Title: Where does the time go? Patterns of physical activity in adolescent youth.

Abstract

Objectives: To explore daily patterns of physical activity in early adolescent youth, and identify whether patterns differed across varying activity levels.

Design: Cross-sectional observational study.

Methods: Adolescent youth (n = 715, 11.8 – 14.4 years) were asked to wear an Actigraph accelerometer for a 9-day period. Average daily and hourly minutes spent in moderate-vigorous physical activity (MVPA) were calculated for each participant. Participants were grouped into sex-specific quartiles (Q) based on average daily MVPA accumulation (Q4 most active, Q1 least active). Principal Components Analysis was used to identify, from hourly MVPA data, distinct time blocks for Weekday and Weekend days. Mixed between-within ANOVA's were conducted separately by gender to assess the impact of Quartile grouping on minutes of MVPA across the distinct time blocks.

Results: Males accumulated significantly more minutes of MVPA daily than females (55.3 ± 21.6 minutes, versus 47.4 ± 18.1 minutes). Principal Components Analysis revealed three distinct time components for MVPA during weekdays, and weekend days. The total difference between Q4 and Q1 was greatest 'Weekend Afternoons' for Males (22 minutes), and 'Weekend Midday' for females (12.8 minutes); with Q4 accumulating significantly more MVPA in these time periods than the other three Quartiles ($p < 0.05$).

Conclusions: This study points to the weekend midday and afternoon periods as particular time blocks to target for intervening with inactive youth. Future research should examine the reasons why some youth choose to be active during these particular periods while others do not, with a view to developing appropriate strategies for intervention.

Key words: Child; Health; Monitoring; Time period; Principal Components Analysis

1. Introduction

Lee et al.[1] estimated that worldwide physical inactivity causes 9% of premature mortality, representing 5.3 million of 57 million deaths in 2008. In their review for the recent Lancet physical activity (PA) series, Hallal et al.[2] report that less than 20% of young people (13 – 15 years) meet the 60 min a day moderate to vigorous physical activity (MVPA) guideline.[3] Studies worldwide have consistently demonstrated an age-related decline in PA participation as children move through adolescence and towards adulthood [3,4], with males significantly more active than females across the lifespan.[5–7] It has been previously established that adolescent PA participation tracks into adulthood at a low-to-moderate level,[8,9] resulting in many researchers and interest groups calling for intervention at the formative younger ages.[5,10,11] While globally, habitual PA participation amongst young people is well reported in terms of total minutes,[5,12] little is known about the daily patterns of PA participation amongst youth, and specifically whether particular time period differentiate children who are over all 'more' active from those who are 'less' active.

Trost et al.[13] demonstrated through principal components analysis (PCA) that adolescents' (aged 12.9 – 15.8 years) weekday participation in MVPA converged into three distinct time components, specifically, 7am – 11.59am, 12pm – 4.59pm, and 5pm – 8.59pm. Similarly, weekend participation also exhibited three distinct time components: 8am – 11.59am, 12pm – 4.59pm and 5pm – 8.59pm. Mota et al.[14] carried out a similar analysis with young people aged 8 – 15 years. Again using PCA, they identified four distinct time components that accounted for 67% of the variance in school day MVPA; 1) school hours (10am -12, and 2 – 7pm); 2) lunchtime and outside-school activities (12 – 2pm, and 7 – 9pm); 3) morning time before school period (9 – 10am); and 4) period before bedtime (9 – 10pm).

Garriguet and Colley[15] found that young people (6 to 19 years) were more active on weekdays than weekend days, with the difference largely reflecting more MVPA accumulation between 7am and 1pm on weekdays. They identified that for younger children (aged 6 to 10), lunchtime was the most active period of the weekday, while for older children (10 – 19 years), PA peaked from 3 – 5 pm. When they considered the data according to MVPA levels of the cohort (participants grouped into tertiles from least to most active), they found that the 'most active' group of children and youth accumulated more minutes of MVPA within each time block (day broken into seven two-hour blocks from 7am to 9 pm) compared to the 'medium active' and 'least active' groups. The largest difference was found in the block just after school from 3 – 5 p.m. In a similar analysis, Fairclough et al.[16] investigated weekday-weekend differences using accelerometer measured PA levels. Children were categorised into sex specific quartiles based on their MVPA levels (with quartile Q1 being the least active group, and Q4 the most active group). They reported that children in Q1 – Q3 were significantly less active on the weekends than on the weekdays, but that interestingly children in Q4 maintained their PA levels consistently across weekdays and weekends.

Findings of Kwon & Janz[17] suggest that targeted youth PA interventions which successfully integrate PA into school day routines may be influential in helping young people (10 – 13 years) to sustain a healthy PA behavior pattern as they grow older. Hesketh et al.[18] indicate that targetted interventions focussing on periods when children are less active may result in larger increases in children's activity. In order to successfully build moderate-vigorous physical activity (MVPA) into children or adolescents daily routines, we must first understand when young people can and do accumulate MVPA across the week, so that the most relevant time periods can be targeted. While the Mota et al.[14] and the Trost et al.[13] studies detailed above went some way to exploring daily patterns of PA participation of young people according data derived time components (PCA), neither explored the variation in these patterns according to the PA level (MVPA accumulation) of the participants, or the extent to which particular periods of the day may account for the differences between active and inactive youth. While Garriguet and Colley[15] did examine patterns according to PA level of participants, the periods of day used were not data derived. Fairclough et al.[16] again looked to examine patterns according to PA level of participants, but analysis was at the more macro level of weekday-weekend, and did not look deeper into the data. There is a need as such to merge the analysis methods of these four studies, to identify whether particular time components of the day may explain more fully differences between active and inactive youth.

The purpose of the current paper was to build upon the work detailed above by investigating adolescents' daily patterns of PA across weekdays and weekends, and across varying time periods within the day. A key goal in this research was to determine whether daily patterns of PA differed across weekday/weekend, sex, and activity level, and to consider how this information could be used to guide future intervention strategies.

2. Methods

This research was carried out as part of a larger study titled 'Y-PATH; Youth-Physical Activity Towards Health'[19], where 109 mixed gender schools from two geographical areas were invited to participate. Principals from 25 post-primary schools who expressed interest and consented to participate nominated one first year class (12 – 14 years) from their school. Informed parental consent and participant assent was granted for 715 from a total possible of 833 participants (86%). All participants were free to withdraw from the research at any stage. Full approval for this study was given by the Dublin City University Research Ethics Committee (DCUREC/2010/081).

Body mass (kg) and height (m) were directly measured using a SECA Leicester Portable Height Measure and a SECA calibrated heavy-duty scale. Participants were asked to wear an Actigraph GT1M, GT3X, or GT3X+ accelerometer (Actigraph LLC, Pensacola, FL) for a period of nine days on their right hip. Accelerometers were set to record using 10-sec epochs. The strategies defined in Belton et al.[20] were employed to increase student compliance with accelerometer wear.

The first and last day of accelerometer data were omitted from analysis to allow for subject reactivity.[21] Monitor non-wear was defined as ≥ 20 consecutive mins of zero counts.[16,21] A day was deemed valid if there was a minimum of 10 hours recorded wear time.[22] The minimum number of valid days required for inclusion in analysis was 3 week days and 1 weekend day.[23] Minutes in MVPA were estimated from the data using the Evenson et al.[24] cutpoints; MVPA: ≥ 2296 counts/min.

Mean Daily, Weekday and Weekend day MVPA were calculated. Sex-specific MVPA quartile cut-off values[16] were calculated to categorise males and females separately into four groups based on Daily MVPA representing the least active quartile (Q1) through to the most active (Q4). All data were analysed using SPSS version 20 with alpha set at $p < 0.05$. Independent sample t-tests were used to identify significant differences in terms of BMI and age between participants that met the accelerometer inclusion criteria and those that did not. Descriptive analyses were calculated for all variables, and preliminary analyses were carried out between genders using paired sample t-tests, a MANOVA, and a Chi-quare test.

To determine whether specific time blocks during the day were representative of participants' daily participation in MVPA, the average minutes of MVPA from each 60 min block between 8:00 a.m. and 9:00 p.m. were subjected to a principal components analysis (PCA) with varimax rotation (as per Trost et al.[13] and Mota et al.[14]); analysed separately for weekday and weekend day. To test if the data set was adequate for factor analysis, a measure of sampling adequacy (MSA) of Kaiser–Meyer–Olkin was applied. A minimum eigenvalue of 1.0 was used to accept a factor as statistically meaningful. Catell's scree test was applied, and where a clear break was identified in the plot the factors above the break were retained. A coefficient of .3 or above was considered an important factor loading. The results of PCA were then used to guide categorisation of Weekday and Weekend day MVPA data into distinct time blocks. Data within each time block were averaged to represent min/hour of MVPA. A mixed between-within subjects ANOVA (4 groups x 6 time periods) was conducted to assess the impact of Quartile grouping on participants' minutes of MVPA across the distinct time blocks; post hoc analysis was carried out with Bonferoni adjustment for multiple comparisons.

3. Results

Of the overall sample of 715 participants, 413 (58%) met the accelerometer inclusion criteria (termed the 'valid sample'). There were no significant differences in age or BMI between the original and valid sample; therefore, remaining analyses were carried out on the valid sample only. Participants (n = 413) were 12.9 ± 0.4 yrs, 20.1 ± 3.2 kg/m^2, and 52.1% male.

Overall, 32.4% met the 60 min MVPA/day guideline (calculated as an average over all valid days); this broke down as 41.4% for males and 22.7% for females, with a significantly greater proportion of males ($\chi 2$ (1, n=413) = 16.39, p<0.0005, phi=0.19). Significant differences between weekday and weekend MVPA accumulation were observed for females (49.14 versus 41.57 min respectively (p<0.005)), but not for males (55.48 versus 54.28 min respectively). A significant difference was observed between males and females (F (6, 406) = 7.04, p < 0.005; Wilks' Lambda = .906, partial eta squared = .094), with males accumulated significantly more MVPA than females Daily, and on both Weekdays and Weekend days.

Three-component solutions explained a total of 51.9% of variance for Weekday data, and 50% of variance for Weekend data. Tables 1 and 2 display the rotated components matrices presenting the loadings for these factors for Weekday and Weekend respectively. The shaded areas highlight the time blocks which load strongly on each component. This rotated solution revealed the presence of a simple structure.[25] Weekday MVPA time blocks were calculated as follows: 'Around School' 8am – 10am and 4-5pm, 'During School' 10am – 4pm, and 'After School' 5pm – 9pm. Weekend time blocks were calculated as: 'Morning' 8am – 11am, 'Midday' 11am – 3pm, and 'Afternoon' 3pm – 9pm.

Table 3 shows the average minutes of MVPA/hour within each time block for each quartile (Q) grouping, for males and females respectively. A significant main effect for time was found for both males (F(5,91) = 11.02, p < 0.000, partial eta squared = .377) and females (F(5,60) = 8.72, p < 0.000, partial eta squared = 421. A significant interaction effect between Q grouping and time was found for males (F(15, 279) = 2.13, p = 0.009, partial eta squared = 0.103) but not for females (F(15, 186) = 1.48, p = .118, partial eta squared = 0.057). On Weekdays males were significantly more active in the Around School period than During School (p < 0.05). No significant differences were observed between time periods on Weekdays for females. On Weekends, both genders were significantly less active in the Morning period than the other two time blocks (p < 0.05). Significant differences in MVPA accumulated in the different time periods across Quartile are shown through annotation in Table 3. On Weekdays Q4 males and females were significantly more active After School ($p < 0.05$) than their Q1 and Q2 counterparts. The magnitude of the differences between groups (calculated as Q4 mins/hr minus Q1mins/hr) was greatest in the Weekend Afternoon period for Males (3.71 mins/hr), and in the Weekend Midday period for females (3.2 mins/hr); with Q4 males and females both accumulating significantly more MVPA in these time periods than the other three Quartiles ($p < 0.05$).

4. Discussion

Consistent with previous research,[4,5,26] male adolescents were significantly more active than females in the current study. Overall, 32.4% met the 60 min MVPA/day guideline (41.4% male, 22.7% female). It must be noted however that accelerometers were used in the current study to determine meeting or not meeting the guidelines, while the guidelines themselves were developed largely based on self-report data; thus one must be cautious in interpretting this statistic. The Health Behaviour in School-Aged Children (HBSC) European study[5] however, which used a self-report measure of PA, similarly found that in Ireland at age 13, 36% of males and 20% of females self-reported accumulating at least 60 minutes of MVPA daily. The levels of MVPA reported in the HBSC study for Ireland was relatively consistent with almost all European countries surveyed. The findings of Woods et al.[4] are lower than those reported in the HBSC study, with only 18% of 12 to 13 year old Irish youth self-reporting to meet the guideline.

Consistent with Faircloiugh et al.,[16] quartiles were chosen as the method to categorise participants in this study, so that patterns across time block according to activity level could be considered. Though the 60-minute PA recommendation in some ways may offer a more defined framework to categorise participants, with only 32.4% of participants meeting this guideline it did not offer sufficient differentiation between participants for the purpose of this analysis. Results of PCA revealed three distinct periods of the Weekday and Weekend day in this study, accounting for 51.9% and 50.0% of variance in MVPA time respectively. As with Garriguet & Colley[15] and Fairclough et al.,[16] our findings indicate that the most active children (males and females) are more active because they accumulate more activity than their less active counterparts in all periods of the day and week (see Table 3).

If we consider male patterns of participation, we see that Q4 males were significantly more active ($p < 0.05$) than Q1 and Q2 males in all periods except for Weekend mornings (the least active period overall for males). We also find that the After School, and Weekend Afternoon periods were the times when the differences between the most and least active Quartile of males were greatest. This difference is further amplified when we consider the length of these time blocks (see Table 3, Total Differences (minutes/day)); the 2.6 more min/hour that Q4 males accumulate when compared to Q1 males in the After School period, means an actual difference of 10.4 minutes each day during this 4 hour time block. This is consistent with the findings of Mota et al.,[14] who found that males generally seemed to be more active in the after school period. Similarly, Garriguet & Colley[15] reported weekday 3-5pm as the period exhibiting the largest difference between the most active tertile of youth and the rest (this was not reported by sex however). Q4 males accumulate 22.26 more minutes in the Weekend Afternoon period than Q1 males; with the difference between Q3 and Q1 males in this period 19.98 minutes.

For females, we see a lower magnitude of differences between Quartiles, and also a more uniform spread of these differences across time periods. This may be explained by the lower levels of MVPA of the female cohort when compared to males, but also suggests lower variation in MVPA in this cohort. Again consistent with Garriguet & Colley[15], the After School period stands out as a period when Q4 females were significantly more active ($p < 0.05$) than the other three Quartiles; accumulating 10.52 more minutes than their Q1 counterparts. Mota et al.,[14] reported that Q3 and Q4 females found opportunities to accumulate MVPA during the school day Q1 and Q2 did not, and findings of the current study support this. Both Q4 and Q3 females were significantly more active in the During School period than Q1 and Q2 females, with a total difference between Q4 and Q1 of 8.46 minutes. In terms of PA weekend behaviour, a slightly different pattern for females emerges when compared to males, with both the Midday and Afternoon periods providing similar total differences between Q4 and Q1; 12.8 and 12.72 minutes respectively.

There is now much evidence supporting multi-component school-based interventions for increasing PA among children and adolescents.[10,27] Researchers highlight however, that while activity levels may be enhanced in PE class, or in school in general, few effects are observed in overall activity.[28] This raises the question of whether children 'compensate' during the rest of the day by doing less PA at other times. Findings from the present study offer researchers insight to better develop intervention strategies, as advocated by Hesketh et al.,[18] so that appropriate time periods throughout the week can be targeted by gender and activity level, for appropriate and achievable increases. Differences in activity levels between Quartiles are present in all time periods, but unsurprisingly they are largest during the periods of the day when adolescents have the most discretionary time (after school, and weekends). Strategies to entice less active males and females to participate during the key periods identified in this study, would likely be beneficial over and above many current intervention strategies that target participation during the school day only. Indeed when evaluation effect of intervention strategies, it may be interesting to consider change in PA according to the different time periods, to determine how and when change (if any) is happening.

It is interesting that although research frequently identifies adolescents as being more active on Weekdays when compared to Weekend days,[13,15,29] this study found the trend to be true only for females, and furthermore highlights Weekend time periods where highly active adolescents of both sexes are at their most active. In an Irish context, this may be in part explained by the fact that club sports for this age group are quite often played on a Saturday or Sunday afternoon. This is consistent to an extent with Fairclough et al.,[16] who found that the most active children maintained their activity levels at weekends.

Limitations of this study include the fact that only mixed gender schools were invited to participate, and the potential for schools to have selected classes which they felt would be most compliant with research conditions (wearing accelerometers for nine days), though we cannot speculate as to whether, or how this potential bias may have impacted on measured PA levels. In addition the low level of students meeting the minimum wear time criteria (58%) must be acknowledged, though we are confident that the valid sample remained representative given there were no significant differences in age or BMI between the original and valid sample.

5. Conclusion

Study findings point to the need for effective PA intervention strategies to simultaneously target gender and PA level specific weekday and weekend time periods to positively affect change in overall adolescent PA behavior. Future research should examine whether patterns identified are consistent across younger and older age cohorts. To better inform strategies for intervention, type of activities participated in during the different time periods, along with the reasons why the most active youth choose to be active during these particular periods, and perceived barriers to the same for inactive youth should be examined.

Practical Implications

- The afterschool and weekend midday and afternoon periods are important to target for PA interventions, as these are the times where the greatest differences between the least and most active youth are observed.
- Interventions need to prioritise the development of more effective strategies, reaching beyond the school environment, to affect change in the weekend period.
- In order to develop effective strategies to target least active youth, we need to understand the reasons why they don’t currently chose to participate in PA during these particular time periods.

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Table 1 Rotated component matrix according to Weekday MVPA hourly time blocks

Time block	Mean (SD)	Component 1	2	3
8-9am	5.90 (4.57)	0.099	0.149	0.762
9-10am	1.22 (0.98)	0.121	-0.1	0.467
4-5pm	5.77 (4.32)	-0.069	0.162	0.744
10-11am	1.78 (1.76)	0.68	-0.019	0.084
11am-12	2.65 (2.58)	0.842	-0.096	-0.004
12-1pm	3.60 (4.19)	0.765	-0.043	-0.078
1-2pm	5.81 (3.84)	0.429	0.073	0.354
2-3pm	2.29 (2.09)	0.667	0.01	0.188
3-4pm	4.78 (3.38)	0.364	0.263	0.313
5-6pm	4.08 (3.59)	0.068	0.693	0.165
6-7pm	4.74 (4.26)	0.02	0.849	-0.035
7-8pm	4.65 (4.28)	-0.04	0.862	-0.018
8-9pm	2.73 (2.75)	-0.092	0.652	0.112

Table 2 Rotated component matrix according to Weekend MVPA hourly time blocks

Time block	Mean (SD)	Component		
		1	2	3
8-9am	0.94 (2.31)	0.073	-0.169	0.627
9-10am	1.87 (4.00)	-0.013	0.002	0.855
10-11am	2.70 (4.56)	0.106	0.286	0.616
11am-12	3.89 (5.22)	0.031	0.751	0.041
12-1pm	4.05 (5.31)	0.031	0.783	0.04
1-2pm	4.20 (5.29)	0.178	0.633	-0.081
2-3pm	4.27 (4.67)	0.362	0.458	0.089
3-4pm	4.81 (5.60)	0.612	0.162	0.184
4-5pm	5.30 (6.45)	0.518	0.296	0.129
5-6pm	5.06 (6.14)	0.631	0.267	0.325
6-7pm	4.75 (5.74)	0.707	0.13	0.157
7-8pm	4.16 (5.47)	0.746	0.032	-0.128
8-9pm	2.42 (3.53)	0.631	-0.123	-0.196

Table 3 Mean (SD) minutes MVPA within each time period per Quartile grouping

Male		Around School ** ±±	During School *** ¥	After School ** ±	Weekend Morning ****	Weekend Midday ** ±±	Weekend Afternoon * ±±
Q4	(mins/hr)	6.74 (2.89)	4.87 (1.56)	7.07 (3.29)	3.70 (4.51)	7.54 (4.51)	8.97 (4.38)
Q3	(mins/hr)	5.25 (2.41)	3.41 (2.19)	5.68 (2.72)	2.27 (2.60)	6.06 (3.77)	5.08 (2.39)
Q2	(mins/hr)	3.52 (1.91)	3.75 (1.63)	3.03 (1.87)	1.65 (1.62)	3.89 (2.11)	4.39 (5.10)
Q1	(mins/hr)	2.46 (1.44)	2.21 (0.80)	1.65 (1.04)	1.19 (1.46)	2.52 (2.18)	1.75 (1.11)
Total	(mins/hr)	4.60 (2.82)	3.63 (1.86)	4.47 (3.27)	2.29 (3.09)	5.11 (3.89)	5.26 (4.53)
Magnitude of differences	(mins/hr)	2.14	1.24	2.6	1.41	2.43	3.71
Total Differences	(mins/day)	6.42	7.44	10.4	4.23	9.72	22.26
Female		Around School ***	During School ** ±	After School *	Weekend Morning	Weekend Midday *	Weekend Afternoon **
Q4	(mins/hr)	5.83 (2.59)	5.05 (2.37)	5.68 (3.54)	3.03 (3.42)	7.07 (5.37)	5.67 (3.30)
Q3	(mins/hr)	3.93 (1.29)	4.80 (1.85)	2.84 (1.93)	1.98 (2.77)	3.36 (1.55)	3.82 (3.23)
Q2	(mins/hr)	4.60 (2.91)	2.56 (0.87)	2.95 (1.46)	1.75 (1.92)	2.86 (2.02)	2.63 (1.97)
Q1	(mins/hr)	3.10 (1.25)	1.78 (0.61)	1.66 (0.99)	0.66 (0.60)	2.02 (1.67)	1.87 (1.06)
Total	(mins/hr)	4.39 (2.32)	3.64 (2.11)	3.32 (2.62)	1.89 (2.55)	3.87 (3.57)	3.55 (2.93)
Magnitude of differences	(mins/hr)	1.44	1.41	2.63	1.14	3.2	2.12
Total Differences	(mins/day)	4.32	8.46	10.52	3.42	12.8	12.72

Magnitude of Differences = Q4 minus Q1; Total Differences = Magnitude of differences x number of hours in the time block

** Q4 > Q3, 2 and 1, p < 0.05*
*** Q4 > Q2 and 1, p < 0.05*
**** Q4 > Q3 and 1, p < 0.05*
***** Q4 > Q1, p < 0.05*
± Q3 > Q2 and 1, p < 0.05
±± Q3 > Q1, p < 0.05
¥ Q2 > Q1, p < 0.05