Abstract

Background: This study examined the volume and patterns of physical activity (PA) and sedentary time (ST) across different segments of the week among boys and girls.

Methods: A total of 188 children aged 7–12 years wore a wrist-mounted ActiGraph GT3X+ accelerometer for 7 days. Time spent in PA and ST was calculated using ActiLife software. The mean number of minutes of light PA, moderate PA, vigorous PA, moderate-to-vigorous PA (MVPA), and ST were calculated per weekday (before school, during school, and after school) and per weekend day (morning and afternoon/evening).

Results: After school represented the greatest accumulation of ST compared with before school and during school segments. Boys engaged in 225.4 min/day of ST (95% confidence interval (CI): 216–235), and girls engaged in 222.2 min/day of ST (95%CI: 213–231). During school, boys engaged in significantly more MVPA than girls (46.1 min/day (95%CI: 44–48) vs. 40.7 min/day (95%CI: 39–43)). Across the whole week, boys participated in significantly more MVPA than girls (103.9 min/day (95%CI: 99–109) vs. 95.7 min/day (95%CI: 90–101)). The weekend afternoon/evening segment represented the larger accumulation of ST, where boys were significantly more sedentary than girls (367.5 min/day (95%CI: 353–382) vs. 339.8 min/day (95%CI: 325–355), respectively).

Conclusion: Our findings suggest that children are highly sedentary and spend little of their time in school in MVPA, especially girls. Routine breaks in school elicit increases in light PA and MVPA. Future work should consider the use of more active breaks within school time to encourage PA and reduce ST.

Keywords: Accelerometry; School; Segments; Weekday; Youth

1. Introduction

Global physical activity (PA) guidelines suggest that children should engage in at least 60 min of moderate-to-vigorous PA (MVPA) per day. Yet many children fail to meet these recommendations. A European study of 7684 children aged 2–11 years concluded that only 10%–34% of boys and 2%–15% of girls achieved the minimal MVPA recommendations. Given the well-established relationship between PA and measures of health and well-being, it is vital that strategies are developed to reverse the current status of youth inactivity levels. Schools are often cited as an ideal setting to introduce multifaceted intervention strategies that provide children with opportunities to be physically active. However, recent large-scale studies have indicated equivocal results.

Childhood PA patterns across the segmented week have been examined to identify the most appropriate time within the week to introduce interventions that will have the most influence on PA engagement. Nonetheless, the lack of control for known confounders in subsequent analysis may limit the generalizability of the findings from some of these studies. Evidence of PA patterns across the segmented week, assessed objectively using hip-worn accelerometers and
controlled for known correlates, suggest that adjusting for known confounders such as age, body mass index (BMI) z-score, socioeconomic status, and device wear time can influence children’s PA level measurements. However, the use of a nonwear time period of 60 min and epoch lengths of 15 s in their methodology may have overestimated participant sample size, failed to capture irregular PA, and overestimated sedentary time (ST). Increased nonwear time periods can overestimate ST by classifying time when the device may not have been worn as time spent being sedentary. As a consequence of this, more subjects are likely to meet the wear time inclusion criteria and present an overestimation of ST.

Furthermore, the lack of consensus regarding an appropriate definition of a sedentary bout and what constitutes a break in ST adds further challenges for researchers who look to quantify ST. In addition, it may be unusual for children to remain completely sedentary for a full hour, because some movement during an hour would be expected even while watching television or playing video games. With this in mind, the generalizability of the findings proposed by Struggnell et al. may be limited. Moreover, the use of 15-s epochs may have failed to capture the sporadic, intermittent nature of children’s PA and consequently may have caused an underestimation of vigorous PA (VPA) and overall activity levels while overestimating ST.

Older ActiGraph GT3M accelerometer models used in previous studies captured vertical axis data only, which may limit comparisons with more recent studies that have used triaxial accelerometers, particularly because it has been suggested that data captured from vector magnitude (VM) may present a more representative picture of PA in comparison with interpretations based only on vertical axis data. Although these studies have aided in our understanding in establishing children’s PA throughout the day, there is a need for more recent interpretations that use triaxial devices and control for known confounders.

A common feature of previous studies that have examined PA levels over the segmented week has been the reliance on the hip placement site to capture accelerometer data. Because wrist placement site has been shown to increase compliance, which can decrease the risk of selection bias and provide researchers with more confidence in their data, recent work by Noonan et al. examined PA levels across the segmented week from accelerometer data captured from the wrist. To the best of our knowledge, this study is the only one that has examined PA levels across the segmented week from accelerometer data captured from the wrist. Nevertheless, their findings are limited given the lack of ST reported and the failure to ensure that only those participants who had full data for each hourly segment were included in their analysis.

Wrist-worn accelerometers are currently being deployed in large population surveys and their use is likely to increase given their enhanced compliance rates and their superior comfort over traditional hip placement. Thus, it is important to build on the findings from Noonan et al. to identify to what extent children’s PA patterns vary across the segmented week and to identify which segments offer the most potential for introducing interventions. Moreover, because no study has examined these patterns by gender, it is important to establish the time segments at which girls and boys are most and least active to inform future interventions. Therefore, the purpose of this study was to measure child activity levels using a wrist-mounted ActiGraph GT3X+ device (ActiGraph LLC, Pensacola, FL, USA) to determine at which time frames across a segmented school week children are most and least active and to investigate the extent to which PA levels and ST differ between boys and girls. It is hypothesized that the greatest accumulation of PA in this sample will occur during school and that boys will be significantly more active than girls across all time segments.

2. Methods
2.1. Participants

Participants were recruited across 7 geographically representative primary schools from South Lanarkshire, Scotland. The children were in year groups 5, 6, and 7 of their respective primary schools. A total of 12 schools of varying socioeconomic status (SES) were initially identified and emailed to gauge their interest in participating. Of these 12 schools, 7 agreed to participate. SES was determined from each school’s postcode, which was input into the Scottish Index of Multiple Deprivation (SIMD) calculator. Each postcode was then given an SIMD rank between 1 and 10, with 1 representing the most deprived areas and 10 representing the least deprived areas in Scotland. Upon ethical approval being received from the Ethical Committee of the University of the West of Scotland, participants and parents were provided with information packs detailing the aims of the study and their involvement. Across the 7 schools, 2 recruitment strategies were used as requested by the schools’ head teachers. The first involved distributing 100 information packs to 3 schools (n = 300) to the target age group. This process resulted in the recruitment from School 1 (SIMD 2) of 58 participants (24 boys), from School 2 (SIMD 5) of 92 participants (40 boys), and from School 3 (SIMD 7) of 73 participants (36 boys). The second recruitment strategy required 2 researchers to attend the parents’ evenings at the remaining 4 schools to recruit participants face to face. This resulted in the recruitment from School 4 (SIMD 7) of 32 participants (20 boys), from School 5 (SIMD 2) of 16 participants (8 boys), from School 6 (SIMD 2) of 15 participants (9 boys), and from School 7 (SIMD 3) of 21 participants (12 boys). Signed informed parental and child consents were received from all participating children (n = 307). No significant differences were evident in the age of participants or distribution of genders across schools. It was clear nonetheless that distributing consent forms to schools rather than recruiting at parents’ evenings resulted in greater participation rates.

2.2. Instruments

Participants’ height was measured barefoot to the nearest 0.1 cm using a portable stadiometer (Seca Stadiometre, Seca Ltd., Birmingham, UK), and weight was measured barefoot with light clothing to the nearest 0.1 kg on electronic scales (Seca Digital Scales, Seca Ltd.). From measured stature and body mass, a BMI
z-score was calculated relative to the UK 1990 BMI population reference data.\textsuperscript{19} Thereafter, all participants wore 1 ActiGraph GT3X + monitor on their nondominant wrist for 7 days. Verbal confirmation of each participant’s nondominant wrist was noted, and device placement was demonstrated. All participants were fitted with their device before leaving the testing session. Before testing, each accelerometer was synchronized with Greenwich Mean Time and initialized to capture data at 80 Hz. Each accelerometer was programmed to commence data collection at 06:00 on the day after participants received the devices. The low-frequency extension was not enabled. Participants were instructed to wear the device at all times (i.e., 24 h/day) for 7 days, except during any water-based activities such as swimming or bathing. Because poor compliance and subsequent selection bias and misclassification is often cited as a limitation of hip-worn accelerometer studies,\textsuperscript{36} we used the 24-h wear time protocol to encourage compliance.

### 2.3. Data processing

Upon the return of the devices, data were downloaded in 5-s epoch lengths using ActiLife (Version 6.13.3; ActiGraph LLC) and saved in raw format as GT3X files. These data were subsequently converted to AgileGraph Data (AGD) format to facilitate data analysis. Patterns of ST and PA during the segmented week were examined using the following time segments: weekdays being before school (06:30–08:59), during school (09:00–14:59), and after school (15:00–21:59). Patterns of ST and PA were also examined during school-specific morning recess and lunch break times. For weekend days, the time segments were morning (06:30–11:59) and afternoon–evening (12:00–21:59). These time segments are similar to those used elsewhere.\textsuperscript{18}

Time spent in ST, light PA (LPA), moderate PA (MPA), VPA, and MVPA were calculated by summing the minutes spent in each activity threshold during each segment of the day. The percentage of the total segment time represented by ST, LPA, MPA, VPA, and MVPA, as well as VM counts/min, was calculated relative to the UK 1990 BMI population reference data.\textsuperscript{19} Finally, rather than including sleep time within the analysis, data captured from 22:00 to 06:29 were removed from subsequent analysis. The GT3X+ device can measure accelerations across 3 axes (i.e., vertical, anteroposterior, and mediolateral), which can be examined individually or together, providing the VM. Our decision to report the VM data will be useful for those interested in reporting the total volume of PA. VM data have been provided for all weekly segments and reported as total counts with 95% confidence intervals (CIs). Finally, mean minutes and 95%CI were plotted graphically to demonstrate the hourly pattern of activity during whole weekdays and weekend days.

Participants were included within the weekday analysis if they wore the accelerometers for a minimum of 3 weekdays and a minimum of 10 h each day as described in a previous study.\textsuperscript{13} To be included within the during school, school-specific morning recess and lunch break times analysis, participants had to provide 3 days of wear time during both segments. Morning recess across all schools lasted 15 min and occurred between 10:00 and 11:00. Lunch breaks ranged from 45 to 55 min in duration and occurred from 12:00 to 13:15 across the schools. Finally, from those participants included within the weekday analysis, only those participants who wore the device for a minimum of 1 weekend day for a minimum of 10 h were included within the weekend day analysis. Device- and wrist-specific VM counts cut-points proposed by Chandler et al.\textsuperscript{40} were used to represent time spent in ST, LPA, MPA, VPA, and MVPA.

### 2.4. Data analysis

Repeated measures analyses of covariance examined between-segment differences across genders for time spent in ST, LPA, MPA, VPA, and MVPA, as well as VM counts/min, while controlling for the following variables: age, BMI z-score, SES, and device wear time. These variables were identified a priori based on previous research.\textsuperscript{10,13} Finally, effect size statistics were established based on Cohen’s (d) classifications: small (0.2 ≤ d < 0.5), moderate (0.5 ≤ d < 0.8), and large (d ≥ 0.8) effect sizes.\textsuperscript{41} All analyses were conducted using IBM SPSS Statistics (Version 24.0; IBM Corp., Armonk, NY, USA) and Microsoft Excel 2016 (Microsoft, Redmond, WA, USA). For all analyses, statistical significance was set at p < 0.05.

### 3. Results

From the 307 individuals who agreed to participate, data were available for 266 participants (134 boys) aged 9.8 ± 1.1 years. Some participants were unable to provide data for the following reasons: absent (n = 27), voluntary withdrawal (n = 3), devices lost (n = 4), and device malfunction (n = 7). Participants not meeting the wear time criteria for inclusion within the weekday analysis (n = 78) were excluded. This resulted in 96 girls (age = 9.7 ± 1.1 years, BMI z-score = 1.1 ± 1.2, school SIMD = 5 ± 2, and device wear time = 3765.6 ± 1273.0 min) and 92 boys (age = 9.8 ± 1.0, BMI z-score = 0.4 ± 1.1, school SIMD = 5 ± 2, and device wear time = 3789.8 ± 1436.9 min) included for the weekday analysis. Of these 188 participants, those not meeting the wear time inclusion criteria for the weekend analysis (n = 52) were excluded from this aspect of the analysis. This resulted in 136 participants (71 boys) being included in the weekend day analysis. There were no significant differences for any of the measured variables between children included in the analyses and those excluded.

Participation in PA and ST across the 3 segmented weekday time periods are presented in Table 1 by gender. Findings for the before school segment revealed significant gender differences, with boys spending more time in VPA (0.5 min, 95%CI: 0–1, d = 0.72). For the during school segment, boys participated in significantly more VPA (2.9 min; 95%CI: 2–4; d = 0.86) and MVPA (5.4 min; 95%CI: 2–8; d = 0.5) compared with girls. Furthermore, significant gender-specific differences were also evident for total VM counts (32.7 counts; 95%CI: 17–49; d = 0.57) for the during school segment, with boys having higher counts than girls. For the afterschool segment, girls spent significantly more time in LPA (−7.1 min; 95%CI: −13 to −2; d = 0.36) than their male counterparts, whereas boys participated in more VPA (3.0 min; 95%CI: 1–5; d = 0.53) compared with girls. No other significant differences were found across the 3 weekday segments between boys and girls.
Participation in PA and ST across the 2-segment weekend day time periods are presented in Table 2 by gender. Findings revealed significant gender differences, with boys spending more time in VPA (2.0 min; 95% CI: 0.3–d = 0.46) in the morning segment than girls. In the afternoon–evening segment, boys spent significantly more time being sedentary (27.6 min; 95% CI: 7–48; d = 0.45) than girls. Furthermore, in the afternoon–evening segment, girls spent significantly more time in LPA (21.8 min; 95% CI: −33 to −10; d = 0.62) and MPA (−8.7 min; 95% CI: −16 to −1; d = 0.37) than boys.

Participation in PA and ST by gender across entire weekdays, weekend days, and the whole week is presented in Table 3. For the whole weekday, findings revealed significant gender differences, with boys spending more time in VPA (6.4 min; 95% CI: 4–9; d = 0.78) and MVPA (8.2 min; 95% CI: 1–16; d = 0.14) than girls. Similarly, significant gender-specific differences were also evident for total VM counts (21.1 counts; 95% CI: 3–39; d = 0.09) during the whole weekday segment, with boys presenting higher counts than girls. For the whole weekend, boys spent significantly more time in ST (32.3 min; 95% CI: 8–56; d = 0.47) and VPA (4.0 min; 95% CI: 1–7; d = 0.48) than girls. In contrast, girls spent significantly more time in LPA (−20.9 min; 95% CI: −34 to −8; d = 0.61) than boys. For the whole week, girls spent significantly more time in LPA (−13.6 min; 95% CI: −23 to −4; d = 0.45) than boys. Furthermore, boys spent significantly more time in VPA (5.0 min; 95% CI: 3–7; d = 0.78) than girls.

Participation in PA and ST during morning recess and the lunch break is presented in Table 4. During morning recess, boys spent significantly more time in MPA (0.7 min; 95% CI: 0–1; d = 0.64), VPA (0.5 min; 95% CI: 0–1; d = 0.83), and MVPA (1.3 min; 95% CI: 1–2; d = 0.78), but significantly less time in ST (−1.1 min; 95% CI: −2 to −1; d = 0.59) than girls. Boys also presented with significantly greater total VM counts (29.1 counts; 95% CI: 10–48; d = 0.43) than girls during this segment. During the lunch break, boys spent significantly more time in MPA (1.8 min; 95% CI: 1–3; d = 0.52) and MVPA (3.3 min; 95% CI: 2–4; d = 0.73), but significantly less time in ST (−2.8 min; 95% CI: −4 to −1; d = 0.64) than girls. Boys also presented with significantly greater total VM counts (34.8 counts; 95% CI: 20–50; d = 0.64) than girls during this segment. In addition to calculating differences between mean minutes spent in ST and PA, percentage time segment differences between boys and girls were calculated for all time segments (Tables 1–4). These largely followed the findings of the mean min differences, although boys did spend significantly less time in LPA (−1.1%; 95% CI: −2 to 0; d = 0.3) during the whole weekday than girls (Table 3).

The participants’ average ST, LPA, and MVPA for each hour across all waking hours on weekdays and weekend days are presented in Fig. 1. Children were highly sedentary during weekdays (Fig. 1A), particularly between 11:00 and 11:59 (38 ± 9 min; 95% CI: 37–39). The duration of ST decreased between 12:00 and 12:59 (29 ± 9 min; 95% CI: 28–30) because of lunch recess, but steadily increased upon returning to class and for the remainder of the day. Time in LPA and MVPA remained stable throughout the weekday and peaked at lunchtime for both LPA (20 ± 4 min; 95% CI: 19–21) and
Table 2
Activity outcomes by gender for weekend day segments.

|                  | Boys (n = 71) | Girls (n = 65) | Boys—girls difference | Boys—girls difference |
|------------------|---------------|----------------|-----------------------|-----------------------|
| **Morning (06:30—11:59)** |               |                |                       |                       |
| ST               | 120.4 (112 to 128) | 64.2 (61 to 67) | 118.9 (111 to 127) | 66.0 (63 to 69) | 1.5 (−10 to 13) | −1.8 (−6 to 3) |
| LPA              | 42.8 (39 to 46) | 23.1 (22 to 25) | 42.6 (39 to 46) | 24.4 (23 to 26) | 0.2 (−5 to 5) | −1.2 (−3 to 1) |
| MPA              | 19.0 (17 to 21) | 9.0 (8 to 10) | 16.8 (15 to 19) | 8.7 (8 to 10) | 2.1 (−1 to 5) | 0.3 (−1 to 2) |
| VPA              | 2.9 (2 to 4) | 1.4 (1 to 2) | 0.9 (0 to 2) | 0.5 (0 to 1) | 2.0 (0 to 3)***,## | 1.0 (0 to 2)**,*## |
| MVPA             | 21.9 (19 to 25) | 10.4 (10 to 12) | 17.7 (15 to 21) | 9.2 (8 to 11) | 4.1 (0 to 8) | 1.2 (0 to 3) |
| VM (counts)      | 277.5 (251 to 304) | 260.9 (233 to 289) | 36.6 (22 to 55) |                       |                       |                       |
| **Afternoon— evening (12:00—21:59)** |               |                |                       |                       |
| ST               | 367.5 (353 to 382) | 65.7 (64 to 68) | 339.8 (325 to 355) | 60.4 (58 to 63) | 27.6 (7 to 48)*** | 5.3 (2 to 8)***,## |
| LPA              | 132.2 (124 to 140) | 23.5 (22 to 25) | 154.0 (146 to 162) | 27.5 (26 to 29) | −21.8 (−33 to −10)***| −4.0 (−6 to −2)***,## |
| MPA              | 53.8 (49 to 59) | 9.5 (9 to 10) | 62.5 (57 to 68) | 11.2 (10 to 12) | −8.7 (−16 to −1)*** | −1.7 (−3 to 0)***,## |
| VPA              | 7.7 (6 to 9) | 1.4 (1 to 2) | 5.4 (4 to 7) | 0.9 (0 to 1) | 2.3 (0 to 5) | 0.4 (0 to 1) |
| MVPA             | 61.5 (55 to 68) | 10.8 (10 to 12) | 67.9 (61 to 75) | 12.1 (11 to 13) | −6.4 (−16 to 3) | −1.3 (−3 to 0) |
| VM (counts)      | 291.5 (271 to 312) | 318.7 (297 to 340) | −27.2 (−56 to 2) |                       |                       |                       |

Notes: Data are presented as mean (95% CI). Significant differences between boys and girls mean min and percent segment time are at: *p < 0.05, **p < 0.01, ***p < 0.001. Effect sizes are indicated as follows: * Small (0.2 < d < 0.5), ** Moderate (0.5 ≤ d ≤ 0.8), *** Large (d > 0.8).

Abbreviation: CI = confidence interval; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; ST = sedentary time. Activity; VM = vector magnitude; VPA = vigorous physical activity.

MVPA (11 ± 7 min, 95%CI: 10—12). Time in LPA then steadily decreased after 16:00 for the remainder of the day, whereas time in MVPA remained stable up until 18:59 and then decreased for the remainder of the day.

On weekend days (Fig. 1B), time spent in ST was greatest between 07:00 and 09:59 (range: 40–42 min) but decreased slightly up until 20:59 (10:00–20:00, range: 35–40 min). Time spent in MVPA was stable throughout the weekend day, with the highest values seen between 11:00 and 19:59 (range: 7–8 min) and the lowest between 08:00 and 08:59 (5 min, 95%CI: 4–7). Finally, time spent in LPA was highest between 12:00 and 12:59 (17 min, 95%CI: 16–18) but remained stable throughout the entire weekend day (range: 13–17 min).

Table 3
Activity outcomes by gender for whole weekdays, weekend days, and the whole week.

|                  | Boys (n = 188, boys = 92; 06:30—21:59) | Girls (n = 116, girls = 71) | Boys—girls difference | Boys—girls difference |
|------------------|--------------------------------------|-----------------------------|-----------------------|-----------------------|
| **Whole weekday** |                                       |                             |                       |                       |
| ST               | 438.2 (447 to 470) | 58.9 (58 to 60) | 453.0 (442 to 464) | 58.8 (58 to 60) | 5.4 (−10 to 21) | 0.1 (−2 to 2) |
| LPA              | 216.2 (210 to 222) | 27.8 (27 to 29) | 223.1 (217 to 229) | 28.9 (28 to 30) | −6.9 (−15 to 1) | −1.1 (−2 to 0)*** |
| MPA              | 88.8 (84 to 93) | 11.3 (11 to 12) | 86.5 (82 to 91) | 11.2 (11 to 12) | 1.9 (−4 to 8) | 0.1 (−1 to 1) |
| VPA              | 15.6 (14 to 17) | 2.0 (2 to 2) | 9.2 (8 to 11) | 1.2 (1 to 1.4) | 6.4 (4 to 9)***,## | 0.8 (0 to 1)***,## |
| MVPA             | 103.9 (99 to 109) | 13.3 (13 to 14) | 95.7 (90 to 101) | 12.4 (12 to 13) | 8.2 (1 to 16)*** | 0.9 (0 to 2)*** |
| VM (counts)      | 354.2 (341 to 367) | 332.3 (321 to 346) | 21.3 (39)*** |                       |                       |                       |
| **Whole weekend** |                                       |                             |                       |                       |
| ST               | 488.8 (472 to 505) | 65.7 (64 to 68) | 456.5 (439 to 474) | 62.0 (60 to 64) | 32.3 (8 to 56)*** | 3.7 (1 to 6)*** |
| LPA              | 175.0 (166 to 184) | 23.4 (22 to 25) | 196.0 (186 to 206) | 26.6 (25 to 28) | −20.9 (−34 to −8)*** | −3.2 (−5 to −1)***,## |
| MPA              | 71.6 (65 to 77) | 9.5 (9 to 10) | 78.1 (72 to 84) | 10.6 (10 to 11) | −7.0 (−16 to 2) | −1.1 (−2 to 0) |
| VPA              | 10.1 (8 to 12) | 1.4 (1 to 2) | 6.2 (4 to 8) | 0.8 (0 to 1) | 4.0 (1 to 7)*** | 0.6 (0 to 1)*** |
| MVPA             | 81.3 (74 to 89) | 10.9 (10 to 12) | 84.3 (77 to 92) | 11.4 (10 to 12) | −3.1 (−14 to 7) | −0.6 (−2 to 1) |
| VM (counts)      | 291.9 (274 to 310) | 302.9 (284 to 321) | −11.0 (−37 to 15) |                       |                       |                       |

Notes: Data are presented as mean (95%CI). Significant differences between boys and girls mean min and percent segment time are at: *p < 0.05, **p < 0.01, ***p < 0.001. Effect sizes are indicated as follows: * Small (0.2 < d < 0.5), ** Moderate (0.5 ≤ d ≤ 0.8), *** Large (d > 0.8).

Abbreviation: CI = confidence interval; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; ST = sedentary time. Activity; VM = vector magnitude; VPA = vigorous physical activity.
Activity outcomes by gender for school special segments.

|                      | Boys (n = 88) | Girls (n = 94) | Boys–girls difference | Boys–girls difference |
|----------------------|--------------|---------------|-----------------------|-----------------------|
|                      | Mean min/total counts | % Segment time | Mean min/total counts | % Segment time | Min/counts | % |
| **Morning recess**   |              |               |                       |                       |           |    |
| ST                   | 5.6 (5 to 6) | 37.9 (35 to 40) | 6.7 (6 to 7) | 45.3 (43 to 48) | -1.1 (-2 to -1)**,## | -7.3 (-11 to -4)**,## |
| LPA                  | 5.1 (5 to 5) | 33.9 (33 to 35) | 5.2 (5 to 5) | 35.0 (34 to 36) | -0.2 (-1 to 0) | -1.1 (-3 to 1) |
| MPA                  | 3.2 (3 to 3) | 21.1 (20 to 23) | 2.4 (2 to 3) | 16.2 (15 to 18) | 0.7 (0 to 1)**,## | 4.9 (3 to 7)**,## |
| VPA                  | 1.1 (1 to 1) | 7.1 (6 to 8) | 0.5 (0 to 1) | 3.6 (3 to 4) | 0.5 (0 to 1)**,## | 3.5 (2 to 5)**,## |
| MVPA                 | 4.2 (4 to 5) | 28.2 (26 to 30) | 3.0 (3 to 3) | 19.8 (18 to 22) | 1.3 (1 to 2)**,## | 8.4 (5 to 11)**,## |
| VM (counts)          | 156.9 (143 to 171) | 127.9 (115 to 141) |                       |                       | 29.1 (10 to 48)**,## |             |
| **Lunch break**      |              |               |                       |                       |           |    |
| ST                   | 18.8 (18 to 20) | 39.4 (37 to 42) | 21.6 (21 to 23) | 45.4 (43 to 47) | -2.8 (-4 to -1)**,## | -5.9 (-9 to -3)**,## |
| LPA                  | 16.1 (16 to 17) | 33.8 (33 to 35) | 16.6 (16 to 17) | 34.9 (34 to 36) | -0.5 (-1 to 0) | -1.1 (-2 to 0) |
| MPA                  | 9.8 (9 to 10) | 20.7 (19 to 22) | 8.0 (7 to 9) | 16.9 (16 to 18) | 1.8 (1 to 3)**,## | 3.9 (2 to 6)**,## |
| VPA                  | 2.9 (2 to 3) | 6.0 (5 to 7) | 1.4 (1 to 2) | 2.9 (2 to 3) | 1.5 (1 to 2)**,## | 3.2 (2 to 4)**,## |
| MVPA                 | 12.7 (12 to 14) | 26.8 (25 to 28) | 9.4 (9 to 10) | 19.7 (18 to 21) | 3.3 (2 to 4)**,## | 7.0 (5 to 9)**,## |
| VM (counts)          | 146.9 (136 to 158) | 112.2 (102 to 123) |                       |                       | 34.8 (20 to 50)**,## |             |

Notes: Data are presented as mean (95%CI). Significant differences between boys and girls mean min and % segment time are at * p < 0.05,** p < 0.01, *** p < 0.001.

Effect sizes are indicated as follows: * small (0.2 ≤ d < 0.5), ** moderate (0.5 ≤ d < 0.8), *** large (d ≥ 0.8).

Abbreviations: CI = confidence interval; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; ST = sedentary time; VM = vector magnitude; VPA = vigorous physical activity.

4. Discussion

Our findings suggest that children were more active and less sedentary during weekdays in comparison with weekend days. When examining the ST and PA patterns by gender, boys spent significantly more time in MVPA than girls during weekdays and more time in ST than girls during the weekend days. A unique element of this study is the comparison of activity patterns by gender across specific time segments, which revealed minimal differences in activity patterns before school. During school hours, boys spent significantly more time in MVPA than girls, which is reflected in boys having significantly higher VM counts in comparison with girls. After school, boys spent significantly less time in LPA but more time in VPA than girls. During weekend days, boys and girls both spent a similar proportion of their time in ST (range: 62%–66%). Although the proportion of time spent in ST and MVPA was broadly similar between the morning and afternoon—evening segments on the weekend days for boys, girls seemed to spend more time in ST but less time in MVPA in the morning segment than in the afternoon—evening segment. These objectively measured time-specific observations are a strength of this study, because only participants with the full 60 min of wear time for each hourly segment were included in the analysis. The results from this study extend the current literature by providing a detailed analysis of gender differences in ST, LPA, MPA, VPA, and MVPA as captured from a wrist-worn ActiGraph GT3X+ accelerometer across specific segments of the week. It is encouraging, therefore, that our findings are comparable with previous research, which suggests that boys engage in significantly more daily MVPA than girls during school hours.11,14,15 Unlike these studies, however, we did not observe any significant differences in ST between boys and girls during the school hours. One plausible explanation for this discrepancy is the use of wrist-worn accelerometers in our study instead of hip-worn accelerometers to capture activity levels. Previous studies have highlighted the difficulties in capturing estimates of ST from wrist accelerometers given the lack of wrist movement.3,42 At present, devices such as the ActiGraph GT3X+ can be used to estimate ST, but they do this based on minimal or nonmovement. Because previous studies have reported considerable differences in estimates of time spent in ST from accelerometers worn at the wrist and hip,32,34 it is encouraging to note that the estimates of time in ST derived from the wrist-worn accelerometers reported in the present study are broadly similar to estimates from studies using hip-worn accelerometers.

In a recent Australian study,15 the authors examined time spent in ST during the school day and found that boys and girls engaged in, on average, 246 min/day and 260 min/day of ST, respectively. These findings are similar to the estimates reported in our study, where boys and girls engaged in, on average, 196.5 min/day and 198.9 min/day of ST, respectively. In the same Australian study, the authors reported that boys and girls engaged in, on average, 102 min/day and 103 min/day of LPA and 62 min/day and 45 min/day of MVPA, respectively. These LPA estimates are very similar to ours, although participants in the Australian sample engaged in more MVPA than was evident in our study. Furthermore, Steele et al.,41 who used hip-worn accelerometers to estimate activity patterns across segmented time periods, reported that boys and girls engaged in, on average, 230 min/day and 240 min/day of...
ST during school hours, respectively. Similarly, van Stralen et al.\textsuperscript{14} using hip-worn accelerometers, reported that children across 5 European countries engaged in, on average, 209 min/day of ST and 16 min/day of MVPA, respectively, during the school day. Therefore, the estimates of ST reported in these studies\textsuperscript{10,14} seem to be higher than our estimates (196.5 min/day and 198.9 min/day for boys and girls, respectively), although it was evident that time spent in MVPA from this study (46.1 min/day and 40.7 min/day for boys and girls, respectively) seems to be lower than estimates reported by van Stralen et al.\textsuperscript{14} during school hours.

When we compare our estimates with those of Noonan et al.\textsuperscript{18}, who also used a wrist-worn accelerometer to estimate activity patterns across segmented times of the week, there were wide differences in estimates for time spent in LPA and MVPA. For instance, Noonan et al.\textsuperscript{18} estimated that time in LPA before, during, and after school were, on average, 35 min/day, 166 min/day, and 130 min/day, respectively, in comparison with the estimates reported in this study, which were 20 min/day, 104 min/day, and 93 min/day, respectively. Similar discrepancies in our findings for time spent in MVPA before, during, and after school were also evident when compared with those of Noonan et al.\textsuperscript{18} who reported, on average 2 min/day, 17 min/day, and 13 min/day, respectively. Our estimates for MVPA before, during, and after school were 9 min/day, 46 min/day, and 42 min/day, respectively. When comparing the estimates across the whole weekday, weekend, and whole week, Noonan et al.\textsuperscript{18} reported more time spent in LPA across these days than is reported here (329 min/day, 284 min/day, and 307 min/day in Noonan et al.\textsuperscript{18} vs. 216 min/day, 175 min/day, and 204 min/day in our study). Conversely, when comparing estimates for time spent in MVPA across these segments, it was evident that the children in our study engaged in, on average, more MVPA (104 min/day, 81 min/day, and 97 min/day) than the children in the study by Noonan et al.\textsuperscript{18} (32 min/day, 28 min/day, and 30 min/day). Although these discrepancies for time spent in

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**Fig. 1.** The hourly average physical activity and sedentary time on weekdays (A; \( n = 188\), boys = 92) and weekend days (B; \( n = 136\), boys = 71). Data are presented as mean (95%CI). CI = confidence interval; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; ST = sedentary time.
MVPA are vast, the variation in accelerometer data processing methods used in the 2 studies is a likely cause.

The low estimates of MVPA reported by Noonan et al. are similar to those reported by Kim et al., who reported estimates ranging from 8.0 min/day to 12.8 min/day when using nearly identical processing methods. In the 2 studies, raw acceleration data were processed in R (R Foundation for Statistical Computing, Vienna, Austria; https://cran.r-project.org/) using the GGIR package, which allows raw accelerations (gravitational acceleration) to be processed and analyzed using the device- and location-specific Hildebrand regression equations. A recent study highlighted the poor classification performance of the Hildebrand thresholds for correctly classifying MVPA, primarily owing to the low recognition of MPA. Because, in our study, we relied on processing our accelerometer data using the device- and wrist-specific VM counts cut-points proposed by Chandler et al., it is not surprising that large differences in time spent in LPA and MVPA were found to exist in our estimates compared with those of Noonan et al. Whether our estimates or those of Noonan et al. are more accurate is not known, because the processing methods used in our study have yet to be validated in an independent study, thus making it difficult to determine which processing technique is more accurate.

Findings in previous studies have suggested that girls are less active and more sedentary than boys, which partly supports our observations. For instance, we found that boys engaged significantly more MVPA during weekdays than girls (104 min/day vs. 96 min/day), respectively, but boys also engaged in significantly more ST during the weekend than girls (498 min/day vs. 457 min/day, respectively). With no comparable studies to compare our ST estimates with, it is not clear why we found boys to be more sedentary than girls during the weekend. What is concerning is that both boys and girls were reported to be sedentary for nearly 8 h/day throughout the week. These estimates are similar to those provided from a large representative sample of 8- to 9-year-old UK children, which estimated that these children spent, on average, 7 h/day being sedentary. Given the accumulating evidence that the total volume and pattern of ST is associated with adverse health outcomes, our observations suggest that appropriate strategies that promote PA while decreasing ST are vital.

Both weekday and weekend day hourly patterns for all levels of activity show striking similarities, despite the obvious differences in the amount of available leisure time. The main difference between weekdays and weekend days was the inclusion of a routine morning and lunchtime break during school hours, which is reflected in peak levels of time spent in LPA and MVPA, with concomitant decreases in ST (Fig. 1). Our findings are similar to those from other studies, which demonstrated that girls spent significantly more time in ST and significantly less time in MVPA during both recess and lunch breaks compared with boys. Schools provide key opportunities for children to engage in PA because of the ability to target a large population, regardless of SES. Moreover, we also observed that children did not record more activity after school than during school, which is in line with recent observations. Our findings suggest that activity levels are low after school, but the opportunity to influence activity levels during this segment may be more challenging because children need to opt-in to attend or participate in afterschool interventions. Moreover, afterschool interventions may come at an additional cost to the school or parent and, thus, discourage the long-term implementation of such afterschool interventions. Such challenges highlight the importance of the school setting as a site of influence because all children are exposed to changes in school policies, environments, and curriculums, each of which can affect levels of PA.

Evidence suggests that children spend more than 60% of their waking hours being sedentary, which is consistent with our observations. Public health guidelines often recommend that overall ST should be limited in children. Yet, attempts at introducing initiatives within Scotland to curb childhood ST have had a limited effect based on recent surveys, which estimate that less than 20% of children and adolescents meet current ST guidelines. To decrease ST at school, introducing activity breaks during class time with the aim of replacing ST with LPA could be a feasible strategy that is time efficient, feasible, and appealing to teachers. Promising evidence has demonstrated that implementing classroom activity breaks can improve child activity levels during school, as well as behaviors in the classroom, but further work is necessary to assess the feasibility and potential efficacy of such approaches in different countries.

When considering the findings from this study, it is important to acknowledge several limitations. First, the fact that the modest sample size of those who met the accelerometer wear time criteria were from 1 geographical location within Scotland limits the generalizability of our findings. Second, although the use of objectively measured PA is a strength of this study, the methods used to collect and process the accelerometer data can directly influence the reported duration spent in activity intensities, which may preclude comparisons with other studies. For instance, given the lack of sleep logs, we assumed that every participant slept between 22:00 and 06:29, which may not have been the case. Furthermore, the ActiGraph GT3X+ device is unable to assess body position, which may overestimate ST by not accurately detecting breaks between ST bouts. Another limitation possibly affecting the results is that we were unable to adjust our analysis for possible clustering of participants within schools, given the low number of participants who met the accelerometer wear time criteria. Moreover, it was evident that for some classes that only a small number of participants met the accelerometer wear time criteria, and the number was too small to form accurate interpretations from multilevel analyses. Failing to account for clustering via multilevel analysis may have therefore affected the coverage of the 95% CI and estimation of the p values. The types of activities in which participants engaged were not recorded throughout the monitoring period, which could also be considered as a limitation. It should also be acknowledged that the estimates of PA and ST may not be a true representation of typical behaviors and may have been influenced by wearing the accelerometer devices.

Crucially, estimates of time spent in ST and activity intensities were derived from age- and device-appropriate wrist VM cut-points. Because the use of VM cut-points are likely to increase as researchers continue to use triaxial accelerometers, we hope that
our findings will allow future studies to compare time spent in ST, LPA, and MVPA across specific time segments with the estimates reported here. Furthermore, this study is the first to report PA data across a segmented week between genders in children, which build on other findings by including levels of ST. Finally, the afterschool period constituted the greatest accumulation of MVPA for both boys and girls during the week. This finding highlights the need for appropriate school-based interventions that can increase activity levels while minimizing ST.

5. Conclusion
Our findings suggest that children were more active and less sedentary during weekdays in comparison with weekend days. When examining the ST and PA patterns by gender, boys spent significantly more time in MVPA than girls during weekdays and more time in ST than girls during the weekend days. These observations highlight the importance of the school environment as an important setting for introducing initiatives that can encourage PA while minimizing ST.

Acknowledgments
The authors thank the children, schools, teachers, and parents who agreed to participate in this study. Our study was funded by University of the West of Scotland’s VP Research Fund. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors’ contributions
GM carried out the study methods, performed the statistical analysis, and drafted the manuscript; RA participated in the study design and coordination; SD participated in carrying out the study methods; and DSB designed and coordinated the study and the statistical analysis and helped draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests
The authors declare that they have no competing interests.

References
1. Strong WB, Malina RM, Binkley CJ, Daniels SR, Dishman RK, Guti B, et al. Evidence based physical activity for school-age youth. J Pediatr 2005;146:732–7.
2. Ekelund U, Tomkinson G, Armstrong N. What proportion of youth are physically active? Measurement issues, levels and recent time trends. Br J Sports Med 2011;45:859–65.
3. Cooper AR, Goodman A, Page AS, Sherar LB, Eslinger DW, van Sluijs EM, et al. Objectively measured physical activity and sedentary time in youth: the International children’s accelerometry database (ICAD). Int J Behav Nutr Phys Act 2015;12:113. doi:10.1186/s12966-015-0274-5.
4. Konstabel K, Veidebaum T, Verbestel V, Moreno LA, Bamman M, Tornaritis M, et al. Objectively measured physical activity in European children: the IDEFICS study. Int J Obes 2005;33(Suppl 2):S135–43.
5. Ekelund U, Luan J, Sherar LB, Eslinger DW, Griew P, Cooper A, et al. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. JAMA 2012;307:704–12.
6. Fishman EJ, Steeves JA, Zipunninik V, Koster A, Berrigan D, Harris TA, et al. Association between objectively measured physical activity and mortality in NHANES. Med Sci Sports Exerc 2016;48:1303–11.
7. Pate RR, Davis MG, Robinson TN, Stone EJ, McKenzie TL, Young JC. Promoting Physical activity in children and youth: a leadership role for schools: a Scientific Statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Physical Activity Committee) in collaboration with the Councils on Cardiovascular Disease in the Young and Cardiovascular Nursing. Circulation 2006;114:1214–24.
8. Kipping RR, Howe LD, Jago R, Campbell R, Wells S, Chittleborough CR, et al. Effect of intervention aimed at increasing physical activity, reducing sedentary behaviour, and increasing fruit and vegetable consumption in children: Active for Life Year 5 (AFLOY5) school based cluster randomised controlled trial. BMJ 2014;348:g3256. doi:10.1136/bmj.g3256.
9. Adab P, Pallan MJ, Lancashire ER, Hemming K, Frew E, Barrett T, et al. Effectiveness of a childhood obesity prevention programme delivered through schools, targeting 6 and 7 year olds: cluster randomised controlled trial (WAVES study). BMJ 2013;346:f2111. doi:10.1136/bmj.f2111.
10. Steele RR, van Sluijs EM, Sharp SJ, Landsbaugh JR, Ekelund U, Griffin SJ. An investigation of patterns of children’s sedentary and vigorous physical activity throughout the week. Int J Behav Nutr Phys Act 2010;7:88. doi:10.1186/1479-5868-7:88.
11. Nettlefold L, McKay HA, Warburton DE, Mcguire KA, Bredin SS, Taylor PJ. The challenge of low physical activity during the school day: at recess, lunch and in physical education. Br J Sports Med 2011;45:813–9.
12. Bailey DP, Fairclough SJ, Savory LA, Denton SJ, Pang D, Deane CS, et al. Accelerometer-assessed sedentary behaviour and physical activity levels during the segmented school day in 10–14-year-old children: the HAPPY study. Eur J Pediatr 2012;171:1805–13.
13. Fairclough SJ, Beighle A, Erwin H, Ridgers ND. School day segmented physical activity patterns of high and low active children. BMC Public Health 2012;12:406. doi:10.1186/1471-2458-12-406.
14. van Stralen MM, Yldrim M, Wulp A, te Velde SJ, Verloigne M, Doessegger A, et al. Measured sedentary time and physical activity during the school day of European 10- to 12-year-old children: the ENERGY project. J Sci Med Sport 2014;17:201–6.
15. Strugnell C, Turner K, Malakellis M, Hayward J, Foster C, Millar L, et al. Composition of objectively measured physical activity and sedentary behaviour participation across the school-day, influence of gender and weight status: cross-sectional analyses among disadvantaged Victorian school children. BMC Public Health 2016;6:e011478. doi:10.1186/1471-2458-16-011478.
16. Schneller MB, Schipperijn J, Nielsen G, Bentsen P. Children’s physical activity during a segmented school week: results from a quasi-experimental study outside the classroom intervention. Int J Behav Nutr Phys Act 2017;14:80. doi:10.1186/s12966-017-0534-7.
17. Taylor S, Curry W, Knowles Z, Noonan R, McGrane B, Fairclough S. Predictors of segmented school day physical activity and sedentary time in children from a northwest England low-income community. Int J Environ Res Public Health 2017;14:E534. doi:10.3390/ijerph14050534.
18. Noonan RJ, Boddy LM, Kim Y, Knowles ZR, Fairclough SJ. Comparison of children’s free-living physical activity derived from wrist and hip raw accelerations during the segmented week. J Sports Sci 2017;35:2067–72.
19. Berglind D, Tynelius P. Objectively measured physical activity patterns, sedentary time and parent-reported screen-time across the day in four-year-old Swedish children. BMC Public Health 2018;18:69. doi:10.1186/s12889-017-6460-5.
20. Toftager M, Kristensen PL, Oliver M, Duncan S, Christiansen LB, Boyle E, et al. Accelerometer data reduction in adolescents: effects on sample retention and bias. Int J Behav Nutr Phys Act 2013;10:140. doi:10.1186/1479-5868-10-140.
21. Logan GR, Duncan S, Harris NK, Hinchson EA, Schofield G. Adolescent physical activity levels: discrepancies with accelerometer data analysis. J Sports Sci 2016;34:2047–53.
22. Aadland E, Andersen LB, Andersen SA, Resaland GK. A comparison of 10 accelerometer non-wear time criteria and logbooks in children. *BMCPubl Health* 2018;18:323. doi:10.1186/s12889-018-5214-4.

23. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act* 2017;14:75. doi:10.1186/s12966-017-0525-8.

24. Ediger DW, Copeland JL, Barnes JD, Tremblay MS. Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. *J Phys Act Health* 2005;2:366–83.

25. Aiba A, Bois JE, Zagarova J, Generelo E, Julian JA, Paillard T. Do epoch lengths affect adolescents’ compliance with physical activity guidelines? *J Sports Med Phys Fitness* 2014;54:326–34.

26. Banda JA, Haydel KF, Davila T, Desai M, Bryson S, Haskell WL, et al. Effects of varying epoch lengths, wear time algorithms, and activity cut-points on estimates of child sedentary behavior and physical activity from accelerometer data. *PloS One* 2016;11:e0150534. doi:10.1371/journal.pone.0150534.

27. Eston RG, Rowlands AV, Ingledew DK. Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children’s activities. *J ApplPhysiol* (1955) 1998;84:362–71.

28. Westerterp KR. Assessment of physical activity level in relation to obesity: current evidence and research issues. *Med Sci Sports Exerc* 1999;31(Suppl. 1):S522–5.

29. Plasqui G, Joosen AM, Kester AD, Goris AH, Westerterp KR. Measuring free-living energy expenditure and physical activity with triaxial accelerometer. *Obes Res* 2005;13:1363–9.

30. Fairclough SJ, Noonan R, Rowlands AV, Van Hees V, Knowles Z, Boddy LM. Wear compliance and activity in children wearing wrist- and hip-mounted accelerometer. *Med Sci Sports Exerc* 2016;48:245–53.

31. Kim Y, Hibbing P, Saint-Maurice PF, Ellingson LD, Hennessy E, Wolff-Hughes DL, et al. Surveillance of youth physical activity and sedentary behavior with wrist accelerometer. *Am J Prev Med* 2017;52:872–9.

32. McLellan G, Arthur R, Buchan DS. Wear compliance, sedentary behaviour and activity in free-living children from hip-and wrist-mounted Actigraph GT3X+ accelerometers. *J Sports Sci* 2018;36:2424–30.

33. Cain KL, Sallis JF, Conway TL, Van Dyck D, Calhoon L. Using accelerometers in youth physical activity studies: a review of methods. *J Phys Act Health* 2013;10:437–50.

34. Rowlands AV, Rennie K, Kozarski R, Stanley RM, Eston RG, Parfitt GC, et al. Children’s physical activity assessed with wrist- and hip-worn accelerometers. *Med Sci Sports Exerc* 2014;46:2308–16.

35. Van Loo CMT, Okely AD, Batterham MJ, Hinklely T, Ekelund U, Brage S, et al. Wrist accelerometer cut points for classifying sedentary behavior in children. *Med Sci Sports Exerc* 2017;49:813–22.

36. Troiano RP, McClain JJ, Brychta RJ, Chen KY. Evolution of accelerometer monitoring. *Optimizing the use of accelerometer data for free-living physical activity assessment using local gravity and temperature: an evaluation on four continents. *J ApplPhysiol* 2014;117:738–44.

37. Trost SG, Rice K, Pfeiffer K. Comparison of wrist accelerometer cut-points for classifying physical activity intensity in youth. *J Sci Med Sport* 2017;20:e104–5.

38. Scottish Government SAH. *Physical activity and sedentary time between Year 1 and Year 4 of primary school in the B-PROACTIV cohort. Int J Behav Nutr Phys Act* 2017;14:33. doi:10.1186/s12966-017-0492-0.

39. Cliff DP, Okely AD, Burrows TL, Jones RA, Morgan PJ, Collins CE, et al. Objectively measured sedentary behavior, physical activity, and plasma lipids in overweight and obese children. *Obesity (Silver Spring)* 2013;21:382–5.

40. Cliff DP, Jones RA, Burrows TL, Morgan PJ, Collins CE, Baur LA, et al. Volumes and bouts of sedentary behavior and physical activity: associations with cardiometabolic health in obese children. *Obes Silver Spring* 2014;22:E112–8.

41. Pau M, Corona F, Leban B, Piredda S, Vacca MM, Mura G. Influence of school schedules on physical activity patterns in primary school children: a case study in Italy. *J Phys Act Health* 2017;14:501–5.

42. Ridgers ND, Timperio A, Cerin E, Salmon J. Within- and between-day associations between children’s sitting and physical activity time. *BMCPubl Health* 2015;15:950. doi:10.1186/s12889-015-2293-3.

43. Department of Health. *Start Active, Stay Active: a report on physical activity for health from the four home countries* Chief Medical Officers. London: Department of Health and Social Care; 2011.

44. Department of Health. *Childhood obesity: a plan for action - GOV.UK*; Available at: https://www.gov.uk/government/publications/childhood-obesity-a-plan-for-action; [accessed 11.09.2017].

45. Tremblay MS, Carson V, Chaput JP, Connor Gorber S, Dinh T, Duggan M, et al. Canadian 24-Hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metab* 2016;41(Suppl. 3):S311–27.

46. Tremblay MS, Gray CE, Akinrude K, Harrington DM, Katzmanzykt, Lambert EV, et al. Physical activity of children: a global matrix of grades and scores. *Int J Environ Res Public Health* 2015;12:2079–95. doi:10.3390/ijerph12072079.

47. Carlson JA, Engelberg JK, Cain KL, Conway TL, Mignano AM, Bonillaalez SA, Katzmarzyk PT, Onywera VO, Lambert EV, et al. Global Matrix 2.0: report card grades on the physical activity, sedentary behavior, and sleep seasons of children in 145 countries. *Int J Environ Res Public Health* 2017;14(Suppl. 1):S113–25.

48. Tremblay MS, Barnes JD, Gonzalez SA, Katzmarzyk PT, Onywera VO, Reilly JJ, et al. Global Matrix 2.0: report card grades on the physical activity of children and youth comparing 38 countries. *J Phys Act Health* 2016;13(Suppl. 2):S343–66.

49. Carlson JA, Engelberg JK, Cain KL, Conway TL, Mignano AM, Bonilla EA, et al. Implementing classroom physical activity breaks: associations with student physical activity and classroom behaviour. *PLoS One* 2017;12:e0169649. doi:10.1371/journal.pone.0169649.

50. Scottish Government SAH. *Scottish Index of Multiple Deprivation*; Available at: http://www.gov.scot/Topics/Statistics/SIMD; [accessed 31.05.2018].

51. Cole TJ, Freeman JV, Preece MA. Body mass index reference curves for the UK, 1990. *Arch Dis Child* 1995;73:25–9.

52. Chandler JL, Brazendale K, Beets MW, Mealing BA. Classification of physical activity intensities using a wrist-worn accelerometer in 8-12-year-old children: wrist-worn accelerometer in children. *Pediatr Obes* 2016;11:120–7.

53. Cohen J. *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: L. Erlbaum Associates; 1988.

54. Hildebrand M, Van Hees VT, Hansen BH, Ekelund U. Age group comparability of raw accelerometer output from wrist- and hip-worn monitors. *Med Sci Sports Exerc* 2014;46:1816–24.