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What can global positioning systems tell us about the contribution of different types of urban greenspace to children's physical activity?

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Abstract

Urban greenspace is hypothesised to be an important location for physical activity in children, but their actual use of the resource to be active is not well known. In this study, global positioning systems (GPS) and accelerometers were used to measure activity within green environments for 902 English children aged 11-12. We summarised activity intensities in different types of greenspace on weekday evenings, weekend days, and by season. Parks were used for as much as 30% of outdoors moderate-vigorous activity at weekends and use was consistent across seasons. The findings suggest the importance of certain types of greenspace to children's physical activity.

INTRODUCTION

Physical activity during childhood is associated with improved health, including reduced likelihood of becoming obese (Trost et al., 2001) or developing symptoms of depression (Motl et al., 2004). Activity during childhood also contributes to development of healthy lifestyles later in life (Hallal et al., 2006) and has long term protective health effects, such as establishing healthy bone structure (Karlsson, 2004). Despite these benefits, low and declining levels of physical activity have been reported among children in developed countries (Dollman et al., 2005; Knuth and Hallal, 2009). In England, only 32% of boys and 24% of girls aged 2-15 meet the government's recommendations for physical activity of doing at least one hour of moderate activity per day (NHS Information Centre for Health and Social Care, 2009).

A growing body of evidence demonstrates the potential influence of environmental factors on children's physical activity (Davison and Lawson, 2006; Ferreira et al., 2007). One such environmental factor is greenspace, as areas such as parks, playgrounds and woodland can be used by children for play and leisure time physical activity. Public greenspaces can provide natural play spaces with multifaceted benefits to children as they, for example, provide opportunities to interact with nature, play creatively, socialise with others and develop independence and confidence in being in an outdoors environment (Muñoz, 2009). Given that children have less autonomy in their behaviour choices than older groups

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(Nutbeam et al., 1989) and that their use of the environment is influenced by parental attitudes (Veitch et al., 2006), the availability of suitable and safe play spaces outdoors may help parents feel more confident to allow their children to be more autonomous and play independently outdoors (Mulvihill et al., 2000). Research shows that children who spend greater amounts of time outdoors have higher levels of physical activity (Cleland et al., 2008) and that outdoor activities such as walking, playing informal ball games and unstructured free play are important contributors to overall energy expenditure (Mackett and Paskins, 2008). Furthermore, in addition to the physical activity benefits of playing in greenspace, a wide body of literature documents the psychological benefits of spending time in natural environments (Taylor and Kuo, 2006).

A recent systematic review identified 14 studies which have looked specifically at the relationship between access to greenspace and children's physical activity, of which 6 found a positive relationship (Lachowycz & Jones, 2011). Therefore, the emerging evidence in this relatively new research field is equivocal (Kaczynski and Henderson, 2007; Lachowycz and Jones, 2011). One reason for this inconsistency may be that studies are largely reliant on measuring cross-sectional associations between overall levels of physical activity and presence of greenspace within a child's living environment, and are often unable to consider the actual locations where physical activity takes place. Therefore, the locations children use for active free-play and physical activity remain largely unknown. One developing approach which can help address this gap is the use of Global Positioning Systems (GPS) to measure how children move around within environments. GPS devices pick up signals from satellites to record positions on the ground, with an accuracy of a few meters. The recent development of affordable, lightweight and accurate GPS allows these devices to collect location data from large samples of individuals and continuously track their movement through the environment. GPS can be used in combination with accelerometers (devices that detect speeds of body movement and generate intensities of physical activity) to simultaneously measure physical activity and location and thus record the environments where different intensities of physical activity take place (Rodriguez et al., 2005). A recent systematic literature review of applications of GPS to physical activity (Maddison and Mhurchu, 2009) concluded that one major advantage is the ability to collect valuable contextual information, such as the occurrence of activity within specific facilities, and thus improve our understanding about how individuals interact with their environments and use different locations for physical activity.

The first applications of these methods amongst children have recently emerged. Combined GPS-accelerometer methods can be used to objectively measure how different types of greenspace are used by children for play and physical activity. A New Zealand study of 184 children aged 5-10 years found that 1.9% of physical activity occurred in public parks with playgrounds (Quigg et al., 2010). That study did not measure activity within other types of greenspace, such as more natural areas and on playing fields. Jones et al (2009) collected GPS and accelerometer data from 100 school children in Norfolk, UK, and found that 7.3% of moderate-vigorous activity bouts occurred in areas defined as parks, 11.8% in grassland, 13.6% in farmland, 3.0% in woodland and 24.0% in gardens (Jones et al., 2009b). That study therefore suggests that different types of green areas, not just those designated as parks, may be important physical activity locations. However, Norfolk is a predominantly rural county and no studies have yet examined the extent to which different types of greenspace are used by children living in urban settings. Given that 82% of people aged less than 20 in the UK live in urban areas (Bayliss and Sly, 2009), it is a major gap in knowledge that so little is understood about how much activity occurs in urban green environments and the extent to which this contributes to overall activity levels. Moreover, we believe there has been no research into how levels of activity within greenspace vary across the week and

throughout seasons of the year. This information could inform design of environments which maximise their health value across different times and weather conditions.

This study uses data from the PEACH (Personal and Environmental Associations with Children's Health) project in Bristol, UK, to examine the use of different types of urban greenspace by children aged 11-12 years. The study uses data collected from the children during their first year at secondary school, as in this phase GPS data was collected during weekday evenings and at the weekend. Prior analysis of data collected from the children a year earlier, in their final year at primary school, found that around 2% of weekday evening time was spent in urban public parks and that activity within these parks was more likely to be of high intensity than activity in other areas, particularly for boys (Wheeler et al., 2010). This study extends this work by measuring the locations of activity during all non-school time, across different types of public parks as well as within other types of greenspace, such as in private gardens and on school playing fields.

The key aims of the analysis were to establish how much physical activity occurs within different types of urban greenspace in children and to assess how this activity contributes to total levels of non-school physical activity. The analyses were stratified by activity intensity, with a particular focus on levels of moderate-vigorous activity as this is thought to be particularly beneficial to health (Steele et al., 2009), and the UK government recommends that children are active at this level for at least one hour per day (NHS Information Centre for Health and Social Care, 2009). In order to investigate if patterns of use vary across the week, analyses were carried out separately for weekday evenings, for weekend days and separately for Saturday and Sunday. To investigate if use of parks varies across the year, summaries of the amount of moderate-vigorous activity occurring outdoors and within greenspace were produced for each season. The results reveal when greenspace is used by children for play and physical activity and which particular types are most used by children.

METHODS

Data collection

The sample was drawn from the PEACH cohort in Bristol, UK, which originally recruited 1,307 children aged 10-11 years from 23 state primary schools. Bristol is the sixth largest city in England, with a population of over 400,000 residents. The city is relatively densely populated and has large socio-economic inequalities, containing areas of considerable affluence and others of significant deprivation (Tallon, 2007). Participants were selected from schools chosen as representative of Bristol according to deprivation and geography. The PEACH methodology is described in detail elsewhere (Page et al., 2009). This study uses data obtained from participants during their first year of secondary school (aged 11-12 years), collected between November 2007 and July 2009. In addition to collection of questionnaire and anthropometry data, participants were asked to wear an accelerometer (Actigraph GT1M) for seven consecutive days, set to record activity counts per 10 second epoch (CPE). Participants were also asked to simultaneously wear a GPS (Garmin Fortrex 201) on four school days between the end of school and bedtime (3pm-10pm) and on at least one weekend day between 8am-10pm. The GPS was set to record latitude-longitude coordinates (up to 10,000 points) every 10 seconds to an accuracy of <3 meters whenever there is sufficient satellite signal (Garmin, 2006). In order to preserve battery life, participants were asked to switch the GPS on after school or upon waking at the weekend and then to turn off at bedtime. The units were recharged after two days of use by research staff.

Data from the GPS and accelerometers were downloaded to a personal computer and integrated using STATA 10 (Statcorp, 2009), based on date/time fields. This produced an

activity count and latitude-longitude coordinate (where recorded) for each 10 second epoch. Any 60-minute (or greater) period where accelerometer counts were continuously zero (allowing for up to two minutes of non-zeros per hour) were classified as 'missing', as these were judged to be periods when the accelerometer was recording but not being worn (Troiano et al., 2008). Any epoch record without a location coordinate were coded as 'indoors'. For sequential GPS locations, the speed of travel was calculated based on the change in location on the ground using Pythagoras theorem to calculate the straight-line distance between points and the time between points. Any datapoints with a travel speed above 15kph were excluded as these were judged to be either journeys in vehicles or erroneous locations caused by deficient signal quality, as GPS receivers are less accurate when the signal is obstructed, for example by heavy tree canopy or dense housing (Maddison and Mhurchu, 2009).

Linkage with land use mapping data

ArcGIS Geographic Information System (GIS) (ESRI ® ArcMap 9.2™) was used to prepare a map of land use across the Bristol Local Authority area. The Ordnance Survey Mastermap (OSMM) topography layer classifies every area within Bristol into one of the following land use types: Buildings, Roads and pavements, Private gardens, Parks, Farmland, Grassland, Woodland and Built surfaces (concreted surfaces such as car parks and pedestrianised thoroughfares). The OSMM is the most comprehensive, detailed and up-to-date digital map available for Great Britain and includes every feature larger than a few meters in size, captured with a positional accuracy scale of 1:1250 in urban areas, meaning that 99% of features are located to within 1 meter (Ordnance Survey, 2011). In addition, a map provided by Bristol City Council included information about the type of parks within the Bristol Local Authority area (Jones et al., 2009a), with each park area classified as: Formal (an organised layout and structured path network aiming for aesthetic enjoyment, and generally well maintained), Informal (an informal design with emphasis on informal recreation), Natural (habitats providing access to nature, such as heathland, woodland and wetland), Young People's (areas designed for use by children or teenagers, including those with play and games equipment), and Sports (areas used for organised and competitive sports, such as playing fields and tennis courts) (Bristol City Council, 2008). Areas designated as parks within the OSMM layer were compared with the map of public parks to confirm a match and any discrepancies were checked and recoded as appropriate. Then the two map layers were combined to create one land use map for the whole of Bristol.

Comparison of the Mastermap data with raster maps and satellite imagery showed that the OSMM landuse categories grassland, woodland and farmland encompassed a wide variety of landuse types, including areas such as school grounds, cemeteries, private sports grounds, allotments, footpaths and small patches of scrubland and grassland such as verges and banks. Any grassland, woodland or farmland area which had been used by a child was visually inspected using maps of Bristol and consultation of online mapping resources in order to determine the specific land use. These areas were then sub-classified into three groups: 1) School grounds: land identified by OSMM as grassland and within an area clearly defined as primary or secondary school, 2) Other greenspace: vegetated areas not defined as public parks, including private sports and recreation facilities, cemeteries, golf courses and gardens of publicly accessible buildings such as universities and hospitals, 3) Green verges: small areas of vegetated land with grass or fragmentary vegetation, such as in the centre of roundabouts and narrow strips or banks of vegetation alongside pavements. These first two classifications were categorised as types of greenspace, whereas green verges were judged unlikely to be specifically used for physical activity due to their small size and fragmentary nature, and were more likely to be walked across whilst traversing roads and paths.

The GPS latitude-longitude coordinates for each 10-second epochs were imported in ArcGIS and plotted as datapoints on a map layer overlaying the land use map. Spatial queries were then conducted to assign these datapoints to a landuse type. Each epoch for which GPS data were available was classified as either Greenspace, sub-classified as specific type of park, private garden, school playing field or other greenspace, or Other land use, sub-classified as roads and pavements, green verges or built surfaces. Datapoints falling outside Bristol Local Authority area were assigned a category of 'Out of study area'. In order to measure how close the parks were to the children's homes, we calculated the straight-line distance from each child's home (based on their home postcode) to the nearest park boundary for each park type.

Analytical methods

Data were included from days when the participant registered at least 1 minute of GPS time. Children with postcodes outside Bristol Local Authority were excluded, as environmental overlay data were only available for this area. Each 10 second epoch was classified into one of three levels of activity: Sedentary (<100 counts per minute (CPM)), <17 counts per epoch (CPE)), Light (Between 100-2296 CPM, 17-383 CPE), Moderate-Vigorous activity (MVPA) (>=2296 CPM, >=383CPE). These cut-points were chosen as a comparison of activity thresholds (Trost et al., 2010) showed that the thresholds produced the most accurate match with energy expenditure for each of the activity levels among children. Each epoch was assigned a season based on the month of data collection. Meteorological seasons were used with Spring defined as March, April and May; Summer as June, July, August; Autumn as September, October, November; and Winter as December, January, February.

Figures 1 and 2 show examples of the overlay of GPS points on the landuse maps, with GPS points shaded according to the level of activity. Figure 1 shows an example of GPS points collected during one hour from one child on a weekday evening. Figure 2 shows an example of one park within Bristol and displays all points within this park collected on weekend days by the eight children who recorded activity within this park. This is a community park in South Bristol, classed as a formal park by Bristol City Council, and also has a children's play area and tennis courts. The two figures illustrate the land classifications used and demonstrate how the GPS coordinates were overlaid with the landuse maps.

Epochs were summarised into total counts per activity level per child per day across all the categories of land use. The data was then expressed as mean minutes (and standard deviations) of activity per child per day across land use types. In addition, total counts of activity for all children were summarised and the percentage of activity within each land use was calculated for each activity level. Analyses were performed separately for weekday evenings, weekend days and for Saturday and Sunday as we hypothesised that play and activity behaviours might vary across the days at the weekend. A summary of moderate-vigorous activity occurring outdoors, within greenspace and within parks was produced for each season. All analyses were conducted using STATA 11.

RESULTS

Accelerometer and GPS data were collected from 902 secondary school children. Exclusion criteria removed 9 participants for having non-Bristol postcodes. After deletion of days with <1 minute GPS activity, data were available for 614 participants on one or more weekday evening and 301 participants on one or more weekend day. Following deletion of any epochs with a speed greater than 15kph, a total of 5,765 person-hours of data were included in the weekday analysis (average 9.4 hours per child) and 3,833 person-hours of data were included in the weekend analysis (average 12.7 hours per child).

Table 1 summarises demographic, anthropometric and physical activity characteristics of the original sample and those included in the analysis. The sample is relatively deprived based on national deprivation scores, with over a third of children living in areas classified within the 25% most deprived areas in England. Compared with the original sample of 902 participants, those included in the analysis included a higher proportion of females and those of White ethnic group, and were less overweight or obese and had higher moderate-vigorous physical activity. These differences were statistically significant ($p<0.05$) for the weekend sample, but not for the weekday evening participants. There were no significant differences between groups in the average distance to the closest parks for all types.

Table 2 summarises the mean minutes of activity per child per day according to level of activity and stratified by whether the activity was classified as indoors, outdoors and within the study area, or outside the study area. The majority of activity took place indoors, with 26.4% of MVPA occurring outdoors and within Bristol during weekday evenings and 17.6% at the weekend.

Table 3 summarises intensities of activity occurring outdoors and within Bristol by the type of land use within which the activity occurred. Results are expressed as mean times per day and percentages of overall outdoor activity across each intensity level. The average amount of time spent in MVPA per child taking place in greenspace was relatively low (4.8 minutes per weekday evening and 3.5 minutes on weekend days), but the contribution of these times to total MVPA was substantial. During weekday evenings, 33.6% of outdoor MVPA was within green environments, with 10.1% in parks and 22.3% in private gardens. Corresponding values for weekends were 46.0%, 29.3%, and 16.1% respectively. The percentage of outdoor MVPA taking place in greenspace overall was higher at the weekend compared with weekday evenings ($p<0.001$) and the percentages of outdoor MPVA occurring within parks were also higher at the weekend for all park types ($p<0.001$) with the exception of sports areas. The percentage of outdoor MVPA taking place in private gardens was higher during weekday evenings than weekend days ($p<0.001$).

Table 4 details the summary of activity separately for Saturdays and Sundays. The percentage of outdoor MVPA occurring in greenspace was highest on Sundays ($p<0.001$). The use of informal and natural park areas was particularly high on Sundays, with over a quarter of all outdoor MVPA occurring in these areas.

Table 5 shows the amount of MVPA by season, expressed as mean times of MVPA per day per child and percentages of overall MVPA activity across the seasons for all children. There were no statistically significant differences across the seasons in the average amount of time spent in MVPA per child in total, outdoors, within all types of greenspace, and within greenspaces classified as parks. Whilst the percentage of total MVPA occurring outdoors and within greenspaces overall was similar across seasons during weekday evenings, the percentage of outdoor MVPA occurring in parks was lower in winter and spring compared with summer and autumn ($p<0.001$). At the weekend, the percentage of MVPA occurring outdoors was highest in the winter and lowest in the summer ($p<0.001$), although the percentage of outdoors MVPA in greenspace overall and within parks was similar across the year.

Discussion

The results show that the amount of activity occurring within greenspace per child is low when expressed as an average daily time, although these figures are broadly in line with a prior study based on the same cohort a year earlier (Wheeler et al., 2010) and also a study of 9-10 year olds in Norfolk (Jones et al., 2009b). However, when expressed as a percentage of

total MVPA across all children, time spent in greenspace contributes over a third of all outdoor MVPA occurring during weekday evenings, over 40% on Saturdays and almost 60% on Sundays. This suggests that some children are particularly high users of green environments for play and physical activities and provides some evidence that, at a population level, greenspace use may be an important contributor to overall levels of activity.

The findings show that all types of parks were used by children for sedentary, light and moderate-vigorous activities. It is noteworthy that a high proportion of weekend light and moderate-vigorous activity was within areas specifically designated for use by children or teenagers, in which around 8% of light and moderate-vigorous activity occurred on both Saturdays and Sundays. These areas are few and small (representing <1% of total park area), but their relatively high usage for activity suggests that provision of facilities specifically targeted at young people is effective and that these facilities are valuable resources for physical activity.

The percentage of weekend outdoor MVPA occurring in greenspace overall and specifically in parks did not differ by season. This is contrary to our prior expectation that greenspace would be used more during warmer weather, and we suggest may partly reflect their use for team sports such as football, which predominately take place in colder seasons. Previous analysis also found evidence of decreased MVPA during longer daylight hours and during British Summer Time (Wheeler et al., 2010). Further research looking at seasonal and climate-related patterns in the use of different environments is needed, potentially linking GPS data with weather variables. This could help plan provision of greenspace which are weather-appropriate and maximise their potential use for physical activity across the seasons. The percentage of outdoor MVPA taking place in parks during weekday evenings did vary throughout the year, with a lower percentage of moderate-vigorous activity undertaken within parks in winter and spring. This almost certainly reflects the fact that parks are less suitable for activity on darker evenings and may indicate a need to provide better lighting in them, particularly along pathways and in play areas. Adequate lighting is a key factor for parents when selecting play spaces for children to use (Sallis et al., 1997).

The majority of activity occurred in non-green environments, such as on roads and pavements and concreted surfaces. This illustrates the broad ways in which children gain physical activity outside of school and the need to consider the many environmental contexts which may be important. In addition to activity within parks, children also made some use of school playing fields, even at the weekend, and other green areas including cemeteries, golf courses and gardens of publicly accessible buildings. Therefore, studies simply looking at access to a public park may miss important contextual factors about other environments which children may be using. These findings reflect the versatility of children’s play and physical activity behaviours and the potential health value of greenspace not formally designated and managed as a public park.

A large proportion of MVPA occurred within private gardens, particularly during weekday evenings, showing the value of private greenspace as a physical activity resource. Evidence suggests that in recent decades children’s play behaviour has become less autonomous and increasingly occurs in private gardens and the space surrounding the home, a trend attributed mainly to parental safety concerns (Valentine and McKendrck, 1997). Children are more likely to use parks and play spaces in the neighbourhood if they have a network of other children to play with (Veitch et al., 2006). Our analysis shows how both private and public greenspace are used for activity, with private space used more during the week and public space at weekends, indicating that both types are important resources for physical activity and their combination allows children to gain their activity in different ways across different

outdoor settings. This has policy implications for ensuring adequate provision of both private gardens and public greenspace in housing developments in the context of increased higher density housing and the potential loss of greenspace. For example a study in Merseyside, England, found that between 1975 and 2000 land identified as greenspace decreased by 6%, with reduction in private garden space and conversion of public open space into new housing (Pauleit et al., 2005).

Strengths of the study include the use of a large sample of GPS and accelerometer data, meaning that objective methods could be used to measure the intensity and location of physical activity. The mapping data was detailed and well characterised and consequently we believe this is the first study which has used GPS data to examine activity within different types of greenspace which also includes information about types of parks. Data was collected throughout the week and across the year, allowing a detailed breakdown of the times when greenspaces are used by children.

In terms of study limitations, Bristol is a relatively deprived and predominantly urban area and, therefore, findings may not be generalisable to other living contexts or other age groups. More rural areas may have different challenges in measuring greenspace, as the need to distinguish inaccessible agricultural land from useable grassland, parks and footpaths will be particularly important. The comparison of included participants with the wider sample showed that children providing GPS data were not representative of the wider PEACH cohort, particularly at the weekend. Excluded participants are those who provided no GPS data, which either means that their GPS receivers were turned off/not worn, or that the children were continually indoors during the data collection period and so not using the outdoors for any activity or play. The comparison of Saturday and Sunday was based on small and different samples as not all participants provided GPS data on both weekend days.

This analysis did not consider how use of greenspace may be affected by how accessible it is to the child (such as how close it is to the child's home) or by demographic factors such as sex, socio-economic factors and other environmental variables which have been shown to influence children's activity and may affect their use of greenspace, such as road layouts, traffic flows and crime rates. Future research could investigate how these factors moderate the use of greenspace. Whilst inclusion of information about type of parks was a major advantage of this study, no information was available about the quality of park, or the specific facilities available in them, both factors which may determine use. The availability of detailed online mapping and visualisation tools potentially allow greenspace quality to be assessed remotely (Taylor et al., 2011), and these methods might be used to supplement GIS data in future research.

The linkage of GPS and accelerometer data with land use maps of the environment is a new and developing approach and there are limitations and uncertainties in the methods used. The exclusion of activity occurring outside the study area meant that the use of greenspaces in the surrounding countryside was not considered. This means we have probably underestimated the overall amount of activity within greenspaces. There are also issues with the accuracy of the GPS data (Duncan et al., 2009). GPS signal dropout occurs when the receiver temporarily loses satellite reception and this creates gaps in the data. Nevertheless, based on the identification of periods of missing GPS data lasting 30 seconds or less which occurred while child was outdoors, we found that this represented only around 2% of outdoors time in our study. Location data may also be missing during longer dropout periods or due to delays acquiring a sufficient satellite signal upon turning the receiver on (Duncan et al., 2009). However, as our analysis did not require generation of street-level routes, further cleaning or the use of algorithms to impute the missing GPS data was not judged necessary in order to meet the aims of this study.

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The removal of any points where participants were travelling >15kph was an attempt to remove time spent in vehicles and erroneous GPS locations, but consequently may also exclude fast bouts of cycling or running and include time spent in slow traffic. Nevertheless, a sensitivity analysis (results not presented) tested the use of 20kph as an alternative threshold and found this made no substantive difference to the findings. A further source of potential error is misclassification in the overlay of GPS points with mapping data, particularly across the land use types 'roads and pavements', concreted 'built surfaces' and 'gardens', as these areas are small and often adjacent, thus requiring extremely accurate location data. In particular, the some of the large proportion of activity in gardens may be in part due to misclassification from children who are actually indoors or who are walking past.

Conclusion

This study demonstrates a new use of GPS to describe how different types of urban greenspace are used by children and provide an insight into how activity within different types of greenspace varies throughout the week and across the year. Our findings show that whilst children gained the majority of their activity in non green environments, urban greenspaces, both public and private, are valuable resources for children's play and physical activity.

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Figure 1. An example of data collected from one child during one hour on a weekday evening, showing GPS locations and intensity of physical activity

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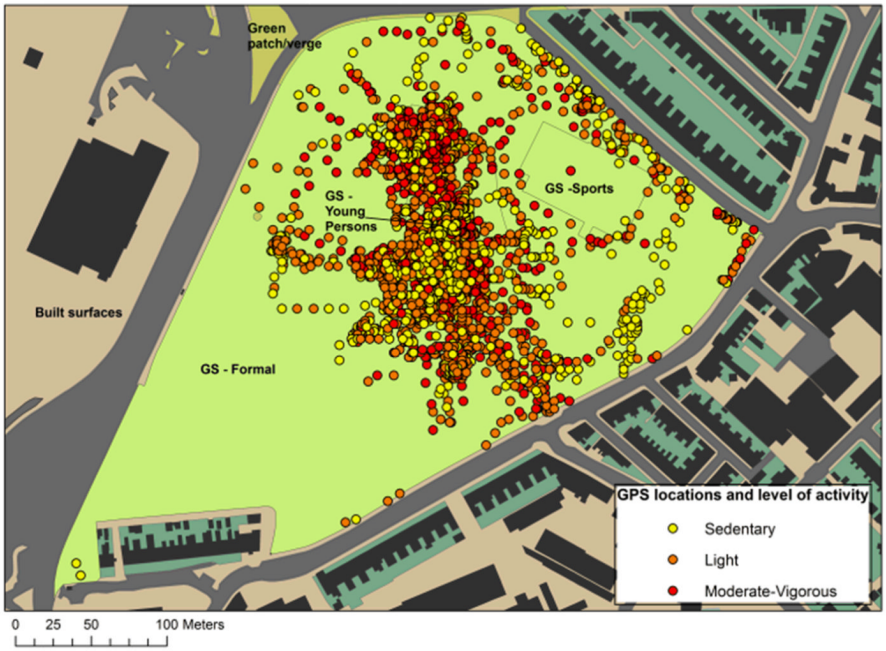

Figure 2.
Example of all GPS data collected within one park at the weekend, showing GPS locations and intensity of physical activity

Table 1

Characteristics of the study sample

	Total sample	Included in analysis of weekday evenings	Included in analysis of weekends
	N = 902	N = 614	N = 301
Age *			
- Mean (SD)		12.0 (0.39)	12.1 (0.40)
Gender (%)			
- Male	47.5	46.7	39.9
- Female	52.5	53.3	60.1
Ethnicity (%)			
- White	85.1	86.2	91.7
- Asian	3.2	3.3	1.7
- Black African	6.4	5.7	2.0
- Mixed	4.2	3.7	3.7
- Unknown	1.0	1.1	1.0
IMD deprivation (%)			
- Most deprived (Quartile 1)	34.5	32.6	31.6
- Quartile 2	22.2	22.2	21.3
- Quartile 3	28.1	28.8	31.2
- Least deprived (Quartile 4)	15.3	16.5	16.0
IOTF weight categories (%)			
- Underweight (BMI <18.5)	8.8	9.0	9.3
- Healthy weight (18.5 to <25)	68.6	69.2	70.8
- Overweight (25 to <30)	17.7	17.4	16.3
- Obese (30+)	4.7	4.1	3.0
- Unknown	0.2	0.3	0.7
Physical activity:			
Mean counts per minute (SD)			
- Weekday evenings 3pm-10pm	562.0 (373.5)	572.4 (389.7)	-
- Weekend days 8am-10pm	453.9 (317.5)	-	512.3 (343.4)
Distance to nearest park:			
Mean meters (SD)			
- All types	193.1 (153.8)	192.7 (157.1)	194.3 (156.6)
- Formal	239.8 (172.8)	238.0 (176.5)	244.6 (177.2)
- Informal	770.8 (604.9)	780.2 (630.3)	796.1 (599.5)
- Natural	442.0 (278.8)	451.6 (288.0)	458.6 (286.1)
- Sports	651.8 (367.0)	641.5 (379.1)	652.9 (384.3)
- Young Persons	389.7 (226.9)	391.2 (227.5)	381.4 (224.6)

N = Number of children included in the analysis

IMD = Index of Multiple Deprivation 2007. Lower Super Output Area (LSOA) scores assigned to participants using their home postcode.

Quartiles based on ranking of all LSOAs in England.

IOTF = International Obesity Task Force.

BMI - Body Mass Index (kg/m2) adjusted for age and sex.

*Mean age of participants on first day they provided GPS/accelerometer data Therefore, ages not available for children not providing data.

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Table 2

Time spent in different activity intensities on weekday evenings and weekend days by location. Values are mean minutes (standard deviation) per day and percentage of total time spent either sedentary or in light or moderate to vigorous physical activity

Location of activity		Weekday evenings 3pm-10pm N = 614			Weekend days 8am-10pm N = 301		
		Sedentary	Light	Mod-Vig	Sedentary	Light	Mod-Vig
Indoors	Mean (SD)	195.7 (90.8)	68.2 (38.6)	19.3 (17.2)	363.4 (154.0)	135.5 (70.7)	33.7 (27.9)
	Percentage	92.5	87.7	72.6	93.2	89.1	78.7
Outdoors	Mean (SD)	14.5 (28.8)	9.1 (14.9)	7.0 (1.4)	20.7 (41.3)	13.0 (24.6)	7.5 (17.2)
	Percentage	7.0	11.7	26.4	5.3	8.5	17.6
Out of study area	Mean (SD)	1.1 (17.2)	0.5 (6.0)	0.3 (4.1)	5.7 (30.0)	3.7 (16.1)	1.6 (10.4)
	Percentage	0.5	0.6	1.0	1.5	2.5	3.7
Total	Mean (SD)	211.4 (74.3)	77.9 (27.4)	26.6 (9.3)	389.8 (145.1)	152.2 (75.8)	42.8 (36.1)

Table 3

Time spent in different activity intensities on weekday evenings and weekend days by location. Values are mean minutes (standard deviation) per day and percentage of outdoor time spent either sedentary or in light or moderate to vigorous physical activity

Location of activity		Weekday evenings 3pm-10pm N = 614			Weekend days 8am-10pm N = 301		
		Sedentary	Light	Mod-Vig	Sedentary	Light	Mod-Vig
Greenspace (overall)	Mean (SD)	6.0 (16.1)	3.5 (7.9)	2.4 (4.8)	9.0 (26.9)	6.1 (15.7)	3.5 (9.1)
	Percentage	41.1	38.8	33.6	43.7	46.7	46.0
- Parks (all types)	Mean (SD)	1.1 (6.8)	1.2 (7.8)	0.7 (4.7)	3.4 (19.1)	3.5 (16.7)	2.2 (10.5)
	Percentage	7.4	12.9	10.1	16.4	26.7	29.3
Formal	Mean (SD)	0.2 (3.0)	0.3 (4.1)	0.2 (3.3)	0.5 (8.7)	0.7 (8.5)	0.4 (4.3)
	Percentage	1.5	3.0	2.7	2.4	5.1	4.8
Informal	Mean (SD)	0.5 (4.9)	0.4 (4.1)	0.2 (1.6)	1.0 (11.9)	1.1 (7.7)	0.7 (5.0)
	Percentage	3.2	4.4	3.2	5.1	8.3	9.9
Natural	Mean (SD)	0.1 (2.3)	0.1 (1.5)	0.1 (1.1)	0.7 (15.2)	0.6 (8.8)	0.5 (6.6)
	Percentage	0.6	0.8	0.8	3.6	4.7	6.1
Sports	Mean (SD)	0.1 (10.2)	0.1 (10.6)	0.1 (7.4)	0.1 (3.2)	0.1 (1.9)	0.05 (1.2)
	Percentage	1.0	1.6	1.5	0.4	0.6	0.6
Young Persons	Mean (SD)	0.2 (4.0)	0.3 (6.6)	0.1 (3.4)	1.0 (19.1)	1.0 (13.9)	0.6 (7.6)
	Percentage	1.1	3.3	2.0	5.0	7.9	7.8
- Private gardens	Mean (SD)	4.8 (15.1)	2.2 (4.2)	1.6 (2.8)	5.6 (23.4)	2.5 (7.7)	1.2 (3.2)
	Percentage	32.9	24.5	22.3	26.9	19.2	16.1
- School grounds	Mean (SD)	0.1 (5.5)	0.1 (5.2)	0.1 (3.3)	0.1 (2.5)	0.1 (5.1)	0.1 (1.8)
	Percentage	0.7	1.3	1.1	0.3	0.7	0.5
- Other greenspace	Mean (SD)	0.01 (0.5)	0.01 (0.5)	0.01 (0.4)	0.03 (1.3)	0.01 (0.4)	0.01 (0.3)
	Percentage	0.1	0.1	0.1	0.1	0.1	0.1
Other land use							
- Roads/ pavements	Mean (SD)	2.8 (7.2)	2.0 (3.7)	1.9 (3.2)	3.9 (12.5)	2.2 (7.6)	1.6 (6.5)
	Percentage	18.9	21.6	26.6	18.9	17.1	20.9
- Green verges	Mean (SD)	0.3 (2.7)	0.2 (2.3)	0.2 (1.8)	0.6 (7.0)	0.5 (5.1)	0.3 (2.7)
	Percentage	2.0	2.6	2.9	3.1	3.5	3.8
- Built surfaces	Mean (SD)	5.5 (12.4)	3.4 (6.1)	2.6 (4.4)	7.1 (14.1)	4.2 (9.3)	2.2 (7.1)
	Percentage	38.0	37.0	36.9	34.3	32.6	29.3

Table 4

Time spent in different activity intensities on Saturdays and Sundays by location: Values are mean minutes (standard deviation) per day and percentage of outdoor time spent either sedentary or in light or moderate to vigorous physical activity

Location of activity		Saturday 8am-10pm N = 216			Sunday 8am-10pm N = 177		
		Sedentary	Light	Mod-Vig	Sedentary	Light	Mod-Vig
Greenspace (overall)	Mean (SD)	7.8 (16.7)	6.5 (15.7)	3.6 (9.0)	10.6 (36.2)	5.5 (15.7)	3.3 (9.2)
	Percentage	38.6%	42.9%	40.3%	49.6%	53.4%	56.6%
- Parks (all types)	Mean (SD)	3.2 (16.8)	3.6 (16.7)	2.1 10.2)	3.6 (22.1)	3.3 (16.8)	2.3 (11.0)
	Percentage	15.9%	23.7%	23.8%	17.0%	32.0%	39.4%
Formal	Mean (SD)	0.7 (10.8)	0.8 (9.6)	0.4 (3.8)	0.3 (3.0)	0.5 (6.3)	0.3 (5.2)
	Percentage	3.5%	5.3%	4.5%	1.2%	4.7%	5.3%
Informal	Mean (SD)	0.9 (6.7)	1.1 (7.0)	0.7 (4.3)	1.3 (16.5)	1.1 (8.7)	0.8 (5.7)
	Percentage	4.4%	7.2%	7.5%	5.9%	10.3%	14.4%
Natural	Mean (SD)	0.3 (3.7)	0.5 (6.9)	0.3 (5.5)	1.3 (22.6)	0.8 (10.9)	0.6 (7.6)
	Percentage	1.3%	3.0%	3.5%	6.2%	7.9%	11.0%
Sports	Mean (SD)	0.1 (1.4)	0.1 (1.8)	0.1 (0.7)	0.1 (4.9)	0.1 (2.0)	0.1 (1.8)
	Percentage	0.3%	0.7%	0.5%	0.5%	0.5%	0.9%
Young Persons	Mean (SD)	1.3 (22.6)	1.1 (13.2)	0.7 (7.5)	0.7 (11.6)	0.9 (15.5)	0.5 (8.0)
	Percentage	6.5%	7.5%	7.8%	3.3%	8.6%	7.8%
- Private gardens	Mean (SD)	4.4 (11.2)	2.8 (6.8)	1.4 (3.0)	6.9 (33.0)	2.2 (8.7)	1.0 (3.4)
	Percentage	22.2%	18.2%	15.9%	32.3%	21.1%	16.5%
- School grounds	Mean (SD)	0.1 (2.9)	0.1 (6.2)	0.1 (2.1)	0.01 (0.6)	0.03 (1.4)	0.03 (1.0)
	Percentage	0.4%	0.9%	0.5%	0.1%	0.2%	0.4%
- Other greenspace	Mean (SD)	0.01 (0.2)	0.02 (0.4)	0.01 (0.3)	0.04 (2.1)	0.01 (0.3)	0.01 (0.4)
	Percentage	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%
Other land use							
- Roads/ pavements	Mean (SD)	4.0 (11.8)	2.9 (9.8)	2.1 (8.3)	3.8 (13.3)	1.4 (3.0)	0.9 (2.7)
	Percentage	19.9%	19.2%	23.9%	17.8%	13.4%	15.3%
- Green verges	Mean (SD)	0.8 (6.8)	0.6 (6.3)	0.3 (2.9)	0.4 (7.3)	0.3 (2.6)	0.3 (2.5)
	Percentage	4.0%	4.0%	3.5%	2.0%	2.6%	4.3%
- Built surfaces	Mean (SD)	7.5 (12.4)	5.1 (10.3)	2.9 (8.9)	6.6 (16.1)	3.2 (7.8)	1.4 (3.5)
	Percentage	37.5%	33.8%	32.3%	30.6%	30.6%	23.8%

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Table 5

Time spent in moderate-vigorous activity per Season by location: Values are mean minutes (standard deviation) per day and percentages of MVPA occurring outdoors, outdoors in greenspaces, and outdoors within parks.

	Weekday evenings 3pm-10pm				Weekend days 8am-10pm			
	Spring	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**
Number of children	170	147	128	190	102	81	62	56
MVPA – Mean (SD)								
- Total	27.7 (22.3)	30.0 (22.4)	25.5 (16.6)	23.8 (20.1)	44.1 (40.0)	39.4 (27.9)	43.0 (28.7)	45.1 (46.1)
- Outdoors	7.5 (12.6)	6.2 (10.6)	7.2 (8.9)	7.0 (9.0)	6.6 (13.8)	3.2 (7.2)	11.0 (15.7)	12.2 (28.7)
- Within greenspace	2.5 (3.9)	2.5 (3.4)	2.4 (2.5)	1.9 (2.0)	3.3 (8.9)	1.7 (5.4)	4.6 (9.9)	5.0 (11.8)
- Within parks	0.6 (4.2)	1.1 (7.7)	0.8 (2.8)	0.5 (3.5)	2.1 (10.0)	1.0 (5.6)	2.7 (11.6)	3.7 (14.1)
Percentage of total MVPA occurring outdoors	27.5	21.1	28.3	29.6	15.7	8.5	26.1	27.8
Percentage of outdoor MVPA in greenspaces (overall)	34.0	41.4	34.6	27.4	52.3	51.9	42.0	40.9
Percentage of outdoor MVPA in parks (all types)	7.7	17.2	11.2	7.0	32.0	30.8	24.5	30.5