Full title: Patterns of objectively measured moderate-to-vigorous physical activity in preschool children

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Abstract

Background:

Identifying periods of the day which are susceptible to varying levels of physical activity (PA) may help identify key times to intervene and potentially change preschool children's PA behaviours. This study assessed variability of objectively measured moderate-to-vigorous physical activity (MVPA) during weekdays and weekend days among preschool children.

Methods:

One hundred and eighty-eight children (aged 3-5 years; 53.2% boys) from a northwest English city wore uniaxial accelerometers for 7 consecutive days.

Results:

Higher levels of MVPA were recorded in boys, particularly those who attended preschool for a half day. Children who attended preschool for a full day engaged in 11.1 minutes less MVPA than children who attended for a half day. After-school hours were characterised by a decrease in activity for all groups. Patterns of activity during the weekend were smoother with less variability.

Conclusion:

This study identified discrete segments of the week, specifically afterschool and during the weekend, when preschoolers engage in low levels of PA. Higher levels of MVPA among children who attended preschool for less time each day suggests that the structured preschool environment is related to decreased activity. Consequently, there is a need for interventions in young children to focus on school and home environments.

Introduction

The preschool years (approximately defined as between the ages of 3 and 5 years) is an important developmental stage during which the pattern of health behaviors such as physical activity (PA) are established [1,2]. Sufficient PA during the early years offers protection against excess weight gain [3], improves bone [4] and cardiovascular health [5], and assists with the development of fundamental movement skills [6]. Unfortunately, empirical research suggests that preschool children are not active enough to benefit their health [7,8]. Despite many countries developing PA recommendations specifically for preschool children, levels of activity among this population remain worryingly low [7,9]. Despite the urgency to increase preschoolers' PA, evidence regarding successful approaches remains equivocal [10]. Prior to conducting intervention-based research, a comprehensive understanding of the target behaviour is warranted as it maximises the potential for improvements. Identifying periods of the day which are susceptible to high and low levels of PA will help to identify key times to intervene and potentially change PA behaviors. Limited information regarding preschool children's patterns of daily PA exists, with most studies investigating daily PA rather than focusing on specific intensities [11], elements of the school day (e.g. recess or physical education classes) [12] or specific discrete segments of the day [13]. The majority of research has focused on the preschool population as a whole or using gender specific analyses [11]. To date, studies among preschoolers have predominately investigated daily PA levels during weekdays and weekends [14-16] or described average PA levels during specific periods of the day, such as recess or physical activity classes [8,17]. Few studies have described the PA variability in preschoolers across different parts of the day, for example whilst at school versus within the home environment [14,16,18], and only one recent study in preschoolers has reported on PA patterns hour-by-hour [11]. Additionally, given the variety of childcare alternatives available [19,20], little is known about how different types of preschool provision, such as attending preschool for a half day or a full day, effect children's PA levels. However, within this setting exists large variability in children's PA levels [21]. Pate and colleagues [22] reported that children in an active preschool engaged in more than twice as much moderate-to-vigorous intensity physical activity (MVPA) as those in a less active preschool. This variability may be as a result of characteristics specific to the preschool and its environment, for example the amount of hours spent at preschool, the programme or curriculum in place or practices, and policies. It may also be attributable to differences in

the physical environments of the setting, including the provision and quality of outdoor play areas and the equipment available to the children.

The primary aim of this study was to assess within-day variability of objectively measured MVPA during weekdays and weekend days among preschool children. A secondary aim was to examine differences in these patterns by sex and enrolment at school.

Method

Participants and settings

Children were recruited from twelve randomly selected preschools in a large urban city in the northwest of England. Preschools were located in the same geographical area of high social and economic deprivation [23]. All children between 3 and 4.9 years attending the preschool were invited to participate (n = 673). Informed parental consent was obtained from 240 children (36% response rate). The number of children was further reduced to 188 once the physical activity cut-points were applied to the data (this is described below under 'statistical analysis'). In England all three and four year olds are entitled to 15 hours free preschool education for 38 weeks of the year. This applies until children reach compulsory school age (the term following their fifth birthday). Although not compulsory, virtually all preschool children attend some form of childcare provision. Classes run from Monday to Friday and start at 9:00 and finish at 15:00. Parents can opt to send their children to preschool for a half day (3 hours) or a full day (6 hours) but must pay an additional fee for attendance exceeding 15 hours per week. The research protocol received ethical approval from the University Ethics Committee.

Instrumentation

ActiGraph accelerometers (GT1M ActiGraph, Pensacola, FL.) measured PA every 5 s. Minutes of MVPA were determined using age specific cut-points of 205-410, 272-412 and 298-418 counts per 5 s epoch for children aged 3, 4 and 5 years, respectively [24]. Time spent in MVPA (min) was the main outcome. MVPA levels per hour (mins/hour) were calculated to assess within-day variability. Patterns of weekday and weekend MVPA were observed between 07:00 and 20:00 for the following time segments during weekdays: preschool

(07:00-9:00), during school (09:00-15:00) and after school (15.00-20.00) and during the weekend: morning (07:00-12.00), daytime (12:00-17:00) and evening (17:00-20:00).

Procedure

PA was monitored on seven consecutive days (Wednesday through Tuesday) during October 2009 and March 2010. Daylight hours and temperatures during both months were very similar ~ 11.5 hours and ~10.5°c, respectively 25. A previous study conducted in a similiar geographical area did not find any variation in children's PA levels across seasons during recess [26]. Participants were instructed to wear the accelerometers on an elastic belt on the right hip (anterior to the iliac crest) during all waking hours except during water-based activities. Body mass was measured to the nearest 0.1kg using digital Tanita scales (Model WB100-MA, Tanita Europe, The Netherlands). Stature was measured to the nearest 0.1 cm using a portable Leicester Height Measure (SECA, Birmingham, UK). Body Mass Index (BMI) (kg/m2) was calculated and children were classified as underweight, normal weight, overweight or obese using sex and age-specific cut-points [27]. To examine potential school-related differences, participants were categorized in two groups: those who attended school for three hours and those who attended school for six hours.

Statistical analyses

Habitual physical activity data were initially checked for compliance to the monitoring protocol using MAHUffe (Analyser v 1.9.0.3). Firstly, the minimum number of hours per day that the ActiGraphs were worn was determined. Twenty minutes of consecutive zeros were considered periods of non-wear time [28]. To be included as a valid measurement day, children were required to wear the accelerometer for 619 and 624 minutes during Weekdays and weekend days, respectively. These wear times were calculated by defining 80% of the total length of time during which 70% of the sample wore the accelerometer [29]. Children were finally included in the analyses if they wore the monitor for a minimum of 3 days including one weekend day [30]. The final sample consisted of 188 children (100 boys and 88 girls). Reasons for missing data included non-compliance when wearing the accelerometer (n=43), technical problems (n=6), and loss of accelerometers (n=3). Independent samples t-tests revealed no significant differences between children with complete and incomplete physical activity data ($p > 0.05$).

Descriptive statistics (mean, SD) were used to describe the study population. Independent samples t-tests examined differences between boys and girls for age, stature, body mass, BMI, enrolment and MVPA. Three-way repeated measures ANOVAs were used to test variability in PA across sex and enrolment (three or six hour). A 13 (hour of the day) x 2 (sex: boys or girls) x 2 (enrolment: half or full day) repeated measures ANOVA was used to assess within-day variability during weekdays and weekend days. A 2 (type of day: weekday or weekend day) x 2 (sex: boys or girls) x 2 (enrolment: half or full day) repeated measures ANOVA was used to assess between-day variability. Post hoc analyses were conducted for significant main effects using Tukey's HSD. Data were analysed using PASW Statistics v.18, and the significance level was set at $p \leq 0.05$.

Results

Participant characteristics and descriptive physical activity data (mean, SD) are shown in Table 1. Overall, boys engaged in significantly more MVPA than girls during both week and weekend days. The largest sex differences were observed during the school day (09:00-15:00) and during the weekend day (12:00-17:00). No gender differences existed for other segments of week days or weekend days.

A significant hour-by-enrolment interaction effect ($F = 3.17$, $p < .001$) revealed that the overall weekday pattern of activity differed by enrolment classification (Figure 1). During weekdays children who attended school for a half day engaged in 6.4 minutes more MVPA during the school day (09:00-15:00) ($F = 14.34$, $p < .001$) and 4.7 minutes more MVPA after school (15:00-20:00) ($F = 6.34$, $p < .001$) when compared to children who attended school for a full day. This equates to a total weekly gain of 41.3 minutes more MVPA per school week. There were no differences between groups in the before school time period (07:00-09:00). Patterns of MVPA in the full day children were characterised by a significant increase in MVPA between 12:00 and 13:00 followed by a significant decrease from 13:00 and 14:00. During this period, the MVPA levels of children enrolled for a half day remained stable.

Figure 2 shows the daily MVPA patterns of boys and girls attending school for a half day and a full day. There was a significant hour by gender interaction ($F = 3.681$, $p <.001$); with boys

accumulating more MVPA at each hour, this was significant at 10:00 and 14:00 (these times are typical morning and afternoon break times for UK). However, there was no overall hour by gender by enrolment interaction (F = 1.08, p = .371). Differences in activity patterns were observed between boys and girls who attended school for a half day, with half-day boys being consistently more active than their half-day counterparts. The activity patterns of children enrolled for a full day demonstrate consistent peaks and troughs, representing the typical school day, with children sitting in classrooms interspersed with periods of free play and recreation. The activity patterns of boys and girls from each enrolment category were very similar, however boys consistently engaged in more MVPA than girls. The period between the end of school and bed-time appeared to be the period of the day where the largest variation occurred, particularly for half-day boys who were significantly more active than the other groups.

Figure 3 shows weekend PA patterns for boys and girls during the weekend. No hour main effects were observed (F = 1.12, p = .305). As before the PA patterns of boys and girls were remarkably similar, differing only in the amount of intensity achieved. Boys engaged in significantly more MVPA during daytime hours (12:00-17:00) (F = 6.05, p = .04) accumulating on average 6.58 minutes more MVPA during daytime hours than girls. Peaks during weekend days are less pronounced than the peaks in MVPA during school attending days. After 11:00 a steady state of activity was observed until 17:00 when both boys' and girls' levels of MVPA decrease.

Discussion

The purpose of this study was to assess within-day variability of objectively measured MVPA during weekdays and weekend days among preschool children. A secondary aim was to examine differences in these patterns by sex and enrolment at school, which has not been reported in the literature to date.

Children who were enrolled at school for half a day accumulated more MVPA than children who attended school for the full day and engaged in a structured routine encompassing a fixed classroom timetable and scheduled recess. In England, children attending preschool for a half day have access to continual outdoor provision, allowing them to move freely

between indoors and outdoors throughout the preschool day. This may afford them an increased opportunity to be active whilst at school. Children attending preschool for a half day may also spend more time in their parents company, and it is feasible that increased parent support and rules inhibiting sedentary behaviours could be associated with increased PA in these children [31]. Children attending school for a full day demonstrated a consistent pattern of activity during weekdays, with morning travel to school, lunchtime (12:00-13:00) and the immediate after-school period being the key times when children were most active. Similar to other studies [11,32,33], the children in our study who attended school for the full day showed several marked peaks and troughs in hour-by-hour. PA patterns on school attending days, closely represented the structured school day with sedentary classroom time with scheduled active breaks. These patterns identified in full day children are likely to be related to the structured curriculum children attending full day preschool in the UK receive, for example children take part in table top activities, quiet learning activities, circle time and story time, all of which are generally sedentary. Equally, children engage in free play and outdoor play, which are both generally active, this type of routine is visible in Figures 1 and 2. Previous research have successfully increased levels of MVPA by integrating opportunities for physical activities into classroom activities that would have otherwise being sedentary e.g. math, language, science and art [34].

Most studies [17,35,36] show that recess and lunchtime are key times for MVPA during the school day, though levels could be higher than they are. Similarly this study indicates that girls and particularly boys, maximised their opportunity to increase their MVPA during free play time. Increased MVPA during this time period emphasises the importance of recess in a preschooler's day. During weekdays boys and girls from each enrolment category demonstrated very similar patterns of activity, however consistent with previous research in older children boys were significantly more active during the lunch time hour [32]. This may be due to their domination of the playground space [26]. Furthermore, previous research on physical structures and markings on the playground have had a positive effect on children's PA levels. When presented with an opportunity to be active during recess, most children will engage in significant amounts of PA [37]. However, without the ability to choose activities based on personal preferences, it has been reported that children may participate in PA in

as little as 20% of their recess time [38]. Therefore, the recess environment should afford children the opportunity to participate in physically active play. Evidence related to PA participation as a result of changes in the environment such as playground markings, additional recreational equipment, physical structures, and designated activity zones during recess is inconsistent [39,40]. For example, in a study conducted by Stratton and Mullan (2005) playground markings proved effective for increasing moderate PA and vigorous PA levels in elementary school children during recess. However, Ridgers and colleagues reported that restructuring the recess environment with playground markings and physical structures and active zones did not significantly change MPA or VPA during recess in the long-term [41]. The reason for these inconsistencies is not apparent but enhancements to recess environments still represent a sustainable, low cost intervention strategy for promoting PA in youth. More research in this area is warranted, especially in preschool environments. The before and after school segments of the day appeared to be the most stable, possibly due to the routines that children are accustomed to from the point of waking to going to school and from finishing school to going to bed. Similar patterns have been demonstrated with older children [32,42,43].

The preschool curriculum is likely to provide more opportunities for active play than the primary school curriculum. However, patterns of activity for children attending school for a full day were highly variable throughout the day, which is comparable to other research in most young children [11] and to older UK children [32]. Previous research reported that as preschool children make the transition into primary education their patterns of activity remain the same but their activity levels decline [14]. This is demonstrated in the current study where preschoolers accumulated more MVPA across the school day than older children in the UK [32]. Moreover, there is a remarkable similarity between preschool children's activity levels and their older counterparts suggesting that blocks of inactivity are already apparent in the preschool environment. A previous classroom based PA intervention has been effective [34] although more intervention research is warranted in this age group.

Consistent with findings from previous studies in this population [11,44], MVPA declined in the afterschool period except for in the case of boys who spent a half day at school. Children in this group were younger than children enrolled for the full day and research suggests that

daytime naps decrease with age [45.] Half day boys experienced significant increases in MVPA from 17:00 to 18:00 which may be explained by increased energy after a period of rest. The drop in activity in half day girls and full day boys and girls may be linked with elements of the home environment preventing children from participating in active play (e.g. increased screen time) [46] or parents perceptions that preschool children are engaging in enough PA at school [47]. Gustafson and colleagues [48] conducted a review on the parental correlates of children's physical activity and despite a lack of existing studies to draw firm conclusions from; unanimous results supported the importance of parent's physical activity on their children's activity levels. From a health promotion perspective findings from this review reinforce the importance of a family approach, by directly involving parents in the intervention programme. Parents play a vital role in the facilitation of their child's physical activity. They are knowledgeable about the barriers to physical activity and have a sense for opportunities that are consistent with their child's preferences [49]. Furthermore, parental behaviour is noted as one of the strongest determinants of both child physical activity [31] and BMI 50. Parents can provide an environment which affords their children playful opportunities, allowing them to practice different motor activities and improve their skills [51]. The role of parents within a physical activity intervention may therefore foster more active lifestyles during the preschool years and beyond.

This study found that weekend patterns of PA demonstrated less variation than school days, which is consistent with previous research [11,46]. Morning hours were characterised by a steady increase in MVPA, possibly due to children waking up later. During the weekend, children were most active during daytime hours (12:00-17:00), with boys engaging in significantly more MVPA than girls. Despite children engaging in more activity during this time period, intervening during the weekend may increase children's MVPA. For example, parental support for PA has been identified as a significant correlate in this age group [48], thus given the increased time children spend with their parents during the weekend, this may hold significant importance for the design of future interventions.

Study limitations and strengths

First, this study is limited by the absence of an activity diary for use after-school and during the weekend which would provide more information about the context in which children

were physically active. Second, though current recommendations for this age group focus on the accumulation of all intensities of activity, this study investigated MVPA as this has the best evidence in relation to health in this age group. Nevertheless, the present study adds to the dearth of literature on patterns of PA in this population. Strengths of this study include high compliance rates of participants to the measurement protocol (78.3%) and the sex specific investigation of both week and weekend day objectively monitored PA in a large sample size.

Conclusions

Within-day variability in preschool children's PA was highlighted and discrete periods of the day were identified which could be targeted to increase pre-schoolers' PA levels. Boys displayed higher levels of MVPA than girls however; all children did not accumulate enough PA for health benefits. Children who attended school for a half day accumulated more MVPA than children who were present at school for a full day, suggesting that the school environment is conducive to sedentary time. Teachers should incorporate more PA into their daily classroom activities. After-school hours and weekends were also susceptible to low levels of PA. Future interventions, with both educational and physical components [52], should target parents given the relationship between parental support for PA and increased activity in this age group.

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Table 1 Mean (SD) demographic and physical activity data for preschool children

		Boys (*n* = 100)	**Girls (*n* = 88)**
Age (year)		4.6 (0.6)	4.5 (0.5)
Stature (cm)		106.4 (6.1)	107.2 (5.5)
Body mass (kg)		18.9 (3.2)	19.4 (3.1)
BMI ($kg \cdot m^{-2}$)		16.6 (1.6)	16.7 (1.6)
% OW/ OB		22.2	24.5
Half day enrolment (n)		27	29
Full day enrolment (n)		68	64
Moderate-to-vigorous physical activity (min)			
Weekday		2.8 (2.5)	2.3 (1.9)
Before school	(07:00-09:00)	**26.5 (12.4)**	**22.2 (9.2) ***
During school	(09:00-15:00)	13.9 (7.6)	12.5 (6.3)
After school	(15:00-20:00)		
Weekend		13.1 (14.8)	9.7 (5.9)
Morning	(07:00-12:00)	**23.9 (15.8)**	**19.3 (9.9) ****
Daytime	(12:00-17:00)	7.5 (6.1)	6.8 (5.2)
Evening	(17:00-20:00)		

Significant gender differences are highlighted in bold; OW/OB = overweight/ obese * $P < 0.001$ ** $P < 0.05$

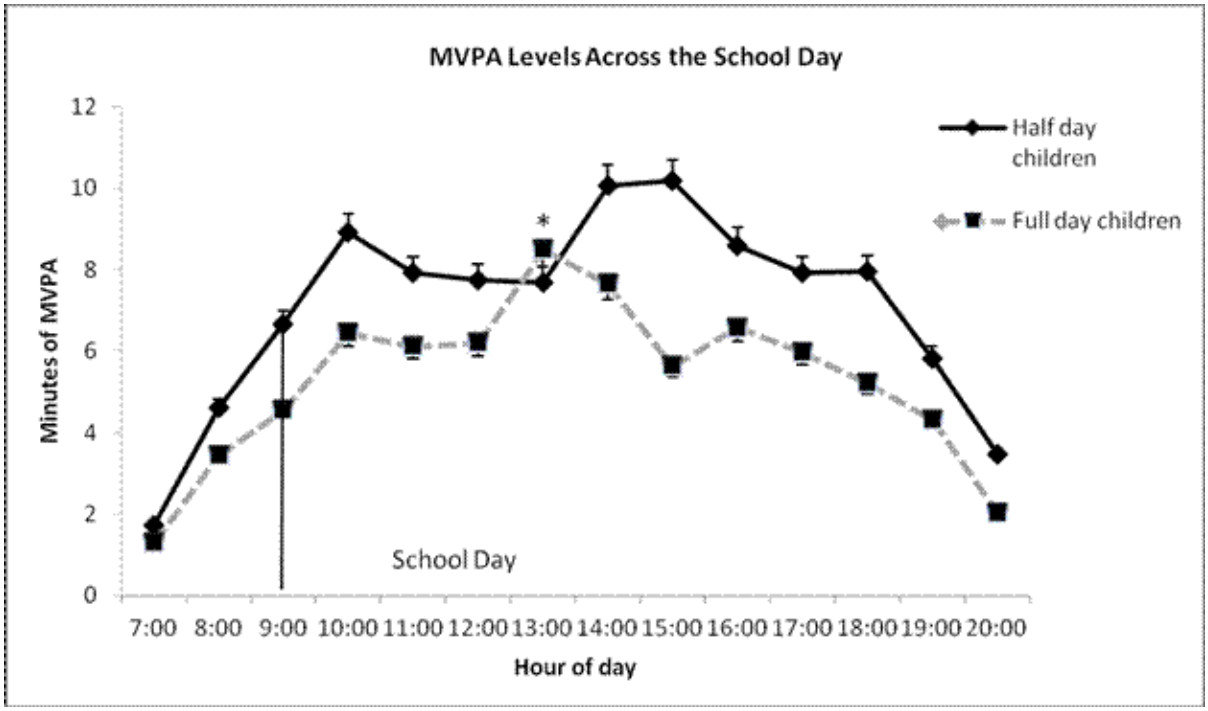

Figure 1 Enrolment specific physical activity pattern (mins/hour) for weekdays for northwest English preschool children (*p < .05)

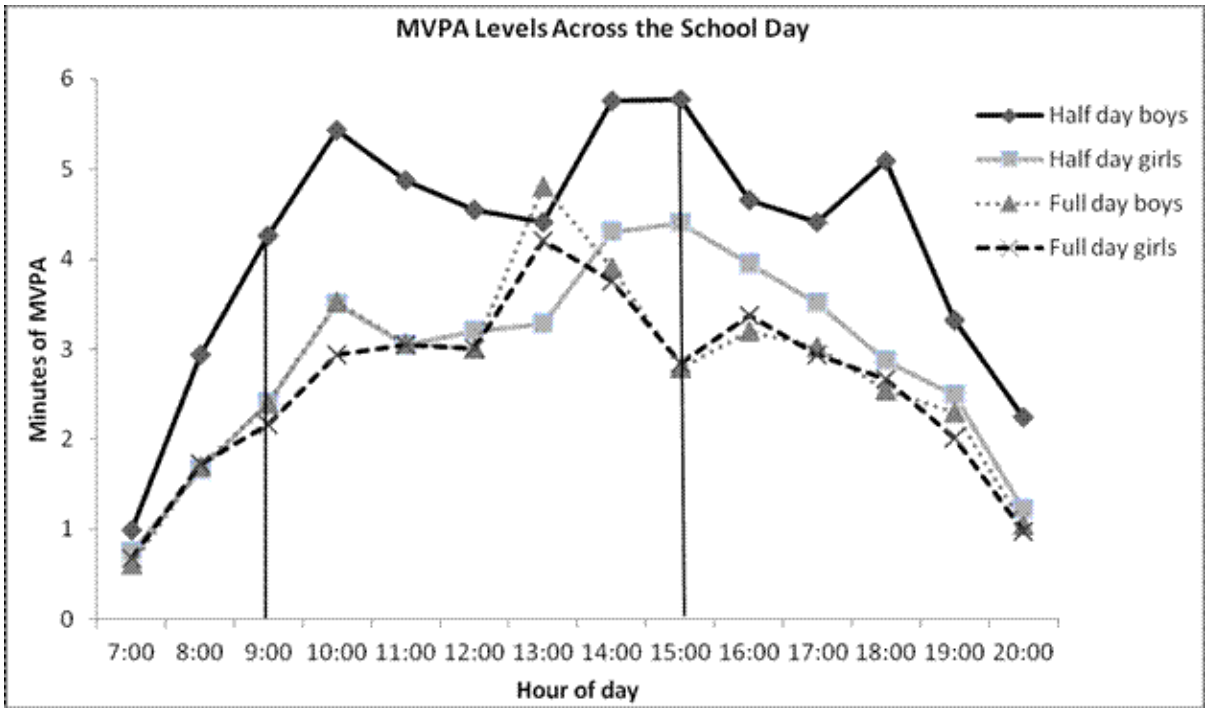

Figure 2 Enrolment and gender specific physical activity pattern (mins/hour) for weekdays for northwest English preschool children (*p < .05)

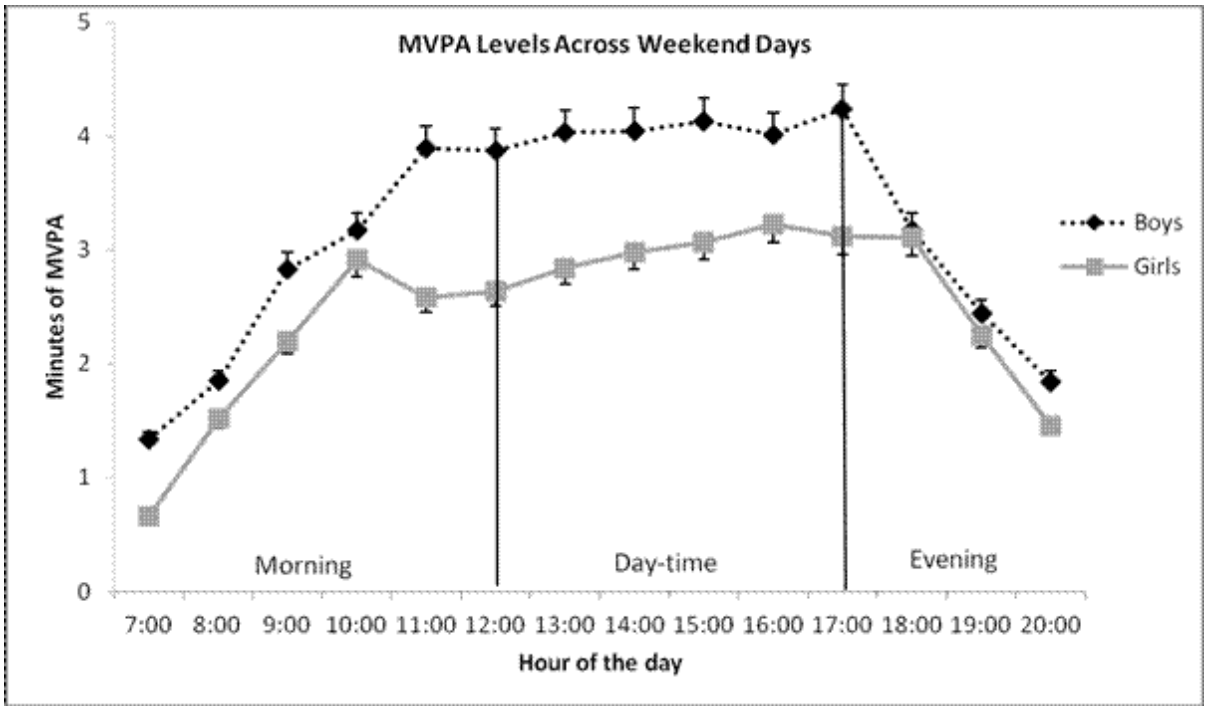

Figure 3 Physical activity patterns (mins/hour) on weekend days for northwest English preschool children