activPAL-measured sitting levels and patterns in 9-10 year old children from a UK city

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Abstract

Background: There is insufficient evidence of sitting time in UK children from validated objective measures. This study explored sitting patterns in primary school children from Bradford, UK, using the validated activPAL inclinometer.

Methods: Seventy-nine children (9.8 (SD 0.3) years old, 52% boys; 70% South Asian) wore activPALs for 7-days. Total sitting time, sitting time accumulated in different bout lengths, and the proportion of wear time spent in these variables were explored and compared across different periods of the week.

Results: Children spent 614±112 (median±IQR) mins/day on school days and 690±150 mins/day on weekend days sitting. The proportion of time spent sitting was significantly higher on weekend days compared to school days (mean±SD: 74±10% vs 68±8%,*P*<0.001), as was the proportion of time accumulated in >30min sitting bouts (mean±CI: 28±27-33% vs 20±20-22%,*P*<0.001). The proportion of time spent sitting after school was significantly higher than during school time (mean±SD: 70±8.4% vs 63±8.3%,*P*<0.001), as was the proportion of time spent in prolonged (>30min) sitting bouts (mean±CI: 19±16-22% vs 11±10-14%,*P*<0.001).

Conclusions: Children spent large proportions of their waking day sitting, often accumulated in prolonged uninterrupted bouts and particularly after school and on weekends. Interventions to reduce sitting time in children are urgently needed.

INTRODUCTION

Sedentary behaviour is defined as “any waking behaviour characterised by an energy expenditure ≤1.5 METs while in a sitting, reclining or lying posture”(1). Early sedentary behaviour research has predominently explored screen-based pursuits (TV viewing, computer use) using self-report measures. In children (ages 6-12yrs), these types of sedentary behaviour are unfavourably associated with cardio-metabolic health, pro-social behaviour, and academic achievement (2).

Recently, total waking sedentary time has been explored using accelerometry. This international evidence has consistently reported that children spend most of their time sedentary (>60% waking hours), both during (4) and outside school hours (5–7). For example, in 1,862 English children (9-10yrs), 64% (7.5hours) of an average day was spent sedentary (5). Unlike screen time, the relationship between total sedentary time and health outcomes in children is unclear (2). However, high sedentary time in children is a public health concern for several reasons. Firstly, sedentary time not only tracks from childhood into adolescence and adulthood (8,9), but also continually increases between these stages of life (9). There is a clear adverse association between high levels of sedentary time (i.e.>8h/day) and mortality in adults (10). Additionally, an increased cardio-metabolic health risk in some demographics is evident during childhood (11). For example, British South Asian children have demonstrated higher glycated haemoglobin, fasting insulin and triglyceride and lower HDL-cholesterol compared to white British children (11). Therefore, these populations may be more vulnerable to the adverse affects of excessive sedentary time. Consequently, it is important to develop strategies to reduce sedentary time during childhood before these behaviours become more established and difficult to change.

There is currently growing interest into how sedentary time is accumulated. Time spent sedentary in bouts (a period of uninterrupted sitting (1)) that are prolonged (>30min) is associated with increased risk of the metabolic syndrome in adults (12). Evidence using isotemporal substitution of prolonged bouts of sitting time with shorter sitting bouts has demonstrated favourable cardio-metabolic outcomes in UK adults (13). In European children, it would appear that sedentary time is rarely spent in prolonged bouts (i.e.>30min) (14,15) which may partly explain the weaker association betwen total sedentary time and health outcomes (16) compared to adults. However, Australian data have demonstrated that children spend up to 20% of waking hours in such bouts (17). While an association between sedentary bouts and health indicators in children is inconsistent (2), evidence has shown that a higher frequency (up to 3.1/day) of >30min bouts of sedentary time is associated with reduced HDL cholesterol in children, independent of total sitting time, moderate-to-vigorous physical activity (MVPA), saturated fat intake and body composition (18). Consequently, the manner in which sedentary time is accumulated needs to be further explored to better understand when and how to target interruptions in sustained sedentary periods.

To date, most published studies describing objectively-measured sedentary time use accelerometry. Accelerometers, which are typically worn on the waist, cannot accurately distinguish between sitting and standing postures (19). This is important because standing is not a sedentary behaviour (1). Consequently, there is a need to differentiate between time spent sitting and standing using inclinometers (2). The activPAL inclinometer has been implemented in a handful of studies in children (8-12yrs) which confirm high prorportions of time at school (70-71%) (20), on school days (53-69%) and weekend days (60-73%) is spent sitting (20–23). More studies need to build on these findings for a better understanding of sitting patterns. Such studies should include the exploration of sitting time in demographics that are typically more sedentary compared to other populations (from accelerometry). In the UK, British Pakistani children have demonstrated higher total sedentary time than white British children on school days and weekend days (6,24). This is particularly important when considering the higher cardio-metabolic health risks that British South Asian children have (11). In the present cross-sectional study, using activPAL inclinometers, we explored total sitting time and sitting bouts of different lengths, during and outside of school hours in a sample of children of mostly British South Asian ethnicity.

METHODS

Sitting patterns during school days and weekend days were explored in Year 5 primary school children (aged 9-10yrs) during term time. Participating children were from two schools within deprived neighbourhoods (top 10% and 30% of UK neighbourhoods) (25), located within the city of Bradford, England. All children were originally approached and recruited for two classroom-based intervention trials conducted in 2014 and 2015; the complete intervention data for the 2014 study have been reported elsewhere (20). These schools were selected due to their engagement with the Born in Bradford Project (26) which has connections to local schools. Five separate classes consisting of 30 children (150 children in total) were approached. Baseline assessments from each study, which employed identical measurement protocols and were conducted during the autumn (November) and winter (December/January) seasons, were included in this study.

Parental written consent and child assent were required for study participation. Children were not included in baseline assessments if they had any disability that prevented them from standing or an illness or injury that prevented them from performing normal daily tasks. Both studies were approved by Loughborough University's Ethical Advisory Committee.

Participants self-reported their age and ethnicity (after ethnicity was explained and a subsequent selection was made from a list of different options i.e. white British, Murpuri Pakistani). Participants wore an activPAL inclinometer (PAL Technologies Ltd, Glasgow, UK) on the anterior aspect of the right thigh, placed within a nitrile sleeve and attached using hypoallergenic medical dressing, for 7 days. This made the device waterproof and enabled a 24hr wear protocol. The activPAL has been shown to be a valid measure of posture in children (27). activPAL data explored in this study included minutes spent sitting accumulated at school, after school, and during total waking hours on school days and weekend days.

Data management

activPAL data were downloaded using standard manufacturer software (activPAL Professional v.7.2.29/v.7.2.32) and then processed with a customised Microsoft

Excel macro. The hours of 11pm-6am were set as sleep time and thus removed from the data (21). A non-wear time of 20 minutes was applied using the accelerometer function of the device to determine when the device was not being worn during waking hours (21,28). Data were analysed in 15-s epochs (21,28). School hours were based on each school timetable (school one-08:50-15:10; school two-08:40-15:15) and included lunch and break times.

Wear time compliance was set at ≥10h/day, ≥3 school days and ≥1 weekend day. (17). A customised macro provided the frequency and accumulated minutes and proportions of wear time spent sitting in bouts of 5-10min, 10-30min and >30min (15). Proportions of wear time spent sitting were also calculated. Sitting variables were compared between sexes and ethnicities (white British compared to a British South Asian category comprising Bangladeshi, Indian, Mirpuri Pakistani, other Pakistani or 'any other Asian background' ethnicities).

Statistical analysis

Statistical analyses were conducted using SPSS v.23 (SPSS Inc., Chicago, IL, USA). Outcome variables were compared between school days and weekend days, and between school time and after school time (end of school time to 11pm). activPAL outcome variables were screened for outliers using box-plots. Box-plots did not identify any extreme outliers (values more than three interquartile ranges from the 25^{th} or 75^{th} percentile) in any sitting variable and therefore all data were included in the analysis. Outcome variables were tested for normality using the Kolmogorov-Smirnov test. This test found both normally distributed and skewed data. Normally distributed data sets were compared between school days and weekend days and during school and after school time using paired sample t-tests. For skewed data, a natural-log transformation was applied. Transformed data were then compared between time periods using paired t-tests. Mean transformed values and confidence intervals were then back transformed and reported in the results. Data that were still skewed following transformations were compared across periods using the Wilcoxon signed-rank test, and the median and inter-quartile range reported. Significant differences were detected (P<0.05) for wear time between school days and weekend days and school time and after school; minute and frequency data are reported as descriptives only. To account for differences in wear time, the proportion of wear time spent sitting were compared between the different time periods. Cohens d was used to calculate effect sizes using mean and standard deviation values (29) for outcome variables for each time period that were compared. Effect sizes were interpreted as small (*d*=0.2-0.4); intermediate (d=0.5-0.7); and large (*d* ≥0.8)(29). Sitting data were compared between boys and girls and between White British and British South Asian ethnicities using Mann-Whitney U tests. Significance was set at $P<0.05$.

RESULTS

One hundred and thirty-seven children provided parental consent to participate in the studies, of which, 79 (58%) provided valid activPAL data (mean age: 9.8 (SD 0.3) years). The sample characteristics by ethnicity and sex are summarised in Table I.

There were no significant sex or ethnic differences between those who provided valid activPAL data and those who did not (*P*>0.05). There were significant differences in just one/32 sitting variables (*P*<0.05) between girls and boys (see appendix Table A1) (school time sitting mins; boys -19.8mins,*P*=0.028). Just two/32 significant differences were observed between White British and British South Asian children in sitting outcomes (frequency and accumulated mins of sitting bouts of 10-30min after school; British South Asian +0.9,*P*=0.018 and +22.2min,*P*=0.010) (appendix Table A2). Consequently, data hereafter are presented for the sample as a whole.

Time spent sitting on school days and on weekend days totalled 614±112 (median±IQR) mins/day and 690±150 mins/day, respectively (Table II), with participants spending a significantly greater proportion of time sitting on weekend days compared to school days (+6.3%,*P*=0.001, intermediate effect size).

On a school day, 38% (227.8min) of total daily sitting time was accumulated at school, 48% (290.2min) was accumulated after school, with the remainder (14%, 96min) accumulated before school. Participants spent a significantly lower proportion of time sitting at school (-6.7%,*P*=0.001, intermediate effect size) compared to time spent sitting after school (Table II).

The highest bout frequencies during all periods was of 5-10min and 10-30min (Table III). Total accumulated bout minutes during all time periods were highest in 10-30min and >30min bouts (Table III). In >30min bouts, over 180 minutes were accumulated from just 3.8 bouts on school days and over 280 minutes from just 5.2 bouts on weekend days.

A significantly greater proportion of wear time was spent in short bouts (5-10min) on school days compared to weekend days (+1.4%,*P*<0.001, intermediate effect size), with no difference in medium bouts (10-30min) and significantly more time spent in long bouts (>30min) on weekend days compared to school days (+7.9%,*P*<0.001)

(Table IV). A significantly greater proportion of wear time was spent in short bouts (5-10min) at school compared to after school (+2.0%,*P*<0.001,intermediate effect size). Conversely, significantly more time was spent after school compared to school time in medium (+2.2%,*P*<0.05,small effect size) and long bouts (+7.7%,*P*<0.001) (Table IV).

DISCUSSION

Main findings of this study

This study explored activPAL-determined sitting patterns during and outside school hours in 9-10 year old children from a deprived northern UK city. This study observed large proportions of wear time spent sitting on school days and weekend days, not only in total but also in prolonged bouts, which has not been observed before in UK children. Sitting time was particularly high after school and on weekends. These findings are concerning for a sample of mostly British South Asian children who are more susceptible to cardio-metabolic risk factors (11).

What is already known on this topic

Internationally, children spend the majority of waking hours sedentary, both during (4) and outside of school hours (typically >60% of waking hours) (5–7). Sedentary behaviour tracks into adulthood (8) where detrimental health effects are clear (10). Time spent in prolonged sitting bouts is associated with attenuated metabolic health (18), but there is limited available evidence of how children accumulate sitting time. Furthermore, most objectively-measured sedentary data is from hip-worn accelerometers, which cannot distinguish between sitting and standing postures (19). Consequently, studies using inclinometers are urgently needed to better determine sitting time, particularly in higher health risk groups such as South Asian children.

What this study adds

This study found that children sat in excess of 10hrs/day (68% of wear time) on school days and 11hrs/day (74% of wear time) on weekend days which are high volumes of sitting for this age group. These proportions are almost identical to activPAL data reported in obese Malaysian children (aged 9-11yrs) on school days (68%) and weekend days (73%) (23). Compared to accelerometer data, our results are similar to the proportions of sedentary time observed in British Pakistani and White British girls (65-70%) (aged 10yrs) (6) and higher than that reported in a sample of White British children (64%) (5). These results are also higher than accelerometer data in US children where 8.7 h/day (aged 9-11yrs) (7) and 41-43% of wear time (aged 6-11yrs) (30) have been observed. The high volumes of sitting time are likely to increase into adolescence, with a recent review showing that sedentary time increases by approximately 10-20 mins/day across the primary-secondary school transition (9). If this yearly change were to hold constant, the current sample will be sitting 11-13 hrs/day (73-85% of current wear time) by the age of sixteen. This could mean as little as 3hrs available for movement-based activities (assuming 8hrs of sleep), which would have major implications for energy expenditure.

This is the first study to explore sitting time accumulated in prolonged bouts in a sample of UK children. Wear time accumulated in sitting bouts of >30min on school days (187mins/20% of wear time) and weekend days (282mins/28%) was considerably higher than that observed in Belgian (school days: 34mins/4%; weekend days: 29mins/4%) (15), European (all days ≤80mins/≤10%) (18), and Australian children (school days: 132mins/16%; weekend days: 129mins/16%) (17). The present results are comparable to those observed in adult office workers (10-30%) (31) and demonstrate that some children do spend a considerable amount of time a day sitting for prolonged periods, contrary to previous conclusions (15). The frequency of prolonged bouts were low (school day 3.8, weekend day 5.2) compared to bouts of 5-10min and >10min (11-17.5), however, the average duration of prolonged bouts were 49 minutes and 54 minutes on school days and weekend days. This demonstrates that children do not need to engage in a high frequency of such bouts to result in a large proportion of waking hours being composed of prolonged sitting. The frequency values we observed exceed those previously reported in obese children demonstrating the highest number of >30min bouts (≤3.1), who exhibiting lower levels of HDL cholesterol compared to children who did not accumulate any sitting bouts of this duration (18). Future research should further examine potential differences of health indicators between children who accumulate high and low volumes of prolonged sitting bouts (frequencies and minutes), particularly in groups of higher health risk (i.e. South Asians, obese), as this is largely unexplored.

Children spent more time sitting on weekend days compared to school days in this study. These findings add to previous inconsistent evidence that either supports this finding (21–23), have found no difference (17,32), or have observed the opposite (6). Children were also the least sedentary at school. This is in contrast to Abbott et al. (17) who observed the highest proportion of wear time spent sedentary in total and in prolonged bouts at school compared to other times of the week in Australian children. In the present study, reduced daylight hours (33) during the autumn/winter as well as less favourable weather associated with these seasons, may have influenced more indoor sedentary pursuits away from school (7) compared to outdoor conditions in the Abbott et al. study (set in western Australia). It is also likely that contrasting school environments between study locations played a role in the differences reported during school time. Despite this, we still observed almost 4 hours of sitting at school, highlighting that the school environment is an important setting to reduce this behaviour. Although in the early stages of evidence, standing desk interventions implemented within the school classroom are emerging as a promising solution for interrupting and reducing sitting time (34,35).

Sitting time in total and in prolonged bouts was particularly high during weekend days and after school periods, suggesting these periods should be targeted for intervention. A recent systematic review into the effectiveness of interventions targeting sedentary time (36) identified just one study in children (7-12yrs), a six-month intervention to reduce media use, that found a reduction in sedentary time outside of school hours (-37min/day of TV viewing) (37). Although screen-based pursuits will surely be common, we do not know which types of sedentary behaviours were adopted in the present study. This highlights the need for the inclusion of self-report measures (i.e. diary logs) to provide information on the mode, dose, and setting of sedentary behaviour to better inform intervention design. An alternative to reducing total sedentary time could be to break up prolonged sitting bouts with short periods of activity, such as standing or stepping. Unfortunately, intervention studies with this objective are limited to a six-week school-based educational program that demonstrated inconsistent intervention effects during out of school hours (38). Future intervention studies may benefit from including parents and children in the intervention design process, which has not been undertaken to date (36), to potentially increase child engagement (39) and the likelihood of tackling sedentary behaviours effectively during leisure time.

Limitations of this study

The cross-sectional design of this study prevents any conclusions about causality. The high non-compliance rate of the activPAL protocol resulted in a large proportion of lost data which may have influenced the outcome of key variables. The small sample spread across just two schools within close proximity to one another, limits the generalisability of the findings. Furthermore, a sample size calculation was not performed due to the exploratory nature of this study. Despite these limitations, this study provides novel information on the composition of accumulated sitting time in a sample of UK children.

In conclusion, this sample of mostly British South Asian children demonstrated very high proportions of time spent sitting in total and in prolonged bouts during school days and weekend days. These proportions are likely to increase into adolescence which is concerning for an ethnic population at higher cardio-metabolic health risk. To inform effective interventions, further longitudinal research is required, with larger sample sizes spread across multiple UK areas, to better understand the levels and patterns of sitting accumulated at and away from school.

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RESULTS

Table I. Sample characteristics by ethnicity and sex

	British South Asian			White British			Mixed ethnicity			Total sample		
	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total
N	29	26	55	8	10	18	3	3	6	40	39	79
Proportion of ethnic group, %	52.7	47.3		44.4	55.6		50.0	50.0				
Proportion of total sample, %	36.7	32.9	69.6	10.1	12.7	22.8	3.8	3.8	7.6	50.6	49.4	100.0

Table II. Time spent sitting in total and in different bout lengths and comparisons during different times of the week. Data presented as mean (SD) unless stated otherwise.

	School day		Weekend day		Difference, *P* (Effect size, d)	At school		After school		Difference, *P* (Effect size, d)
Number of valid days [a] ‡	5.2	(1.2)	1.9	(0.3)		5.2	(1.2)	5.2	(1.2)	
Wear time, mins/d †	910.7	(82.9)	956.2	(51.0)	0.001	372.3	(29.7)	419.7	(48.2)	<0.001
Time sitting, % of wear time	67.7	(7.9)	74.0	(9.9)	<0.001 (0.7 IE)	63.0	(11.6)	69.7	(8.4)	<0.001 (0.7 IE)
Sitting, mins	† 614.0	(112.0)	† 690.7	(150.4)		227.8	(46.4)	290.2	(38.6)	

[a] In total, 410 valid school days and 151 valid weekend days of activPAL data were provided.

‡ Number of valid days (wear time ≥10 hrs/d) included in the analysis.

† Data represent the median and interquartile ranges due to skewed distributions. The Wilcoxon-signed rank test was used if values were compared (see 'Difference' column) and log transformation did not normalise the distributions.

IE, intermediate effect size; SE, small effect size.

Table III. Bout frequencies and accumulated minutes spent sitting during different times of the week. Data presented as mean (SD) unless stated otherwise.

	School day		Weekend day		At school		After school	
Frequency								
5-10 minutes	† 12.6	(4.5)	† 11.0	(5.5)	5.8	(2.0)	5.5	(1.7)
10-30 minutes	11.7	(2.3)	11.6	(4.0)	† 4.7	(1.9)	† 5.8	(1.7)
>30 minutes	3.8	(1.0)	5.2	(1.8)	† 1.0	(0.7)	† 1.7	(0.9)
Total accumulated minutes								
5-10 minutes	87.6	(23.5)	75.3	(28.8)	40.9	(14.3)	38.9	(11.8)
10-30 minutes	196.3	(40.4)	196.9	(70.5)	76.9	(26.4)	97.8	(25.6)
>30 minutes †	186.9	(79.6)	281.6	(138.2)	43.5	(33.7)	83.4	(51.6)

† Values represent the median and interquartile ranges due to skewed data.

Table IV. Proportion of wear time spent sitting in different bout lengths and comparisons between different times of the week. Data presented as mean (SD) unless stated otherwise.

	School day		**Weekend day**		**Difference, *P* (Effect size, d)**	**At school**		**After school**		**Difference, *P* (Effect size, d)**
Wear time, mins	910.7		956.2			372.3		419.7		
5-10 minutes, %	9.6	(2.5)	8.2	(3.0)	<0.001 (0.5 IE)	11.3	(3.7)	9.3	(2.8)	<0.001 (0.6 IE)
10-30 minutes, %	21.6	(5.0)	21.4	(7.3)	NS	21.3	(7.3)	23.5	(6.1)	<0.05 (0.3 SE)
>30 minutes, % *	20.4	19.5 – 22.0	28.3	27.1 - 33.1	<0.001	11.3	10.0 - 13.5	19.0	16.4 – 22.2	<0.001

*Mean value and confidence intervals taken from log transformed data which were then back transformed. Data compared using paired t-tests.

[b] Effect sizes not calculated due to median and interquartile range reported for minute data.

IE, intermediate effect size; NS, not significant.