children around to them appears to promote movement in class, in addition to reductions in sedentary time, as reported previously.<sup>18,21</sup>

Overall on a school day, both samples spent a high proportion of time sitting. This was particularly evident in the UK sample who accumulated just under 10 h sitting per day, equivalent to 70% of their waking hours. The Australian children accumulated 8.25 h/day, accounting for 62% of waking hours. Reductions in total daily sitting time were observed in both intervention groups; these changes were not statistically significant; however, the study was not powered to detect significant changes. The present findings, in agreement with others,<sup>16–18,21</sup> suggest that while the classroom environment is an ideal setting to target reductions in sedentary behaviour and increases in activity, in highly sedentary populations such as the UK sample multi-setting interventions which target both the school and home environment<sup>15</sup> may be necessary for reducing overall daily sitting time.

### Limitations of this study

Limitations of the study include the relatively small sample sizes, the relatively short intervention periods (9–10 weeks), potential changes in school schedules during baseline and follow-up (although this would be equivalent for the intervention and control groups within each school) and the lack of long-term follow-up. The lower compliance to the activPAL protocol seen in the UK study is also a limitation. Reasons for the differences in compliance could be attributable to differences in SES, sample age and attachment methods between studies. Lastly, in both studies the control groups consisted of children from the same school as the intervention groups. Contamination of the intervention appears to be evident, as seen elsewhere,<sup>16</sup> as small reductions in sitting were observed in both control groups.

Despite these limitations, strengths of the present study include the ethnically and socioeconomically diverse samples. The UK school was located in a region known for its high levels of deprivation and childhood morbidity.<sup>23</sup> Children attending the school represent a range of ethnic groups, with the majority being South Asian. It is widely acknowledged that South Asians living in the UK have an increased risk of

numerous chronic diseases,<sup>29</sup> with South Asian children exhibiting a number of elevated risk factors for disease in comparison to White children.<sup>30–32</sup> In contrast, the Australian study sample was drawn from a middle-high socioeconomic area in Melbourne. These pilot studies suggest that the implementation of sit-to-stand desks is a feasible way of reducing classroom sitting in children from a range of socioeconomic groups, including ethnic minority and high-risk groups. Longer term efficacy trials are needed to confirm these findings and to determine the impact of such interventions on children's health, cognition and academic achievement.

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## Conflict of interest statement

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## References

- 1 Rey-Lopez JP, Vicente-Rodriguez G, Biosca M *et al*. Sedentary behaviour and obesity development in children and adolescents. *Nutr Metab Cardiovasc Dis* 2008;**18**:242–51.
- 2 Marshall SJ, Biddle SJ, Gorely T *et al*. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *Int J Obes Relat Metab Disord* 2004;**28**:1238–46.
- 3 Salmon J, Tremblay MS, Marshall SJ *et al*. Health risks, correlates, and interventions to reduce sedentary behavior in young people. *Am J Prev Med* 2011;**41**:197–206.
- 4 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.
- 5 Hu FB, Li TY, Colditz GA *et al*. Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. *JAMA* 2003;**289**:1785–91.
- 6 Lynch BM. Sedentary behavior and cancer: a systematic review of the literature and proposed biological mechanisms. *Cancer Epidemiol Biomarkers Prev* 2010;**19**:2691–709.
- 7 Wilmut EG, Edwardson CL, Achana FA *et al*. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. *Diabetologia* 2012;**55**:2895–905.
- 8 Katzmarzyk PT, Church TS, Craig CL *et al*. Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc* 2009;**41**:998–1005.
- 9 Steele RM, van Sluijs EM, Cassidy A *et al*. Targeting sedentary time or moderate- and vigorous-intensity activity: independent relations with adiposity in a population-based sample of 10-y-old British children. *Am J Clin Nutr* 2009;**90**:1185–92.
- 10 Cledes SA, O'Connell SE, Edwardson CL. Office workers' objectively measured sedentary behavior and physical activity during and outside working hours. *J Occup Environ Med* 2014;**56**:298–303.
- 11 Abbott RA, Straker LM, Mathiassen SE. Patterning of children's sedentary time at and away from school. *Obesity* 2013;**21**:E131–3.
- 12 Biddle SJ, Pearson N, Ross GM *et al*. Tracking of sedentary behaviours of young people: a systematic review. *Prev Med* 2010;**51**:345–51.
- 13 Pearson N, Salmon J, Campbell K *et al*. Tracking of children's body-mass index, television viewing and dietary intake over five-years. *Prev Med* 2011;**53**:268–70.
- 14 Ridgers ND, Salmon J, Ridley K *et al*. Agreement between activPAL and ActiGraph for assessing children's sedentary time. *Int J Behav Nutr Phys Act* 2012;**9**:15.
- 15 Salmon J, Arundell L, Hume C *et al*. A cluster-randomized controlled trial to reduce sedentary behavior and promote physical activity and

- health of 8–9 year olds: the Transform-Us! study. *BMC Public Health* 2011;**11**:759.
- 16 Hinckson EA, Aminian S, Ikeda E *et al.* Acceptability of standing workstations in elementary schools: a pilot study. *Prev Med* 2013;**56**:82–5.
  - 17 Benden ME, Blake JJ, Wendel ML *et al.* The impact of stand-biased desks in classrooms on calorie expenditure in children. *Am J Public Health* 2011;**101**:1433–6.
  - 18 Lanningham-Foster L, Foster RC, McCrady SK *et al.* Changing the school environment to increase physical activity in children. *Obesity* 2008;**16**:1849–53.
  - 19 Cardon G, De Clercq D, De Bourdeaudhuij I *et al.* Sitting habits in elementary schoolchildren: a traditional versus a “Moving school”. *Patient Educ Couns* 2004;**54**:133–42.
  - 20 Koeppe G, Snedden B, Flynn L *et al.* Feasibility analysis of standing desks for sixth graders. *ICAN* 2012;**4**:89–92.
  - 21 Benden ME, Zhao H, Jeffrey CE *et al.* The evaluation of the impact of a stand-biased desk on energy expenditure and physical activity for elementary school students. *Int J Environ Res Public Health* 2014;**11**:9361–75.
  - 22 Blake JJ, Benden ME, Wendel ML. Using stand/sit workstations in classrooms: lessons learned from a pilot study in Texas. *J Public Health Manag Pract* 2012;**18**:412–5.
  - 23 Wright J, Small N, Raynor P *et al.* Cohort Profile: the Born in Bradford multi-ethnic family cohort study. *Int J Epidemiol* 2013;**42**:978–91.
  - 24 Ginsburg H, Opper S. *Piaget's Theory of Intellectual Development*. 3rd edn. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1988.
  - 25 Atkin AJ, Gorely T, Cledes SA *et al.* Methods of measurement in epidemiology: sedentary behaviour. *Int J Epidemiol* 2012;**41**:1460–71.
  - 26 Davies G, Reilly JJ, McGowan AJ *et al.* Validity, practical utility, and reliability of the activPAL in preschool children. *Med Sci Sports Exerc* 2012;**44**:761–8.
  - 27 Cain K, Sallis J, Conway T *et al.* Using accelerometers in youth physical activity studies: a review of methods. *J Phys Act Health* 2013;**10**:437–50.
  - 28 Buman MP, Winkler EA, Kurka JM *et al.* Reallocating time to sleep, sedentary behaviors, or active behaviors: associations with cardiovascular disease risk biomarkers, NHANES 2005–2006. *Am J Epidemiol* 2014;**179**:323–34.
  - 29 Misra A, Khurana L, Vikram NK *et al.* Metabolic syndrome in children: current issues and South Asian perspective. *Nutrition* 2007;**23**:895–910.
  - 30 Jebb SA, Rennie KL, Cole TJ. Prevalence of overweight and obesity among young people in Great Britain. *Public Health Nutr* 2004;**7**:461–5.
  - 31 Whincup PH, Gilg JA, Papacosta O *et al.* Early evidence of ethnic differences in cardiovascular risk: cross sectional comparison of British South Asian and white children. *BMJ* 2002;**324**:635.
  - 32 Whincup PH, Nightingale CM, Owen CG *et al.* Early emergence of ethnic differences in type 2 diabetes precursors in the UK: the Child Heart and Health Study in England (CHASE Study). *PLoS Med* 2010;**7**:e1000263.



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