Examining Influences on Boy’s and Girls’ Physical Activity Patterns: The A-CLASS Project

Nicola D. Ridgers, Lee E.F. Graves, Lawrence Foweather, and Gareth Stratton
Liverpool John Moores University

Understanding children’s physical activity (PA) patterns and the factors that may influence PA are important for developing interventions within this population. One hundred and ten children aged 9–10 years from 8 schools had their PA patterns assessed over 7 days. Physiological and self-report data were also collected. Multilevel analyses revealed that cardiorespiratory fitness was a consistent, significant and positive predictor of weekday and weekend PA, while the availability of home sedentary activities was a significant but negative predictor of PA. Since a range of variables were associated with PA levels, intervention developers should be cognizant of variables that may influence children’s activity.

Physical activity (PA) is an integral component of a healthy lifestyle. The establishment of healthy PA patterns in childhood is a public health priority, as research suggests that PA tracks across the lifespan (18,34), and higher activity levels are associated with lower health risks such as clustered cardiovascular risks (2) and metabolic syndrome (33). It is recommended that children should engage in at least sixty minutes of at least moderate intensity PA a day (23). However, there is some debate as to whether children are sufficiently active to benefit health. Studies have noted that the proportion of children achieving these guidelines range from 2.5 to 97% (1,9,27,28,38). While the analysis of accelerometry data may contribute to some of the variation reported, it also suggests that more research is needed to understand children’s PA patterns, particularly with a view to promoting activity in this population.

The use of accelerometry to objectively measure children’s PA has enabled researchers to examine activity patterns across the day, and to identify periods of high and low activity. It has been demonstrated that both school and after school hours are important times for children to engage in PA (9,11,25), though after school may be
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an important period for PA (22). In addition, weekend PA has typically been found to be lower than weekday PA, and that boys are more active than girls (9,25,28).

To date, little research has focused on potential variables that may influence PA levels across segments of the day. One such study found that walking to school was associated with higher PA across the school day compared with traveling to school by car, though this was only significant for boys (7) and may be explained, in part, by the distance traveled to school (39). However, there is a lack of data that investigates patterns of PA and its association with a range of variables across segments of the day. Consequently, there is a need to examine the association of physiological, behavioral and environmental variables with children’s PA levels across both weekdays and weekend days.

One framework that attempts to link physiological, behavioral and environmental behaviors together is the Youth Physical Activity Promotion Model (YPAM; 40). It provides a hierarchical structure for categorizing correlates into four main domains, namely enabling, reinforcing, predisposing, and demographic factors (40). In the YPAM, emphasis is placed on correlates that are causally related to PA so as to inform promotional efforts (40). Reviews into correlates of physical activity have generally shown positive effects of predisposing factors on children’s physical activity (31,37). However, the associations between PA and correlates such as weight category (demographic factor), home exercise aids and home sedentary alternatives (enabling factors) have shown inconclusive associations (31,37). Typically, studies investigating associations between PA and correlates have investigated whole day PA, yet associations may change when specific segments of the day are investigated. In addition, variables that have a known association with PA may be influenced when other variables are considered.

The aim of this study, therefore, was to examine boy’s and girls’ PA patterns across weekday and weekend days, and to determine the association of physiological, behavioral and environmental variables with activity levels during the whole day and segmented day.

Method

Participants

Following ethical approval from the University Ethics Committee, 16 Liverpool elementary schools met preset criteria of school size (>400 pupils on role (grades K-5); >250 pupils on role (grades 2–5)), deprivation (Index of Multiple Deprivation >40), current after-school provision (limited) and availability of school sports facilities (accessible) and were invited to an initial meeting to outline the Active City of Liverpool, Active Schools and SportsLinx (A-CLASS) Project. All schools consented to participate in the program. Subsequently, 8 schools were randomly selected to participate and were randomly allocated to 1 of 4 groups (two-schools per group) in the program (Physical Activity Signposting Scheme (PASS); High-Intensity Physical Activity (HIPA); Fundamental Movement Skills (FMS); Control). All children from year 5 (aged 9–10 years) in each participating school (n = 491) were invited to participate in the project and asked to return informed written parental consent, child assent, and medical forms. Exclusion criteria included
current use of prescription medication, any personal history of asthma/respiratory problems, heart or vascular complaints, a body mass index (BMI) score within the lower 50th percentile relative to children in their year at their school, and a family history of sudden death. Two hundred and ninety-two children consented to participate in the study (58% response rate), with 152 children (62 boys, 90 girls) meeting the inclusion criteria. For the purpose of this study, cross-sectional baseline data, which were collected during term-time between September and November 2006, are reported.

**Procedures and Measures**

Before the assessment of PA, every child attended the university laboratory on one day to complete a range of measures, including anthropometric measures, VO₂peak testing, and a self-report questionnaire. Once every child had completed the laboratory visit, research staff visited the school to fit the accelerometers to the children at the start of the school day. Following a familiarization session, children were asked to wear the monitors for seven consecutive days and to return them to school for collection by the research staff.

**Physiological variables**

**Anthropometry.** Body mass was measured to the nearest 0.1kg using a calibrated mechanical flat scale (Seca, Birmingham, UK). Stature and sitting height were measured to the nearest 0.1cm using the Leicester Height Measure (Seca, Birmingham, UK). Leg length was calculated by subtracting sitting height from stature. BMI was calculated using \( \frac{\text{mass (kg)}}{\text{stature}^2 (\text{m})} \), and children were classified as normal weight or overweight using age-specific UK cut-points (6). All measurements were taken by ISAK trained research staff using standard procedures (16).

**Maturity Status.** Maturity status was estimated by calculating years from attainment of peak height velocity (APHV), which is the age of maximum growth in stature during adolescence (21). This is a commonly used technique in longitudinal studies (19) where stature, sitting height, leg length, mass, chronological age and their interactions are used in gender-specific equations to predict each individual’s maturity offset (years from APHV; 21).

**Cardiorespiratory Fitness.** Peak oxygen uptake (VO₂peak) was assessed using a discontinuous, incremental exercise test to volitional exhaustion, which involved walking (4 and 6km·h⁻¹) and running (8, 10, 12, and 14km·h⁻¹ or until volitional exhaustion). Participants exercised at each speed for 3 min with 30 s passive recovery between stages. Carbon dioxide production (VCO₂) and VO₂ were measured breath-by-breath throughout using an on-line gas analysis system (Jaeger Oxycon Pro, Warwick, UK). Following volitional exhaustion, participants actively recovered for 5 min at 3.5km·h⁻¹. Respiratory variables were averaged every 15 s and VO₂peak was accepted as the highest 15 s VO₂ value when participants exhibited subjective indicators of peak effort that were confirmed by a respiratory exchange ratio \( \geq 1.00 \) and/or heart rate \( \geq 195 \text{ beats.min}^{-1} \) (3). Throughout, participants wore a heart rate monitor (Polar, Kempele, Finland) and a uniaxial accelerometer (Actigraph, GT1M, ActiGraph LLC, Pensacola, FL).
Behavioral and Environmental Variables

Home Environment, Local Environment, and Leisure Behaviors. During their visit to the laboratories, children completed a short self-report questionnaire that consisted of a number of items. Home exercise equipment availability and sedentary leisure activities were assessed using a list of 17-items which asked children to indicate whether they had any of the equipment or activities in their home using a yes/no response format (adapted from 30; 32). The sum of yes responses for indoor equipment (e.g., trampoline, workout videos/DVDs; 7 Items), outdoor equipment (e.g., bicycle, sports equipment; 5 items), and sedentary activities (e.g., television, computer console; 5 items) was recorded for each child. Perceptions of the local environment were assessed using a 15-item list that asked children to indicate whether the features could be found in their neighborhood. Positive (e.g., footpaths, street lights) and negative features (e.g., speeding traffic, pollution) were calculated as the sum of yes responses to the relevant items (adapted from 30). Neighborhood safety was rated using a 1 (very unsafe) to 5 (very safe) scale (30).

For active travel to school, children were asked to indicate how they usually traveled to school, and were classified as either active (on foot, bicycle) or passive (car, bus, train) travelers. Sports club membership (yes/no) was also assessed.

Physical Activity. PA was objectively measured every 5 s for 7 consecutive days using uni-axial accelerometers (GT1M Actigraph). The Actigraph has acceptable validity and reliability for use in pediatric studies (35), and it is the most commonly used accelerometer in field-based research (8). Children were asked to wear the accelerometer during all waking hours, except during water-based activities (such as swimming and bathing), on their right hip using an adjustable nylon belt. A log sheet was provided to all participants to record when the monitor was worn, for example, and reasons for removal during the day.

At the end of the data collection, the accelerometers were downloaded using Actilife software (v.2.1.8, ActiGraph LLC, Pensacola, FL) and data were checked for compliance to the monitoring protocol using customized software (MAHUffe; www.mrc-epid.cam.ac.uk). Sustained bouts of 20 min of zero counts were deemed to indicate the accelerometer had not been worn, and the total ‘missing’ counts for these periods represented the duration that the monitor was not worn (5). For inclusion in the analysis, each child was required to have produced counts for a minimum of 9 hr a day for at least 3 days (including a minimum of 1 weekend day). These minimum criteria have demonstrated acceptable reliability in similar aged children (20). Forty-two children (17 boys, 25 girls) did not meet the compliance criteria, leaving a final sample of 110 children (45 boys, 65 girls).

PA data were analyzed using individually calibrated thresholds determined from the accelerometry data collected during the VO2peak test. Individual thresholds were determined for each completed speed (i.e., 3 min stage) by removing the first and last 30 s of data, and calculating the mean of the remaining 2 min of accelerometer data (13). This process obtained accelerometer count cut-points for each child at each speed. For the purpose of this study, a threshold of 4km·h⁻¹ was used to determine the hourly amount of time per day children spent equal to or above this speed (PA≥4) between 7am and 10pm, and for following time segments: school day (weekday 7am-3pm), after school (3–10pm), weekend morning (7am-12pm) and weekend afternoon (12–10pm).
Data Analysis

Descriptive statistical analyses (mean (SD)) were initially calculated for all variables. Exploratory analyses were conducted to explore gender differences in anthropometric data and PA data. Gender differences in PA patterns across weekdays and weekend days were assessed using one-way analyses of variance. These analyses were conducted using SPSS version 15 (SPSS Inc., Chicago, IL).

In line with the multilevel structure of the YPAM (40), multilevel models were used to determine the impact of physiological, behavioral and environmental predictor variables on children’s PA. Multilevel modeling was used as it is considered to be the most appropriate technique for analyzing nested data (12). A two-level structure was used, with children defined as the first level unit and schools as the second level unit (36). School was included as the second level unit to control for the effect that this particular context could have on children’s PA behavior (36). The data were analyzed using MLwiN 1.10 software (Institute of Education, University of London, UK).

A prediction model was used to identify which variables best predicted PA levels. Six outcome variables were assessed, namely the time spent in minutes above PA≥4 during weekdays (7am-10pm), weekend days (7am-10pm), the school day (weekday 7am-3pm), after school (weekday 3pm-10pm), weekend morning (7am-12pm) and weekend afternoon (12–10pm). Predictor variables included gender, anthropometric variables, fitness tertiles, maturity offset and environmental and leisure behaviors identified above. Regression coefficients were assessed for significance using the Wald statistic. Significantly associated variables were retained in the final model, with statistical significance set at $p \leq .05$ (36).

Results

Exploratory Analyses

The descriptive (mean (SD)) anthropometric characteristics of the children are shown in Table 1. Boys had a significantly higher VO$_{2\text{peak}}$ than girls ($p < .001$). No other significant differences were found between boys and girls in this sample. No significant differences were found between included and excluded children on all measure variables. The environmental and behavioral characteristics of interest are shown in Table 2.

PA Patterns Across the Day

Figures 1 and 2 show the hourly PA patterns of boys and girls for weekdays and weekend days, respectively.

During the weekdays, boys engaged in significantly more PA$_{≥4}$ than girls between 12 and 1pm (14.1 ± 6.0 vs. 10.2 ± 3.8 min), respectively (Figure 1). Girls engaged in more PA≥4 from 2pm than boys, though these differences were not significant. During the weekend, boys were significantly more active than girls between 7–8am (2.4 ± 1.9 min vs. 0.9 ± 1.0 min), 8–9am (2.9 ± 3.1 min vs. 1.7 ± 1.3 min), 9–10am (6.7 ± 9.6 min vs. 3.3 ± 3.3 min), 10–11am (7.5 ± 8.6 min vs.
Table 1  Descriptive Anthropometric and Physical Activity Characteristics by Gender (mean (SD))

<table>
<thead>
<tr>
<th></th>
<th>Boys (n = 45)</th>
<th>Girls (n = 65)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>9.7 (0.3)</td>
<td>9.7 (0.3)</td>
<td>0.65</td>
</tr>
<tr>
<td>Stature (m)</td>
<td>1.39 (0.07)</td>
<td>1.39 (0.06)</td>
<td>0.68</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>36.4 (8.6)</td>
<td>37.3 (7.0)</td>
<td>0.54</td>
</tr>
<tr>
<td>Body mass index (m•kg⁻²)</td>
<td>18.6 (3.2)</td>
<td>19.3 (2.6)</td>
<td>0.22</td>
</tr>
<tr>
<td>Maturity offset (yr)</td>
<td>-3.2 (0.5)</td>
<td>-3.3 (0.4)</td>
<td>0.49</td>
</tr>
<tr>
<td>VO₂peak (ml.kg⁻¹.min⁻¹)</td>
<td>51.7 (6.7)</td>
<td>43.4 (6.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weekday wear time (min)</td>
<td>735.4 (51.8)</td>
<td>734.5 (54.0)</td>
<td>0.93</td>
</tr>
<tr>
<td>Weekend wear time (min)</td>
<td>674.2 (85.3)</td>
<td>654.1 (82.2)</td>
<td>0.21</td>
</tr>
<tr>
<td>Weekday PA₄ (min)</td>
<td>82.8 (28.7)</td>
<td>81.7 (26.4)</td>
<td>0.84</td>
</tr>
<tr>
<td>Weekend PA₄ (min)</td>
<td>86.5 (42.5)</td>
<td>74.3 (35.3)</td>
<td>0.10</td>
</tr>
<tr>
<td>Total week PA₄ (min)</td>
<td>84.0 (30.4)</td>
<td>80.2 (26.1)</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Note. Mean number of valid weekdays and weekend days for the sample is 4.5 and 1.6, respectively.

Table 2  Environmental and Behavioral Characteristics by Gender (mean (SD) unless stated)

<table>
<thead>
<tr>
<th></th>
<th>Possible range</th>
<th>Boys (n = 45)</th>
<th>Girls (n = 65)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports club membership (%)</td>
<td>N/A</td>
<td>62.2</td>
<td>69.2</td>
</tr>
<tr>
<td>Active travel to school (%)</td>
<td>N/A</td>
<td>66.7</td>
<td>67.7</td>
</tr>
<tr>
<td>Perception of safety</td>
<td>1–5</td>
<td>4.0 (1.0)</td>
<td>3.7 (1.1)</td>
</tr>
<tr>
<td>Outdoor home-use exercise equipment</td>
<td>0–5</td>
<td>3.5 (1.1)</td>
<td>3.9 (0.9)</td>
</tr>
<tr>
<td>Indoor home-use exercise equipment</td>
<td>0–7</td>
<td>3.2 (1.8)</td>
<td>3.1 (1.7)</td>
</tr>
<tr>
<td>Home sedentary leisure activities</td>
<td>0–5</td>
<td>4.1 (1.2)</td>
<td>4.2 (1.1)</td>
</tr>
<tr>
<td>Positive environmental features</td>
<td>0–11</td>
<td>7.8 (2.2)</td>
<td>6.7 (2.3)</td>
</tr>
<tr>
<td>Negative environmental features</td>
<td>0–4</td>
<td>0.9 (0.9)</td>
<td>1.3 (1.0)</td>
</tr>
</tbody>
</table>

Key: N/A not applicable

4.6 ± 3.6 min), and 1–2pm (9.2 ± 7.6 min vs. 6.7 ± 5.0 min), respectively (Figure 2). With the exception of 3–4pm and 8–9pm, boys were more active than girls across weekend hourly periods. When considering total week PA, 71.1% of boys and 72.3% of girls accumulated more than 60 min in PA₄ a day.
Predictor Variables Influencing PA Levels

The results of the multilevel models are shown in Table 3. Fitness was a significant positive predictor of PA≥4 for all periods except weekend mornings. Children in the moderate (VO2peak 44.6–50.6 ml.kg⁻¹.min⁻¹) and high fitness (VO2peak >50.6 ml.kg⁻¹.min⁻¹) tertiles engaged in more activity than the lowest fitness tertile (VO2peak <44.6 ml.kg⁻¹.min⁻¹). The number of available sedentary activities at home was a
Table 3  Multilevel Analyses of the Variables Predicting Physical Activity Engagement Across Weekdays, Weekend Days, and Segmented Days

<table>
<thead>
<tr>
<th>Variable</th>
<th>Weekday</th>
<th>Weekend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole Day</td>
<td>School Day</td>
</tr>
<tr>
<td>Constant</td>
<td>95.1 (9.6)</td>
<td>30.0 (2.3)</td>
</tr>
<tr>
<td>Sex1</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Overweight2</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Obese3</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Moderate fitness4</td>
<td>13.6 (5.8)</td>
<td>6.2 (2.9)</td>
</tr>
<tr>
<td>High fitness5</td>
<td>15.1 (5.9)</td>
<td>10.2 (2.9)</td>
</tr>
<tr>
<td>Active Transport6</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Maturity offset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Sports club membership7</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Home exercise equipment—inside</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Home exercise equipment—outside</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Home sedentary alternatives</td>
<td>-5.2 (2.1)</td>
<td>NE</td>
</tr>
<tr>
<td>Positive environment features</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Negative environment features</td>
<td>NE</td>
<td>NE</td>
</tr>
</tbody>
</table>

1 Boys were the reference category.
2–3 BMI group was divided into normal weight, overweight and obese (Chin & Rona, 2002). Normal weight was used as the reference category.
4–5 Fitness was divided into tertiles and the lowest tertile was used as the reference category.
6 Active travel to school was the reference category.
7 No sports club membership was the reference category
NE = Not entered in final model.
significant negative predictor of PA≥4 for the weekdays, weekend days and afternoon periods, where decreased PA was correlated with increased availability of sedentary activities. Contrasting results were found for sex, as girls engaged in 6.9 min more PA than boys after school but 6.1 min less on weekend mornings. BMI group was a significant negative predictor of PA≥4 for weekend mornings, with overweight and obese children engaging in 6.5 min and 14.1 min less activity than their normal weight peers. Maturity offset was a significant positive predictor for all weekend variables. Results suggested that children nearer to APHV engaged in more PA. A significant positive association was also found between PA≥4 and positive environmental features.

**Discussion**

This study aimed to examine boy’s and girls’ PA patterns across weekdays and weekend days, and to establish the association between a range of demographic and enabling factors and PA levels. Results indicated that approximately two-thirds of boys and three quarters of girl’s met activity recommendations (23). Boys were found to be more active than girls during weekends (Table 1) with significant differences occurring during the morning period (Figure 2), though this difference was not significant when the whole day was considered. Weekday differences were largely attributable to gender differences observed between 12pm and 1pm, which coincides with recess where children are able to be active in the playground environment (29). This provides some support that the school day structure provides opportunities for PA engagement (9), though our data suggest that primarily boys benefit. Interestingly, the multilevel models indicated that girls engaged in more PA after school than boys, which contrasts previous studies (11,22,28). This may be attributable to girls’ access to home exercise equipment and sports club membership, though as this is based on self-report data. Further research would be required to investigate this further within this population. However, it suggests that the after school period may be a critical period for girls to engage in volitional PA.

Previous research has indicated that sedentary behaviors occupy a large proportion of children’s home-based leisure time (15). This study found that the number of sedentary leisure pursuits available to children at home was a significant negative predictor of PA engagement (Table 3). Moreover, while boy’s and girl’s reported a similar number of home sedentary leisure activities (Table 2), and these were less than the amount of home-based exercise equipment available (indoor and outdoor combined), only sedentary leisure activities influenced PA levels both during weekdays and weekends. This contrasts previous research that has found that more exercise equipment has been associated with greater PA participation (14). Laurson et al. (15) noted that children who failed to meet PA and screen time recommendations were at a greater risk of being overweight. Therefore, interventions could focus on time periods where sedentary behaviors are negatively associated with PA, which may influence the risk of being overweight.

With the exception of weekend mornings, significant and positive associations were found between physical activity engagement and the moderate or high fitness tertiles compared with the low fitness tertile. This supports previous research positive associations between fitness and PA levels have been reported (17,33). Since low physical fitness levels tend to track in to adulthood (18), albeit poorly (4), and
fitness is associated with a healthy cardiovascular disease risk profile (24), it is a concern that differences in habitual PA are discernable between fitness tertiles in prepubertal children. Though differences occurred during both weekdays and weekend days, larger differences were observed during weekend afternoons. To this end, interventions may need to focus on increasing children’s activity levels beyond the context of the school day to benefit physical activity levels and fitness.

In this current study, maturity offset was found to be a significant and positive predictor of weekend PA engagement. This is of note, particularly as habitual activity has been found to decline in adolescence (27) and late maturers are more active than early maturers (10,28). While children in the current study were, on average, 3 years from APHV, it may be that children who are nearer to APHV are afforded more opportunities to engage in PA than their less mature counterparts. There is concern that safety concerns and restriction of play opportunities are impacting on PA levels, particularly in girls (14). Moreover, children who report greater independent mobility recorded higher daily accelerometer counts (26). While our study did not measure independent mobility, it may be that early maturers have greater independent mobility and less adult constraints, particularly at weekends, which in turn could impact on PA levels. Interestingly, Page et al. (26) found that pubertal status was negatively related to weekday counts though positively related to independent mobility. Further research is required to examine this issue and to determine how maturity can influence activity levels.

There is increasing interest in examining children’s activity patterns across weekdays and weekends. This study built on previous research by investigating the impact of different variables on individually calibrated activity using multilevel analyses, which account for the nested data within the study. However, there are some limitations that should be noted. First, information concerning neighborhood safety and home and neighborhood environmental features was examined using adaptations of validated questionnaires. In addition, the children were below the recommended age for self-report techniques, which may have reduced the strength of the associations seen in the data. Future studies should investigate whether objectively assessed environmental features and parental perceptions may also impact on children’s activity levels. Secondly, the sample size was relatively small, was influenced by the specific inclusion criteria, focused on one-year group of children in elementary schools, and data were collected over a 9 week period. These may affect this study’s generalisability to other populations. Thirdly, it is not possible to demonstrate causality between the variables investigated.

Conclusions

This study contributed to the current literature base by examining children’s PA patterns across weekdays and weekend days, and investigating the association between a range of enabling and demographic variables and PA (40) during whole days and segmented days. Boys were more active than girls, though differences were smaller than previously noted and girls’ PA participation was higher outside the structure of the school day. Fitness was a consistent positive predictor of PA, while maturity offset and home sedentary leisure activities were also associated with weekday and weekend activity. Since a range of variables were associated with PA levels, intervention developers should be cognizant of variables that may influence children’s PA during whole days and segments of days.
Acknowledgments

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References


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