Schoolyard physical activity in 14-year-old adolescents assessed by mobile GPS and heart rate monitoring analysed by GIS

INGUNN FJØRTOFT¹, OWE LÖFMAN² & KINE HALVORSEN THOREN³

¹Telemark University College, Faculty of Arts, Folk Culture and Teacher Education, Notodden, Norway, ²Norwegian University of Life Sciences, Department of Mathematical Sciences and Technology, Ås, Norway, and ³Norwegian University of Life Sciences, Department of Landscape Architecture and Spatial Planning, Ås, Norway

Abstract
Background: Environmental settings seem to influence the activity patterns of children in neighbourhoods and schoolyards, the latter being an important arena to promote physical activity (PA) in school children. New technology has made it possible to describe free-living PA in interaction with the environment. Aims of study: This study focused on how schoolyard environments influenced the activity patterns and intensity levels in 14-year-old children and whether PA levels in adolescents complied with official recommendations. Another objective was to introduce methodology of using a mobile global positioning system (GPS) device with synchronous heart rate (HR) recordings as a proxy for PA level and a geographical information system (GIS) for spatial analyses. Methods: The sample constituted of 81 children (aged 14 years) from two schools. Movement patterns and activity levels were recorded during lunch break applying a GPS Garmin Forerunner 305 with combined HR monitoring and analysed in a GIS by an overlaid grid and kriging interpolation. Results: Spatial data from GPS recordings showed particular movement patterns in the schoolyards. Low activity levels (mean HR < 120 bpm) dominated in both schools with no gender differences. Activities located to a handball goal area showed the highest monitored HR (>160 bpm) with higher intensity in girls than in boys. Conclusions: Movement patterns and PA generated in GIS for visualisation and analysis enabled direct and realistic description of utilising of schoolyard facilities and activity levels. Linking GPS data and PA levels to spatial structures made it possible to visualise the environmental interaction with PA and which environments promoted low or high PA.

Key Words: Adolescents, GPS, GIS, heart rate, movement patterns, physical activity, school children, schoolyard, 9-graders

Background
Physical activity (PA) is an important life-style factor with preventive potential also in early ages [1,2]. In 11–15-year-old children, the degree of PA is also related to the quality of life [3]; however, PA seems to decrease with age, starting in early teenage, and is more pronounced in girls than in boys [4–7]. A national survey of PA and fitness among children and youth in Norway reported 9-year-olds to be 43% more active than 15-year-olds, both age groups being more active during week days than in weekends [8]. Gender differences were found even among the 9-year-olds, the boys being more physically active than girls, while these differences were not as profound in the 15-year-olds [8].

WHO recommends children and youth to practise at least 60 minutes moderate to vigorous PA (VPA) every day. This recommendation is supported in studies by Strong et al. [2], while Andersen et al. [1] suggested a minimum of 90 minutes VPA.

A longitudinal study by Nader et al. [5] showed a remarkable decrease in moderate to vigorous PA (MVPA) between the ages 9 and 15 years. They estimated the age at which the recommended 60 minutes of MVPA was no longer achieved to be 12.6 years for boys and 13.4 years for girls. The study by Anderssen et al. [8] also confirmed that 91% of
9-year-old boys and 75% of 9-year-old girls satisfied the recommendations of 60 minutes of daily MVPA, while among the 15 year olds, only 54% of the boys and 50% of the girls met these recommendations.

Environmental factors may have an important influence on children's PA, although these perspectives have not been widely assessed [9]. Recent studies on PA during school breaks showed that the probability of being physically active is dependent on the facilities provided [10,11]. Children attending schools with a wide range of facilities for PA seemed to have higher odds ratios for being active during recess compared to children with more limited options. This was more evident in secondary schools, where the schoolyards usually are considerably less equipped with facilities for PA than in primary schools. Studies by Haug et al. [10,11] revealed that children with a low interest in PA were not influenced by the standard of the equipments and suggested that secondary school programmes should focus on environmental facilitation of schoolyards and incorporate strategies that promote children’s interest for PA.

Later studies have explored that free-living PA in interaction with the environment is possible to describe through new monitoring technology. In a review study Maddison and Mhurchu [12] described the potentials of the global positioning system (GPS) for monitoring human movement patterns with focus on free-living PA. Combined with geographical information systems (GIS), this methodology may provide more knowledge about how people interact with the environment. Jones et al. [13] used accelerometry and GPS technologies to identify characteristics of environments being attractive for performing PA in 9–10-year-old children. A feasibility study by Duncan et al. [14] combining GPS with heart rate (HR) monitoring concludes this to be promising technology for investigating spatial locations linked to children’s PA and energy expenditure. Combining the same technology, Fjortoft et al. [15] described the interaction of schoolyard environments and PA intensity in 6-year-old children, showing space determined levels of PA and gender-related environmental preferences. Telford et al. [16] described adolescent PA during school breaks by using the monitoring technology of GPS and HR. Their findings indicated that 14-year-old boys displayed significantly higher HR levels than girls at the same age, all students spent more time in grassed areas, but girls spent more time in seated areas than boys. The study stated a relatively stable activity level during school breaks of 20 minutes among adolescents across days.

The purpose of this paper was to describe the interaction between school environments and PA in 14-year-old children in two different school settings during the lunch break. Expanding the potentials from technologies explored in previous studies we wished to expound the idea of combining HR monitoring for PA intensity with GPS simultaneously in order to determine how space and place in schoolyard settings may interact with PA in adolescents.

**Methods**

**Objectives**

The primary objective was to measure the levels of and geographical variation in PA in two schoolyards during recess. Furthermore, to describe how movement patterns and levels of PA in 14-year-old adolescents (9-graders) may indicate the use of schoolyard facilities and whether this differed by study population subgroups like gender, school, area, and time for recess. A secondary objective was to introduce the methodology of using a mobile GPS device with synchronous HR recordings as a proxy for PA level and GIS for spatial analysis. Another objective was to assess whether PA levels in adolescents complied with official recommendations.

**Study area**

Two schools located in the same district in southern Norway were selected for the project by the local educational authorities. Gudeberg school with 420 children was located in an sub-urban area with open fields and residential areas in the surroundings, while Begby school, attended by 520 children, was located in a semi-rural area with mostly forest surroundings. Both schools ranged from grade 1–10 organised in levels from grade 1–3, 4–7, and 8–10.

Gudeberg had the facilities for PA in the open fields surrounding the school and the schoolyard comprised a volleyball field, a ballgame bin, and a combined court for handball and volleyball (Figure 1a). These facilities were available to the 9-graders included in the study. This school was also well equipped with play equipment for smaller children and for children with special needs.

Begby was appreciably more provided with outdoor facilities. The schoolyard included a little forested area that was available to the children during recess. Furthermore, the school had playground areas for children in the lower grades and
ballgame areas for handball, basketball, soccer, and volleyball available for the 9- graders (Figure 1b).

Study subjects
One hundred and twenty-one 14-year-old children (9-graders) were invited to participate in the study at the two schools, of which 81 responded (67%). The external dropout was thus 40 subjects (33%) for both schools combined and 81 subjects were included in the study, 36 girls and 45 boys. There was a considerable difference in dropout frequency between the schools with lower participation in Gudeberg, particularly among girls (38%). Anthropometric characteristics of the samples showed only minor differences between groups of the total sample. Six boys (13.3%) were defined overweight (body mass index (BMI) > 22.62 kg/m²) and two boys (4.4%) were defined as obese (BMI > 27.63 kg/m²). Three of the girls (8.3%) were overweight (BMI > 23.34 kg/m²) but none of the girls were obese according to definitions by Cole et al. [17]. It should be noted that only eight of the total of 12 girls at Gudeberg volunteered to
participate in the anthropometric measurements. The anthropometrics of our limited sample are comparable to the national survey of 15-year-old adolescents [8].

**Data sampling**

In a period of 7 days in October with good weather, except for one rainy day, the children were monitored for outdoor activities during lunch break. Due to the difference in time of lunch break, 25 minutes at Gudeberg and 45 minutes at Begby, recordings at Begby contributed with a considerably larger amount (71%) compared to Gudeberg (29%). Due to available devices, the children were monitored in smaller groups of maximum 12 children at a time and each child was monitored only once.

**Spatial tracking and heart rate monitoring**

X- and Y-coordinates for tracking the children’s movements were assessed by mobile GPS equipment (Garmin Forerunner 305) recording signals from available satellites. This device is a wrist watch with a chest belt recording HR, which was used as a proxy variable for PA. Heart rate is an indirect estimate of PA which makes assumptions based on the linear relationship between HR and oxygen uptake [18]. The HR signal was recorded by use of a chest belt sending data wireless to the GPS device. All recorded data (X- and Y-coordinates and HR counts, date, and time) were stored in the memory of the GPS device at an average time interval of 7 seconds. Cases with loss of HR signals for more than 10 minutes continuous monitoring time were deleted from the analysis.

The combined movement patterns and HR in different parts of the schoolyard were used to evaluate how different areas and facilities promoted PA. The reliability of spatial monitoring was estimated by Sageie et al. [19] to be ±4 metres for static measurements.

Levels of PA were defined according to Reily et al. [20] and Ridgers et al. [21] where HR < 120 bpm represents low PA (LPA), HR 120–140 bpm represents low to moderate PA (LMPA), HR 140–160 bpm represents MVPA, and HR > 160 bpm represents VPA. The percentage time each child spent at LPA, LMPA, MVPA, and VPA or above during recess was calculated and used in subsequent analysis. Activity levels of MVPA and VPA was applied for considering whether the recommended 60 minutes of PA was reached during recess at the schools. By combining tracking patterns and schoolyard maps, the correlation between landscape elements in various spatial locations and PA was identified.

**Spatial data analysis and statistics**

GPS data and HR recordings were exported to a dbf database, converted to a projected coordinate system (Transverse Mercator; WGS 1984, Zone North 32) and geo-coded in a GIS software (ArcInfo vers. 9.2) using metric units (metres). Spatial variations of HR within the schoolyard areas were analysed by three approaches: visually, in a 20 × 20 metre grid and by a continuous surface modelled by ordinary kriging. For the grid analysis, the average HR of measured point recordings was used as a summary measure. To smooth the data, the kriging prediction map was converted into a raster file and the values extracted by the centroid points of the raster pixels using a bilinear resampling method. The schoolyard HR variation surface was then converted to a 3-dimensional wire graph. Basic geostatics were calculated in ArcInfo and ordinary statistics and graphs in SPSS v. 15 and Axum. All tests of significance were 2-tailed and p-values <0.05 were considered significant.

**Code of ethics**

The children were selected in a voluntary manner according to the Helsinki declaration. Written informed consent was given from parents and children. Anthropometric data were collected by the school nurse and reported anonymously to the project organisers. All monitoring, data collection, and analysis were treated anonymously in accordance with ethical guidelines. The project was approved by the Norwegian Data Inspectorate.

**Results**

**Movement patterns and PA levels in the schoolyards and nearby surroundings**

**Gudeberg School** GPS recordings of 9-graders at Gudeberg School during the 25 minutes lunch break showed movement patterns that were mostly clustered in one main part of the schoolyard (Figure 1c). These were located near by the school buildings where the 9 graders had their classrooms. Another typical movement pattern of the 9-graders was the tracks along two different routes extending outside schoolyard to a market centre and a kiosk as depicted by upper and lower white arrows, respectively, in Figure 1c. Sixteen boys and 2 girls were identified along these routes, which provoked few recordings in...
the higher PA levels. Figure 2 shows a grid polygon of average HR variation throughout the schoolyard, indicating low intensity levels. The distribution of time spent in different PA levels differed markedly between subjects. Nine children (five boys and four girls) were recorded in all activity levels within the schoolyard (Figure 3b). In the lowest PA level (HR < 120 bpm), the range between subjects was 15–80% of total time, while activities within the highest level (HR > 160 bpm) showed low values (range 0.1–4%). Cumulated moderate and vigorous activity was engaged in 10–50% of total time.

Bøgby School GPS recorded PA of 9-graders at Bøgby was measured during the 45-minute lunch break. Two localities in the schoolyard were recorded as noticeable cluster areas. One locality was identified to be the area between the school buildings at the entrance of classrooms for the 9-graders and around the school buildings. The other cluster of recordings

Figure 2. Average heart rate (HR) for Gudeberg school yard, 10 metre grid. Four HR intervals: up to 120 (green), 121–140 (yellow), 141–160 (orange), over 160 (red). The red line is the “boundary” of the school yard. The dark dots show the observations
Figure 3. Intensity levels of physical activity in the schoolyards. (a) Begby schoolyard. Distribution of time spent in different activity zones for students (n = 9) that entered all activity zones according to internationally defined intervals of physical activity levels for the respective gender (percentage and minutes). Figures in white and above bars depict number of minutes in highest activity interval and shattered line delimits moderate and vigorous activity from lower intervals. (b) Gudeberg schoolyard. Distribution of time spent in the different activity zones for students (n = 8) that entered all activity zones when walking around buildings during recess (percentage and minutes). Figures in and above bars depict number of minutes (abbreviated) in the respective interval. Shattered line delimits the two highest activity intervals.
was located area around the handball goal (Figure 1d). A typical movement pattern was strolling around the school buildings as recorded in 18 girls and 16 boys, indicating that the girls spent more time in this area ($p < 0.01$).

The distribution of time spent on strolling around buildings in the Begby schoolyard differed between subjects. Two boys and six girls were monitored in all activity levels, with less than 20% of total time (<10 minutes) spent in the MVPA intensity levels (HR > 140 bpm). Time spent in the lowest PA level (HR < 120 bpm), showed a difference of 12–48 minutes or 43–86% (Figure 3a).

Figure 4a shows a model of HR variation surface of the schoolyard converted to a 3-dimensional wire graph by ordinary kriging in GIS. The prominent peak is located in the ball game area labelled with number 3 in Figure 1b and was identified as the cluster of GPS recordings located around the handball goal as shown in Figure 1d. Levels of intensity within this peak area, representing HR > 140 bpm, were analysed through the frequency distribution of HR in 18 boys and 15 girls observed at the handball court (Figure 4b). Almost half of the HR recordings in this area represented moderate or vigorous activity levels. Although the boys showed a slightly higher maximal HR ($p < 0.01$) the mean HR was significantly higher for girls, 155 vs. 127 bpm for boys ($p < 0.01$, see inset table in Figure 4).

**Physical activity related to recommendations**

The distribution of HR recordings in all recordings grouped by international recommendations of PA level intervals showed a rather similar pattern for the two schools (Figure 3a,b). Approximately 70% of the time in the schoolyard during lunch break was allocated to low levels of physical activities and less than 15% to moderate and vigorous activity levels. There was a skewed distribution of recorded time for recess at the two schools, 25 and 45 minutes, respectively.

**Discussion**

The current study involved identification of movement patterns of PA in 14-year-old children in schoolyards during recess periods. By GPS tracking we found movement patterns expressed in clusters and lines that were spatially linked to dwelling areas between school buildings, while one cluster was located around a ballgame area. Movement patterns in lines corresponded to walking around school buildings or commuting to the kiosk, as visualised in Figure 1c,d. Except for the cluster around the goal area, movement patterns in clusters and lines did not provoke high intensity levels of PA. Several studies have documented associations between environmental facilities and PA [11,22]. Tucker et al. [23] showed clear correlations between access to sport facilities and time spent on PA. Such correlations were not so prominent in our study. A review study by Ferreira et al. [24] found few potential determinants for PA at the school level, but school
environments for PA in school and neighbourhood in that study expressed their request for improved behaviour among adolescents. However, the students fulfilled the recommendations [8,26].

54% of the boys and 50% of the girls in this age group among 15-year-olds also revealed the fact that only PA for children [25]. The Norwegian survey of PA correspond with the global recommendations of daily were generally at a low intensity level and did not provide more PA except for the handball area. Telford et al. [16] found that PA levels among adolescents during lunch breaks were relatively stable across days, where boys were significantly more active than girls.

Tracking movements with GPS showed how schoolyard environments were used during lunch breaks. Typical patterns were strolling around school buildings and commuting to the kiosk (Figure 1C,D). Heart rate monitoring in these areas indicated low PA levels in such movement patterns as showed in Figure 3.

The diagram of HR values linked to spatial coordinates in the Begby schoolyard showed a differentiated landscape of activity levels, mostly at low levels as seen in Figure 4A. The peak in the diagram corresponds to HR of GPS points clustered in this area as visualised in Figure 1D. This cluster was identified as the goal area of the handball court showing higher levels of intensity with MPA levels in girls and LMPA levels in boys which means that girls were physically active at higher intensity levels than the boys in this area as seen in the inset table in Figure 4. The goal area can be identified as a determinant for moderate to high levels of PA. In our study, both schools provided sport facilities as part of the outdoor environment, but, except for the goal area, the available facilities within the schoolyard and the surrounding fields were not extensively used by the 9-graders during lunch break and recess.

Meeting the guidelines of physical activity

Tracking of movement patterns did not identify specific places that accumulated high PA in the schoolyards, except for the goal area. The activities were generally at a low intensity level and did not correspond with the global recommendations of daily PA for children [25]. The Norwegian survey of PA among 15-year-olds also revealed the fact that only 54% of the boys and 50% of the girls in this age group fulfilled the recommendations [8,26].

Hohepa et al. [27] confirmed the image of sedate behaviour among adolescents. However, the students in that study expressed their request for improved environments for PA in school and neighbourhood settings. Wheeler et al. [28] found that one-third of MVPA activities occurred outdoors with slightly higher intensity in green spaces. In our study the schoolyards were surrounded by green environments and sport facilities, but only one spatial determinant, the goal area, was associated with MVPA in the 9-graders. A survey by Limstrand and Rehrer [29] documented low use of sport facilities in schoolyards and questioned whether sport facilities significantly increase PA among young people. Other explanations to low PA levels may be the time limitation of the recess periods. However, it still remains an unanswered problem why the youngsters did not use the different possibilities for PA in the two schoolyards.

Methodological approach

Applying GPS and HR monitoring for tracking children’s use of the schoolyard and their level of PA provide a more objective picture of children’s movement patterns. A feasibility study carried out by Duncan et al. [14] demonstrated the application of a combined GPS/HR receiver to monitor PA expressed as HR, speed, and distance in primary school children. GPS data was not implemented into GIS and consequently the spatial information of children’s play and accumulated PA was missing. Also the studies by Jones et al. [13] and Teleford et al. [16] have explored the application of GPS technology combined with HR monitoring. The study by Fjortoft et al. [15] applied the methodology of combining GPS, HR implemented into GIS, describing how primary school children in two different schoolyards used different environments for play and PA. In our study we have explored those methods even further. Tracking movement patterns and PA was monitored and generated in GIS for visualisation and analysis, which enabled direct and realistic description of utilising schoolyard facilities and activity levels. Furthermore, we explored the possibilities of visualising HR data and PA intensity levels linked to spatial structures. This made it possible to visualise the environmental interaction with PA and which environments promoted low or high PA.

Study limitations and strengths

Certain shortcomings in this study limit the generalisation of the findings. First of all the samples are small and restricted to Norwegian 14-year-old adolescents. Although 67% of invited children participated in the study, inclusion of subjects was ruled by voluntary principles. The data sampling period was limited to 2 weeks and collected in one season only. However, we consider the monitoring methods to be
the particular strength of this study as this enables objective proxy recordings of outdoor PA. The tracking of movements identified spatial elements for PA. The combination of GPS and HR monitoring described both activity patterns and activity levels where special attributes for low, moderate, and vigorous activity were possible to identify in accordance with international recommendations. However, inter-individual variation in resting HR was not considered in this study. The equipment for combining recordings of GPS data and HR values in the same device proved to stable and reliable. There were no GPS signal loss and only one case was deleted from the analyses due to signal loss from HR recordings due to impaired contact of chest belt and body. Data from GPS and HR monitoring implemented in GIS proved to be a feasible method to assess, visualise, and analyse movement patterns, PA levels, and site-specific elements for such activities. Assessment of personal data and anthropometric measurements were somewhat restricted due to issues concerning integrity and compliance skewed between schools. Unfortunately it was not possible to link anthropometric data to individual project codes and therefore relations between anthropometric characteristics, PA patterns, and environmental interaction were inaccessible.

Conclusions and implications

Despite the above-mentioned limitations, this study assessed, analysed, and visualised movement patterns and aggregated levels of PA among 9-graders in two schoolyards with different environments and facilities. The methodological approach of applying GPS combined with HR monitoring made objective assessment possible. Data was converted into GIS which made spatial analysis of movement patterns and aggregated PA possible.

Clusters identified areas with PA at high intensity levels as well as areas with low activity. In general, the study revealed a low activity level in 14-year-old children during recess, and the recommended activity levels of moderate to vigorous intensity were hardly obtained. The time spent outdoors during lunch break was considered too short to initiate activity, especially when the break was scheduled at 25 minutes including lunch. In both schoolyards the traditional sport facilities were not associated with PA in the 9-graders, except for one handball goal area that was related to moderate and high levels of PA. It seems important to gain more knowledge of how and what environmental factors influence PA levels in youth.

The present study is the first part of a more comprehensive project aiming at analysing and identifying determinants for PA in adolescents in schoolyards and neighbourhoods. The applied monitoring technology by directly combining GPS and HR monitoring implemented in GIS seemed promising for future studies.

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Conflict of interest statement

The authors declare that they have no competing interests.

References


