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Indoor and outdoor context-specific contributions to early adolescent MVPA as measured by combined diary, accelerometer and GPS

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Abstract

Background

The distribution of adolescent MVPA across multiple contexts is unclear. This study examined indoor and outdoor leisure-time in terms of being structured or unstructured, and explored relationships with total daily MVPA.

Methods

Between September 2012 and January 2014, seventy 11-13 year olds from 4 schools in Edinburgh wore an accelerometer and GPS receiver over 7 days, also reporting structured physical activity using a diary. Time spent and MVPA were summarised according to indoor/outdoor location and whether activity was structured/unstructured. Independent associations between context-specific time spent and total daily MVPA were examined using multivariate linear regression.

Results

Very little time or MVPA was recorded in structured contexts. Unstructured outdoor leisure-time was associated with an increase in total daily MVPA almost twice that of unstructured indoor leisure-time (b-value [95% CI]: 8.45 [1.71, 14.48] vs. 4.38 [0.20, 8.22] minute increase per hour spent). The association was stronger for time spent in structured outdoor leisure-time (35.81 [20.60, 52.27]).

Conclusions

Research and interventions should focus on strategies to facilitate time outdoors during unstructured leisure-time and maximise MVPA once youth are outdoors. Increasing the proportion of youth engaging in structured activity may be beneficial as although time spent was limited, association with MVPA was strongest.

Introduction

The UK Government advises that children and young people aged 5 to 18 should participate in structured and unstructured activities throughout the day to achieve the recommended 60 daily minutes of moderate-to-vigorous physical activity (MVPA). Physical activity of this intensity stimulates the cardiorespiratory, musculoskeletal and metabolic systems resulting in health benefits[1]. Structured physical activities are those with elements of formality and are commonly facilitated by adults; sport, dance classes and after school clubs are typical examples[1]. Unstructured physical activities such as indoor or outdoor play tend to be child directed, intermittent and informal[2]. Young people can also accumulate physical activity during school-time. Developing our awareness of how these varied contexts contribute towards daily MVPA targets is essential because each is likely to have different determinants and/or supplementary social benefits[3].

The outdoors is a potentially lucrative environment to encourage participation in physical activity. Participation in unstructured outdoor physical activity is of particular interest due to the absence of barriers such as cost or need for facilities/equipment, and the high yield of MVPA per unit time[4,5]. However, activity in the informal outdoor locations which young people prefer[6], is increasingly restricted due to parental fears about strangers, crime and older teenagers[7]. Simultaneously, young people are lured indoors by attractive screen-based sedentary behaviours[8]. Limited outdoor time and restricted independent mobility denies an important source of physical activity[9,10]. Compensating for this through structured sport and exercise may not be feasible due to financial or time barriers[11], or the absence of appropriate facilities.

It is hypothesised that rather than engaging in independent activity outdoors, children spend most time indoors alone, and when they do leave the home, are transported by car to take part in structured adult-facilitated sport and exercise[12]. At present the distribution of physical activity engagement across different contexts is unclear, and as such it is uncertain where intervention efforts should be directed. The pattern of activity may be particularly complex during early adolescence, when independence from adults begins to develop, allowing greater access to the outdoor environment[13]. Conversely, adolescents are also reported to undergo a shift away from unstructured physical activity with age[14]. A key challenge to increasing our understanding of how young people make use of different contexts for physical activity is measurement[15]. Accelerometers measure change in intensity with time at high resolution but fail to capture contextual detail, while self-report diaries permit detailed descriptions of physical activity but are cognitively demanding and burdensome for the participant[16]. These difficulties are exacerbated in unstructured activities which are typically sporadic and unmemorable[17]. By dividing adolescent leisure-time physical activity into context-based dimensions, and combining data from global positioning system (GPS) receivers, diaries and accelerometers, it may be possible to more accurately characterise the specific contexts where MVPA occurs.

Consistent with an ecological approach to modifying health behaviours[18], context-specific data of this kind are necessary to guide future research and inform intervention strategies. To identify contexts which could have greatest impact on overall daily physical activity, two types of data are required: 1) within each day, the existing contributions of different contexts towards total MVPA (i.e. the MVPA profile); and 2) the independent association of time in each context with daily MVPA. Data of this kind relating to structured and unstructured leisure-time occurring indoors and outdoors have not been reported using combined objective and subjective tools. This paper therefore aims to answer two research questions:

1. How much time is spent and how much MVPA is accumulated in different contexts each day?
2. What are the strength and nature of associations between time spent in these contexts and total daily MVPA?

Methods

Participants and procedure

Eighty-two early adolescents in the S1 year group (aged 11-13 years) were recruited from secondary schools in Edinburgh, between September 2012 and January 2014 across autumn, winter and spring terms. Twenty-five schools were contacted, with 3 state schools and 1 independent school selected based upon their willingness to take part. Pupils who returned a consent form signed by a parent/guardian and verbally agreed to take part were included in the study. Ethical approval was granted by Moray House School of Education Ethics Committee.

Accelerometer, GPS receiver and diary

For 7 continuous days including both weekend days. physical activity intensity was recorded using an accelerometer (GT3X+; ActiGraph LLC, FL, USA) worn on the right hip during all waking hours except when bathing, showering or swimming. Participants also wore a GPS receiver (Qstarz BT-Q1000eX; Qstarz International, Taiwan, Republic of China) set to record location every 10 seconds (0.1 Hz). A signal-to-noise ratio (SNR) threshold of 212 was used to label each epoch as indoors and outdoors[19]. Participants used a diary adapted from one used in a similar population[20] to record only the duration of structured physical activity out of school hours. A description of the activity (e.g. football training) and its start and end times was recorded. No other information (e.g. intensity or location) was requested, as this was captured by the other devices. After checking, diary content was used to dichotomise leisure-time as structured or unstructured. Participants were asked to complete the diary with the help of their parent(s) or guardian if necessary. If a child returned an empty diary, it was confirmed verbally that no structured activity had occurred. A detailed definition of structured physical activity was provided with several examples, and a demonstration diary entry was provided for guidance.

Other variables

Height (m) and body mass (kg) were measured with shoes removed and indoor clothing using a stadiometer (Seca 213; Seca; CA, USA) and digital scales (Seca Clara 803; Seca; CA, USA); weight status was determined using international standard definitions[21]. One school preferred their pupils to not have height and weight measured. Age, sex, ethnicity and post-code were reported with the help of a parent or guardian. Minutes of daylight were determined using standard tables[22]. The Scottish Index of Multiple Deprivation (SIMD) vigintile was defined using the full home postcode[23].

Data processing

Data processing was conducted using STATA (Stata/SE v12.0, Stata Corp. College Station, TX, 2011). In this study a 10 second epoch was used due to limitations of the storage capacity of the GPS device. Each epoch of accelerometer data was labelled as MVPA when counts exceeded 560 per 10 seconds[24]. Consecutive zero values of 60 or more minutes, with no allowance for interruptions, were identified and excluded and assumed to be accelerometer non-wear time. Days with < 9 hours of accelerometer wear time were excluded from the analyses[25]. Data collected during the first day of measurement were excluded for all participants due to risk of reactivity bias and variation in the hour of commencement of the study. Spuriously high accelerometer counts were excluded based upon a threshold of 15000 counts per minute[26]. Data points from GPS data with high speed (> 15 km/h) were assumed to arise from motorised transport and excluded[9]. Some GPS epochs were missing so these were assumed to be indoors. The GPS and accelerometer data were matched by date and time stamp, and diary data were used to label each epoch as structured or unstructured. A summary of how contexts of physical activity were derived is shown in Table 1. Minutes of time spent and MVPA in each context were summed by participant and day. Based on individual means across days of measurement, week-day values were calculated for overall daily MVPA, context-specific MVPA and context-specific wear time.

Data analyses

All data analyses were conducted using SPSS (IBM SPSS Statistics, v19.0, SPSS Inc., Chicago, IL, 2010). There were no statistically significant differences in estimates of overall daily MVPA (One-way analysis of variance; $p = 0.91$), or context-specific MVPA (Kruskal-Wallis tests; $p = 0.77 – 0.86$) by number of valid days of measurement, so all participants who recorded at least 1 valid day were included in analyses. Independent samples t-tests and Chi-squared tests were used to examine differences between included and excluded participants. Means (with standard deviations in parentheses) and percentages were used to examine total daily wear time, total daily MVPA and demographic characteristics. Owing to non-normal distributions, the median and interquartile range (IQR) were used to assess absolute (minutes) and relative (percent) context-specific contributions to daily wear time and daily MVPA.

A multivariate linear regression model was used to assess associations between time spent in each of the 4 leisure-time contexts and total week-day MVPA. This was expressed as the mean increase in minutes of MVPA for each hour in that context after adjusting for wear time spent in all other contexts. Bivariate associations of potential confounders (age, sex, SIMD, daylight hours) with independent and dependent variables were tested using Pearson correlation coefficients and a criterion for the alpha-level of $p < 0.20$[26]. Presence of confounding was also assessed by comparing unadjusted and adjusted regression coefficients. Factors which resulted in adjusted coefficients differing from unadjusted coefficients by 10% or more were retained in the model[27]. Hypothesising a large effect ($R^2 > 0.26$) based on previous similar work[20], and with a maximum of 8 predictors, the sample size for this study was appropriate to achieve power of 0.80[28].

Results

Accelerometer and GPS compliance

Seventy participants provided at least 9 hours of accelerometer data on at least 1 measurement day. A mean of 3.1 (1.3) valid days of data were provided per participant. Seventy participants provided a mean of 2.7 (1.1) week-day data with a mean of 11.3 (1.4) hours per day. Twenty-seven participants provided a mean of 1.2 (0.4) weekend-day data with a mean of 12.9 (4.1) hours per day; due to insufficient wear-time on weekend-days and non-suitability to combine with week-days, these data were not analysed No participants supplied weekend-day but not week-day data. Those who failed to meet inclusion criteria did not differ by sex, age, ethnicity, SIMD, BMI or school attended (p = 0.15–0.97). Valid GPS data were present for time matching to a high proportion (> 99.9%) of retained accelerometer epochs.

Participant characteristics

The final sample consisted of 23 boys and 47 girls of mean age 12.4 (0.4) years. Of the 57 participants who provided height and weight measurements, 1/57 (1.75%) was overweight, 1/57 (1.75%) was obese, and 55/57 (96.5%) were of normal weight status. Of the final sample, 64/70 (91.4%) were white and 44/70 (62.9%) attended the independent school. On average participants resided in areas within the 16th vigintile for SIMD compared to the 14th vigintile for Edinburgh as a whole[23].

Overall MVPA

Participants recorded a mean of 67.6 (25.8) minutes of MVPA on week-days, and 42/70 (60%) recorded on average at least 60 minutes MVPA per day. Of the 70 participants who met inclusion criteria, 22/70 (31.4%) reported no structured physical activity during the measurement period. Structured activity was reported by 32/70 (45.7%) of participants on week-days.

Context-specific time spent and MVPA on week-days

Table 2 summarises time spent and MVPA during school-time and 4 leisure-time contexts. Most time was spent at school, followed by periods spent indoors during unstructured leisure-time. Time in structured leisure-time physical activity was limited. Approximately 80 minutes of unstructured outdoor time were recorded per participant per week-day. Most minutes of MVPA were recorded at school; there was no evidence of clustering of MVPA by school (Intra-cluster correlation coefficient = 0.00; $p = 0.92$). Across all participants, structured MVPA contributed very little toward week-day totals.

Associations between time in specific leisure-time contexts and MVPA on week-days

Table 3 shows output from the multivariate linear regression model. Time in structured outdoor contexts was most strongly associated with MVPA. Leisure-time spent in unstructured outdoor contexts was associated with an increase in daily MVPA almost double that of unstructured indoor contexts.

Discussion

This is the first study to investigate the contributions of indoor and outdoor contexts of health-related MVPA in terms of whether they are structured or unstructured, an important variable relating to the location, level of independence and cost of physical activity. The research utilised a novel combination of accelerometer, GPS receiver and diary tools to characterise the context of MVPA in a way that has not previously been performed. The results showed that early adolescents in the first year of Scottish secondary school children recorded the majority of their total daily MVPA during school-time and unstructured leisure-time (both indoors and outdoors). In comparison, the contributions of structured leisure-time contexts to daily MVPA were minimal. Despite this limited contribution overall, multivariate regression analysis revealed that time spent in structured outdoor contexts was most strongly associated with total daily MVPA.

The finding that on average, 11-13 year olds spent few minutes per day in structured physical activity contexts, and that these periods contributed little towards daily minutes of MVPA, echoes previous research from the Health Survey for England[14]. The proportion of youth with no weekly participation in structured physical activity at all (31.4%), also closely matches reports from the Scottish Health Survey, which indicated that 31% of Scottish 2 – 15 year olds did not engage in any sport each week[29]. It must be noted that results for MVPA in structured contexts, total MVPA, and the yield of MVPA for time spent in structured contexts are all likely to be underestimated due to accelerometer non-wear during swimming and contact sports.

Limited frequency and duration indicated by diary data highlights structured outdoor physical activity as a potentially fruitful intervention target, especially in view of the – likely underestimated – high yield of MVPA per hour. However, encouraging participation in structured physical activity in those who are more inactive, more overweight, and less affluent than those represented by this sample may be a significant challenge, especially given limited investment in after-school sport[30], and that competitive sports-oriented opportunities do not suit some adolescents' preferences[31]. Furthermore, the extrapolation of MVPA accrued during very little time spent in this context to periods of an hour or more may not be justified, because the relationship between time spent and MVPA may not be linear.

The present study showed that after school time, unstructured indoor contexts were how the majority of time was spent and how most MVPA was recorded. This reflects previous findings indicating that indoor leisure time is a vital contributor of MVPA[9]. However, participants also spent over an hour in unstructured outdoor leisure-time contexts. This was unexpected, given that independent outdoor time is thought to be restricted for today's children[12,32], and that the majority of data collection occurred during winter months when outdoor time is less common[9,10]; in fact, the predominance of winter data likely means that habitual time outdoors is underestimated by this study. Minutes of unstructured outdoor time recorded are therefore encouraging and show that access to the outdoor environment may not be as restricted as feared, at least for this relatively active sample. Furthermore, these periods were almost twice as strongly associated with daily MVPA than the indoor equivalent, reinforcing the importance of outdoor time for physical activity.

Previously, the activity intensity of informal behaviours such as play has been questioned. For example, Brockman et al.[2] reported that behaviours such as chatting, computer games or hanging out with friends were identified as 'active' play. The present study supports this hypothesis, indicating that although unstructured outdoor leisure-time contains a higher proportion of MVPA than the indoor equivalent, it must also include large portions of sedentary behaviour and light physical activity. Therefore, whilst fostering social and physical environments that encourage outdoor time might be possible intervention targets, strategies to maximise MVPA once young people are outdoors could also be necessary. More detailed exploration of the contextual components of outdoor time is warranted so that we may understand which environments are most supportive of MVPA. The use of GPS information adds contextual detail to accelerometer data, and more complex analyses are already being conducted to show which geographic locations and features are most supportive of physical activity [15,33,34]. These sophisticated techniques will continue to provide greater understanding of the location, but still fail to capture some contextual detail. This information must instead come from self- or proxy-report, and the merging of diary data to describe the structured or unstructured nature of physical activity is a key strength of the dataset used here.

On average, participants in this study met the 60-minute target for daily MVPA, but no single context contributed enough MVPA to meet this guideline. Context-specific information about MVPA contributions is important as it provides guidance as to where and when improvements may be needed, and what level of benefit to daily minutes of MVPA could be expected. Restricted unstructured outdoor time has been proposed as barriers to meeting activity guidelines. Data presented here do not support this hypothesis, and this is common with self-report data for outdoor play from a nationally representative sample in England[14]. In fact, these results suggest a potential imbalance in the opposite direction, with structured physical activity contributing very little towards daily MVPA, even in an active and relatively affluent sample that might be expected to have better access to sports clubs, classes and after school activities led by adults. This is more surprising considering the high proportion of females and those from less deprived areas in the sample, characteristics of those reported to have more restricted outdoor time[6,35-37]. The fact that this sample had relatively high activity levels and low deprivation may mask context-specific barriers to physical activity for the wider population.

Strengths of this study include the combination of 3 sources of data which allowed detailed analysis of the contexts of physical activity in a way that has not been performed previously. Combing these methods capitalised on the strengths of each to estimate the contributions of different contexts to total daily MVPA, producing a unique physical activity profile. The use of accelerometry does not record swimming and underestimates the contributions of movement during activities such as cycling, upper body exercise and load-bearing, and this must be considered when viewing these results. The GPS receiver used in present study demonstrated limited signal loss, and this means that a very large proportion of valid accelerometer epochs were successfully matched to a GPS record. This proportion of matched data offers greater confidence in the estimation of indoor or outdoor location using the SNR. However, some misclassification is likely and in particular, time indoors and in motorised transport may have been erroneously classified as time outdoors. Steps were taken to remove GPS data with high speed; however, periods spent in slower traffic may have led to overestimation of the total time adolescents spend outdoors. The high proportion of matched GPS and accelerometer data also demonstrates that this group of adolescents were capable of following instructions to charge the GPS unit using the charging device provided. These findings are promising for future studies which seek to use GPS data to determine geographic location in adolescent populations.

Mean days of measurement per participant are comparable to studies using similar methods in youth of approximately the same age[25], however the findings of this study are limited by inclusion of those with only 1 valid day of monitoring. Typically, 4 or 5 days of measurement are deemed to be sufficient to provide a reliable estimate of habitual youth physical activity[38]. In this study, there were no differences in mean daily MVPA or context-specific MVPA by number of valid days of measurement, and so those providing at least 1 day of measurement were retained to maximise sample size. As noted by Klinker at al.[33], it is presently unclear how many days of measurement are required to obtain reliable estimates of context-specific physical activity. This may be a particular concern for structured physical activity which appears to occur less frequently. Increasing focus on context-specific behaviours and determinants highlights further methodological research on the design of studies combining GPS and accelerometry as a priority. Other weaknesses of this work include the small sample size which precluded control for potential clustering effects by school and stratification by sex. Pubertal status is a potentially important determinant of where and how adolescents are active; but these data were not collected. Exploration of the determinants of the distribution of physical activity contexts should be area of future research. Analyses are limited to term-time only data and cannot be generalised to school holidays. A large proportion of participants attended an independent school and the mean daily minutes of MVPA does indicate selection bias towards active individuals. Findings should therefore be treated with caution, as the physical activity profile reported may not be generalisable to the wider population. In particular, it could be expected that the general population has lower involvement in structured physical activity than individuals from less deprived neighbourhoods[14,39], and not obtain as many minutes outdoors as the active and predominantly normal weight sample measured here. It is therefore important to reproduce this work in larger samples, particularly with the inclusion of youth from more disadvantaged areas and schools.

There may be errors in the report of activity and consequent MVPA classification as reported in previous work[40]. The purpose of the study was to examine structured and unstructured physical activities, and by asking for only structured activities to be reported, leisure-time was dichotomised. It is possible that some structured activities may have gone unreported, however, because these activities tend to occur at regular times and that parents were requested to help complete diaries, errors are likely to have been minimised. Steps were also taken to ensure empty dairies were representative of the actual pattern of behaviour. Dichotomisation of leisure-time may be a simplification and ignores the possible existence of semi-structured activity or further subcategories of behaviour. This demonstrates the complexity of measuring the type and context of physical activity and reinforces the need for further work investigating the health-related social and physical environments encountered by young people during their leisure-time.

Conclusions

This research used a novel multi-tool approach to ensure MVPA could be recorded throughout the day and simultaneously record difficult to capture contextual detail. The results indicate that research and strategies to increase MVPA in the adolescent population should target multiple contexts and that specific focus may be required to: increase the proportion of adolescents participating in structured leisure-time physical activity (especially outdoors); increase the frequency of these sessions; maximise the time adolescents spend outdoors during unstructured leisure-time; develop environments or opportunities that facilitate greater MVPA participation once outdoors.

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Tables

Table 1 *Source of data and decision rules for coding of context-specific physical activity outcome variables.*

	Source of data and decision rule		
Coded variable	GPS	Diary	Accelerometer
Unstructured outdoor MVPA	SNR ≥ 212	Time points not included in diary	> 560 counts per ten second epoch
Unstructured indoor MVPA	SNR < 212	Time points not included in diary	> 560 counts per ten second epoch
Structured outdoor MVPA	SNR ≥ 212	Time points included in diary	> 560 counts per ten second epoch
Structured indoor MVPA	SNR < 212	Time points included in diary	> 560 counts per ten second epoch
School MVPA	Not applicable	Specified by school timetable	> 560 counts per ten second epoch

Abbreviations: Moderate to vigorous physical activity (MVPA); Global Positioning System (GPS); signal-to-noise ratio (SNR).

Table 2 *Context-specific time spent and MVPA per participant per week-day (n = 70).*

		SCHOOL TIME	LEISURE TIME			
			Unstructured		Structured	
			Outdoors	Indoors	Outdoors	Indoors
Total Time	Minutes	333.2 (299.8 – 352.1)	79.8 (50.3 – 114.3)	235.8 (181.8 – 292.7)	0.5 (0.0 – 27.0)	0.6 (0.0 – 12.4)
	% daily minutes	47.2% (40.5 – 53.2)	11.7% (0.8 – 16.2)	35.2% (27.3 – 43.0)	0.1% (0.0 – 4.3)	0.1% (0.0 – 1.7)
MVPA	Minutes	24.2 (18.9 – 30.7)	12.2 (5.7 – 22.5)	14.1 (8.4 – 25.9)	0.0 (0.0 – 7.1)	0.0 (0.0 – 0.9)
	% daily MVPA	42.1% (29.7 – 50.0)	18.2% (11.0 – 31.8)	24.6% (13.9 – 40.4)	0.0% (0.0 – 12.5)	0.0% (0.0 – 1.4)

Abbreviation: Moderate to vigorous physical activity (MVPA).

Note: Figures presented are median (interquartile range) per participant per week-day.

Table 3 *Multivariate linear regression model of hours spent in four leisure-time contexts and minutes of week-day MVPA (n = 70).*

Leisure-time context		*b*-value	95% CI		t	*p*
Unstructured	Outdoors	8.26	2.85	13.66	3.05	0.003
	Indoors	4.19	0.47	7.91	2.25	0.028
Structured	Outdoors	34.67	18.09	51.25	4.18	< 0.001
	Indoors	8.71	-11.26	28.67	0.87	0.387

Abbreviation: Moderate to vigorous physical activity (MVPA).

Note: Adjusted for sex and daylight hours. *b*-value: mean increase in minutes of daily MVPA for each hour spent in that context. $R^2 = 0.408$, $p < 0.001$.