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Andersen, Henriette Bondo; Christiansen, Lars Breum; Pawlowski, Charlotte Skau; Schipperijn, Jasper

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Research Paper

What we build makes a difference – Mapping activating schoolyard features after renewal using GIS, GPS and accelerometers

Henriette Bondo Andersen\textsuperscript{a,b,⁎}, Lars Breum Christiansen\textsuperscript{a}, Charlotte Skau Pawlowski\textsuperscript{a,b}, Jasper Schipperijn\textsuperscript{a,b}

\textsuperscript{a} Research Unit for Active Living, Department of Sport Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark
\textsuperscript{b} Center for Intervention Research in Health Promotion and Disease Prevention, National Institute of Public Health, University of Southern Denmark, Odense, Denmark

A B S T R A C T

Schoolyard renewal can increase physical activity during recess, but it remains unclear how features and layout can promote physical activity for both genders. This paper aims to investigate physical activity in renewed schoolyards. Three Danish schools were selected for this exploratory case study. The intervention areas consisted primarily of a large asphalt area with few features. Extensive changes were made to the schoolyard layouts involving adding innovative features tailored to the local needs. In total, 349 students (grade 4–9) at baseline (spring 2014) and 300 students (grade 4–9) following renewal (spring 2016) were asked to wear an accelerometer (ActiGraph GT3X) and a GPS (Qstarz BT-Q1000XT) during five school days. Total time and proportions of time spent sedentary, in light (LPA) and moderate-to-vigorous physical activity (MVPA) were calculated per area, by gender. Spatial clusters of high and low physical activity spots were identified after renewal in the asphalt area. At two schools, time and physical activity increased in the renewed area, but for one school they decreased. The percentage of time spent in MVPA and LPA only increased in the renewed area at school 1, while the percentage of time and PA decreased in the intervention area at school 3 after renewal. Courts for ballgames, foursquare markings and hills generated activity spots for both genders. Girls were active at a large screen for dancing activities, a lowered multi-court, a spider-web climbing structure and in an area with big tree stumps whereas the boys were active in-between features and on an obstacle trail. These findings emphasize the importance of providing a schoolyard with a variety of functional features close to each other when building activating schoolyards for both genders.

1. Introduction

Schoolyards are ideal settings for promoting children’s physical activity (PA) (Ridgers, Stratton, Fairclough, 2006; Mota et al., 2005; Sallis, Prochaska, Taylor, 2000). Throughout recess, schoolchildren have the opportunity to be active and in particular for the least active children recess has shown to be an important part of daily PA (Erwin et al., 2012; Fairclough, Beighle, Erwin, Ridgers, 2012; Dressing et al., 2013). With the significant proportion of time children spend at school, schoolyards can play a critical role in enabling students to have a more active school day (Escalante, Garcia-Hermoso, Backx, & Saavedra, 2014; Ridgers et al., 2012). Despite the well-documented health related benefits of an active lifestyle, a high percentage of children in Denmark and other western countries do not meet the recommendation of at least 60 min of PA each day (Andersen et al., 2006; Fedewa and Ahn, 2011; Lubans, Morgan, Cliff, Barnett & Okely, 2010; Tobias, Steer, Mattocks, Riddoch, & Ness, 2007; Rothon et al., 2010; Jo Inchley & Young, 2013; Troiano et al., 2008). Numerous studies have shown gender differences in PA with boys being more active in all domains of daily life, including recess and in the schoolyard (Troiano et al., 2008; Ridgers et al., 2012; Andersen et al., 2015; Klinker, Toftager, Pawlowski, & Schipperijn, 2015). Studies have ascribed the gender difference in recess PA to the types of activities boys and girls engage in (Nielsen, Pfister, & Andersen, 2011; Andersen et al., 2015; Blatchford et al., 2003; Ridgers, Stratton & McKenzie, 2010) and in Danish schoolyards soccer fields are the dominant play facility at most schools, favoring the boys’ play (Pawlowski, Egler, Tjornhoj-Thomsen, Schipperijn, & Troelsen, 2015). However, very little is known about the gender-specific PA behaviors related to specific schoolyard features and a suitable schoolyard design with activating facilities for both genders has not yet been found (Nettlefold et al., 2011; Colabianchi, Kinsella, Coulton, & Moore; Dalene et al., 2016).

Consistent evidence shows positive associations between outdoor time and use of schoolyard facilities with moderate to vigorous physical activity (MVPA) and less time in sedentary behaviour (Gray et al., 2015; Pagels et al., 2014). Improving the outdoor school environment is considered an important strategy in PA promoting school programs (Escalante et al., 2014; Haug, Torsheim, Sallis & Samdal, 2010). Previous cross-sectional studies have specified areas important for activity such as green areas, fields and playgrounds (Andersen et al., 2015;...
The Activating Schoolyard Study in Study 2.1. Setting

Methods

In the Activating Schoolyard Study, three paved schoolyards underwent renewal to promote physical activity focusing on both an innovative schoolyard layout and features present in traditional schoolyards. We assumed that the renewed areas would attract boys and girls differently and that some areas would be more attractive and generate more physical activity than others.

The aim of this paper was to investigate time spent and PA levels in three renewed paved schoolyards in Denmark, with special interest in finding activating areas and facilities with high levels of physical activity using objective location-specific measures.

2. Methods

2.1. Setting

Three Danish schools participating in The Activating Schoolyard Study were selected for this exploratory case study based on similarities in their schoolyard design prior to the renewals. Schools participating in The Activating Schoolyard Study were selected based on an open call for proposals issued by a partnership consisting of three non-governmental organisations. The following criteria were weighted in the selection of the schools, i.e. innovativeness of solutions promoting PA, focus on least physically active children, organizational initiatives to support the renewals, student involvement, and diversity in geographic locations and target groups for the renewals. A detailed description of the selection of the schools is found in (Andersen et al., 2015). At all three schools selected for this exploratory case study the main part of the intervention areas consisted of a large open asphalt area with few markings and none or few permanent features, which is typical for many Danish schoolyards.

At baseline (2014) and following renewal (2016), two samples of students representing the target group (4th to 9th grade) for the schoolyard renewals at each school at the time of data collection, participated. In Denmark children in 4th to 9th grade represent children at the age of 11–15 years old. The two-sample design was used because students often change classroom location and schoolyards, when they get older, and to avoid the influence of the students’ expected age-dependent decline in recess-based PA (Toftager et al., 2014). Data were collected between April and June at both time points to minimize potential seasonal differences.

The study and its data-management procedures were registered and approved by the Danish Data Protection Agency (2014-41-2801). According to the Danish National Committee on Health Research Ethics formal ethical approval was not required as the project was not a biomedical research project. Data were collected in accordance with the Helsinki Declaration. All included students provided their assent and active informed consent for each wave of the data collection.

In Danish schools, approximately 60 min per day are allocated to recess, distributed over two to four periods, including the lunch break, lasting 25–30 min. All students have recess at the same time and recess is typically characterized by free play without any organized activities. Some schools divide the school ground into grade specific areas which is the case at school 3, at this school students in preschool class to 3th class have their own separate schoolyard area and are not allowed to use the rest of the schoolyard including the intervention area. There is a great variation between and within schools in whether different grades are required to go outside during recess. Different outdoor rules excited for the middle block (grade 4th–6th) at all the three schools participating in this study and at school 1 it changed from baseline to follow-up. At school 1 outdoor rules required students to go outside during all recess periods only at follow-up. At school 2 and 3 outdoor rules remained the same. At school 2 outdoor rules required students to go outside during half of the first recess period and at school 3 students were required to go out during all recess periods the whole time. However, in the everyday school life the retention of these outdoor rules can vary from recess to recess and from day to day often depending on the teacher, class time table and the weather. In Denmark seniors (7th–9th grade) are often allowed to leave the school during recess however this was only the case at School 1. School 1 was located in an urban area with no field or green areas on or in close connection to the school ground. The share with a non-Danish ethnicity was 20% and the parents income range was in the lower end of the national range list. School 2 was located in a rural area with a large sports field and in close connection to a forest. The share with a non-Danish ethnicity was 14% and the parents income range was above the national average. School 3 was located in sub urban area with a large sports field and parks in connection to the school ground. The share with a non-Danish ethnicity was 3% and the parents income range was above the national average (Andersen et al., 2015). In comparison the percentage of non-Danish ethnicity in Denmark is 13.1%.

2.2. Interventions

The renewals were tailored to each school context through participatory processes involving children in the development process which lead to substantial variation in design and scale. It was up to the schools to decide how the children participated in the process. The total budget for each of the three schoolyard renewals ranged from $86,000 to 670,000 USD and at least 50% was financed by the schools, the rest was provided by the project funding. All three schools were selected for this exploratory study based on their similar intervention areas primarily consisting of flat open asphalt areas. However, as the renewals were tailored to the local school context two schools (2 and 3) utilized and connected the asphalt area with some of the adjacent school grounds. Although the design and layout of the renewals varied widely, some features were present across the three areas, e.g., balance-bars, small hills, areas for dancing, skating areas, multi-courts and panna-courts. A panna-court is a small circular game area with two goals designed for games like street football or hockey. The skating areas varied in design across the schools. School 2 designed and built their own skating pool and at school 3 the skating area consisted of a large asphalt area with markings and small hills designed for skating. An overview and pictures of features in the three intervention areas before and after renewal is provided in Fig. 1 including a short description of the other outdoor areas available for the participating students at recess. The renewals were constructed between summer 2014 and spring 2016.

2.3. Data collection procedures

A combination of GIS, GPS, accelerometer and class time table data were used to assess location specific PA levels in the intervention areas during recess prior to and following the schoolyard renewals. Objective PA was measured in intensity counts every 15 s using the ActiGraph accelerometer model GT3X, a valid and reliable tool for measuring children’s PA levels (Reilly et al., 2008; Rowlands, 2007). The students’ locations were recorded every 15 s using the QStarz BT-Q1000xt GPS tracker which has a small median dynamic positional error of 2.9 m (Schipperijn et al., 2014). The students were asked to wear the accelerometer and GPS on an adjustable belt around their waist for seven
consecutive days (five schooldays). Verbal and written instructions on wearing the equipment were given to the students by the research team. To increase compliance, short reminder text messages were sent out to the participants’ mobile phones twice a day asking them to take the belt off at night when charging the GPS, and to put on the belt in the morning (Andersen et al., 2015).

2.4. Data processing

The Personal Activity and Location Measurement System (PALMS) was used to filter, process, and merge accelerometer and GPS data (Carlson et al., 2015; Demchak, Kerr, Raab, Patrick, & Kruger, 2012). A dataset of combined accelerometer and GPS data was formed matching the timestamps of each GPS point with the accelerometer data. The counts-per-minute (CPM) cut points defined by Evenson and colleagues were used to define different PA levels for the accelerometer data: sedentary (SED), 0–100 CPM; light physical activity (LPA), 101–2295 CPM; and moderate to vigorous physical activity (MVPA), >2295 CPM (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008). Continuous periods of at least 60 min with zero counts were excluded as non-wear (Colley et al., 2011; Sherar et al., 2011).

All data points were categorized into time spent in recess, schoolyard and intervention area using a purpose-built PostgreSQL geodatabase. School time was defined based on the class time tables for each participating class, for each day of measurement in combination with GPS points on school grounds during school time. In the analysis, recess refers to the sum of all breaks (including lunch) per day for each individual. The schoolyards were mapped and the interventions areas (the areas planned for renewal) were identified in GIS at baseline and following renewal. The data processing resulted in four schoolyard time variables for each school at each time point: time in intervention area during recess per day with PA levels; MVPA in intervention area during recess; LPA in intervention area during recess; and SED in intervention area during recess.

School days with at least 80% of combined accelerometer and GPS wear time data at school during school hours were considered valid and included in the analysis of overall difference in PA levels pre and post renewal. For the intervention area, specific analyses only for days with measured recess time spend in the designated area were included.

2.5. Analysis

Statistical analyses were carried out in STATA 15.0 to test for differences in total time spent, time in PA levels and the proportion of time spent in MVPA, LPA and SED in the intervention area prior to and following renewal (for students generating time in the area). Changes in time spent and PA levels in the intervention areas after renewal were analyses using Wilcoxon’s rank-sum test, as these variables were not normally distributed. Change in the percentage of time spent in MVPA, LPA and SED were also conducted per intervention area by gender after renewals. The threshold for achieving significance was set at p < 0.05.

We conducted an ‘optimized hot-spot analysis’ in ArcGIS 10.5 for all recess periods in order to find locations important for PA in the intervention area. The ArcGIS ‘optimized hot-spot analysis tool’ was used to calculate the Getis-Ord Gi* statistic (ArcGIS, 0000) for the activity count values of each GPS point in the intervention area. The tool identifies statistically significant spatial clusters of GPS points with high activity values (hot spots) and low activity values (cold spots) and corrects for both multiple testing and spatial dependence (ArcGIS, 0000). The tool helps identify the optimal spatial scale of analysis, i.e. the maximum distance to neighboring GPS points, which in this study was set at 5 m. The tool provides z-scores (standard deviations) and p-values for each GPS point that identify where features with either high or low values cluster spatially. A GPS point with a high relative activity count (i.e., a high z-score) that is surrounded by other GPS points with high activity counts will be a significant hot-spot if the observed local sum of the activity counts of a GPS point and its neighbors is significantly (i.e. has a significant p-value) higher than the expected local sum. A cold-spot is significant if the local sum of activity counts is significantly lower than expected. The calculated p-values were used to visualize hot- and cold-spots with three levels of confidence: a p-value < 0.01 indicates a 99% confidence level, < 0.05 indicates 95%, and < 0.1 indicates 90% confidence.

The ‘hot and cold’ spot analyses were conducted for all data points

<table>
<thead>
<tr>
<th>Intervention area school 1:</th>
<th>Target group: Grade 7-9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane asphalt学校 with few markings for different kinds of ball games</td>
<td></td>
</tr>
<tr>
<td>Intervene area school 1:</td>
<td>Target group: Grade 7-9</td>
</tr>
<tr>
<td>Three hills is 1.5 meter tall covered with rubber. At one side of the hills three trampolines are located. Beside the hill area a dancing area is placed with mirrors on the surrounding wall separated with tree poles. A big moveable loudspeaker to which students could connect their mobile phone. An outdoor classroom surrounded. Playground kitchen/outdoor canteen, fenced multi-court, small soccer court with artificial grass, one panna court, one parkour facility, one hammock</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intervention area school 2:</th>
<th>Target group: Grade 5-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane asphalt学校 with basketball court surrounded by a woodland area (forest).</td>
<td></td>
</tr>
<tr>
<td>Intervene area school 2:</td>
<td>Target group: Grade 5-8</td>
</tr>
<tr>
<td>The area was divided into different area types: oval basketball area with elevated enclosure, two foursquare markings, two panna-courts, a picnic area, an area with a big screen placed under a tent roof for dancing activities (youtube videos etc.), a settled paved multi-court, three hopscotchs. A leveled obstacle trail running through the woodland area and the asphalt area separating it into different area types. The trail varies in the design and takes form as a hench, a broken climbing-ladder, swings, a spider’s web for climbing, balance-bars and a small tree house. In the woodland area a skating pool and a round swing facility (8 swings) and log stumps are located.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Intervention area school 3:</th>
<th>Target group: Grade 4-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane asphalt school with one marked ball court, a worn down tennis court, few foursquare markings and one basket hoop</td>
<td></td>
</tr>
<tr>
<td>Intervene area school 3:</td>
<td>Target group: Grade 4-6</td>
</tr>
<tr>
<td>A tall hill with rubber surface containing a cave with a climbing wall inside. Surrounded by several small hills and markings for skiing. A tall tower for climbing and hang-outs. A woodland area with sand, bushes, hammocks, balance-bars, changeable facilities. One enclosed asphalt soccer-field. Sand and grass covered area with a parkour facility and three small houses to sit on or inside, allowed writing on.</td>
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</tbody>
</table>

Fig. 1. Description of schoolyard intervention areas before and after renewals (with before and after pictures).
in the intervention area at each school during recess at both time points by gender. In short, the ‘hot and cold’ analysis was performed separately for boys and girls, thus hot-spots generated by the boys relate to the average absolute PA level generated by the boys in the intervention area at that time point.

In order to outline the ‘hot and cold’ spots and study the underlying features, the results were transformed to a raster surface and visualized in four maps per school; two for boys and two for girls.

For each ‘hot-spot’ and ‘cold-spot’ the underlying layout and features were examined using high resolution aerial photographs from the Danish Geodata Agency taken in April 2016, and pictures taken by the research team during the data collection and a professional photographer (summer 2016). ‘Hot and cold’ spots for boys and girls at each school were listed in a table to describe differences and similarities between gender and across schools.

3. Results

3.1. Participant characteristics and differences in recess physical activity

Participant characteristics and overall recess PA before and after the renewal are presented by school in Table 1.

For school 1 at baseline, 117 (62% girls) participants with 328 valid days of combined accelerometer and GPS data were included in the study. At follow-up, 60 (72% girls) students with 183 valid days were included. At school 1, students from grade 7 to 9 participated. Average daily recess wear-time at baseline was 42.5 min (MVPA 3.3 min) and at follow-up 76.9 min (MVPA 9.2 min) (Table 1). The students spent 17.9% of time the recess time in the schoolyard before the renewal and 33% after renewal (Table 1). Time in the intervention area represented 39.3% of the schoolyard time before and 43.9% after the schoolyard renewal at school 1 (Table 1).

The percentage of days with time spent in the intervention area increased from 61% to 82% for girls and from 63% to 98% for boys after renewal at school 1. The intervention area generated more time and PA for both genders and both absolute and percentage of time in PA levels in the area increased significantly. The boys almost tripled their time in the area (7.0–18.2 min per day) and had the highest proportional increase in MVPA (0.6–6.2 min per day) (Fig. 2). Additionally the percentage of time spent in MVPA in the intervention area increased by 30.7% (p < 0.001) for the boys after renewal and a decrease of 13% (p < 0.001) was seen in the percentage of time being SED. Girls also almost tripled their time spent in the area (6.2 min to 16.9 min) at school 1, but did not increase their MVPA (0.5 min to 1.8 min) as much as the boys. The percentage of time girls spent in MVPA in the area increased by 12.5% (p < 0.001) and 10.3% (p < 0.001) for time spent in LPA while a decrease of 22.8% (p < 0.001) was found for the percentage of time being SED.

For school 2 at baseline, 133 (49% girls) participants were included in the study with 451 valid days of combined accelerometer and GPS data. At follow-up, 149 (52% girls) students with 644 valid days were included. At school 2, students from grade 4 to 8 participated. Average daily recess wear time at baseline was 24.7 min (2.9 min in MVPA) and at follow-up 65.1 min (10.1 min in MVPA) (Table 1).

The percentage of days with time spent in the intervention area increased at school 2 from 54% to 65% for girls and from 56% to 65% for boys after renewal.

The students spent 45% of time the recess time in the schoolyard before the renewal and 45.6% after renewal (Table 1). Time in the intervention area represented 26.9% of the schoolyard time before and 48.3% after the schoolyard renewal at school 2 (Table 1). No differences were seen in schoolyard utilization and PA across the participating grades (data not shown).

The intervention area generated significantly more time and PA for both genders, with an even increase across PA levels. Time spent in the intervention area did not differ by gender after renewal (17.1 min to 18.0 min), but boys spent 1.8 additional minutes per day in MVPA compared to girls (Fig. 2). The range of time spent in MVPA varied widely for both genders (0–14 min for girls and 0–17 min for boys) after renewal (additional file). No statistically significant change was found in the percentage of time in MVPA and SED in the intervention areas after renewal for both genders however boys increased time spent in LPA after renewal with 6.2% (p = 0.003).

For school 3, at baseline, 78 (58% girls) participants were included in the study with 298 valid days of combined accelerometer and GPS data. At follow-up, 61 (70% girls) students with 291 valid days were included. At school 3, students from grade 4 to 6 participated. Average daily recess wear-time at baseline was 58.7 min (12.2 min in MVPA)

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Descriptives of the students participating.</th>
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<tbody>
<tr>
<td></td>
<td>School 1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants invited</td>
<td>275</td>
</tr>
<tr>
<td>Participants with GPS &amp; acc data</td>
<td>128 (47%)</td>
</tr>
<tr>
<td>(% of all invited)</td>
<td></td>
</tr>
<tr>
<td>Participants with valid GPS &amp; acc data (% girls)</td>
<td>117 (62%)</td>
</tr>
<tr>
<td>Participants per grade level</td>
<td></td>
</tr>
<tr>
<td>4-5. Age (11–12)</td>
<td>–</td>
</tr>
<tr>
<td>6-7. Age (13–14)</td>
<td>41</td>
</tr>
<tr>
<td>8-9. Age (14–15)</td>
<td>76</td>
</tr>
<tr>
<td>Days with valid data</td>
<td>328</td>
</tr>
<tr>
<td>Mean valid days (CI)</td>
<td>2.8</td>
</tr>
<tr>
<td>Mean daily wear time hours (SD)</td>
<td>704.8 (148.3)</td>
</tr>
<tr>
<td>Mean recess wear time minutes (SD)</td>
<td>42.5 (7.4)</td>
</tr>
<tr>
<td>Mean recess MVPA minutes (SD)</td>
<td>3.3 (4.0)</td>
</tr>
<tr>
<td>Mean recess LPA minutes (SD)</td>
<td>9.2 (4.8)</td>
</tr>
<tr>
<td>Mean recess SED minutes (SD)</td>
<td>29.9 (9.6)</td>
</tr>
<tr>
<td>Days in intervention area</td>
<td>203</td>
</tr>
<tr>
<td>Percentage of time in SY during recess (%) (SD)</td>
<td>17.9 (17.6)</td>
</tr>
<tr>
<td>Percentage of time in IA during SY time (%) (SD)</td>
<td>39.3 (25.5)</td>
</tr>
</tbody>
</table>

Note: Valid data = days with 80% of school day with combined accelerometer (acc) & GPS data, intervention area = area planned for renewal, 2014 = baseline (spring), 2016 = Follow-up (spring).

Mean recess wear time = mean wear time during all breaks per day.

MVPA moderate to vigorous physical activity, LPA light physical activity, SED sedentary behavior.

SY Schoolyard, IA Intervention Area.
and at follow-up 74.5 min (14.9 min in MVPA). The percentage of days with time spent in intervention area changed from 66% to 65% for girls and 59% to 70% for boys after renewal. The students spent 56.1% of the recess time in the schoolyard before the renewal and 32% after renewal (Table 1). Time in the intervention area represented 43.1% of the schoolyard time before and 23.9% after the schoolyard renewal at school 2 (Table 1). The intervention area at school 3 generated significantly less time spent and PA for the girls after renewal corresponding to a decrease in time spent from 19.9 min to 7.3 min and in MVPA from 3.5 to 1.1 min. The same decrease was seen for the boys in time spent (10.6 min to 6.8 min), but only the change in SED time was significant (3.4 min to 2.8 min) (Fig. 2). Referring to the percentage of time spent in MVPA and LPA in the intervention area both decreased significantly for the girls after renewal while this was only evident for the boys in the percentage of time spent in LPA. No significant change was found in the percentage of time being SED for both genders.

### 3.2. Activity hot-spot and cold-spot analyses

In Fig. 3(a–c), hot-spots and cold-spots after renewal are visualized and pictures of some of the activating feature are presented.

For school 1, at baseline only a few small activity hot-spots were generated at the markings on the asphalt area close to the building for both genders. No cold-spots were found for girls at baseline and only few were found for boys at the marking for ball games. At follow-up new activity hot-spots were distributed across the intervention area with more PA in a distant corner of the outdoor school area after renewal. The multi-court and the small soccer court with artificial grass
Figure 3a-c. Hot-spots and cold-spots in intervention areas by school and gender after renewal

A: Hills
B: Multi-court
C: Soccer court
D: Outdoor kitchen area

Hot and cold spots
(Confidence level)
- cold spot (96%)
- cold spot (95%)
- cold spot (90%)
- hot spot (90%)
- hot spot (95%)
- hot spot (99%)

Figure 3b.

A: Panna-court
B: Screen for dancing
C: Lowered Multi-court
D: Four-square markings
E: Obstacle trail
F: Round basket court
G: Picnic area
H: Spider-web
I: Hopscotch markings
J: Tree stumps

Hot and cold spots
(Confidence level)
- cold spot (99%)
- cold spot (95%)
- cold spot (90%)
- hot spot (90%)
- hot spot (95%)
- hot spot (99%)

(caption on next page)
were activity hot-spots for both genders. Smaller hot-spots were also found on and adjacent to the hills for both genders. Cold-spots were located near the outdoor kitchen area (close to the multi-court) and near the entrances (Fig. 3.a).

For school 2, differences in PA patterns between genders existed at baseline, where boys generated more activity hot-spots than girls. At follow-up, both genders generated more hot-spots and these were most common in the asphalt area distributed across the area (Fig. 3.b). In contrast, most of the activity hot-spots were found closer to the buildings and the entrances at baseline.

At follow-up, panna-courts and foursquare markings generated activity hot-spots for both genders, though a cold-spot was found for the boys by the panna-court as well. Boys were highly active on the obstacle trail in the asphalt area and in the space between the obstacle trail in the asphalt area and lowered multi-court and next to the round basket court. Girls were active in an area with a big screen used for dancing activities, on the lowered multi-court, on the spider-web climbing structure and in an area with big tree stumps in the woodland area.

Activity cold-spots generated by the girls were located in the picnic area, the hopscotch markings, around the spider-web climbing structure, and near the big stumps in the forest (Fig. 3.b). In contrast boys generated a cold-spot in the area with big tree stumps in the woodland area.

For school 3 at baseline hot-spots were generated close to the building for both genders. The few elements located in this area were a worn down panna-court, foursquare markings and a basketball hoop. At follow-up the activity was more spread out across the intervention area for both genders, with fewer activity hot-spots for boys than for girls. Following renewals few activity hot-spots were generated in the area with markings for skating (scooters, rollerblades) close to the building, while the tall hill generated both hot-spots and cold-spots (Fig. 3.c). Boys generated an activity hot-spot on the small paved soccer court, whereas girls were active next to the court. Only the girls generated activity hot-spots and cold-spots in the area with changeable features, e.g., hammocks and balance-bars, while cold-spots were found in the secluded area with picnic tables.

4. Discussion

A higher proportion of days with valid data were recorded in the intervention area at all three schools after renewal. The increase was most evident at school 1, where 98% of the boys spent time in the area after renewal. In the intervention areas at school 1 and 2, time spent and PA in minutes during recess increased for both genders, however the percentage of time in MVPA and LPA only increased in the intervention area at school 1, and at school 3 both the percentage of time and PA decreased in the intervention area after renewal. In relation to the increase in the recess time happening at the same time as the schoolyard renewal, it could be that the increase in time and activity found in two intervention areas simply reflects the overall increase in recess time. However, looking at the percentage of time spent in the schoolyard during recess after renewal, more recess time did not necessarily equal more time in the schoolyard and the intervention area. Only at school 1 the percentage of time spent in the schoolyard during...
recess increased, at school 2 it stayed the same and at school 3 it decreased. Interestingly, an increase was found in the percentage of schoolyard time spent in the intervention area at school 2. So even though the overall recess PA behavior remained the same, the use of the intervention area changed, however the percentage of time spent in MVPA and LPA in the area did not change significantly. So, what can we conclude based on this information? Renewal of an area in the schoolyard can attract students to stay longer, but this does not necessarily lead to more time in MVPA and LPA, and in some cases both time and activity can even decrease. The question is how we should define the success of a renewed area? Is it defined by the utilization in minutes, time spent in MVPA, or the percentage of time spent in specific PA levels? From a public health perspective, the absolute minutes spent in MVPA are more important for health-related consequences than the percentage of time spent in specific PA levels. On the other hand, minutes spent in specific PA levels are always related to the time spent in the schoolyard. But is it even possible to pre-define expectations as to what percentage of time in specific PA levels an area of a schoolyard should generate? All these questions are important to reflect further upon when evaluating the impact of schoolyard renewal on physical activity in future studies using a combination of GPS and accelerometer.

The school context in which the behavior takes place is also really important to take in to consideration when interpreting the results of the proportion of time in the schoolyard. As mentioned there was a great variation between and within schools in whether different grades were required to go outside during recess which could potentially affect the results. However, in the everyday school life the retention of these outdoor rules can vary from recess to recess and from day to day often depending on the teacher, class time table and the weather, thus accounting for these differences in the analysis was rather difficult. The importance of documenting the local everyday practice of the outdoor rules better in future studies is essential for better understanding the complexity of the outdoor behavior during recess.

Referring to the hotspot analysis, physical activity was more dispersed after renewal and more hot-spots were identified for both genders. These results indicate that the layout and added features were effective in creating new places for PA compared to an asphalt schoolyard with none or few features. However, the decrease in the percentage of time and PA in the intervention area at school 3 warrants more explanation.

One explanation might be, that the overall number of features is not that important, as was found in other studies (Nielsen et al., 2011), but instead the availability of functional features that are perceived useful and accessible by students (Morton, Atkin, Corder, Suhrcke, & van Sluijs, 2016). Students participating in a qualitative user-evaluation at school 3 were disappointed with the new features in the intervention area after renewal, due to the lack of functionality for riding on scooters or skateboards (wrong incline of slopes and locations of the hills); a function they asked for during the intervention development process. It is likely that the negative perceptions of that area influenced the use and PA behavior in that area. Additionally, the hot-spots at baseline were generated on the asphalt area with some functional features e.g., one panna-court and foursquare markings. The students expressed a need for these removed functional features in the user-evaluation, which could have influenced the time spent in the intervention area after renewal. Another schoolyard study focusing on children’s perspectives stated that activity friendly schoolyards are influenced by characteristics of both the playground design as well as the social situation, and how children perceive and experience these conditions are important for actualizing the activating potential of schoolyard features (Caro, Altenburg, Dedding, and Chinapaw, 2016).

The unexpected finding in the intervention area at School 3 warrants attention about insuring sufficient functionality of new schoolyard features.

4.1. Schoolyard features

The ‘hot and cold’ spot analyses revealed examples of activating features across the three intervention areas which are presented and discussed in the following sections.

4.2. Multi-court

In one intervention area (school 1), the percentage of time spent in MVPA and LPA increased significantly after renewal. At this school hot-spots for both genders were found primarily at the multi-court and the small soccer field with artificial grass. School 1 had only a few markings for ball games and no multi-courts or soccer fields before renewal which might explain the significant change in the percentage of PA in the intervention area after renewal. At school 2 and 3, which already had large soccer fields, additional hot-spots analyses (not shown) of the whole outdoor school grounds showed activity hot-spots at soccer fields. In a case study of the students at school 3 (at baseline), the most active students were found at the field being active for most of their recess time (Pawlowski, Andersen, Troelsen, & Schipperijn, 2016), thus it is likely that the high intensity PA was generated in these settings at school 2 and 3 after renewal. The lowered multi-court and paved soccer field at School 2 and 3 might have attracted students with other ball-game preferences which could explain the differences in PA found between the schools.

Activity hot-spots were found at multi-courts and paved courts for both genders. Previous studies found gender differences in PA levels in multi-court areas (Andersen et al., 2015; Dyment et al., 2009; Martensson et al., 2014) which Dyment et al. (2009) explained with girls being more sedentary, standing at the periphery of the courts. Blatchford, Baines, and Pellegrini (2009) indicated that boys were significantly more likely to be involved in ball games, and girls more in conversation, sedentary play and verbal games (Nielsen et al., 2011; Blatchford et al., 2003). In contrast to this, a previous study found a relatively large number of girls in the schoolyard identifying themselves as soccer girls. These girls wanted to play soccer and sought-after more soccer facilities in the schoolyard because they felt excluded by the boys being dominant at the soccer field (Pawlowski et al., 2015). Therefore it is likely that a schoolyard with different courts for ball games can generate activity hot-spots for both genders as seen in our study.

4.3. Dancing

The area with a large screen for dancing activities generated a hot-spot for girls (School 2). During visits at the schools we noticed that the dancing area at school 1 was also very popular. However, the children using this area were younger than the intended target group (7–9th grade) for that school, and the hot-spot analysis did not reveal any activity spots in the dancing area for our participants. In a previous study observing recess activities, dancing was found to be a popular recess activity among girls. Interestingly, girls who did not participate in other physical activities during recess were observed participating in dancing (Pawlowski et al., 2016). This indicates that features and a schoolyard layout that support dancing are important to increase PA among girls. In line with this, a study by Janssen, Twisk, Toussaint, van Mechelen, and Verhagen (2013) found their PLAYground program consisting of e.g., skipping and dance areas more appealing to girls and found the strongest effect on PA for girls aged 10–12 years old (Janssen et al., 2013).

4.4. Markings

The foursquare markings generated activity hot-spots for both genders and cold-spots for boys. In the study by Blaes et al. (2013),
recess PA increased following completion of schoolyard markings in three specific areas: non-active games (chess and draughts), multi-activity areas (fitness motor skills improvement, and ‘sports’ area (football, basketball) interventions (Blaes et al., 2013). Several studies have shown effects of schoolyard markings on overall recess PA, but direct comparisons with our findings of the activity in the intervention areas are not possible (Ridgers et al., 2007; Stratton and Mullan, 2005). Children in the age of 9–11 years old were previously found to consider colored markings inviting for active play (Willenberg et al., 2010). The sedentary spots found in the present study might illustrate the variation in games played in these areas or that the students were waiting for their turn to play (Dyment et al., 2009). A previous study found four-square games to be a popular activity in the schoolyard, but since only four students could actively participate at one time, many children were waiting in line for their turn to play (Pawlowski et al., 2016).

Some of the features added into the schoolyard require loose equipment for actualizing some of the activating potential of the feature e.g., foursquare and ball-courts. In the study of Willenberg et al. (2010) children were well aware of the provision of more sports equipment in stimulating PA and unfortunately they observed a dwindling access to balls as the school term progressed, due to the balls thrown onto roofs or in trees during play (Willenberg et al., 2010). The provision of sport/unfixed equipment was found to increase recess PA in several studies (Escalante et al., 2014) and familiarity with the schoolyard features increase as children grow older, making variation in unfixed equipment and games even more important. Consequently schools provision or lending of equipment may play a critical role in maintaining the promotion of PA in the intervention areas.

4.5. Nature inspired elements

Nature inspired element as seen in the woodland and hill areas generated both hot-spots and cold-spots and the spider’s web climbing frame generated a hot-spot for girls after renewal. In the study of Fjortoft et al. (2009) using GPS and heart-rate monitoring the forest area seemed to invite to more activity in girls than boys among six-year-olds. Natural inspired elements on school grounds can encourage creative and ‘risky play’ and provide the opportunities for MVPA and the development of key fundamental motor skills in children and youth (Dyment et al., 2009; Lim, Donovan, Harper, & Naylor, 2017). In the study of Willenberg et al. (2010) children aged 9–11 years old acknowledged the benefits of the ‘natural’ wooden play equipment and being surrounded by trees (Willenberg et al., 2010).

Another study highlighted the value of greened areas in engaging girls in MVPA and accommodating a wide range of active and quiet, competitive and cooperative, rule-bound and open-ended play activities (Dyment et al., 2009). The hot-spots and cold-spots found in the woodland area (school 2) in the present study reflect the same variety in play activities.

4.6. Schoolyard layout

Across the intervention areas, multi-courts, small soccer courts, panna-courts, foursquare markings and hills generated activity hot-spots for both genders, whereas girls were found being active above average at a large screen for dancing activities, on a lowered multi-court, on a spider-web climbing frame and in an area with big tree stumps in a woodland area. Girls were also found next to a paved soccer court at school 3 and boys were found being active above average in-between features and on the obstacle trail at school 2. Active hot-spots on and in between features illustrate the relevance of dividing open areas into smaller spaces using e.g., obstacle-trails, natural inspired elements, small hills, court fences or different levelled surfaces in the schoolyard.

Even though boys and girls to some extent favored different feature or places, the hot-spots and cold-spots were found in close proximity, which could indicate that they in some cases might join the same type of games. The close proximity of the hot and cold-spots highlights the social potential closely located features can add to the games and activity played on and between the features. Designing a schoolyard for both genders should go beyond reinforcing simplistic gender stereotypes and should offer a wide range of functional features in close connection to each other. In a Dutch schoolyard study students expressed that fun and active play involved a variety of activities in a social and physically safe environment in which the permission to do a variety of activities existed (Caro et al., 2016). This was supported by the results of a recently published study finding that students preferred schoolyards divided into several different settings with multiple functional features and natural elements for social and physical activities (Jansson, Abdullah, & Eriksson, 2018).

The evenly distributed activity-hot-spots found after the schoolyard renewal and the great variation in features generating these support previous findings of children desiring a mix of playground surfaces to play a variety of activities (Willenberg et al., 2010). Another study found that green and built elements in close connection and in proximity to buildings were well-used favorites offering many opportunities to socialize and be physically active (Martensson et al., 2014).

Promoting recess PA in older students is challenging and placing the features close to the classrooms or entrances could be a practical solution to encourage use, as mentioned in previous studies (Martensson et al., 2014; Christiansen et al., 2017). At School 1 hot-spots were located in and around the multi-court in a distant corner of the intervention area. This indicates that students did use the multi-courts in spite of the distant location, however students were also found to hang out close to the buildings near the entrances being sedentary supporting the mentioned assumption. Other cold-spots were primarily found for the girls (school 2 & 3) at the out-door kitchen area and in picnic areas with tables (Fig. 3.a). Dyment et al. (2009) found the canteen courtyard to be used by girls sitting and talking which could reflect the behavior in the present study. In another study students requested secluded places suitable for social interaction and hanging out (Pawlowski, Tjorhøj-Thomsen, Schipperijn, & Troelsen, 2014). Recess offers time to engage in peer interactions and promote children’s physical, social and emotional development and if schoolyards are to realize their potential to promote this the schoolyards must offer options for active play that appeal more broadly to students with a variety of interests and abilities (Murray, Ramsay, Council on School H, & American Academy of P., 2013). These considerations highlight the importance of focusing more on the types of activities and games we want to promote and how the design, layout and social interactions support active play for all students.

4.7. Strengths and limitations

Studies using the combination of GIS, GPS and accelerometer to evaluate renewals are still limited (Andersen et al., 2015) and this study is among the first to explore schoolyard behavior in renewed areas. The main strength of this study is the use of objective measurements of time, location and PA, for a relatively large sample, compared to previous studies, of 323 participants at baseline and 270 at follow-up with 1127 and 1118 days with recess data, respectively (Van Kann et al., 2016). The combination of GIS, GPS and accelerometer enables an area specific evaluation of time and PA. The time dimension adds new important aspects toward understanding PA levels in schoolyards. Time can indicate how attractive an area is for the students and the proportion of time spent in different PA levels can give insights to how students actualized the activating potential provided by adding the new features. However, the combination of GIS, GPS and accelerometer cannot identify the actual behaviour e.g., the activity or play that generate the activity measured, nor can the social interaction be determined, which is one of the advantages using on-site observation tools (Dyment et al., 2009; Anthamatten et al., 2014; Willenberg et al., 2010). Additionally
the time aspect provides new information that can be challenging to interpret.

If all students wear the monitors a very detailed, specific and objective dataset can be collected, but in this study the average participation rate was 47% at baseline and 45% after renewal. Consequently caution should be given to the proportion of included students which may have introduced a systematic bias in the sample. It is quite demanding for the students to wear the equipment for five consecutive days (Borde, Smith, Sutherland, Nathan, & Lubans, 2017; Audrey, Bell, Hughes, & Campbell, 2013) and it was difficult to recruit students to participate in the present study. The relatively low number of boys participating at follow-up might have affected the number of hotspots found in the renewed areas after renewal and this could underestimate the activating potential of some features. If the full potential of the GPS is to be utilized more students have to wear the equipment. The average number of days with valid data differed across the three schools participating and between the two time points. More days with valid data as seen at follow up may have captured more variety in PA behavior in the schoolyard which could potentially affect the results. Hot-spot analysis is very informative when exploring activating features, though it should be noticed that this information is generated based on the relative PA generated at that time (baseline or follow-up) in that area. In other words, the identified hot-spots and cold-spots are relative to their context and the average absolute PA level at a hot-spot can vary from context to context. Previous analyses focusing on the features have divided schoolyards into predefined zones based on structures and features (Andersen et al., 2015). This method enables a direct comparison of absolute time and PA on different features in different areas between schoolyards finding the features with the highest PA levels. However, the subdivision of the schoolyards into predefined zones can result in a fragmented description of dynamic behavior patterns going across the zones, consequently the few minutes of utilization and the few seconds in each PA level on the different features can be hard to interpret (Andersen et al., 2015).

Some schools struggled with substantial delays in the construction of the schoolyard interventions. These delays affected the timespan between when the schoolyard renovations were finished and the follow-up data-collection, ranging from two-three month at school 2, six month at school 3 and 11 month at school 1. For this reason, the results may reflect both short and long-term effects of the schoolyard renovations, thus it is quite interesting that school 1 is the only school where the percentage of time in MVPA increased, even 11 months after the opening of the new schoolyard. This paper aimed at investigating the PA behavior in three renewed schoolyard areas with the focus of finding areas and new facilities with high physical activity using a combination of GPS, accelerometer and GIS. The hotspot analysis enabled finding the features and areas with PA above average reflecting the activity in that specific area of interest. The case study design and the substantial cost of the renewal in the present study limits the generalizability of these findings, still the findings of this evaluation of three schoolyard layouts with examples of features with the potential to promote activity in the schoolyard can serve to qualify future development and support of schools undergoing schoolyard renewals.

5. Conclusion

Evidence informed solutions for schoolyard design can assist in the effort to provide good opportunities for boys and girls to be more physically active during recess. Schoolyards with large open asphalt areas offer opportunities for physical activities for some children. Our findings suggest, however, that schoolyard layouts including more functional features such as multi-courts, alternative ball-courts, four-square markings, dancing areas and nature inspired elements (hills and climbing features) in close proximity to each other but still physically separated can generate more spots for physical activity for both genders and potentially increase utility and activity during recess. Functionality, variation, connected-but-separated seem to be the keywords, and more important than aesthetics and architectural design elements.

6. Authors’ contributions

HBA was responsible for the data collection and cleaning, statistical analysis, and drafting the manuscript. LBC assisted with the analyses and contributed with significant inputs to the manuscript. JS conducted the hot-spot analyses, conceived the study design, handled and processed data and contributed with significant inputs to the outline of the manuscript. CP contributed significant input to the manuscript. All authors revised the manuscript critically and read and approved the final manuscript.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2019.103617.

References

Available from.
